DESIGN
AND
FABRICATION
2212

TEACHER RESOURCE GUIDE

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Foreward

Design and Fabrication 2212 is the second of two design and fabrication courses that are included in the new Skilled Trades and Technology program for Level I, II, and III high school students in Newfoundland and Labrador. This two-term course reinforces and extends on the basics of engineering design, fabrication processes and shop safety covered in Design and Fabrication 1212. Although not a required pre-requisite, completion of Design and Fabrication 1212 is recommended before commencing studies in Design and Fabrication 2212.

The Skilled Trades and Technology program was introduced by the Division of Program Development, Department of Education, in 2006, based on the recommended model for K-12 technology education presented in the Atlantic Canada Foundation document for Technology Education (2001). This new program replaces the former Industrial Arts program and offers students a modernized curriculum that reflects current industry practice in a variety of trades and technology areas.

Design and Fabrication 2212 introduces students to the advanced technologies being used today in engineering design and manufacturing including 2D and 3D Computer Aided Design and Drafting (CADD) software, Computer Aided Manufacturing (CAM) software and Computer Numerical Control (CNC) machining. Through participation in group labs and the major group Design Project, students also learn the value of the collaborative approach to problem-solving in engineering and manufacturing. This course also prepares students for related further study in Production Technology 3201 and Integrated Systems 3205 in Level III.

The Teacher Resource Guide is a supplement to the Curriculum Guide for Design and Fabrication 2212. This guide is a practical and comprehensive instructional resource for teachers and contains detailed lesson plans for each sub-unit included in UNITS 1-8 presented in the Curriculum Guide. The lesson plans are presented in a consistent format that includes:

1. Specific Curriculum Outcomes – expected lesson outcomes
2. Teacher Resources - a listing of the resources required for lesson delivery
3. Student Resources - a listing of the resources required for lesson participation
4. Teacher Preparation - online, text and other sources that can be referenced in preparation for the lesson
5. Introduction – motivation and background for the lesson
6. Presentation – detailed lesson content
7. Suggested Student Activities – lesson related assignments, computer labs, shop exercises and projects
8. Suggested Assessment and Evaluation – assessment metric for student evaluation
9. Wrap-up and Closing – summary of the key points presented in the lesson
10. Learning Resources – summary of reference materials for the lesson

Design and Fabrication 2212 immerses students in a problem-based learning environment in which they actually experience each step of the CAD/CAM/CNC process. Following an initial four weeks during which students acquire a basic knowledge of and proficiency in CAD/CAM/CNC through teacher-led instruction, the teacher takes on the role of facilitator. Students, working in groups of 2 or 4, are then expected to "learn by doing" as they progress through a series of practical shop projects and a major design project. This approach helps students to develop problem-solving skills and an appreciation for the various career opportunities available in this field. Since CAD/CAM/CNC technologies continuously evolve, course content should be regularly reviewed and modified as required to keep abreast of the latest "best practices" in the field of engineering design and manufacturing. Consequently, the teacher is encouraged to focus on helping students to develop the communication, problem-solving, and teamwork skills considered fundamental to engineering and manufacturing, rather than on developing student proficiency in a particular software or hardware application. One of the most important outcomes of Design and Fabrication 2212 will be that students "learn how to learn" - arguably the key to career success in these exciting and dynamic fields.

Sincerely,

John O'Leary, M.Eng

Acknowledgements

The development of this Teacher Resource Guide for Design and Fabrication 2212 was an iterative process that involved the support and contribution of a variety of professionals working in both the industrial and educational sectors in Newfoundland and Labrador. First, I would like to acknowledge Mr. Eldrid Barnes, Director, Division of Program Development, Dept. of Education, and wish him future success in leading the continued development of a new Skilled Trades and Technology education program for Levels I, II, and III. Secondly, I would like to thank Mr. John Barron, Program Development Specialist for Technology Education/Career Education, for his guidance and help in obtaining teacher feedback that proved invaluable in development of this guide.

Overview

Design and Fabrication 2212 is based conceptually, philosophically and practically on the Atlantic Canada Foundation document for Technology Education (2001). The teacher is directed to the document for specific information that forms the basis for this and other technology education curricula in the province of Newfoundland and Labrador.

This two-term course reinforces and extends on the basics of engineering design, fabrication processes and shop safety covered in Design and Fabrication 1212. Design and Fabrication 2212 introduces students to some of the more advanced design and manufacturing tools used today including 2D and 3D Computer Aided Drafting and Design (CADD) software, 3D Computer Aided Manufacturing (CAM) software, and Computer Numerical Control (CNC) machining.

Rationale

This course is designed for delivery using a problem-based learning approach which reflects standard industry practice in the fields of engineering design and advanced manufacturing. Using this approach, the teacher takes on the role of facilitator in helping students to acquire the technical knowledge and basic proficiency needed to perform each of the major operations that comprise the CAD/CAM/CNC process for part production, including creating the CAD model, generating the CNC part program using CAM software, and setting-up/operating a CNC machine.

Students first learn the basics of CAD/CAM/CNC through direct teacher-led instruction followed by completion of a series of practical shop projects that allow them to actually experience the CAD/CAM/CNC process from the initial design concept to the finished part. Students then apply the knowledge and skills developed through these activities in the completion of a major Design Project that must incorporate the CAD/CAM/CNC process.

This experiential approach encourages students to "learn by doing" and, thereby, develop the problem-solving and teamwork skills fundamental to industry practice in the fields of engineering and manufacturing. The major Design Project allows students to generalize, apply and synthesize the concepts learned over the duration of the course. Students, working in groups of 2 or 4, must identify the required project activities, develop a related project timeline, assign and schedule project activities, identify/procure the raw material and equipment needed, and determine a per unit production cost. Ideally, projects will support a real need in industry and directly involve industry representatives in student learning.

General Curriculum Outcomes

The General Curriculum Outcomes (GCOs) for technology education as defined in the Atlantic Foundation document on Technology Education include:

GCO 1: Technological Problem Solving
Students will be expected to design, develop, evaluate, and articulate technological solutions.

GCO 2: Technological Systems
Students will be expected to evaluate and manage technological systems.

GCO 3: History and Evolution of Technology
Students will be expected to demonstrate an understanding of the history and evolution of technology, and of its social and cultural implications.

GCO 4: Technology and Careers
Students will be expected to demonstrate an understanding of current and evolving careers and of the influence of technology on the nature of work.

GCO 5: Technological Responsibility
Students will be expected to demonstrate an understanding of the consequences of their technological choices.

Key Stage Curriculum Outcomes

The Key Stage Curriculum Outcomes (KSCOs) for Design and Fabrication 2212 elaborate on these five GCO's and indicate what is expected of students at the end of Level III. By the end of Level III, students will be expected to:

GCO 1: Technological Problem Solving

[1.401] articulate problems that may be solved through technological means
- assess diverse needs and opportunities
- construct detailed design briefs that include design criteria & work schedule

[1.402] conduct design studies to identify a technological solution to a problem
- investigate related solutions
- document a range of options to solve this problem
- determine and justify the best option
- determine resource requirements and availability
- develop detailed action plans, including technical drawings and sequences

GCO 1: Technological Problem Solving (Continued)

[1.403] develop (prototype, fabricate, make) technological solutions to problems
- match resources and technical processes for specific tasks
- construct and test models and prototypes as needed
- construct the solution with adherence to the design criteria
- document activities, decisions, and milestones

[1.404] critically evaluate technological solutions and report their findings
- develop detailed evaluations of both their own and others' technological solutions, with reference to independently developed criteria
- employ a continuous assessment methodology with the purpose of continuous improvement of the design
- document and report their changes, the rationale for change, and conclusions

[1.405] communicate ideas and information about technological solutions through appropriate technical means
- accurately present technical information by using a representative sample of analog and digital tools, including, for example, two- and three-dimensional, computer-assisted drafting and modeling tools
- create accurately scaled models and prototypes

GCO 2: Technological Systems

[2.401] operate, monitor, and adjust technological systems of increasing complexity

[2.402] manage technological systems of increasing complexity

[2.403] modify programming logic and control systems to optimize the behaviour of systems

[2.404] deconstruct complex technological systems into their simpler systems and components

[2.405] troubleshoot and maintain systems

GCO 3: History and Evolution of Technology

[3.401] evaluate technological systems in the context of convergence where one system has multiple functions, or divergence where multiple systems have the same function

[3.402] evaluate the symbiotic roles of technology and science in modern society

[3.403] analyse the symbiotic relationship between technology and education, including factors that influence standards for technological literacy and capability, and ways that the community responds

[3.404] critically evaluate the effects of accelerating rates of technological change on self and society

[3.405] account for effects of cultural diversity on technological solutions
- critically examine the effects of cultural diversity on market forces and technological products, and vice versa
- incorporate knowledge of cultural diversity into technological solutions

GCO 4: Technology and Careers

[4.401] assess and evaluate employability profiles for a variety of workplaces and careers and determine the level of technological literacy and capability they would need to achieve for job entry

[4.402] employ design and invention as tools to create entrepreneurial activity

[4.403] envision their short- and longer-term future and develop a plan for acquiring the technological literacy/capability required to achieve their vision

GCO 5: Technological Responsibility

[5.401] demonstrate responsible leadership in employing legal and ethical rules and principles

[5.402] demonstrate responsible leadership in employing health and safety rules and standards

[5.403] demonstrate responsible leadership in taking proper measures to manage current and future technological risk

These KSCOs form the basis of the Specific Curriculum Outcomes (SCOs) for Design and Fabrication 2212. The SCOs indicate what is expected of at the end of a lesson or series of lessons on a particular topic.

Specific Curriculum Outcomes

The Specific Curriculum Outcomes (SCOs) for Design and Fabrication 2212 are derived from Stage 4 (Grade 10-12) of the Key Stage Curriculum Outcomes (KSCOs) outlined in the Atlantic Canada Foundation document for Technology Education (2001). The SCOs are organized into eight Units delivered over two terms for a total of 110 instructional hours as follows:

UNIT 1.0: Engineering Design and Manufacturing (5 hrs)

1.1 The Engineering Design Process (1 hr)
Students will be able to:

1.1.1 Identify the steps in the design process [1.401]
1.1.2 Apply the process in the design of a simple project [1.402, 1.403]

1.2: The Design Project and Design Portfolio (1 hr)
Students will be able to:

1.2.1 List the requirements of the design portfolio [1.405]
1.2.2 Identify Design Project critical activities [1.401]
1.2.3 Develop a schedule for completion of project activities [1.402, 1.403]

1.3 Design for Manufacturing and Assembly (1 hr)
Students will be able to:

1.3.1 Explain the relationship between product design, manufacturing and assembly [1.403]
1.3.2 Demonstrate a recognition of the importance of a team approach in design, manufacturing and assembly [4.401]
1.3.3 List at least 3 of the main principles governing good design for manufacturing and assembly (DFMA) [1.403]

1.4 Demonstration #1 - The CAD/CAM/CNC Process (1 hr)
Students will be able to:

1.4.1 List the main steps that comprise the CAD/CAM process from product concept to finished product [1.403]
1.4.2 Identify computer software and equipment available in the lab/shop related to CAD/CAM [1.403, 1.405]

1.5 Design Project – Activity #1: Problem Definition (1 hr)
Students will be able to:

1.5.1 Develop a problem statement [1.401]
1.5.2 Develop design objectives and related criteria [1.401, 5.401, 5.402, 5.403]
1.5.3 Identify design constraints [1.401]

UNIT 2.0: Basic 2D CAD (7 hrs)

2.1 Overview of Basic 2D CAD Functions (1 hr)
Students will be able to:

2.1.1 Identify the command input, status display, menu areas, drawing window, and toggle areas of the CAD interface [1.403, 1.405]
2.1.2 Identify the commands used to create basic 2D objects including point, line, circle, arc, rectangle, and polygon [1.403, 1.405]
2.1.3 Identify the commands used to modify basic 2D objects including trim, extend, offset, copy, move, rotate, and stretch
2.1.4 Identify the display manipulation commands for panning and zooming
2.1.5 Start\Open\Save a 2D CAD drawing [1.403, 1.405]

2.2 Basic 2D Object Drawing, Modifying and Display – Project #1 (3 hrs)
Students will be able to:

2.2.1 Create basic 2D objects including point, line, circle, arc, rectangle, and polygon [1.403, 1.405]
2.2.2 Apply object snaps in the creation of basic 2D objects [1.403, 1.405]
2.2.3 Use absolute, relative and polar co-ordinate entry in the creation of basic 2D objects [1.403, 1.405]
2.2.4 Use trim, extend, offset, rotate, move, fillet, chamfer, copy and stretch commands to modify 2D objects [1.403, 1.405]

2.3 Dimensioning, Plotting and File Export – Project #1 (1 hr)
Students will be able to:

2.3.1 Use the dimension commands to define a dimension style [1.403, 1.405]
2.3.2 Use the dimension commands to apply bi-directional dimensions to a multi-view 2D drawing [1.403, 1.405]
2.3.3 Use the plot commands to set-up and plot a multi-view 2D drawing [1.403, 1.405]
2.3.4 Use the save command to output a 2D CAD drawing in a format suitable for import into CAM [1.403, 1.405]

2.4 Project #2 – 2D CAD (2 hrs)
Students will be able to:

2.4.1 Use basic create and modify tools to develop a single view drawing for export to CAM [1.403, 1.405]

UNIT 3.0: CNC Programming Basics (7 hrs)

3.1 Overview and History of CNC Machines (1 hr)
Students will be able to:

3.1.1 Identify the major events in the historical evolution of CNC machines [3.404]
3.1.2 List the advantages\disadvantages of CNC machining when compared to traditional manual machining [1.401, 1.403]
3.1.3 Describe the basic operation of CNC machines [2.404]

3.2 General CNC Machine Types and Applications (1 hr)
Students will be able to:

3.2.1 Identify an industrial application for CNC turning, CNC milling, CNC bending and CNC cutting [3.404]
3.2.2 Describe the general construction and capabilities of a CNC lathe [2.404]
3.2.3 Describe the general construction and capabilities of a CNC milling machine [2.404]
3.2.4 Explain the basic operation of CNC machine controllers [2.404]

3.3 CNC Programming: G & M Codes – Project #1 (3 hrs)
Students will be able to:

3.3.1 Explain the relationship between CNC programs and CNC machine operation [2.404]
3.3.2 Differentiate between Blocks, Words, and Address characters used in CNC programs [2.404]
3.3.3 Differentiate between preparatory G codes and miscellaneous M codes used in CNC programs [2.404]
3.3.4 Differentiate between absolute and incremental co-ordinates [1.401]
3.3.5 Identify the G or M codes for linear interpolation, circular interpolation, rapid traverse, absolute mode, incremental mode, spindle on/off, coolant on/off, tool change, and program end [2.404]

3.4 Project #2 – Basic CNC programming (2 hrs)
Students will be able to:

3.4.1 Use a CNC text editor to develop a CNC program for a simple 2D shape [2.403]
3.4.2 Use a CNC program simulator to verify a CNC program for a simple 2D shape [2.403]

UNIT 4.0: Shop CNC Machine Operation (15 hrs)

4.1 Machining Basics (3 hrs)
Students will be able to:

4.1.1 Identify the common tools used for turning and milling [2.404]
4.1.2 Determine the optimal speeds and feeds for machining of various materials including wood, metals, and plastics [2.401]
4.1.3 Overview jig and fixture requirements for machining [2.401]
4.1.4 Demonstrate proper set-up of the shop CNC machine [2.401]

4.2 The Shop CNC Machine Safety Rules/Guidelines (1 hr)
Students will be able to:

4.2.1 State the general shop rules [5.402]
4.2.2 Identify potential hazards in the shop environment [5.402, 5.403]
4.2.3 Recognize the need to consult Material Data Safety Sheets (MSDS) when handling chemicals [5.402, 5.403]
4.2.4 Demonstrate proper procedure for handling shop emergencies [5.402, 5.403]

4.3 The Shop CNC Machine Construction and Operation – Project #1 Demonstration (1 hr)
Students will be able to:

4.3.1 Identify the main components of the shop CNC machine [2.404]
4.3.2 Explain the general operation of the shop CNC machine [2.404]
4.3.3 Identify the safety features of the shop CNC machine operation [5.402]

4.4 Project #1 to #6 - CNC Production by Student (6 hrs)
Students will be able to:

4.4.1 Upload a CNC program to cut a simple 2D shape to the shop CNC machine [2.403]
4.4.2 Perform CNC program verification and define tools, feeds, and speeds[2.401, 2.403]
4.4.3 Identify the required clamp, fixture and/or jig for positioning/holding of stock [2.405]
4.4.4 Set-up stock and establish origin and tool(s) reference(s) [2.401]
4.4.5 Operate the shop CNC machine to produce a simple 2D shape [1.403, 2.401]

4.5 Design Project - CNC Production by Student (4 hrs)
Students will be able to:

4.5.1 Upload a CNC program to cut the design project to the shop CNC machine [2.403]
4.5.2 Perform CNC program verification and define tools, feeds, and speeds[2.401, 2.403]
4.5.3 Identify the required clamp, fixture and/or jig for positioning/holding of stock [2.405]
4.5.4 Set-up stock and establish origin and tool(s) reference(s) [2.401]
4.5.5 Operate the shop CNC machine to produce a simple 2D shape [1.403, 2.401]

UNIT 5.0: 3D CAD Design Software (19 hrs)

5.1 3D CAD Design Software Overview (1 hr)
Students will be able to:

5.1.1 Differentiate between CAD drafting and CAD design [2.404]
5.1.2 List the advantages/disadvantages of using 3D parametric solid modeling in the CAD/CAM process versus 2D drafting to define a part to be produced [2.404]
5.1.3 Identify the main areas of the 3D CAD design software user interface [2.404]
5.1.4 Identify the command tools available for file management, 2D profile creation/editing, 3D feature creation/editing and display manipulation [2.404]

5.2 Creating 2D Profiles and Assigning Constraints – Project #3 (2 hrs)
Students will be able to:

5.2.1 Use the 2D sketching tools to define a 2D sketch plane [2.401, 2.403]
5.2.2 Use the basic 2D sketching tools including point, line, arc, and circle in creating a 2D profile of a simple 3D part [2.401, 2.403]
5.2.3 Use the basic 2D editing tools including trim and extend in creating a 2D profile of a simple 3D part [2.401, 2.403]
5.2.4 Define 2D geometric constraints including parallel, perpendicular, horizontal, vertical, fix, and equal in creating a 2D profile of a simple 3D part [2.404]
5.2.5 Assign basic 2D geometric constraints including parallel, perpendicular, horizontal, vertical, fix, and equal in creating a 2D profile of a simple 3D part [2.401]
5.2.6 Assign, and edit, dimension constraints in creating a 2D profile of a simple 3D part [2.401]

5.3 Creating Part Features – Project #3 (2 hrs)
Students will be able to:

5.3.1 Extrude a 2D profile in creating a simple 3D part [2.401]
5.3.2 Revolve a 2D profile in creating a simple 3D part [2.401]
5.3.3 Add hole features in creating a simple 3D part [2.401]
5.3.4 Add fillet and chamfer features in creating a simple 3D part [2.401]
5.3.5 Add pattern features in creating a simple 3D part [2.401]

5.4 Project #3 – #6 3D CAD (8 hrs)
Students will be able to:

5.4.1 Develop the 3D CAD model for a simple part for export to CAM [2.401,2.403]

5.5 Design Project – 3D CAD Parts (6 hrs)
Students will be able to:

5.5.1 Develop the 3D CAD models for the design project components [2.401,2.403]

UNIT 6.0: Computer Aided Manufacturing (CAM) (19 hrs)

6.1 Overview of CAM Software and Features (1 hr)
Students will be able to:

6.1.1 Identify the main areas of the CAM software user interface [2.404]
6.1.2 Identify the command tools available for file management, 3D CAD file import, tool definition, toolpath definition, post-processing and display manipulation [2.404]

6.2 CAD File Import and Defining Tools – Project #3 CAM (2 hrs)
Students will be able to:

6.2.1 Import the 3D CAD geometry for a simple 3D part [2.401]
6.2.2 Define the stock [2.401]
6.2.3 Define the tools [2.401]

6.3 Defining Toolpaths - Project #3 CAM (2 hrs)
Students will be able to:

6.3.1 Specify feeds and speeds [2.401]
6.3.2 Define toolpaths [2.401]
6.3.3 Verify toolpaths using machining simulation [2.401]

6.4 Project #4 – #6 CAM (6 hrs)
Students will be able to:

6.4.1 Generate NC code for machining of a simple 3D part using CAM software [2.401]
6.4.2 Specify feeds and speeds [2.401]
6.4.3 Define toolpaths [2.401]
6.4.4 Verify toolpaths using machining simulation [2.401]
6.4.5 Post-process NC part file for the shop CNC machine [2.401]

6.5 Design Project – CAM (8 hrs)
Students will be able to:

6.5.1 Generate NC code for machining of a design project component using CAM software [2.401]
6.5.2 Specify feeds and speeds [2.401]
6.5.3 Define toolpaths [2.401]
6.5.4 Verify toolpaths using machining simulation [2.401]
6.5.5 Post-process NC part file for the shop CNC machine [2.401]

UNIT 7.0: 3D CAD Design Software Intermediate (35 hrs)

7.1 Assembly, Render and Animate Overview (1 hr)
Students will be able to:

7.1.1 Identify the command tools available for assembly, render, and animation [2.404]
7.1.2 List two advantages of using assembly constraints to build 3D CAD assemblies [2.404]
7.1.3 List two advantages of animation in engineering design [2.404]

7.2 Creating Assemblies – Design Project (2 hrs)
Students will be able to:

7.2.1 Assemble the design project components [2.401, 2.403]

7.3 Rendering and Animation – Design Project (2 hrs)
Students will be able to:

7.3.1 Render the design project assembly [2.401, 2.403]
7.3.2 Manually animate the design project assembly to simulate operation [2.401, 2.403]

7.4 Major Tutorial #1 and #2 (10 hrs)
Students will be able to:

7.4.1 Identify the advanced command tools for 3D part feature creation, parts assembly, rendering, and animation.

7.5 Reverse Engineering Project (5 hrs)
Students will be able to:

7.5.1 Following disassembly, determine the critical dimensions for the components of a common product assembly using conventional shop metrology tools [2.401, 2.403]
7.5.2 Develop the 3D CAD part models for each component of the product assembly based on field measurements of critical dimensions using conventional shop metrology tools [2.401, 2.403]
7.5.3 Develop the rendered 3D CAD exploded assembly of the product [2.401, 2.403]
7.5.4 Animate the assembled virtual prototype of the product [2.401, 2.403]

7.6 Computer Aided Engineering (5 hrs)
Students will be able to:

7.6.1 Explain the purpose of engineering analysis in design [1.403]
7.6.2 Identify the engineering analysis tools available in 3D CAD Design software [2.404]
7.6.3 Perform a basic bending stress analysis on a simply supported beam using 3D CAD Design software [2.401]
7.6.4 Perform basic hydrodynamic flow analysis on a simple 3D part using 3D CAD Design software [2.401]

7.7 Design Project – 3D CAD Assemble, Render, Animate and Present (10 hrs)
Students will be able to:

7.7.1 Develop an exploded assembly of the design project [2.401, 2.403]
7.7.2 Render an exploded assembly of the design project [2.401, 2.403]
7.7.3 Record an animation of the design project [2.401, 2.403]
7.7.4 Deliver a Powerpoint presentation describing their final design [2.401, 2.403]

UNIT 8.0: Careers in CAD/CAM/CAE (3 Hrs)

8.1 Overview Careers in CAD/CAM/CAE (1 hr)
Students will be able to:

8.1.1 Identify the various career roles in CAD, CAM, CNC, and CAE [4.401, 4.403]
8.1.2 Summarize the primary duties and responsibilities associated with each of the primary career roles in CAD, CAM, CNC, and CAM [4.401, 4.403]

8.2 Research Careers and Employment Statistics (1 hr)
Students will be able to:
8.2.1 Retrieve career descriptions for each of the primary career roles in CAD, CAM, CNC, and CAM [4.401, 4.403]
8.2.2 Retrieve employment statistics for each of the primary career roles in CAD, CAM, CNC, and CAM [4.401, 4.403]

8.3 Identify Education Programs/ Entry Pre-requisites (1 hr)
Students will be able to:

8.3.1 Determine the entrance requirements for enrollment in post-secondary studies in a CAD, CAM, CNC, or CAE related field [4.401, 4.403]
8.3.2 Summarize the key topics of study in a post-secondary program of study aimed at a career in CAD, CAM, CNC, and CAE related field [4.401, 4.403]

Student Assessment and Evaluation

The recommended student assessment for Design and Fabrication 2212 reflects the problem-based learning approach and emphasizes the importance of the design portfolio and prototype. It is recommended that the design project account for a significant portion of a student's assessment with both the design portfolio documentation and the performance of the physical prototype being considered. Student participation throughout the course should also be considered given the frequency of group work and related discussions in this course. Finally, the use of the more conventional class/lab assignments and unit quizzes should also be considered in the assessment of the students. Overall, it is recommended that students be assessed in accordance with the following guideline:

Participation	20%
Design Portfolio	30%
Prototype Performance	20%
Class/Lab Assignments	10%
Quizzes	20%

Suggested Delivery Schedule

Design and Fabrication 2212 introduces students to the advanced technologies being used today in engineering design and manufacturing including 2D and 3D Computer Aided Design and Drafting (CADD) software, Computer Numerical Control (CNC) programming, Computer Aided Manufacturing (CAM) software and Computer Numerical Control (CNC) machining systems. Through participation in group labs and the major group Design Project, students also learn the value of the collaborative approach to problem-solving in engineering and manufacturing.

The suggested course delivery schedule presented in table 1, "Suggested Delivery Schedule for Design and Fabrication 2212" immerses students in a problem-based learning environment in which they actually experience each step of the CAD/CAM/CNC process through the completion of a number of hands-on shop exercises, independent study tutorials and a major Design Project. The suggested schedule assumes a class size of 22 students subdivided into 11 groups of 2 students per group. Group work is encouraged since it helps students to recognize the value of the collaborative approach used in industry and facilitates teacher scheduling of limited shop resources, particularly the CNC machining systems. The suggested schedule also accounts for the need for direct teacher supervision of students when they are using the shop CNC machine. While the teacher is engaged in supervising the student group(s) using the shop CNC machine, the remaining student groups are assigned to independent study learning activities.

The suggested schedule spans two terms. Term 1 provides an introduction to the CAD/CAM/CNC process through which students develop a basic knowledge of and proficiency in using 2D CAD, 3D CAD, CNC programming, CAM, and CNC machining. The emphasis on teacher led instruction during the first four weeks of the course is intended to ensure that students acquire the basic background in CAD/CAM/CNC deemed pre-requisite to safe and effective operation of the shop CNC machine. Following this initial four weeks of instruction, the course delivery alternates between one week in the shop followed by one week of teacher led instruction in a CAD/CAM/CNC related topic area.

In term 2, students independently carry out several shop projects, complete a series of self-directed tutorials that introduce some of the more advanced features of 3D CAD, and finish CNC production and testing of their major design project. The teacher now takes on the role of facilitator while students take the lead in managing completion of assigned activities. The shop projects completed during term 2 and the major design project engage students in each step of the CAD/CAM/CNC process. In each case, students must develop the CAD model for a given design, generate the CNC program using CAM, and then produce the physical prototype using the shop CNC machine. Term 2 concludes with prototype field testing and student group presentation of their final major project design.

Table 1: Suggested Delivery Schedule for Design and Fabrication 2212

TERM 1		Group #										
Class #		1	2	3	4	5	6	7	8	9	10	11
UNIT 1.0: Engineering Design and Manufacturing (5 hrs)												
1	1.1 The Engineering Design Process (1 hr)											
2	1.2 The Design Project and Design Portfolio (1 hr)											
3	1.3 Design for Manufacturing and Assembly (1 hr)	GROUPS 1-11 TEACHER PRESENTATION - CAD/CAM/CNC DEMONSTRATION #1										
4	1.4 The CAD/CAM/CNC Process - *Demonstration #1* (1 hr)											
5	1.5 *Design Project* - Activity #1: Problem Definition (1 hr)											
UNIT 2.0: Basic 2D CAD (5 hrs)												
6	2.1 Overview of Basic 2D CAD Functions (1 hr)											
7	2.2 Basic 2D Object Drawing, Modifying and Display - *Project #1* (3 hrs)	GROUPS 1-11 TEACHER GUIDED TUTORIAL - PROJECT #1 CAD										
8												
9												
10	2.3 Dimensioning, Plotting and File Export - *Project #1* (1 hr)											
UNIT 3.0: Basic CNC Programming (5 hrs)												
11	3.1 Overview and History of CNC Machines (1 hr)											
12	3.2 General CNC Machine Types and Applications (1 hrs)											
13		GROUPS 1-11 TEACHER GUIDED TUTORIAL - PROJECT #1 CNC PROGRAMMING										
14	3.3 CNC Programming: G & M Codes - *Project #1* (3 hrs)											
15												
UNIT 4.0: Basic CNC Machine Operation (5 hrs)												
16	4.1 Machining Basics (3 hrs)											
17												
18		GROUPS 1-11 TEACHER PRESENTATION – CNC PRODUCTION PROJECT #1										
19	4.2 The Shop CNC Machine Safety Rules/ Guidelines (1 hr)											
20	4.3 The Shop CNC Machine Construction/ Operation – *Project #1* CNC Production (1 hr)											
CNC Shop #1												
21	Legend for Student Group Activities:	A1	A1	B1	B1	B1	B1	B1	B1	B1	B1	B1
22	A1 = CNC Production - *Project #1* (1 hr)	B1	B1	A1	A1	B1	B1	B1	B1	B1	B1	B1
23	B1 = Basic 2D CAD - *Project #2* (2 hrs)	B1	B1	B1	B1	A1	A1	C1	C1	C1	C1	C1
24	C1 = Basic CNC Programming - *Project #2* (2 hrs)	C1	C1	C1	C1	C1	C1	A1	A1	C1	C1	C1
25		C1	C1	C1	C1	C1	C1	C1	C1	A1	A1	A1

Table 1: Suggested Delivery Schedule for Design and Fabrication 2212 (Continued)

TERM 1		Group #										
Class #		1	2	3	4	5	6	7	8	9	10	11
UNIT 5.0: 3D CAD Design Software Basics (5 hrs)												
26	5.1 3D CAD Design Software Overview	GROUPS 1-11 TEACHER GUIDED TUTORIAL – PROJECT #3 3D CAD										
27	5.2 Creating 2D Profiles and Assigning Constraints – *Project #3* (2 hrs)											
28												
29	5.3 Creating Part Features – *Project #3* (2 hrs)											
30												
CNC Shop #2												
31	Legend for Student Group Activities:	A2	A2	B2	B2	B2	B2	B2	B2	B2	B2	B2
32	A2 = CNC Production - *Project #2* (1 hr)	B2	B2	A2	A2	B2	B2	B2	B2	B2	B2	B2
33	B2 = 3D CAD - *Project #3* (2 hrs)	B2	B2	B2	B2	A2	A2	C2	C2	C2	C2	C2
34	C2 = *Design Project* - Activity #2: 3D CAD Parts (2 hrs)	C2	C2	C2	C2	C2	C2	A2	A2	C2	C2	C2
35		C2	C2	C2	C2	C2	C2	C2	C2	A2	A2	A2
UNIT 6.0: Computer Aided Manufacturing (CAM) (5 hrs)												
36	6.1 Overview of CAM Software and Features (1 hr)	GROUPS 1-11 TEACHER GUIDED TUTORIAL – PROJECT #3 CAM										
37	6.2 CAD File Import, Defining Tools – *Project #3* CAM (2 hrs)											
38												
39	6.3 Defining Toolpaths – *Project #3* CAM (2 hrs)											
40												
CNC Shop #3												
41	Legend for Student Group Activities:	A3	A3	B3	B3	B3	B3	B3	B3	B3	B3	B3
42	A3 = CNC Production - *Project #3* (1 hr)	B3	B3	A3	A3	B3	B3	B3	B3	B3	B3	B3
43	B3 = 3D CAD - *Project #4* (2 hrs)	B3	B3	B3	B3	A3	A3	C3	C3	C3	C3	C3
44	C3 = CAM - *Project #4* (2 hrs)	C3	C3	C3	C3	C3	C3	A3	A3	C3	C3	C3
45		C3	C3	C3	C3	C3	C3	C3	C3	A3	A3	A3
UNIT 7.0: 3D CAD Design Software Intermediate (5 hrs)												
46	9.1 3D CAD Assembly, Render and Animate Overview	GROUPS 1-11 DESIGN PROJECT – ASSEMBLY, RENDER AND ANIMATION										
47	9.2 Creating Assemblies (2 hrs)											
48												
49	9.3 Rendering and Animation (2 hrs)											
50												
CNC Shop #4												
51	Legend for Student Group Activities:	A4	A4	B4	B4	B4	B4	B4	B4	B4	B4	B4
52	A4 = Project #4 - CNC Shop (1 hr)	B4	B4	A4	A4	B4	B4	B4	B4	B4	B4	B4
53	B4 = *Design Project* - Activity #3: 3D CAD Parts (4 hrs)	B4	B4	B4	B4	A4	A4	B4	B4	B4	B4	B4
54		B4	B4	B4	B4	B4	B4	A4	A4	B4	B4	B4
55		B4	B4	B4	B4	B4	B4	B4	B4	A4	A4	A4

****** END OF TERM 1******

Table 1: Suggested Delivery Schedule for Design and Fabrication 2212 (Continued)

		TERM 2									
		CAD/CAM/CNC Projects/Tutorials									
		Group #									
Class #	1	2	3	4	5	6	7	8	9	10	11
56	3D CAD Major Tutorial #1 (5 hrs)								Project #5 - CAD/CAM/CNC (5 hrs)	
57											
58											
59											
60											
61	Design Project – Activity #5: CAD/CAM/CNC (5 hrs)						Project #5 CAD/CAM/ CNC (5 hrs)		3D CAD Major Tutorial #1 (5 hrs)	
62											
63											
64											
65											
66	3D CAD Major Tutorial #2 (5 hrs)				Project #5 - CAD/CAM/ CNC (5 hrs)		Design Project – Activity #5: CAD/CAM/CNC (5 hrs)			
67											
68											
69											
70											
71	Design Project – Activity #6: CAD/CAM/CNC (5 hrs)		Project #5 - CAD/CAM/ CNC (5 hrs)		3D CAD Major Tutorial #2 (5 hrs)				
72											
73											
74											
75											
76	Project #5 - CAD/CAM/ CNC (5 hrs)		Design Project – Activity #6: CAD/CAM/CNC (5 hrs)							
77											
78											
79											
80											

Table 1: Suggested Delivery Schedule for Design and Fabrication 2212 (Continued)

Class #	1	2	3	4	5	6	7	8	9	10	11
	TERM 2										
	CAD/CAM/CNC Projects/Tutorials										
	Group #										
81	3D CAD Reverse Engineering Project (5 hrs)								Project #6 - CAD/CAM/CNC (5 hrs)		
82											
83											
84											
85											
86	Design Project – Activity #7: CAD/CAM/CNC (5 hrs)						Project #6 - CAD/CAM/CNC (5 hrs)		3D CAD Reverse Engineering Project (5 hrs)		
87											
88											
89											
90											
91	3D CAD Computer Aided Engineering Tutorial (5 hrs)					Project #6 - CAD/CAM/CNC (5 hrs)	Design Project – Activity #7: CAD/CAM/CNC (5 hrs)				
92											
93											
94											
95											
96	Design Project – Activity #8: CAD/CAM/CNC (5 hrs)		Project #6 - CAD/CAM/CNC (5 hrs)		3D CAD Computer Aided Engineering Tutorial (5 hrs)						
97											
98											
99											
100											
101	Project #6 - CAD/CAM/CNC (5 hrs)		Design Project – Activity #8: CAD/CAM/CNC (5 hrs)								
102											
103											
104											
105											
	UNIT 8.0: Careers in CAD/CAM/CAE (3 Hrs)										
106	8.1 Overview Careers in CAD/CAM/CAE										
107	8.2 Research Careers and Employment Statistics										
108	8.3 Identify Education Programs and Entry Pre-requisites										
109	DESIGN PROJECT – ACTIVITY #9: STUDENT GROUP PROTOTYPE DEMONSTRATION AND PRESENTATION OF DESIGN (2 hrs)										
110											

****** END OF TERM 2******

The shop projects chosen should progressively challenge the students. Projects #1 and #2 should be able to be completed using 2D CAD and manual CNC programming. This will allow students to reinforce the basic knowledge and proficiency considered pre-requisite to 3D CAD and CAM. Projects #3-#6 should be of increasing complexity and incorporate 3D CAD and CAM. The design project should synthesize concepts learned throughout the course. Suggested demonstrations, projects, tutorials are presented on the following page.

Suggested Demonstrations/Projects/Tutorials:

Demonstration #1:

CNC Router - Shop Door Course Nameplate
Teacher introduces the CAD/CAM/CNC process by demonstrating each step through the production of a simple wooden nameplate for the shop door using the CNC router.

OR

CNC Lathe – Single Stepped Shaft
Teacher introduces the CAD/CAM/CNC process by demonstrating each step through the production of a stepped shaft using the CNC lathe.

Project #1:

CNC Router - Personalized Student Nameplate
Students repeat the CAD/CAM/CNC process demonstrated by the teacher by producing a personalized door nameplate with their initials.

OR

CNC Lathe – Multi-stepped Shaft
Students repeat the CAD/CAM/CNC process demonstrated by the teacher by producing a Multi-stepped shaft.

Project #2:

CNC Router – Mold
Students create the 2D CAD files for a simple mold to produce various jello shapes.   Students then write the CNC program for their production using the shop CNC router. A simple text editor or a freeware CNC editor, such as AutoEdit NC, is recommended at this stage for development of the CNC program. After completing the CNC program, students produce the mold using the shop CNC router.

OR

CNC Lathe – Mini Pool Stick
Students create the 2D CAD files for a scaled model of a pool stick, essentially a tapered shaft, and then write the CNC program for its production using the shop CNC lathe. A simple text editor or a freeware CNC editor, such as AutoEdit NC, is recommended at this stage for development of the CNC program. After completing the CNC program, students produce the mini pool stick using the shop CNC lathe.

Suggested Demonstrations/Projects/Tutorials (cont.'d):

Project #3:

CNC Router - Crib board
Students create the 3D CAD files for a crib board and then develop the CNC program for production using the shop CNC router using CAM software such as FeatureCAM or MasterCAM. After posting the CNC program, students produce the crib board using the shop CNC router.

OR

CNC Lathe – Gear Shifter Knob
Students create the 3D CAD files for a wooden gear shifter knob and then develop the CNC program for production using the shop CNC lathe using CAM software such as FeatureCAM or MasterCAM. After posting the CNC program, students produce the gear shifter knob using the shop CNC lathe.

Project #4:

CNC Router – Sunglasses Case (Top and Bottom Pieces)
Students create the 2D CAD files for the top and bottom pieces of a wooden case for sunglasses then write the CNC program for their production using the shop CNC router. A simple text editor or a freeware CNC editor, such as AutoEdit NC, is recommended at this stage for development of the CNC program. After completing the CNC program, students produce the case pieces using the shop CNC router.

OR

CNC Lathe – Candlestick Holder
Students create the 3D CAD files for a wooden candlestick holder and then develop the CNC program for production using the shop CNC lathe using CAM software such as FeatureCAM or MasterCAM. After posting the CNC program, students produce the holder using the shop CNC lathe.

Project #5:

CNC Router – Techno Doll Rocker
Students create the 3D CAD files for a doll-sized wooden rocking chair and then develop the CNC program for production using the shop CNC router using CAM software such as FeatureCAM or MasterCAM. After posting the CNC program, students produce the rocker pieces using the shop CNC router.

OR

CNC Lathe – Drum Stick
Students create the 3D CAD files for a drumstick and then develop the CNC program for production using the shop CNC lathe using CAM software such as FeatureCAM or MasterCAM. After posting the CNC program, students produce the drumstick using the shop CNC lathe.

Suggested Demonstrations/Projects/Tutorials (cont.'d):

Project #6:

CNC Router – Personalized Picture Frame
Students create the 3D CAD files for a personalized picture frame and then develop the CNC program for production using the shop CNC router using CAM software such as FeatureCAM or MasterCAM. After posting the CNC program, students produce the frame using the shop CNC router.

OR

CNC Lathe – Wooden Vase
Students create the 3D CAD files for a wooden vase and then develop the CNC program for production using the shop CNC lathe using CAM software such as FeatureCAM or MasterCAM. After posting the CNC program, students produce the vase using the shop CNC lathe.

3D CAD Major Tutorial #1:

SolidWorks Mountain Skateboard Tutorial
In this tutorial, students design and analyze a mountain skateboard. Individual 3D parts are created and then assembled into several subassemblies. 2D drawings are then created for several of the parts for manufacture. The various part components of the mountain skateboard are then assembled and analyzed for strength using the COSMOS computer aided engineering analysis utility to make sure they are strong enough to meet their intended use.   Finally, using PhotoWorks and Animator, photorealistic images and animations of the project are prepared.

3D CAD Major Tutorial #2:

SolidWorks Trebuchet Tutorial
In this tutorial, students design a trebuchet using Solidworks. They create the parts, assemblies, and drawings for the Trebuchet assembly and perform strengths analysis on key components using the COSMOS computer aided engineering utility.

3D CAD Reverse Engineering Project:

Skateboard Reverse Engineering
In this project, students reverse engineer a skateboard. This involves dis-assembling a skateboard into its component parts or sub-assemblies, measuring the key dimensions necessary to develop 3D CAD models for each component, developing a 3D CAD assembly or virtual prototype of the skateboard, and generating 2D CAD drawings for several key components.

3D CAD Computer Aided Engineering:

SolidWorks COSMOS CO_2 Car Tutorial
In this tutorial, students design a CO_2 car by building the car body, assembling a complete car, analyzing the car drag using COSMOSFloworks, creating a photorealistic rendered image, and developing an animation.

Suggested Demonstrations/Projects/Tutorials (cont.'d):

Major Design Project:

CO_2 F1 Racing Car
Students are given a brief to design a model CO_2 powered F1 Car of the future using a CAD (Computer Aided Design) package such as SolidWorks. Once the cars are designed, the 3D CAD file for the car body is exported to a CAM (Computer Aided Manufacture) package such as FeatureCAM to generate the CNC program. The car bodies are then manufactured on the shop CNC router. Students assemble the complete car and then race their model in a time trial final presentation.

This project is modeled on the F1 in Schools competition held in the U.K., U.S. and Australia. F1 in Schools is a not-for-profit company with the aim of raising the profile of engineering as a career through the CAD/CAM Design Challenge. The Challenge has a wide base of support and major UK sponsors include The IET, Denford, Jaguar Cars, The Learning Grid, City University London, Make your Mark, The Royal Academy of Engineering and the Year in Industry. There are a wealth of resources and networks available in support of this project, which has become popular in high schools worldwide.
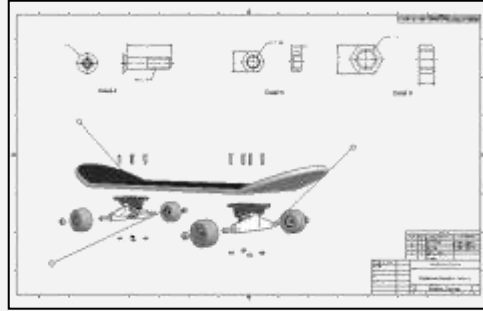
Lesson Plans

The lesson plans included in this guide address all topics in UNITS 1 to 8 and are intended as a practical resource for teachers that will both facilitate course delivery and help ensure student learning. A standard format is used for each lesson with the following main sections:

1. Specific Curriculum Outcomes – expected lesson outcomes
2. Teacher Resources - a listing of the resources required for lesson delivery
3. Student Resources - a listing of the resources required for lesson participation
4. Teacher Preparation -   online, text and other sources that can be referenced in preparation for the lesson
5. Introduction – motivation and background for the lesson
6. Presentation – detailed lesson content
7. Suggested Student Activities –   lesson related assignments, computer labs, shop exercises and projects
8. Suggested Assessment and Evaluation – assessment metric for student evaluation
9. Wrap-up and Closing – summary of the key points presented in the lesson
10. Learning Resources – summary of reference materials for the lesson

UNIT 1.0

Engineering Design And Manufacturing

Unit Overview

This unit introduces students to engineering design, advanced manufacturing processes, and the interrelation between these two fields in industry. The relationship between engineering design and manufacturing is a critical consideration for both the designer and the manufacturer. Designers must consider the constraints imposed by manufacturing technologies, operator skills and material properties. This need for a team approach is reflected in the major group design project. The teacher should encourage an interactive co-operative learning environment in which each student is given the opportunity to actively participate. An emphasis should be placed on students "learning by doing" with the teacher taking on the role of facilitator.

UNIT 1.0 provides the basis for the remaining units in Design and Fabrication 2212 and is subdivided into the following sub-units:

    1.1 The Engineering Design Process (1 hr)
    1.2 The Design Project and Design Portfolio (1 hr)
    1.3 Design for Manufacturing and Assembly (1 hr)
    1.4 Demonstration #1 - The CAD/CAM Process (1 hr)
    1.5 Design Project – Activity #1: Problem Definition (1 hr)

In sub-unit 1.1, students are introduced to each of the main steps in the engineering design process from initial design concept to physical prototype. The major group design project is then overviewed and the requirements for the design portfolio presented in sub-unit 1.2. Next, in sub-unit 1.3, the interrelationship between design and manufacturing and best practices in design that account for manufacturing early on are discussed. Students are then given an opportunity to observe the CAD/CAM process through a demonstration of the shop CNC machine in the production of a simple part in sub-unit 1.4 Finally, students, working in groups of 2, apply the engineering design process to the major design project in sub-unit 1.5 and develop the design objectives with criteria, identify constraints on the project, and brainstorm alternative conceptual design solutions.

<div style="border:1px solid black; text-align:center;">

Lesson 1.1
The Engineering Design Process

</div>

Suggested Duration: 1 hour
Suggested Format: Classroom/Computer Lab

Following completion of this lesson, students will be able to:

1.1.1 Identify the steps in the design process [1.401]
1.1.2 Apply the process in the design of a simple project [1.402, 1.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide

Student Required Resources

Teacher Handouts

Teacher Preparation

(1)   Review how the design process has expanded into a multidiscipline approach that relies on people with varied disciplines and backgrounds.

Refer to http://www.creatingtechnology.org/history.htm - 1 for an overview of the history of engineering.

(2)   Review the steps in the engineering design process.

Refer to http://iisme.org/etp/HS%20Engineering-%20Engineering.pdf. for a detailed explanation of each of the steps in the design process. This document was developed by Industry Initiatives for Science and Math Education (IISME), a consortium of San Francisco Bay Area companies in partnership with the Lawrence Hall of Science at the University of California at Berkeley.

Refer to figure 1.1-1, "The Design Process" for an illustration of the design process and figure 1.1-2, "Powered Wheelchair Design" for a case study example.

Introduction

- Overview Design and Fabrication 2212 with a focus on the Design Project

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Overview how the design process has expanded into a multidiscipline approach that relies on people with varied disciplines and backgrounds.**

A description of a common student-relevant product, such as a skateboard or IPOD, and a related discussion on the various stakeholders from engineering, manufacturing, purchasing, marketing, and sales could facilitate this.

- **Review the design process using a case study example of a common product.**

It is essential in any design that the student be familiar with the steps in the design process and the interrelationship between design and manufacturing. Using a case study example, the teacher should discuss a sample product or system that started as an identified need and evolved through the design process to a built prototype. The discussion should consider: (1) Needs identification, (2) Defining the Problem, (3) Generating Options, (4) Selecting the Best Option, (5) Developing the Solution, (6) Prototyping and Testing, and (7) Evaluation and Redesign. The cyclic nature of design should also be discussed. Refer to figure 1.1-1, "The Design Process".

The teacher should also introduce the concept of brainstorming as a means of generating design solution options for consideration.   The advantages and disadvantages of using a group approach and the associated individual group member responsibilities should also be discussed.

Suggested Student Activities

In groups of 2 or 4, students assess the current design for a common tool or product and identify needed improvements in design. Using a brainstorming approach, each student group will write a problem statement, develop design objectives with criteria, and identify any design constraints. Each group will then develop 3 different design concepts that address the needed improvements.

Assessment and Evaluation

The teacher should informally assess quality of student participation in class discussion and group participation using a rubric.

Wrap-up and Closing

- Review the steps in the design process and the need for designers to recognize the interrelation between design and manufacturing.

- Preview the next lesson on the Design Project and Design Portfolio.

Learning Resources

(1)   http://deed.ryerson.ca/~fil/t/history0.html
        This site provides a brief one- page overview of engineering design form Brunelleschi in the 14thcentury through to the 21st century. It reviews the one-person approach to engineering design by Brunelleschi and traces the evolution of engineering design to the modern team multi disciplined approach used today.

(2)   http://www.greatachievements.org/
        This site lists the top engineering achievements and how engineering shaped a century and changed the world in 20 different categories from electrification to high performance materials. The site features an historical timeline of developments in each of the 20 categories and forecasts future developments in each area.

(3)   http://www.asme.org/Communities/History/Resources/20th_Century_Achievements.cfm
        This site presents an alphabetical listing of the mechanical engineering achievements of the 20th century from agricultural mechanization to xerography. A brief summary of each achievement is provided and, in several cases, links to additional websites that further explore the topic in question are provided.

(4)   http://www.memagazine.org/supparch/medesign/index.html
        This site is sponsored by the American Society of Mechanical Engineers and provides an overview of the design process, its evolution and the multidiscipline approach required in today's design environment. The site is an excellent reference for the teacher or the student interested in further study on engineering design.

(5)   http://www.creatingtechnology.org/history.htm#1
        This site considers the history of engineering design in four distinct stages including Pre- scientific Revolution, the Industrial Revolution, the Second Industrial Revolution and Information Revolution.

(6)   http://iisme.org/etp/HS%20Engineering-%20Engineering.pdf.
        This document was developed by Industry Initiatives for Science and Math Education (IISME), a consortium of San Francisco Bay Area companies in partnership with the Lawrence Hall of Science at the University of California at Berkeley

Figure 1.1-1: The Design Process

The Design Process, as defined in the Atlantic Canada Foundation document on technology Education (2001), is essentially a methodology that can facilitate technological problem-solving. It is an iterative process that begins with an identified need or opportunity and progresses through a series of pre-defined steps to a final implemented solution. As shown in the figure below, there are six distinct steps in the process including Design Brief, Investigative Research, Generate Options, Select Best Option, Develop Solution, and Evaluate Redesign[1]. While there are numerous variations of this process contained in the literature, all include these essential steps.

The Design Process
1.   Source: Atlantic Canada Foundation Document on Technology Education (2001)

Figure 1.1-2: Powered Wheel-Chair Design

Needs Identification (Opportunities)

As lead engineer at your company, you have been requested to design a powered wheel-chair for persons with full upper body function (paraplegic).

Defining the Problem (The Design Brief and Investigative Research)

A critical first step in design is to define the problem by identifying the design objectives or goals. For each objective, criteria that quantify or qualify the design objective must be assigned. For example, "must be able to provide variable speed" is quantified as "0 to 5 km/hr". Constraints or the physical, time, and cost limitations on the design must also be considered. For example, "the retail price should not exceed $5000.00". The powered wheel-chair design must satisfy the following objectives within the criteria and constraints noted.

- Must be able to fit through standard sized doorways
- Vertical distance from the floor to the bottom of the chair seat, or knee height, should accommodate 95% of the male/female populations according to anthropometric standards;
- Must be capable of transport in a minivan or compact pick-up
- Must be able to structurally accommodate user payload for 95% of the male and female populations according to anthropometric standards;
- Must be able to provide variable speed from 0 to 5 km/hr; speed adjustment should be possible using hand-operated controls
- Must be reliable and capable of 12 hours continuous operation
- Must be equipped with brakes capable of bringing the chair to a stop from the maximum speed of 5 km/hr in a distance of 2 meters; brakes should be capable of actuation using hand-operated control; emergency manual braking to stop should be possible in a distance of 4 meters in the event of power failure
- Overall weight of unit without passenger should not exceed 80 kg.
- Retail price of unit should not exceed $5000.00
- Final design must be completed in one month

Investigative research reveals the following:

- The most common standard doorway width is 813 mm
- The available cargo space in a minivan is 1200 mm wide x 1100 mm high x 1500 mm long
- Anthropometric standards recommend a knee height of 675 mm

Generate Options

Three alternative solutions are considered:

- A commercially available powered scooter
- A commercially available powered wheel-chair

- A custom designed and built powered wheel-chair

Select Best Option

The best option is selected by comparing how well each meets the design objectives within the identified constraints. This decision is often made after developing a decision matrix. The decision matrix is essentially a comparison table which quantifies the degree to which each alternative solution meets the various objectives. For example, on a scale of 0 to 10, the expected cost of alternative #1 may be rated at 10/10 ($3500.00), that for alternative #2 at 8/10 ($4500.00), and alternative #3 at 7/10 ($5000.00). Students will have the opportunity to develop a decision matrix in Unit 6, the Design Project. The time, cost and physical constraints imposed on the design are particularly significant in selecting the best option. In this case, the best solution appears to be a commercially available powered wheel-chair custom fit to the end-user.

Develop Solution

The best solution option is developed in detail at this stage. This often involves various engineering calculations and the development of detail and assembly drawings. Following this, a physical or virtual prototype is usually produced and tested to ensure functional compliance.

Since in this case a commercially available wheel-chair appears to be the best solution, the solution is "developed" through extensive research and consultation with prospective suppliers, existing users of similar systems, and experts in the related health field. Based on this research, the C300 CS from Permobil (http://www.permobil.com/templates/ProductPage.aspx?id=1558) appears to meet all design objectives within the defined constraints.

Prototype and Testing

Since the vehicle already exists, there is no need to construct a physical prototype and then test its performance. The vehicle could be purchased and the user then monitored to determine further areas for improvement.

Evaluate and Redesign

Prototype testing will often reveal the need for improvement in a number of areas. The need to minimize weight and reduce production costs, for example, are sometimes identified at this stage. The design process essentially repeats at this stage in an effort to optimize the design – hence, design becomes a cyclic process.

In this case, preliminary use of the vehicle by the end user will likely reveal needed improvements such as leg height and other size adjustments. Other improvements may be identified that require custom modification of the vehicle. Product manufacturers often survey end-users in this manner to identify needed improvements that later appear as enhancements in future releases of their product.

Lesson 1.2
The Design Project and Design Portfolio

Suggested Duration: 1 hour
Suggested Format: Classroom/Computer Lab

Following completion of this lesson, students will be able to:

1.2.1 List the requirements of the Design Portfolio [1.405]
1.2.2 Identify Design Project critical activities [1.401]
1.2.3 Develop a schedule for completion of project activities [1.402, 1.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide

Student Required Resources

Teacher Handouts

Teacher Preparation

(1)   Review the steps in the engineering design process.

Refer to http://iisme.org/etp/HS%20Engineering-%20Engineering.pdf. for a detailed explanation of each of the steps in the design process. This document was developed by Industry Initiatives for Science and Math Education (IISME), a consortium of San Francisco Bay Area companies in partnership with the Lawrence Hall of Science at the University of California at Berkeley.

Refer to figure 1.1-1 for an illustration of the design process and figure 1.1-2 for a case study example.

(2)   Review the Design Portfolio requirements.

Refer to figure 1.2-1, "Design Project General Guidelines".

(3)   Review the F1 Racer CO_2 Car Project Guidelines

Refer to http://www.f1inschools.co.uk/rules.asp for online resources related to F1Racer CO_2 Cars. F1 in Schools is a not-for-profit company with the aim of raising the profile of engineering as a career through the CAD/CAM Design Challenge. The Challenge has a wide base of support and major UK sponsors include BAE SYSTEMS, Jaguar Cars, Denford, SEMTA, ETB and UGS PLM Solutions.

Introduction

- Engineering design is an iterative process and documentation of this process is essential to justifying and communicating the final proposed design solution. Literature research, group meetings, brainstorming activities and expert consultation are just some of the many ongoing activities for which records should be kept. Similarly, student groups will be required to document such activities over the duration of the Design Project in a Design Portfolio.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Overview the major group Design Project, how each step in the design process will be followed and how CAD/CAM/CNC will be incorporated.**

In view of resource availability, class size, and the need for direct teacher supervision of students in the shop, it is suggested that one common project be assigned to each group. Further, the design brief including the general problem statement and specific guidelines for the project, should be provided by the teacher. Student groups would then be required to identify the critical project activities, estimate associated timelines and manage the project to completion.

One recommended project that incorporates the CAD/CAM/CNC process, demonstrates the interrelation between design and manufacturing, and actively engages high school students by giving them control over learning is the F1 Racer CO_2 Car project. This project has been well proven by schools worldwide at both the secondary and post-secondary levels as an excellent application of engineering design and CAD/CAM/CNC. There is also a wealth of available technical support and participant networks that teachers and students can resource during completion of the Design Project. In addition, the main component of the CO_2 car, the body, may be produced using a CNC router, manually using files and sandpaper, or through a combination of these operations.

- **Discuss the Design Portfolio Requirements.**

Use figure 1.2-1, "Design Project General Guidelines" to facilitate discussion of the required design portfolio contents, good record keeping practices, and the project log.

Suggested Student Activities

Following review of the design brief, each student group will develop a list of critical project activities with estimated durations. The teacher, through an interactive class discussion, should then facilitate compilation of a single "master" list with associated timelines which will be used by all student groups to guide project activities.

Assessment and Evaluation

Students evaluated based on group participation as rated on a rubric.

Wrap-up and Closing

- Review the Design Project tasks and timelines from the master list.

- Preview the next lesson on design for manufacturing and assembly.

Learning Resources

(1)   http://iisme.org/etp/HS%20Engineering-%20Engineering.pdf.
This document was developed by Industry Initiatives for Science and Math Education (IISME), a consortium of San Francisco Bay Area companies in partnership with the Lawrence Hall of Science at the University of California at Berkeley

(2)   http://www.f1inschools.co.uk/rules.asp
An online resource related to F1Racer CO2 Cars. F1 in Schools is a not-for-profit company with the aim of raising the profile of engineering as a career through the CAD/CAM Design Challenge. The Challenge has a wide base of support and major UK sponsors include BAE SYSTEMS, Jaguar Cars, Denford, SEMTA, ETB and UGS PLM Solutions.
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Figure 1.2-1: Design Project General Guidelines

Group Organization:

The group members must be compatible and have skills that complement each other. The members of the group must also have commitment to each other and to the project. Personalities, work ethics and attitudes must also be considered in formation of the project groups. The teacher will have to draw on their professional and observational skills when forming the groups. Student input on team composition is vital.

Design Portfolio:

A portfolio is a folder that contains papers or drawings. In the case of an engineering design, the portfolio contains all of the materials related to the design of a product or service. The portfolio is the record of the whole process and the work involved in the engineering process from the initial problem statement to the final project report.

All of the work related to the project including phone calls, e-mail and other correspondence must be kept. These records are essential to the actual project and any related activities. Electronic and hard copies must be kept and organized. A filing system has to be developed and implemented.

The first thing that the students will have to do is to present the teacher with a design brief or proposal. This brief will be the start of their design portfolio and the following is a suggested format:

1. Problem statement
2. Identification of the need for the project
3. Background and description of any existing system
4. Project constraints
5. Project goals and objectives
6. Criteria to determine the successful completion of the goals and objectives
7. A schedule and timeline for completion of project activities
8. Physical and financial resources required to complete the project

Record Keeping:

There will be a lot of information involved with each project including research, meetings, progress reports, drawings and other documents. The efficiency of a project will depend to a large extent on the ability to store and retrieve data when needed. Therefore organization of information is vital. This is where the group has to decide on how they are going to store their data and who will maintain security and access. As an example how are they going to handle computer files? If everyone in the group has access to all files, what happens if someone makes a change to a file without consulting the other members? Who is going to be responsible for the research file? The drawing files? How about security of backup files?

The computer files cause the least physical problem but there are physical problems caused by hard copies of meetings, notes, drawings etc. Each design team will have to devise a filing system to handle this.   A common mistake for beginners is to let the paper and other records pile up until they become frustrated by the inability to find material and then they panic. Taking the time to organize material at the beginning of the project and continually updating it will make the project easier.

Project Log:

One important piece of record keeping is the project log. This is a record of how things are progressing on the project and includes records of meetings, important milestones in the project, research activities etc. All designers use these log books and a suggested basic layout is shown below:

Design and Fabrication 1212

Project Log Book

(Project Name)

(Team Members)

(Teacher)

Date:_____   **Recorder:**_____

Things to Do Today (Action List)	Appointments And Scheduled Events		Phone Calls E-mail Faxes Letters	Expenses
	Time	Place Subject		
	O800			
	0900			
	1000			
	1100			
	1200			
	1300			
	1400			
	1500			
	1600			

Project Name Detail of Meetings, Summary of Activities Decisions	Time (Hours)

Lesson 1.3
Design for Manufacturing and Assembly

Suggested Duration: 1 hour
Suggested Format: Computer Lab/Shop

Following completion of this lesson, students will be able to:

1.3.1 Explain the relationship between product design, manufacturing and assembly [1.403]
1.3.2 Demonstrate a recognition of the importance of a team approach in design, manufacturing and assembly [4.401]
1.3.3 List at least 3 of the main principles governing good design for manufacturing and assembly (DFMA) [1.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide

Student Required Resources

Teacher Handouts

Teacher Preparation

(1)   Review the design for manufacturing principles that engineers rely on to help ensure that specified product and component designs are capable of being manufactured cost effectively using available resources. These are presented as figure 1.3-1, "Principles of Design for Manufacture and Assembly".

Refer to http://www.me.berkeley.edu/ME110/presentations/DesignForManufacturingAndAssembly.pdf for an excellent overview of the design for manufacturing and design for assembly principles from Berkeley University.

Introduction

- Engineering design must consider the limitations imposed by time, cost, and physical constraints The capability of manufacturing equipment and/or equipment operators, for example, may limit the tolerance to which parts can be manufactured. Designs which don't initially consider the capability of manufacturing must be reworked and this can increase both cost and time to completion. To help ensure the limitations of manufacturing are considered early in the engineering design process, design for manufacture (DFM) and design for assembly (DFA) or DFMA guidelines have been developed.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Review the design for manufacturing principles that engineers rely on to help ensure that specified product and component designs are capable of being manufactured cost effectively using available resources.**

Using some common simple product to illustrate, the teacher should review the DFMA principles with the students. The teacher should also emphasize that this collaboration between engineering design and manufacturing will be needed throughout the entire design process as designs will evolve over time. Refer to figure 1.3-1, "Principles of Design for Manufacture and Assembly".

Suggested Student Activities

In groups of 2 or 4, students will study a simple common product and assess how its design does or does not adhere to DFMA principles. Groups will then develop a list of design improvements that are based on better incorporation of the principles governing DFMA.

Assessment and Evaluation

Students evaluated based on group participation as rated on a rubric.

Wrap-up and Closing

- Review the DFMA principles and the need for the designer to consider these early in the design process.

- Preview the next lesson on the CAD/CAM/CNC process.

Learning Resources

(1)   http://www.me.berkeley.edu/ME110/presentations/DesignForManufacturingAndAssembly.pdf , an excellent overview of the design for manufacturing and design for assembly principles from Berkeley University.

Figure 1.3-1: Principles of Design for Manufacture and Assembly

The primary aim of Design for Manufacturing (DFM) is to minimize the cost of production and/or time to market for a product, while maintaining an appropriate level of quality. This typically involves minimizing the number of parts in a product. Similarly, Design For Assembly (DFA) involves making attachment directions and methods simpler[1]. There are several fundamental principles governing DFM and DFA including:

- Minimize part count by incorporating multiple functions into single parts. Several parts could be fabricated by using different manufacturing processes (sheet metal forming, injection molding). Ask yourself if a part function can be performed by a neighboring part.
- Modularize multiple parts into single sub-assemblies.
- Design to allow assembly in open spaces, not confined spaces. Do not bury important components.
- Parts should easily indicate orientation for insertion. Parts should have self-locking features so that the precise alignment during assembly is not required. Or, provide marks (indentation) to make orientation easier.
- Standardize parts to reduce variety.
- Design parts so they do not tangle or stick to each other.
- Distinguish different parts that are shaped similarly by non-geometric means, such as color coding.
- Design parts to prevent nesting. Nesting is when parts are stacked on top of one another clamp to one another, for example, cups and coffee lids.
- Design parts with orienting features to make alignment easier.
- Provide alignment features on the assembly so parts are easily oriented.
- Design the mating parts for easy insertion. Provide allowance on each part to compensate for variation in part dimensions.
- Design the first part large and wide to be stable and then assemble the smaller parts on top of it sequentially.
- If you cannot assemble parts from the top down exclusively, then minimize the number of insertion direction. Never require the assembly to be turned over.
- Joining parts can be done with fasteners (screws, nuts and bolts, rivets), snap fits, welds or adhesives.

1 Source: Course Notes for Introduction to New Product Development (ME110), Berkley, University of California
http://www.me.berkeley.edu/ME110/presentations/DesignForManufacturingAndAssembly.pdf

Lesson 1.4
Demonstration #1 - The CAD/CAM/CNC Process

Suggested Duration: 1 hour
Suggested Format: Computer Lab/Shop Demonstration

Following completion of this lesson, students will be able to:

1.4.1 List the main steps that comprise the CAD/CAM process from product concept to finished product[1.403]
1.4.2 Identify computer software and equipment available in the lab/shop related to CAD/CAM [1.403, 1.405]

Teacher Required Resources

Design and Fabrication 2212 Teacher's Resource Guide
2D CAD software
CAM software
Shop CNC router
3/8" Ballnose Endmill
1" x 6" x 12" MDF wood sample
Coveralls
Safety Glasses
Safety Footwear

Student Required Resources

Teacher Handouts
Coveralls
Safety Glasses
Safety Footwear

Teacher Preparation

(1)   Review the CAD/CAM/CNC process.

Refer to http://www.answers.com/topic/cad-cam for a brief overview of the key aspects of CAD/CAM/CNC and the primary advantages of this process.

Introduction

- The CAD/CAM/CNC process enables the seamless progression from design concept to finished product without the need for the traditional engineering blueprint for interpretation by shop personnel. Currently available Computer Aided Drafting and Design (CADD) software extends on traditional 2D CAD tools by enabling the development of 3D virtual prototypes that can be animated to test functionality, analysed to assess strength, and then imported into Computer Aided Manufacturing (CAM) software. CAM software available today facilitates the multiple tool definitions and complex toolpaths that must be specified in the part program used to control Computer Numerical Controlled (CNC) machining systems.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Identify and demonstrate the steps in the CAD/CAM/CNC process.**

Using a case-study example, the teacher should identify each of the main stages in the CAD/CAM/CNC process being sure to summarize the primary activities performed and the advanced technologies used at each stage. This presentation should be followed by a demonstration of the CAD/CAM/CNC process using the available technologies in the computer lab/shop. A suggested demonstration is presented in figure 1.4-1, "The CAD/CAM/CNC Process – Demonstration #1".

Suggested Student Activities

Students will be required to participate in interactive discussions during the initial presentation and shop tour and note the primary activities and required technologies at each stage in the CAD/CAM/CNC process.

Assessment and Evaluation

Students are evaluated at the end of the shop tour by completing a multiple choice test of their ability to identify each stage in the CAD/CAM/CNC process and the related technologies employed.
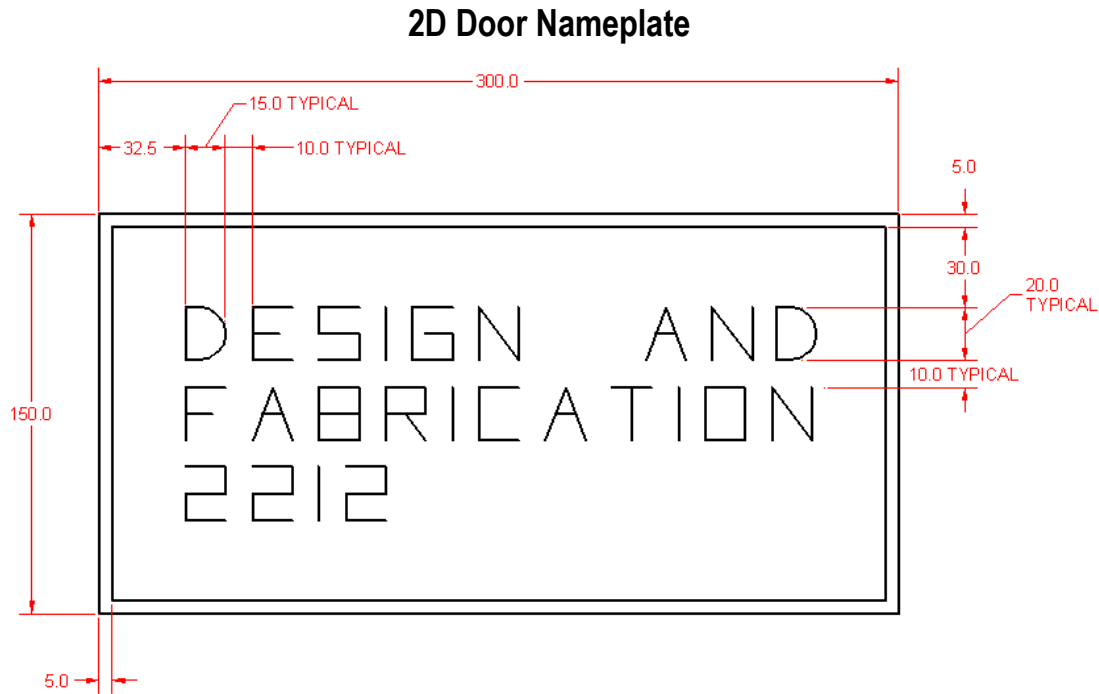
Wrap-up and Closing

- Review the CAD/CAM/CNC process using the demonstration piece to facilitate

- Preview the next lesson on the Design Project.

Learning Resources

(1)   http://www.answers.com/topic/cad-cam
         a brief overview of the key aspects of CAD/CAM/CNC and the primary advantages of this
         process from answers.com.

Figure 1.4-1: The CAD/CAM/CNC Process – Demonstration #1

Demonstrate each step in the CAD/CAM/CNC process required to create the simple 2D door nameplate shown below. Emphasis should be on defining each step in the process, explaining how each is related, and identifying the software and equipment technologies used. A 1" x 6" x 12" prepared piece of MDF stock is required. A 3/8" ballnose milling tool can be used to engrave the letters.

2D Door Nameplate

Step 1: Create the 2D CAD Drawing using AutoSketch. The completed drawing should be produced before the demonstration. Each letter should be created using basic line and arc objects. The edge of the stock and framing can be represented using a rectangle. This will allow for manual development of a simple CNC program to cut this part in a later exercise.

Step 2: Import the 2D CAD file into ArtCAM or FeatureCAM and define the toolpaths, generate the CNC program, and post-process for the shop CNC router. The tested complete CNC program should be produced before the demonstration.

Step 3: Download the CNC program to the shop CNC router, set-up the stock, and produce the part.

Lesson 1.5
Design Project – Activity #1: Problem Definition

Suggested Duration: 1 hour
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

1.5.1 Develop a problem statement [1.401]
1.5.2 Develop design objectives and related criteria [1.401, 5.401, 5.402, 5.403]
1.5.3 Identify design constraints [1.401]

Teacher Required Resources

Design and Fabrication 2212 Teacher's Resource Guide

Student Required Resources

Teacher Handouts

Teacher Preparation

(1)   Review the major group Design Project..

Refer to http://www.f1inschools.co.uk/rules.asp, an online resource related to F1Racer CO2 Cars. F1 in Schools is a not-for-profit company with the aim of raising the profile of engineering as a career through the CAD/CAM Design Challenge. The Challenge has a wide base of support and major UK sponsors include BAE SYSTEMS, Jaguar Cars, Denford, SEMTA, ETB and UGS PLM Solutions.

Refer to http://www.rea.org.au/initiatives/sch_summ.htm, an online resource on the F1inschools Challenge from the Re-Engineering Australia Forum (REA). REA is a group of like-minded organizations from industry, government and education, working together for the future of Australian Industry and all Australians.

Introduction

- The group Design Project, as with engineering design in practice, begins with defining the problem. This usually involves developing a problem statement and identifying the design objectives along with the associated criteria. The time, cost, and physical constraints imposed on the design are also determined at this stage. This is a critical stage in the design process since the viability of a proposed solution will be judged on the basis of how well it meets these objectives.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Present the design brief for the major group Design Project.**

The teacher should review the design brief for the group Design Project with the class and then generally discuss the need for design objectives with criteria and the limitations imposed on designs by time, cost, and physical constraints. This general discussion should then be directly related to the group Design Project.

Suggested Student Activities

In groups of 2, students will develop a list of design objectives, related criteria, and design constraints for the group Design Project. The teacher, through an interactive class discussion, should then facilitate compilation of a single "master" list with design objectives, criteria, and constraints which will be used by all student groups for the Design Project.

Assessment and Evaluation

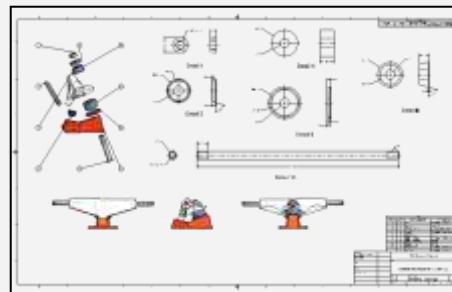Students evaluated based on group participation as rated on a rubric.

Wrap-up and Closing

- Review the compiled master list of design objectives, criteria and constraints.

- Preview UNIT 2.0: Basic 2D CAD.

Learning Resources

(1)   http://www.f1inschools.co.uk/rules.asp
        An online resource related to F1Racer CO2 Cars. F1 in Schools is a not-for-profit company with the aim of
        raising the profile of engineering as a career through the CAD/CAM Design Challenge. The Challenge has a
        wide base of support and major UK sponsors include BAE SYSTEMS, Jaguar Cars, Denford, SEMTA, ETB
        and UGS PLM Solutions.

(2)   http://www.rea.org.au/initiatives/sch_summ.htm
        An online resource on the F1inschools Challenge from the Re-Engineering Australia Forum (REA). REA is a
        group of like-minded organizations from industry, government and education, working together for the future
        of Australian Industry and all Australians.

UNIT 2.0

Basic 2D CAD

Unit Overview

2D CAD software is the tool of choice for today's designer for design detailing and subsequent development of working drawings. UNIT 2.0 moves students from the conceptual stage in the design process by introducing them to one of the main tools used to refine initial design concepts: 2D Computer Aided Drafting (CAD) software. A "hands-on" approach is emphasized through the use of a series of self-directed tutorials that allow students to develop basic proficiency in using 2D CAD to create engineering drawings and generate files for export to CAM. UNIT 2 features the following sub-units:

        2.1 Overview of Basic 2D CAD Functions (1 hr)
        2.2 Basic 2D Object Drawing, Modifying and Display – Project #1 (3 hrs)
        2.3 Dimensioning, Plotting and File Export – Project #1 (1 hr)
        2.4 Project #2 – 2D CAD (2 hrs)

In sub-unit 2.1, students are provided an overview of the function and capability of 2D CAD software through a teacher demonstration. The command tools used for drawing, modifying, and displaying 2D objects are then presented in sub-unit 2.2. Next, in sub-unit 2.3, the commands for dimensioning, plotting and file export are introduced. Finally, students are given the opportunity to apply these tools through completion of project #2 in sub-unit 2.4.

Lesson 2.1
Overview of Basic 2D CAD Functions

Suggested Duration: 1 hour
Suggested Format: Computer Lab Demonstration/Student Tutorial

Following completion of this lesson, students will be able to:

2.1.1 Identify the command input, status display, menu areas, drawing window, and toggle areas of the CAD interface [1.403, 1.405]
2.1.2 Identify the commands used to create basic 2D objects including point, line, circle, arc, rectangle, and polygon [1.403, 1.405]
2.1.3 Identify the commands used to modify basic 2D objects including trim, extend, offset, copy, move, rotate, and stretch
2.1.4 Identify the display manipulation commands for panning and zooming
2.1.5 Start\Open\Save a 2D CAD drawing [1.403, 1.405]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
AutoSketch

Student Required Resources

Teacher Handouts
AutoSketch

Teacher Preparation

(1)   Review the functions for drawing, modifying and displaying basic 2D objects in
         AutoSketch.

Refer to http://www.cadinfo.net/reviews/asketch.htm, an online overview of AutoSketch functionality by CADinfo.NET, a publication of Digital Business Media Pty Ltd which has been published online since 1996.

Refer to http://images.autodesk.com/adsk/files/4497508_AutoSketch9_GSG_imperial.pdf,
The online Getting Started Guide for AutoSketch 9.0 by AutoDesk. The Getting Started Guide provides a quick visual way to learn basic CAD concepts. The guide includes an introduction to beginning CAD concepts (making the transition from paper to CAD), an overview of the AutoSketch interface and tools, and a series of tutorials.

Introduction

- The CAD operator has to be familiar with the CAD interface before learning the methods to create and modify drawings. The teacher should provide students with an overview of the CAD interface including the drawing area, menu areas, status areas, and so on. Key identifiers and related terminology should be introduced at this stage. The optional methods available to execute commands should also be reviewed including the mouse, keyboard, and menus.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Overview the 2D CAD interface and the functions for drawing, modifying, and displaying basic 2D objects.**

The teacher will identify the various areas of the CAD interface, introduce key terminology that will be used, and demonstrate each of the basic 2D drawing/editing operations that will be studied in UNIT 2.0.

Suggested Student Activities

After the teacher demonstration, each student will complete a self-directed tutorial which introduces the CAD software interface and the basic 2D drawing/editing operations available. For this tutorial, students should read chapters 2 and 3 of the AutoSketch Getting Started Guide.

Assessment and Evaluation

Students evaluated based on a multiple choice post-test of their recall of the user interface and basic 2D drawing/editing operations.

Wrap-up and Closing

- Review the basic functionality of 2D CAD and the general approach used to draw, modify, and display basic 2D objects.

- Preview the next lesson on drawing, modifying and displaying basic 2D CAD objects.

Learning Resources

(1)   http://www.cadinfo.net/reviews/asketch.htm
An online overview of AutoSketch functionality by CADinfo.NET, a publication of Digital Business Media Pty Ltd and has been published online since 1996.

(2)   http://images.autodesk.com/adsk/files/4497508_AutoSketch9_GSG_imperial.pdf,
The online Getting Started Guide for AutoSketch 9.0 by AutoDesk. The Getting Started Guide provides a quick visual way to learn basic CAD concepts. The guide includes an introduction to beginning CAD concepts (making the transition from paper to CAD), an overview of the AutoSketch interface and tools, and a series of tutorials.

Lesson 2.2
Basic 2D Object Drawing, Modifying and Display – Project #1

Suggested Duration: 3 hours
Suggested Format: Computer Lab Demonstration/Student Tutorial

Following completion of this lesson, students will be able to:

2.2.1 Create basic 2D objects including point, line, circle, arc, rectangle, and polygon [1.403, 1.405]
2.2.2 Apply object snaps in the creation of basic 2D objects [1.403, 1.405]
2.2.3 Use absolute, relative and polar co-ordinate entry in the creation of basic 2D objects [1.403, 1.405]
2.2.4 Use trim, extend, offset, rotate, move, fillet, chamfer, copy and stretch commands to modify 2D objects [1.403, 1.405]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
AutoSketch
AutoSketch Getting Started Guide

Student Required Resources

Teacher Handouts
AutoSketch
AutoSketch Getting Started Guide

Teacher Preparation

(1)   Review the functions for drawing, modifying and displaying basic 2D objects in AutoSketch.

Refer to http://www.cadinfo.net/reviews/asketch.htm, an online overview of AutoSketch functionality by CADinfo.NET, a publication of Digital Business Media Pty Ltd and has been published online since 1996.

Refer to http://images.autodesk.com/adsk/files/4497508_AutoSketch9_GSG_imperial.pdf, The online Getting Started Guide for AutoSketch 9.0 by AutoDesk. The Getting Started Guide provides a quick visual way to learn basic CAD concepts. The guide includes an introduction to beginning CAD concepts (making the transition from paper to CAD), an overview of the AutoSketch interface and tools, and a series of tutorials.

Introduction

- In CAD, technical drawings are generally developed by drawing and modifying a number of basic elements called objects including lines, circles, arcs, and points. The drafter's first requirement in order to use CAD is the ability to accurately create these basic objects.

- During and following the creation of objects, the display may need to be modified. Display manipulation in CAD involves using one of a number of commands to control the size and position of the objects displayed on the monitor. For example, an object can be displayed at enlarged or reduced scale by using one of several ZOOM commands.

- Finally, objects have to be edited or modified. CAD software provides several commands that allow for efficient and quick editing. This is one of the advantages of using CAD.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Demonstrate the AutoSketch commands for drawing, modifying, and displaying basic 2D objects. Absolute, relative and polar co-ordinate entry as well as object snaps should also be defined and demonstrated.**

By developing a simple 2D CAD drawing, the teacher should demonstrate the commands used for drawing, modifying, and displaying. Commands demonstrated should include point, line, circle, arc, rectangle, and polygon, trim, extend, offset, rotate, move, fillet, chamfer, copy and stretch. The use of absolute, relative and polar co-ordinate entry as well as assist tools such as object snap should also be defined and demonstrated. Samples for demonstration are included as figure 2.2-1.

Suggested Student Activities

After the teacher demonstration, each student will complete a self-directed tutorial which introduces the basic 2D drawing, modifying and display tools. For this exercise, Tutorial 1 in the AutoDesk Getting Started Guide is recommended.   This tutorial is available online at http://images.autodesk.com/adsk/files/4497508_AutoSketch9_GSG_imperial.pdf. Students will then modify a copy of the teacher's 2D CAD file for figure 1.4-1 to produce a 2D CAD file of Project #1 - Personalized Student Nameplate.

Assessment and Evaluation

Students evaluated based on a multiple choice post-test of their recall of the drawing, modifying and display tools.

Wrap-up and Closing

- Review the commands used to draw, modify, and display basic 2D objects.

- Preview the next lesson on dimensioning, plotting and file export.

Learning Resources

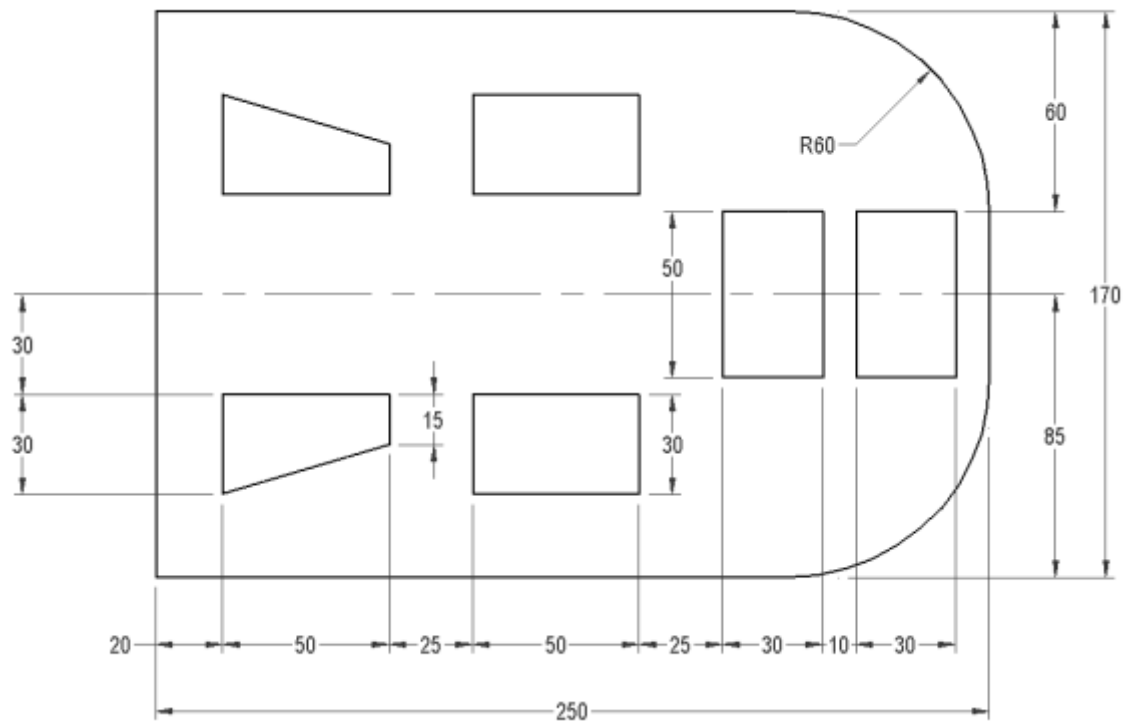(1)   http://www.cadinfo.net/reviews/asketch.htm
An online overview of AutoSketch functionality by CADinfo.NET, a publication of Digital Business Media Pty Ltd and has been published online since 1996.

(2)   http://images.autodesk.com/adsk/files/4497508_AutoSketch9_GSG_imperial.pdf,
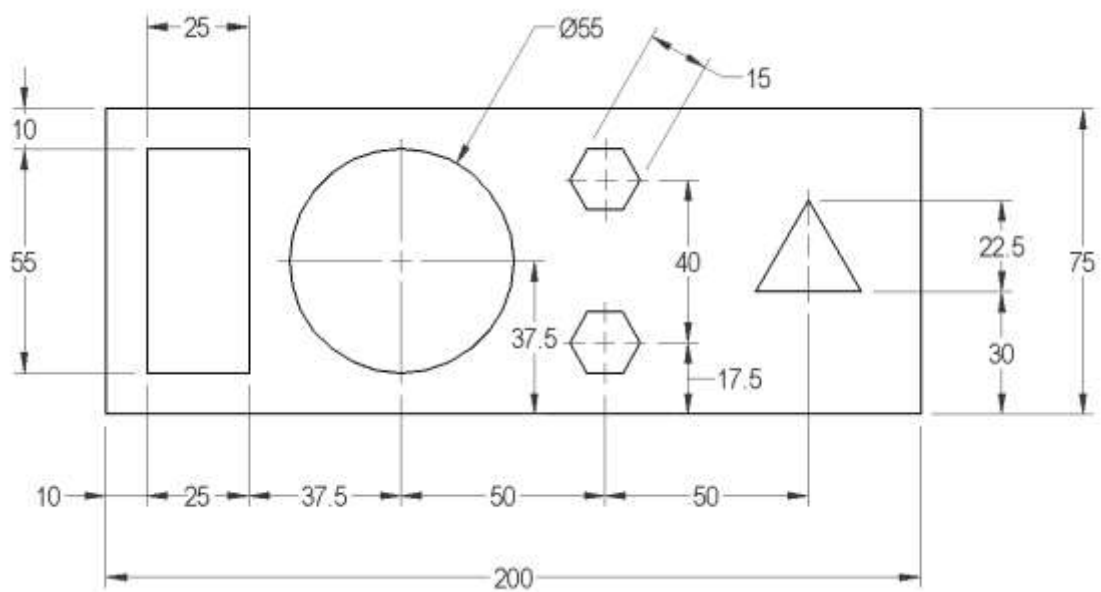The online Getting Started Guide for AutoSketch 9.0 by AutoDesk. The Getting Started Guide provides a quick visual way to learn basic CAD concepts. The guide includes an introduction to beginning CAD concepts (making the transition from paper to CAD), an overview of the AutoSketch interface and tools, and a series of tutorials.

Figure 2.2-1: Sample 2D Drawings

Gasket

Drafting Template

Lesson 2.3
Dimensioning, Plotting and File Export – Project #1

Suggested Duration:　　　　　1 hour
Suggested Format:　　　　　　Computer Lab Demonstration/Student Tutorial

Following completion of this lesson, students will be able to:

2.3.1 Use the dimension commands to define a dimension style [1.403, 1.405]
2.3.2 Use the dimension commands to apply bi-directional dimensions to a multi-view 2D drawing [1.403, 1.405]
2.3.3 Use the plot commands to set-up and plot a multi-view 2D drawing [1.403, 1.405]
2.3.4 Use the save command to output a 2D CAD drawing in a format suitable for import into CAM [1.403, 1.405]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
AutoSketch
AutoSketch Getting Started Guide

Student Required Resources

Teacher Handouts
AutoSketch
AutoSketch Getting Started Guide

Teacher Preparation

(1)　　　Review the functions for dimensioning, plotting and file export in AutoSketch.

Refer to http://www.cadinfo.net/reviews/asketch.htm, an online overview of AutoSketch functionality by CADinfo.NET, a publication of Digital Business Media Pty Ltd and has been published online since 1996.

Refer to http://images.autodesk.com/adsk/files/4497508_AutoSketch9_GSG_imperial.pdf,
The online Getting Started Guide for AutoSketch 9.0 by AutoDesk. The Getting Started Guide provides a quick visual way to learn basic CAD concepts. The guide includes an introduction to beginning CAD concepts (making the transition from paper to CAD), an overview of the AutoSketch interface and tools, and a series of tutorials.

Introduction

- While the drawing views provide the "picture" of the part, the addition of dimensions permits its fabrication. As with manual drawing, the dimensions provide the size and feature location information that fabricators need to make the part. In different technical areas the drafter will use different styles to show the dimensions and notes on a drawing. Styles can also vary for specific applications and industries.

- Although a CAD drawing is stored electronically, a hardcopy or plot is still sometimes required for reference on-site. Plotting a drawing requires consideration of the plot scale, the sheet size, and the plotting device. One of the first steps in the plotting process involves setting up the page or specifying the sheet size, plot scale, and printer type. This page setup helps ensure consistent high quality plots. The CAD/CAM/CNC process eliminates the need for a hardcopy plot and the CAD file is instead exported for use in CAM software.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Demonstrate the commands for dimensioning, plotting, and file export in AutoSketch.**

Using the sample 2D CAD drawing created in sub-unit 2.2, the teacher should demonstrate the commands used for creating dimension styles, applying bi-directional dimensions, plotting, and file exporting for CAM.

Suggested Student Activities

After the teacher demonstration, each student will complete a self-directed tutorial which introduces the basic dimensioning, plotting and file exporting tools. For this exercise, Tutorial 2 in the AutoDesk Getting Started Guide is recommended.   This tutorial is available online at http://images.autodesk.com/adsk/files/4497508_AutoSketch9_GSG_imperial.pdf. Students will then dimension, plot, and export Project #1 – Personalized Student Nameplate.

Assessment and Evaluation

Students evaluated based on dimensioning, plotting and file export of project #1.

Wrap-up and Closing

- Review the commands used to dimension, plot, and file export.

- Preview the next lesson in which students use basic draw and modify commands to develop a single view drawing for export to CAM .

Learning Resources

(1)   http://www.cadinfo.net/reviews/asketch.htm
An online overview of AutoSketch functionality by CADinfo.NET, a publication of Digital Business Media Pty Ltd and has been published online since 1996.

(2)   http://images.autodesk.com/adsk/files/4497508_AutoSketch9_GSG_imperial.pdf,
The online Getting Started Guide for AutoSketch 9.0 by AutoDesk. The Getting Started Guide provides a quick visual way to learn basic CAD concepts. The guide includes an introduction to beginning CAD concepts (making the transition from paper to CAD), an overview of the AutoSketch interface and tools, and a series of tutorials.

| Lesson 2.4 |
| Project #2 – 2D CAD |

Suggested Duration: 2 hours
Suggested Format: Computer Lab Student Exercise

Following completion of this lesson, students will be able to:

2.4.1 Use basic create and modify tools to develop a multi view drawing for export to CAM [1.403, 1.405]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
AutoSketch
AutoSketch Getting Started Guide
2D CAD software
Shop CNC router
3/8" Square End Endmill
1" x 6" x 12" Cutting Board
Coveralls
Safety Glasses
Safety Footwear

Student Required Resources

Teacher Handouts
AutoSketch
AutoSketch Getting Started Guide

Teacher Preparation

(1)   Review the functions for drawing/modifying basic 2D objects in AutoSketch.

Refer to http://www.cadinfo.net/reviews/asketch.htm, an online overview of AutoSketch functionality by CADinfo.NET, a publication of Digital Business Media Pty Ltd and has been published online since 1996.

Refer to http://images.autodesk.com/adsk/files/4497508_AutoSketch9_GSG_imperial.pdf,
The online Getting Started Guide for AutoSketch 9.0 by AutoDesk. The Getting Started Guide provides a quick visual way to learn basic CAD concepts. The guide includes an introduction to beginning CAD concepts (making the transition from paper to CAD), an overview of the AutoSketch interface and tools, and a series of tutorials.

Introduction

- The teacher should complete this exercise before assigning it to students in order to confirm the degree of difficulty and estimated time to completion. The teacher will serve only as resource expert for this exercise and students will work independently yet collaboratively with their peers. Students should be referred to the software's online help and tutorials for inquiries related to use of the various software command functions.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Briefly review the student lab exercise requirements with the class.**

Refer to figure 2.4-1, "Project # 2 – Mold".

Suggested Student Activities

Each student will develop the 2D CAD drawing for Project #2 - Mold as shown in figure 2.4-1.

Assessment and Evaluation

Students final drawing evaluated based on a rubric.

Wrap-up and Closing

- Preview the next lesson in which students dimension, plot, and file export Project #2 – Mold.

Learning Resources
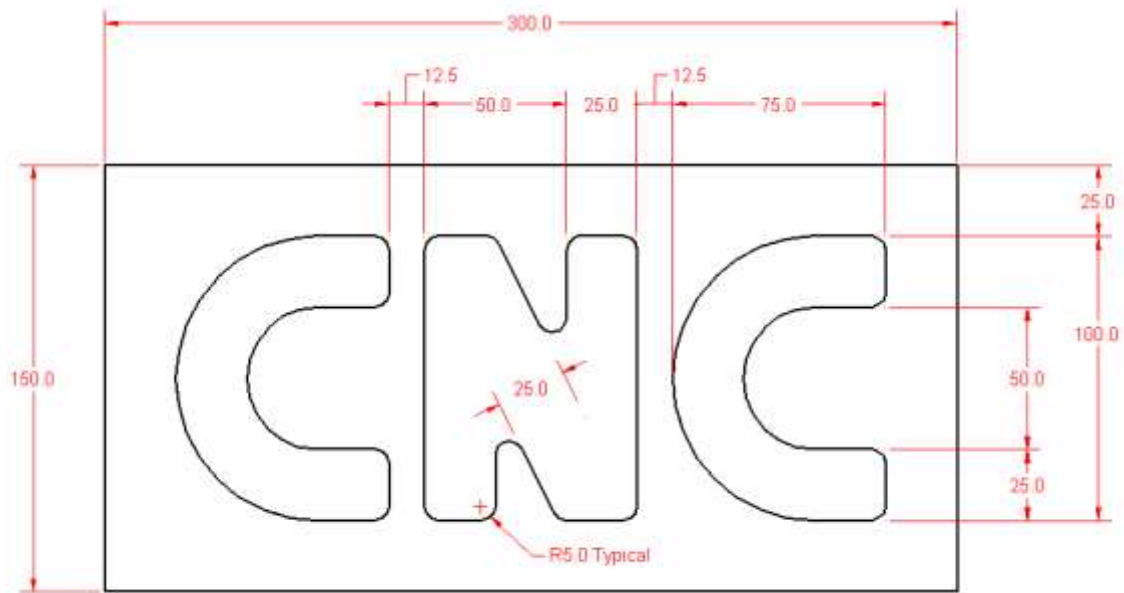
(1)   http://www.cadinfo.net/reviews/asketch.htm
An online overview of AutoSketch functionality by CADinfo.NET, a publication of Digital Business Media Pty Ltd and has been published online since 1996.

(2)   http://images.autodesk.com/adsk/files/4497508_AutoSketch9_GSG_imperial.pdf,
The online Getting Started Guide for AutoSketch 9.0 by AutoDesk. The Getting Started Guide provides a quick visual way to learn basic CAD concepts. The guide includes an introduction to beginning CAD concepts (making the transition from paper to CAD), an overview of the AutoSketch interface and tools, and a series of tutorials.

Figure 2.4-1: Project #2 - Mold

Using Autosketch, reproduce the plan view for the Mold illustrated in the drawing below.

Mold

UNIT 3.0

```
%
O0003
N10 G20 G40 G54 G80 G90 G98
N20 M06 T03
. . . .
N100M30
%
```

Basic CNC Programming

Unit Overview

UNIT 3.0 introduces students to basic Computer Numerical Control (CNC) programming with G and M codes using a text editor. This unit is considered pre-requisite to using the shop CNC machine in UNIT 4.0 and to completing UNIT 5.0 on CAM. Students learn the basic format of CNC programs and the common G and M codes used to control operation of a CNC machine through completion of the following sub-units:

       3.1 Overview and History of CNC Machines (1 hr)
       3.2 General CNC Machine Types and Applications (1 hr)
       3.3 CNC Programming: G & M Codes – Project #1 (3 hrs)
       3.4 Project #2 – Basic CNC programming (2 hrs)

In sub-unit 3.1, students review the historical evolution of the CNC machine from the manually programmed punch-tape fed numerical control (NC) machines of the early 1950s to today's advanced computer controlled machines that can be directly linked to a PC and digitally fed programs that have been automatically generated by CAM software. The common types of CNC machines available today and the related industrial applications are then overviewed in sub-unit 3.2. Next, in sub-unit 3.3, students are introduced to the common coded instructions (G and M codes) used to manually develop CNC programs using a text editor through development of the CNC program for Project #1 - Personalized Student Nameplate. Students then apply concepts learned in the manual development of a CNC program for Project #2 – Mold in sub-unit 3.4.

Lesson 3.1
Overview and History of CNC Machines

Suggested Duration: 1 hour
Suggested Format: Computer Lab/Shop Demonstration

Following completion of this lesson, students will be able to:

3.1.1 Identify the major events in the historical evolution of CNC machines [3.404]
3.1.2 List the advantages\disadvantages of CNC machining when compared to traditional manual machining [1.401, 1.403]
3.1.3 Describe the basic operation of CNC machines [2.404]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
Shop CNC router
3/8" Ballnose End-mill
1"x6"x12" hardwood stock
Stock Clamps
Exported 2D CAD File of Class Door Nameplate
Coveralls
Safety Goggles
Safety Footwear

Student Required Resources

Teacher Handouts
Coveralls
Safety Goggles
Safety Footwear

Teacher Preparation

(1)   Review the historical evolution of CNC machines.

Refer to figure 3.1-1, "History of Computer Numerical Control (CNC)".

(2)   Review the advantages/disadvantages of CNC, the general operation of CNC machines, and the shop CNC operation guidelines.

Refer to http://www.mmsonline.com/articles/cnc98intro.html, a comprehensive online series of CNC related articles for the teacher by Modern Machine Shop Online.

Refer to http://www.technologystudent.com/cam/camex.htm, an excellent online CNC resource for students by The World Association of Technology Teachers (WATT). WATT aims to support teachers/lecturers and educators across the world in the delivery of Design and Technology.

Refer to the manual for the shop CNC machine for a description of set-up and operation.

Refer to figure 3.1-2, "Advantages and Disadvantages of CNC".

Introduction

- Numerical control (NC), which was the pre-cursor to today's CNC, was developed in the early 1950s to make it possible for large quantities of a desired component to be precisely and efficiently produced (machined) in a reliable repetitive manner. An NC machine is essentially a machine that automatically operates in response to coded instructions it receives from its processing unit. Early NC machines were fed instructions using paper tape or punch cards. Today the computer has replaced this form of input and the instructions needed to control the NC machine can now be written in the form of a CNC program using a text editor. CNC programs consist of a series of coded instructions referred to as G and M codes that control the motion and actions of the machine. A G01 code, for example, would instruct the machine to move in a straight line while an M03 code would instruct the machine to turn on its spindle.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Briefly review the history of CNC and the advantages/disadvantages of this technology.**

Refer to figure 3.1-1, "History of Computer Numerical Control (CNC)" and figure 3.1-2, "Advantages and Disadvantages of CNC".

- **Introduce the shop CNC machine and its general function.**

A general description is adequate for this lesson. Safety related concerns should also be generally noted at this point.

- **Demonstrate the basic operation of a CNC machine using the shop CNC machine.**

The teacher should produce a sample of Project #1 - Personalized Student Nameplate for this demonstration. Preparatory work including CNC program development, transfer to the machine controller, stock set-up, and stock origin referencing should be completed before the demonstration. Focus should be on reinforcing student knowledge acquired through the preceding discussion on basic construction and operation.

Suggested Student Activities

Interactive class/shop discussion.

Assessment and Evaluation

Students participation in discussion evaluated based on a rubric.

Wrap-up and Closing

- Review the historical evolution, key concepts regarding construction and operation, and the advantages/disadvantages of CNC machines.

- Preview the next lesson on general CNC machine types and industry applications.

Learning Resources

(1)   http://www.mmsonline.com/articles/cnc98intro.html, a comprehensive online series of CNC related articles for the teacher by Modern Machine Shop Online.

(2)   http://www.technologystudent.com/cam/camex.htm, an excellent online CNC resource for students by The World Association of Technology Teachers (WATT). WATT aims to support teachers/lecturers and educators across the world in the delivery of Design and Technology.

Figure 3.1-1: History of Computer Numerical Control (CNC)[1]

1955   John Parsons and US Air Force define a need to develop a machine tool capable of machining complex and close tolerance aircraft parts with the same quality time after time (repeatability).   MIT is the subcontractor and builds the machine for the project.

1959   MIT announces Automatic Programmed Tools (APT) programming language

1960   Direct Numerical Control (DNC). This eliminates paper tape punch programs and allows programmers to send files directly to machine tools

1968   Kearney & Trecker machine tool builders market first machining center

1970's   CNC machine tools & Distributed Numerical Control

1980's   Graphics based CAM systems introduced. Unix and PC based systems available

1990's   Price drop in CNC technology

1997   PC- Windows/NT based "Open Modular Architecture Control (OMAC)" systems introduced to replace "firmware" controllers.

1.   Sourced from http://mfg.eng.rpi.edu/CAM/Powerpoint/CAMSYSOverview.ppt, a lecture entitled "Cam Systems and CNC Overview", by S. Chiappone, Rensselaer Polytechnic Institute, Troy, New York.

Figure 3.1- 2: Advantages and Disadvantages of CNC[2]

Advantages

1. CNC machines can be used continuously 24 hours a day, 365 days a year and only need to be switched off for occasional maintenance.
2. CNC machines are programmed with a design which can then be manufactured hundreds or even thousands of times. Each manufactured product will be the same within allowable tolerances.
3. Less skilled/trained people can operate CNCs unlike manual lathes / milling machines etc.. Manual machining of complex parts requires experienced skilled machinists.
4. CNC machines can be updated by improving the software used to drive the machines
5. Training in the use of CNC is available through the use of 'virtual software'. This is software that allows the operator to practice using the CNC machine on the screen of a computer. The software is similar to a computer game.
6. CNC machines can be programmed by advanced 3D CAD design software, enabling the manufacture of products that cannot be made by manual machines, even by the most skilled machinists.
7. Modern design software allows the designer to simulate the manufacture of his/her idea. There is no need to make a prototype or a model. This saves time and money.
8. One person can supervise many CNC machines as once they are programmed they can usually be left to work by themselves. Sometimes only the cutting tools need replacing occasionally.
9. A skilled machinist can make the same component many times. However, if each component is carefully studied, each one will vary slightly. A CNC machine will manufacture each component within precise allowable variation.

Disadvantages

1. CNC machines are more expensive than manually operated machines, although costs are slowly coming down.
2. The CNC machine operator only needs basic training and skills, enough to supervise several machines. In years gone by, machinists needed years of training to operate centre lathes, milling machines and other manually operated machines. This means many of the old skills are being lost.
3. Less workers are required to operate CNC machines compared to manually operated machines. Investment in CNC machines can lead to unemployment.
4. Many countries no longer teach pupils / students how to use manually operated lathes / milling machines etc... Pupils / students no longer develop the detailed skills required by machinists of the past. These include mathematical and engineering skills.

2.   Sourced from http://www.technologystudent.com/cam/cncman4.htm, an excellent online CNC resource for students by The World Association of Technology Teachers (WATT).

Lesson 3.2
General CNC Machine Types and Applications

Suggested Duration: 1 hour
Suggested Format: Computer Lab/Shop Demonstration

Following completion of this lesson, students will be able to:

3.2.1 Identify an industrial application for CNC turning, milling, bending and cutting [3.404]
3.2.2 Describe the general construction and capabilities of a CNC lathe [2.404]
3.2.3 Describe the general construction and capabilities of a CNC milling machine [2.404]
3.2.4 Explain the basic operation of CNC machine controllers [2.404]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
Shop CNC router
Coveralls
Safety Goggles
Safety Footwear

Student Required Resources

Teacher Handouts
Coveralls
Safety Goggles
Safety Footwear

Teacher Preparation

(1)   Review industrial applications for CNC machines.

Refer to http://www.eckelmann.de/en/cnc-steuerungen_anwendungen.html, a site by
ECKELMANN, a German company founded in 1970, that includes an extensive list of industry
applications, which incorporate the company's CNC controller product.

(2)   Review the general construction and operation of a CNC lathe and CNC milling machine.

Refer to http://en.wikipedia.org/wiki/Lathe_(metal)#Construction, the Wilkepedia reference
information on lathes and http://en.wikipedia.org/wiki/Milling_machine, the Wilkepedia reference
information on milling machines.

(3)   Review the basic operation of CNC machine controllers

Refer to http://www.mmsonline.com/articles/cnc98intro.html, a comprehensive online CNC article

series by Modern Machine Shop Online and http://www.technologystudent.com/cam/camex.htm, an excellent online CNC resource for students by The World Association of Technology Teachers.

Introduction

- In industry, CNC machines are used in a wide variety of applications such as turning, milling, bending, and cutting of metals. The CNC lathe and CNC milling machine are arguably the most common types used. CNC lathes are capable of precisely turning a high volume of complex revolved shapes, such as a stairway spindle, quickly and reliably. CNC milling machines are capable of producing complex 3D surfaces that would be impossible to produce manually, such as the curved surface of a propeller blade.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Identify and discuss common industrial applications of CNC.**

Using a slideshow or other visual, the teacher should overview the various CNC applications used in industry. The primary advantage of using this technology in each of these particular applications should also be pointed out. Local industry examples should be identified where available.

- **Identify the main components in the general construction of industrial CNC lathes and CNC mills and explain the function of each component.**

A slideshow or other visual should be used to facilitate this. The shop CNC router can also be used as an example of a CNC milling machine.

- **Explain the purpose and function of CNC machine controllers.**

A slideshow or other visual should be used to facilitate this. The basics of motion control for a CNC mill (ie. the shop CNC machine) should be discussed including the use of ball-screws, servo motors, and the need for a controller to receive/send instructions to the servo motors. The need for CNC programs that contain the coded instruction for a particular cut should be introduced.

Suggested Student Activities

Interactive class/shop discussion.

Assessment and Evaluation

Students participation in discussion evaluated based on a rubric.

Wrap-up and Closing

- Review the common industrial applications of CNC machines, the general construction and operation of CNC lathes and milling machines, and the purpose and function of controllers.

- Preview the next lesson on CNC programming.

Learning Resources

(1)   http://www.eckelmann.de/en/cnc-steuerungen_anwendungen.html, a site by ECKELMANN, a German company founded in 1970, that includes an extensive list of industry applications, which incorporate the company's CNC controller product.

(2)   http://en.wikipedia.org/wiki/Lathe_(metal)#Construction, the Wilkepedia reference information on lathes and http://en.wikipedia.org/wiki/Milling_machine, the Wilkepedia reference information on milling machines.

(3)   http://www.mmsonline.com/articles/cnc98intro.html, a comprehensive online series of CNC related articles for the teacher by Modern Machine Shop Online.

(4)   http://www.technologystudent.com/cam/camex.htm, an excellent online CNC resource for students by The World Association of Technology Teachers (WATT). WATT aims to support teachers/lecturers and educators across the world in the delivery of Design and Technology.

Lesson 3.3
CNC Programming - G & M Codes

Suggested Duration: 3 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

3.3.1 Explain the relationship between CNC programs and CNC machine operation [2.404]
3.3.2 Differentiate between Blocks, Words, and Address characters used in CNC programs [2.404]
3.3.3 Differentiate between preparatory G codes and miscellaneous M codes used in CNC programs [2.404]
3.3.4 Differentiate between absolute and incremental co-ordinates [1.401]
3.3.5 Identify the G or M codes for linear interpolation, circular interpolation, rapid traverse, absolute mode, incremental mode, spindle on/off, coolant on/off, tool change, and program end [2.404]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
AutoEdit NC or equivalent CNC Text editor preferably with graphical machining simulation

Student Required Resources

Teacher Handouts
AutoEdit NC or equivalent CNC Text editor preferably with graphical machining simulation

Teacher Preparation

(1)   Review the function of CNC programs in the control of CNC machines.

Refer to http://www.answers.com/topic/cnc, a concise overview of CNC programs by answers.com

(2)   Review the Cartesian co-ordinate system and absolute vs. relative co-ordinates.

(3)   Review G codes and M codes and their general function.

(4)   Review the programming format typically used when manually writing CNC programs using a text editor.

Refer to http://www.utm.edu/departments/engin/lemaster/Auto%20Prod%20Sys/Lecture%2025.pdf, an online lecture by Dr. R. A. LeMaster, Department of Engineering, Univeristy of Tennessee at Martin that overviews the common G and M codes and demonstrates a simple CNC program.

Introduction

- CNC machine controllers must control the various electro-mechanical systems that produce machine motion and control tool actions. These instructions are sent to the controller from a PC where they are written in the form of a CNC program. A CNC program is essentially a set of coded instructions that the machine controller interprets to determine the machine motion and tool actions.

- There are two general categories of coded instructions used to write CNC programs: G and M codes. G-codes, or preparatory functions, control the motion of the machine and/or machine tool. M-codes, or miscellaneous functions, control actions necessary for machining such as turning the spindle or coolant on/off. CNC programs are typically written in a pre-defined format of sequential "blocks" of code that include both G and M codes.

- Knowledge of the Cartesian co-ordinate system and absolute and incremental co-ordinates is an important pre-requisite to writing CNC programs.

- State the purpose of this lesson and the expected learning outcomes.

- State how this lesson relates to other topics in Design and Fabrication 2212.

- Summarize what will be covered in this lesson and the related student activity.

Presentation

- **Discuss the function of CNC programs in the control of CNC machines**

Explain how a CNC program is essentially a set of coded instructions that the machine controller interprets to determine the machine motion and tool actions. There are two general categories of coded instructions used to write CNC programs: G and M codes. CNC programs are typically written in a pre-defined format of sequential "blocks" of code that include both G and M codes. A text editor can be used to write a CNC program in a universal form that must later be translated or post-processed to suit the particular type of controller that is employed by the machine

- **Explain the Cartesian co-ordinate system and absolute vs. incremental co-ordinates.**

Using the 2D CAD drawing of sample Project #1 – Personalized Student Nameplate to help illustrate, review the basics of the Cartesian co-ordinate system and explain how absolute and relative co-ordinates can be used to geometrically describe the features.

- **Define G codes and M codes and their general function.**

G-codes or preparatory functions control the motion of the machine and/or machine tool. M-codes or miscellaneous functions control actions necessary for machining such as turning the spindle or coolant on/off. Using a CNC text editor with graphic simulation capability such as AutoEdit NC or commercial package such as ArtCAM or FeatureCAM, demonstrate the common G and M codes for linear interpolation, circular interpolation, rapid traverse, absolute mode, incremental mode, spindle on/off, coolant on/off, tool change, and program end.

- **Explain the programming format typically used when manually writing CNC programs using a text editor.**

This should be done through a demonstration during which the CNC program for sample Project #1 - Personalized Student Nameplate is written through interactive discussion with the class. The full program should be written and verified by the teacher before the demonstration. The programming demonstration should focus on introducing the available functions of the CNC text editor being used, defining blocks, word addresses, letter codes and other programming formats, and writing the blocks of code needed to cut one of the features. Students will be required to complete the remaining blocks of code.

Suggested Student Activities

Each student will complete a tutorial
http://www.utm.edu/departments/engin/lemaster/Auto%20Prod%20Sys/Lecture%2025.pdf, an online lecture by Dr. R. A. LeMaster, Department of Engineering, Univeristy of Tennessee at Martin that overviews the common G and M codes and demonstrates writing of a simple CNC program. Students will then complete writing the CNC program for Project #1 – Personalized Student Nameplate.

Assessment and Evaluation

Student's CNC program for Project #1 – Personalized Student Nameplate is evaluated based on a standard solution.

Wrap-up and Closing

- Review the purpose of CNC programs, common G and M codes, and standard CNC programming format.

- Preview the next sub-unit in which students develop the CNC program for Project #2 – Mold.

Learning Resources

(1)   http://www.answers.com/topic/cnc, a concise overview of CNC programs by answers.com.

(2)   http://www.utm.edu/departments/engin/lemaster/Auto%20Prod%20Sys/Lecture%2025.pdf,
        an online lecture by Dr. R. A. LeMaster, Department of Engineering, Univeristy of Tennessee at Martin that
        overviews the common G and M codes and demonstrates writing of a simple CNC program.

Lesson 3.4
Lesson 3.4: Project #2 – Basic CNC Programming

Suggested Duration: 2 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

3.4.1 Use a text editor to develop a CNC program for a simple 2D shape [2.403]
3.4.2 Use a CNC program simulator to verify a CNC program for a simple 2D shape [2.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
AutoEdit NC or equivalent CNC Text editor preferably with graphical machining simulation

Student Required Resources

Teacher Handouts
AutoEdit NC or equivalent CNC Text editor preferably with graphical machining simulation

Teacher Preparation

(1)   Review absolute vs. relative co-ordinates, G codes and M codes and their general
       function, and the programming format typically used when manually writing CNC programs
       using a text editor.

Refer to http://www.utm.edu/departments/engin/lemaster/Auto%20Prod%20Sys/Lecture%2025.pdf,
an online lecture by Dr. R. A. LeMaster, Department of Engineering, Univeristy of Tennessee at
Martin that overviews the common G and M codes and demonstrates a simple CNC program.

Introduction

- The basic knowledge of G and M codes that students acquire in sub-unit 3.3 should be generalized through completion of a shop exercise that requires them to manually write a CNC program to cut Project #2 – Mold.

- State the purpose of this lesson and the expected learning outcomes.

- State how this lesson relates to other topics in Design and Fabrication 2212.

- Summarize what will be covered in this lesson and the related student activity.

Presentation

- **Review the CNC program for Project #1 – Personalized Student Nameplate**

Before students begin programming, the teacher should once again demonstrate the CNC text editor software by reviewing the CNC program for Project #1 – Personalized Student Nameplate.

Following this brief demonstration, this should be a student-directed lab exercise with the teacher taking on the role of facilitator.

Suggested Student Activities

In groups of 2, the students will continue development of the CNC program to cut Project #2 – Mold using a CNC text editor to write the necessary sequence of G and M codes.

Assessment and Evaluation

Student group CNC program evaluated based on comparison to a standard solution.
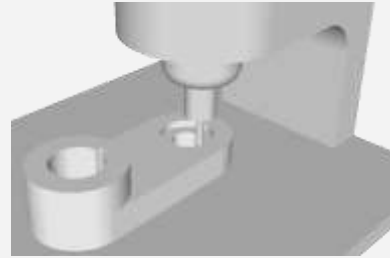
Wrap-up and Closing

- Display the verified and complete CNC program for CNC routing of Project #2 – Mold.

- Preview UNIT 4.0: Basic CNC Machine Operation.

Learning Resources

(1)   http://www.utm.edu/departments/engin/lemaster/Auto%20Prod%20Sys/Lecture%2025.pdf,
       an online lecture by Dr. R. A. LeMaster, Department of Engineering, Univeristy of Tennessee at Martin that
       overviews the common G and M codes and demonstrates writing of a simple CNC program.

UNIT 4.0

Basic CNC Machine Operations

Unit Overview

In UNIT 4.0 students progress from the basics of CNC programming to actual operation of a CNC machine. Using the CNC program for Project #2 - Mold written in sub-unit 3.4, students set-up and operate the shop CNC machine to produce their own mold. Students also revisit the shop safety rules and the construction and operation of CNC machines. UNIT 4.0 consists of the following sub-units:

> 4.1 Machining Basics (3 hrs)
> 4.2 The Shop CNC Machine Safety Rules and Guidelines (1 hr)
> 4.3 The Shop CNC Machine Construction and Operation – Project #1 Demonstration (1 hr)
> 4.4 Project #1 - #6 CNC Production by Student (6 hrs)
> 4.5 Design Project - CNC Production by Student (4 hrs)

In sub-unit 4.1, students are introduced to the basics of machining considered fundamental to the field including speeds, feeds, fixtures, and jigs. In sub-unit 4.2, students review the general shop safety rules, emergency response procedures, and safe practice when setting up and operating the shop CNC router. The construction and operation of the shop CNC machine is then discussed in detail with particular emphasis on the control software user interface in sub-unit 4.3 through a demonstration in which sample Project #1 – Personalized Student Nameplate is produced. In sub-unit 4.4, students complete production of Projects #1-#6. Finally, students produce their final design for their major design project using the shop CNC machine in sub-unit 4.5.

<div style="border:1px solid black; padding:10px; text-align:center;">

Lesson 4.1
Machining Basics

</div>

Suggested Duration: 3 hours
Suggested Format: Shop Demonstration

Following completion of this lesson, students will be able to:

4.1.1 Identify the common tools used for turning and milling [2.404]
4.1.2 Determine the optimal speeds and feeds for machining of various materials including wood, metals, and plastics [2.401]
4.1.3 Overview jig and fixture requirements for machining [2.401]
4.1.4 Demonstrate proper set-up of the shop CNC machine [2.401]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
Shop CNC router
Common milling and routing tools
Common jigs and fixtures for milling
Assorted hold-down clamps
Assorted stock samples
Safety footwear
Safety glasses
Coveralls

Student Required Resources

Teacher Handouts
Sample MSDS
Safety footwear
Safety glasses
Coveralls

Teacher Preparation

(1)   Review the basics of machining including feeds, speeds, jigs, fixtures, and tools.

Refer to http://en.wikipedia.org/wiki/Cutting_speed, the Wilkepedia reference for a comprehensive definition of feed and speed.

Refer to http://www.denford.com/Feeds%20and%20Speeds.html, for information from Denford, a CNC machine manufacturer in the U.K., on how to calculate speeds and feeds.

(2)   Review the common tools used for routing in wood.

Refer to http://www.rockler.com/articles/display_article.cfm?story_id=135, a site by Rockler Woodworking and Hardware, Minneapolis, Minnesota, US, which provides an excellent overview with graphics of the different types of router bits available and their related application

(3)   Review the available clamps, jigs and fixtures for the shop CNC router.

Refer to the user's manual for the shop CNC router.

Introduction

- The teacher through actual demonstration using the shop CNC machine will identify the common tools used for turning and milling operations. The teacher should also present an overview on determining feeds and speeds based on material type and inform students that much of this information is available for reference in the Machinery's Handbook.

- The available tools for clamping of stock and standard jigs and fixtures used for common operations should also be discussed. The proper use of the available clamping tools should then be demonstrated by completing machine set-up for several stock samples that vary in shape and size.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Discuss how material type relates to feeds and speeds in machining.**

The teacher should first define feed and speed as they relate to the shop CNC router operation and the quality of the finished part. The use of references such as the Machinery's Handbook for determining these values for a particular material should also be discussed.

- **Identify the common bit types used for routing.**

The common bit profiles available for routing of wood should be identified and the related applications discussed.

- **Identify and demonstrate the clamps, jigs and fixtures available for the shop CNC machine.**

The proper use of the available clamping tools should be demonstrated by completing machine set-up for several stock samples that vary in shape and size.

Suggested Student Activities

Students will participate in the related discussions and directly observe the process. At the end of the session, the teacher can assess student learning through use of formal or informal metrics.

Assessment and Evaluation

Student participation in the group activity will be evaluated based on a rubric. Students will also be required to complete a multiple choice test of their knowledge of concepts learned.

Wrap-up and Closing

- Review feed, speed, jigs and fixtures for CNC routing of wood.

- Preview the next sub-unit on The Shop CNC Machine Safety Rules/Guidelines.
.

Learning Resources

(1)   http://en.wikipedia.org/wiki/Cutting_speed, the Wilkepedia reference for a comprehensive definition of feed and speed.

(2)   http://www.denford.com/Feeds%20and%20Speeds.html, for information from Denford, a CNC machine manufacturer in the U.K., on how to calculate speeds and feeds.

(3)   http://www.rockler.com/articles/display_article.cfm?story_id=135, a site by Rockler Woodworking and Hardware, Minneapolis, Minnesota, US, which provides an excellent overview with graphics of the different types of router bits available and their related applications.

(4)   The shop CNC router users manual.

Lesson 4.2
The Shop CNC Machine Safety Rules/Guidelines

Suggested Duration: 1 hour
Suggested Format: Computer Lab/Shop Demonstration

Following completion of this lesson, students will be able to:

4.2.1 State the general shop rules [5.402]
4.2.2 Identify potential hazards in the shop environment [5.402, 5.403]
4.2.3 Recognize the need to consult Material Data Safety Sheets (MSDS) when handling chemicals [5.402, 5.403]
4.2.4 Demonstrate proper procedure for handling shop emergencies [5.402, 5.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
Shop CNC router
Sample MSDS
Safety footwear
Safety glasses
Full face shield
Leather gloves
Coveralls
Ear plugs
Ear muffs
Equipment Manuals

Student Required Resources

Teacher Handouts
Sample MSDS
Safety footwear
Safety glasses
Coveralls

Teacher Preparation

(1)   Review the general shop safety rules.

Refer to http://mielsvr1.ecs.umass.edu/mie213/Generalshopsafetyrules.pdf, an on-line document from the University of Massachusetts that includes both general safety rules and equipment specific safety rules samples.

Introduction

- While all shop activities, such as the use of hand tools, demand constant attention to potential hazards, the operation of CNC machines arguably requires an even stronger focus on safety given direct control of the machine is not in the hands of a human operator. Once set-up is completed and machining started, the CNC machine operator essentially takes on the role of an observer. For the initial CNC production run, the operator must constantly monitor tool actions and machine motion and interrupt the process if safety hazards appear such as a loosening clamp.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Review the shop rules governing protective clothing, emergency response, and MSDS.**

The teacher should discuss the shop rules and policies governing protective clothing, emergency response, and use of Materials Safety Data Sheets, such as those for any machining coolants. A sample MSDS should be reviewed with the class. Refer to figure 4.1–1, "Shop Emergency Response Plan" and figure 4.1–2, "Hazardous Condition Report Form".

- **The policy on clean-up and/or disposal of machining byproducts should also be discussed.**

The environmental impact of shop byproducts should be discussed and a plan for disposal, re-use, and/or recycling should be discussed.

Suggested Student Activities

In groups of 2 or 4, students generate a list of potential hazards arising from use of the shop CNC machine such as loosely clamped stock, tool breakage, and operator clothing tangles. The groups will also develop a list of how machining byproducts can be re-used, recycled and/or disposed. Each group will be required to present their findings and, through interactive class discussion, the teacher will oversee the generation of a final "master" list of these potential hazards and re-use, recycling, and disposal options.

Assessment and Evaluation

Student participation in the group activity will be evaluated based on a rubric.

Wrap-up and Closing

- Review the general shop safety rules, emergency response plan, and policy on disposal/recycling/re-use of machining byproducts.

- Preview the next lesson on the shop CNC machine construction and operation.

Learning Resources

(1)   http://mielsvr1.ecs.umass.edu/mie213/Generalshopsafetyrules.pdf, an on-line document from the University of Massachusetts that includes both general safety rules and equipment specific safety rules samples.

Figure 4.1–1: Shop Emergency Response Plan

Medical Emergencies or Injuries in the Shop

Immediately contact the course instructor or nearest other teacher. If the first aid or medical problem is beyond the scope of the teacher's training and qualifications he or she will :

1. Dial 911 or the number for the nearest medical response facility
2. State his/her name
3. Give the location of the school and the shop
4. Describe the extent of the injury or emergency
5. Request an ambulance
6. Stay on the line unless and until you are directed to hang up
7. Contact the school's administrative office and record the incident

Shop Evacuation

1. Upon hearing the school's alarm system or the teacher's directions, all students will immediately proceed to the nearest exit.
2. Once outside students will proceed to a spot previously identified by the teacher.
3. The teacher will ensure that all students have left the shop before he or she evacuates.
4. The teacher will proceed to the previously designated location occupied by the students and complete a roll call to ensure that everyone is out.
5. The appropriate outside agency or 911 will be contacted.
6. No students or teachers will be allowed back into the shop until the situation is declared safe by the responding team.

Figure 4.1–2: Hazardous Condition Report Form

(1)   Date of hazard identification: _____

(2)   Name of Person reporting the hazard: _____

(3)   Description of the hazard:

      1.   Operating procedure

         _____
         _____
         _____
         _____

      2.   Equipment

         _____
         _____
         _____
         _____

      3.   Environment

         _____
         _____
         _____
         _____

(4)   Description of corrective action taken and by whom:

      _____
      _____
      _____
      _____

(5)   General Comments:

      _____
      _____
      _____
      _____

Lesson 4.3
The Shop CNC Machine Construction/ Operation – Project #1 Demonstration

Suggested Duration: 1 hour
Suggested Format: Shop Demonstration

Following completion of this lesson, students will be able to:

4.3.1 Identify the main components of the shop CNC machine [2.404]
4.3.2 Explain the general operation of the shop CNC machine [2.404]
4.3.3 Identify the safety features of the shop CNC machine operation [5.402]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
Shop CNC router
3/8" Ballnose End-mill
Hardwood Stock – 1"x6"x12"
Safety footwear
Safety glasses
Coveralls

Student Required Resources

Teacher Handouts
Sample MSDS
Safety footwear
Safety glasses
Coveralls

Teacher Preparation

(1)   Review the safe operating guidelines and user operation manual for the shop CNC router.

Refer to the users manual for the shop CNC router.

Introduction

- The teacher through actual demonstration using the shop CNC machine will identify the main machine components, overview their primary function, and identify the sequence of operations required to go from a CNC program to the finished product.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Identify the shop CNC router main components and discuss the control software user interface.**

The basic jogging functions, machine home, tool referencing and stock referencing functions should be identified and demonstrated.

- **Operate the shop CNC router to produce sample Project #1 – Personalized Student Nameplate.**

Proper stock set-up should be demonstrated and the related need for clamps, fixtures and jigs discussed. The emergency stop procedure for the machine should be demonstrated next. Finally, the machine startup procedure, including tool and stock referencing, should be demonstrated and the machine operated to produce Project #1 – Personalized Student Nameplate. During machining, the teacher can discuss with students potential hazards to look for such as loose clamps or worn tools. After the machining cycle has ended, the proper procedure for part removal should be demonstrated. The process for downloading the CNC program should also be demonstrated and the relationship between coded instructions and the corresponding machine movement should be noted.

Suggested Student Activities

Students will participate in the related discussions and directly observe the process. At the end of the session, the teacher can assess student learning through use of formal or informal metrics.

Assessment and Evaluation

Student participation in the group activity will be evaluated based on a rubric. Students will also be required to complete a multiple choice test of their knowledge of the user interface for the shop CNC machine.

Wrap-up and Closing

- Review the construction and operation of the shop CNC router.

- Preview the next sub-unit in which students produce Projects #1-#6.

Learning Resources

(1)   Shop CNC router users manual.

Lesson 4.4
Project #1- #6 CNC Production by Student

Suggested Duration: 6 hours
Suggested Format: Computer Lab/Shop

Following completion of this lesson, students will be able to:

4.4.1 Upload a CNC program to cut a simple 2D shape to the shop CNC machine [2.403]
4.4.2 Perform CNC program verification and define tools, feeds, and speeds[2.401, 2.403]
4.4.3 Identify the required clamp, fixture and/or jig for positioning/holding of stock [2.405]
4.4.4 Set-up stock and establish origin and tool(s) reference(s) [2.401]
4.4.5 Operate the shop CNC machine to produce a simple 2D shape [1.403, 2.401]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
Shop CNC router
Common milling and routing tools
Common jigs and fixtures for milling
Assorted hold-down clamps
Assorted stock samples
Safety footwear
Safety glasses
Coveralls

Student Required Resources

Teacher Handouts
Sample MSDS
Safety footwear
Safety glasses
Coveralls

Teacher Preparation

(1)   Review the basics of machining including feeds, speeds, jigs, fixtures, and tools.

Refer to http://en.wikipedia.org/wiki/Cutting_speed, the Wilkepedia reference for a comprehensive definition of feed and speed.

Refer to http://www.denford.com/Feeds%20and%20Speeds.html, for information from Denford, a CNC machine manufacturer in the U.K., on how to calculate speeds and feeds.

Introduction

- This sub-unit provides students with the opportunity to independently, under the direct supervision of the teacher, set-up the shop CNC machine to produce Projects #1 - #6. For each project, students are required to verify the CNC program or check for any errors using the machining simulator capability of the shop CNC machine control software. Students are also responsible for selection of the stock clamping method (subject to teacher approval) loading/clamping of the stock in the machine, and defining tools.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

This should be a student driven exercise that is directly monitored by the teacher to ensure safety. The teacher should verify, interceding where required, that each step in the process has been completed correctly before permitting students to proceed.

Suggested Student Activities

For Projects #1 - #6, students download the CNC program, select clamping methods, select tools, set-up stock, set-up tools, and produce the part.

Assessment and Evaluation

Student participation in the shop activity will be evaluated based on a rubric.

Wrap-up and Closing

- Review CNC program downloading, stock and tool set-up, and CNC machine production.

- Preview the next sub-unit in which students produce a main component of the major design project using the shop CNC machine.
.

Learning Resources

(1)   http://en.wikipedia.org/wiki/Cutting_speed, the Wilkepedia reference for a comprehensive definition of feed and speed.

(2)   The shop CNC router users manual.

Lesson 4.5
Design Project - CNC Production by Student

Suggested Duration: 4 hours
Suggested Format: Computer Lab/Shop

Following completion of this lesson, students will be able to:

4.5.1 Upload a CNC program to cut the design project to the shop CNC machine [2.403]
4.5.2 Perform CNC program verification and define tools, feeds, and speeds[2.401, 2.403]
4.5.3 Identify the required clamp, fixture and/or jig for positioning/holding of stock [2.405]
4.5.4 Set-up stock and establish origin and tool(s) reference(s) [2.401]
4.5.5 Operate the shop CNC machine to produce a simple 2D shape [1.403, 2.401]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
Shop CNC router
Common milling and routing tools
Common jigs and fixtures for milling
Assorted hold-down clamps
Assorted stock samples
Safety footwear
Safety glasses
Coveralls

Student Required Resources

Teacher Handouts
Sample MSDS
Safety footwear
Safety glasses
Coveralls

Teacher Preparation

(1)   Review the basics of machining including feeds, speeds, jigs, fixtures, and tools.

Refer to http://en.wikipedia.org/wiki/Cutting_speed, the Wilkepedia reference for a comprehensive definition of feed and speed.

Refer to http://www.denford.com/Feeds%20and%20Speeds.html, for information from Denford, a CNC machine manufacturer in the U.K., on how to calculate speeds and feeds.

Introduction

- This sub-unit provides students with the opportunity to independently, under the direct supervision of the teacher, set-up the shop CNC machine to produce a main component of the major design project. Students are required to verify the CNC program or check for any errors using the machining simulator capability of the shop CNC machine control software. Students are also responsible for selection of the stock clamping method (subject to teacher approval) loading/clamping of the stock in the machine, and defining tools.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

This should be a student driven exercise that is directly monitored by the teacher to ensure safety. The teacher should verify, interceding where required, that each step in the process has been completed correctly before permitting students to proceed.

Suggested Student Activities

For a main component of the major design project, students download the CNC program, select clamping methods, select tools, set-up stock, set-up tools, and produce the part.

Assessment and Evaluation

Student participation in the shop activity will be evaluated based on a rubric.

Wrap-up and Closing

- Review CNC program downloading, stock and tool set-up, and CNC machine production.

- Preview UNIT 5.0: 3D CAD Design Software Basics.

Learning Resources

(1)   http://en.wikipedia.org/wiki/Cutting_speed, the Wilkepedia reference for a comprehensive definition of feed and speed.

(2)   http://www.denford.com/Feeds%20and%20Speeds.html, for information from Denford, a CNC machine manufacturer in the U.K., on how to calculate speeds and feeds.

(2)   The shop CNC router users manual.

UNIT 5.0

3D CAD Design Software Basics

Unit Overview

UNIT 5.0 introduces students to 3D CAD design software and its use in the CAD/CAM process. While 2D CAD software is used primarily to develop working drawings for a chosen design, 3D CAD design software can be used from initial design concept to engineering working drawings. 3D CAD design software can be used at the initial stage of the design process to create 2D design concept "sketches" (electronic), which can be easily modified until a preferred design is found. The 2D concept sketch can then be transformed into a 3D model or "virtual" prototype, which can be "tested" using the software's engineering analysis functions. A unique feature of 3D CAD design software is the ease with which models can be modified by simply changing a number of geometric and dimension constraints that control the shape, size and form of the 3D model. UNIT 5.0 includes the following sub-units:

    5.1 3D CAD Design Software Overview (1 hr)
    5.2 Creating 2D Profiles and Assigning Constraints – Project #3 (2 hrs)
    5.3 Creating Part Features – Project #3 (2 hrs)
    5.4 Project #3 – #6 3D CAD (8 hrs)
    5.5 Design Project – 3D CAD Parts (6 hrs)

In sub-unit 5.1, students are introduced to the general features and functionality of SolidWorks, a 3D parametric design software package for 3D CAD solid modeling and virtual testing of design concepts. The commands required to create 2D profiles, the basis for 3D construction, are presented in sub-unit 5.2. Next, in sub-unit 5.3, students are introduced to the commands used to add 3D features, such as threaded holes, to a part that has been extruded or revolved from the 2D profile.   In sub-unit 5.4, students apply these basic command tools in the development of the 3D CAD models for Project #3 - #6. Finally, in sub-unit 5.5, students complete development of 3D CAD models for the various components of the major design project.

Lesson 5.1
3D CAD Design Software Overview

Suggested Duration: 1 hour
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

5.1.1 Differentiate between CAD drafting and CAD design [2.404]
5.1.2 List the advantages/disadvantages of using 3D parametric solid modeling in the CAD/CAM process versus 2D drafting to define a part to be produced [2.404]
5.1.3 Identify the main areas of the 3D CAD design software user interface [2.404]
5.1.4 Identify the command tools available for file management, 2D profile creation/editing, 3D feature creation/editing and display manipulation [2.404]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
SolidWorks
SolidWorks Teacher Guide

Student Required Resources

Teacher Handouts
SolidWorks
SolidWorks Student Workbook

Teacher Preparation

(1)   Review the SolidWorks user interface and the 2D sketching and 3D feature commands needed to create a simple 3D CAD model.

Refer to the SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Introduction

- Instruction in 3D CAD design software should begin with a discussion on its unique features when compared to 2D CAD software, which is generally used for drafting. The approach taken when building the 3D CAD model mirrors the actual manufacturing process used to produce the physical part. Design is an iterative process during which the size, shape, and form of the part will often change. In the case of 3D CAD design software, this is facilitated through use of "parametric" dimensions that actually control the part size. When these are changed, the model size automatically changes in response.

- Another significant difference between 2D CAD software and 3D CAD design software is the method used to generate engineering drawings. In 2D CAD, 2D orthographic views are drawn to represent a 3D part. In 3D CAD design software, any required 2D orthographic view can be automatically derived from the 3D model.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Generally compare 2D CAD drafting software with 3D CAD design software.**

Compare how the general approach taken is essentially reversed. To create 2D CAD drawings, you have to view a 3D part physically or conceptually and then determine the 2D orthographic views needed to represent the part. If a design changes, the drawings have to be updated. To create 3D CAD designs, you create a virtual 3D part for which any orthographic view can be automatically generated. If a design changes, a simple change in dimension or geometric constraints automatically updates the 3D model and the 2D drawings. 3D CAD design software also allows intelligent assemblies, animation, engineering analysis and photorealistic representation of design concepts.

- **Identify the main areas of the SolidWorks user interface and demonstrate 2D sketching, 3D feature modeling and display manipulation by developing the 3D CAD model for Project #3 – Crib board.**

Create only the basic 3D body shape at this stage and demonstrate the placement of a hole feature.

Suggested Student Activities

Following discussion and demonstration of the software, each student will complete a self-directed tutorial that provides an introduction to the software's user interface and how to access available command tools. Lesson 1 in the SolidWorks Student Workbook is recommended for this tutorial.

Assessment and Evaluation

Student participation in the activity will be evaluated based on a rubric.

Wrap-up and Closing

- Review the general features and functionality of SolidWorks.

- Preview the next sub-unit on creating 2D profiles and assigning constraints.

Learning Resources

(1)   SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Lesson 5.2
Creating 2D Profiles and Assigning Constraints

Suggested Duration: 2 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

5.2.1 Use the 2D sketching tools to define a 2D sketch plane [2.401, 2.403]
5.2.2 Use the basic 2D sketching tools including point, line, arc, and circle in creating a 2D profile of a simple 3D part [2.401, 2.403]
5.2.3 Use the basic 2D editing tools including trim and extend in creating a 2D profile of a simple 3D part [2.401, 2.403]
5.2.4 Define 2D geometric constraints including parallel, perpendicular, horizontal, vertical, fix, and equal in creating a 2D profile of a simple 3D part [2.404]
5.2.5 Assign basic 2D geometric constraints including parallel, perpendicular, horizontal, vertical, fix, and equal in creating a 2D profile of a simple 3D part [2.401]
5.2.6 Assign, and edit, dimension constraints in creating a 2D profile of a simple 3D part [2.401]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
SolidWorks
SolidWorks Teacher Guide

Student Required Resources

Teacher Handouts
SolidWorks
SolidWorks Student Workbook

Teacher Preparation

(1)   Review the SolidWorks user interface and the 2D sketching and 3D feature commands needed to create a simple 3D CAD model.

Refer to the SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Introduction

- The construction of a 3D model using 3D CAD design software begins with the development of a basic 2D sketch or profile. 2D sketching involves the drawing and modifying of basic objects including point, line, arc, and circle using techniques similar to those used in 2D CAD. The sketch is then constrained by assigning geometric and dimension constraints. Geometric constraints control geometric relations such as parallelism and perpendicularity. Dimension constraints are parametric dimensions applied to control the size of the part. This 2D sketch can then be easily transformed into a 3D model using one of a variety of commands used to create part features, such as Extrude and Revolve.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Demonstrate the common 2D sketching tools; define and demonstrate geometric and dimension constraints by repeating development of the 2D profile for Project #3 – Crib board.**

The teacher should repeat creation of the 2D profile for Project #3 – Crib board using the basic draw tools such as point, line, arc, and circle. The basic 2D editing tools including trim and extend should also be demonstrated and the 2D geometric constraints including parallel, perpendicular, horizontal, vertical, fix, and equal explained. The teacher should also demonstrate the effect of changing parametric dimensions and geometric constraints and explain how this flexibility is well suited to the engineering design process.

Suggested Student Activities

Following discussion and demonstration of the software, each student will complete a self-directed tutorial that provides an introduction to the software's command tools for 2D sketch creation and editing. Lesson 2 in the SolidWorks Student Workbook is recommended for this tutorial. Students will then complete development of the 3D CAD model for Project #3 – Crib board.

Assessment and Evaluation

Student participation in the activity will be evaluated based on a rubric.

Wrap-up and Closing

- Review the 2D sketching tools, geometric constraints, and dimension constraints in SolidWorks.

- Preview the next sub-unit on creating part features.

Learning Resources

(1)   SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

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Lesson 5.3
Creating Part Features

</div>

Suggested Duration: 2 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

5.3.1 Extrude a 2D profile in creating a simple 3D part [2.401]
5.3.2 Revolve a 2D profile in creating a simple 3D part [2.401]
5.3.3 Add hole features in creating a simple 3D part [2.401]
5.3.4 Add fillet and chamfer features in creating a simple 3D part [2.401]
5.3.5 Add pattern features in creating a simple 3D part [2.401]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
SolidWorks
SolidWorks Teacher Guide

Student Required Resources

Teacher Handouts
SolidWorks
SolidWorks Student Workbook

Teacher Preparation

(1)   Review the SolidWorks user interface and the 2D sketching and 3D feature commands
        needed to create a simple 3D CAD model.

Refer to the SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational
Curriculum CD.

Introduction

- After the 2D sketch has been constrained, there are a number of command tools that can be used to create 3D part features. Usually the first step in transforming a 2D sketch into a 3D model is to either Extrude or Revolve the 2D sketch. Other 3D features such as holes, fillets, chamfers and patterns are then added to this basic 3D model to finish the virtual prototype.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Demonstrate the commands for extruding the 2D profile and adding fillets, chamfers, holes, and patterns by completing the 3D CAD model for sample Project #3 – Crib board.**

The teacher should extrude a 2D profile, add a hole feature, add a fillet features and pattern the holes to create the 3D CAD model for Project #3 – Crib board.

Suggested Student Activities

Following discussion and demonstration of the software, each student will complete a self-directed tutorial that provides an introduction to the software's command tools for 3D part feature creation and editing. Lesson 3 in the SolidWorks Student Workbook is recommended for this tutorial. Students will then develop the 3D CAD model for Project #3 – Crib board. A sample Crib board is illustrated in figure 5.3-1, "Sample Crib Board".

Assessment and Evaluation

Student participation in the activity will be evaluated based on a rubric.

Wrap-up and Closing

- Review the commands for extruding 2D profiles and for adding 3D features including fillets, holes, and patterns.

- Preview the next sub-unit in which students complete the 3D CAD models for Project #3 - #6.
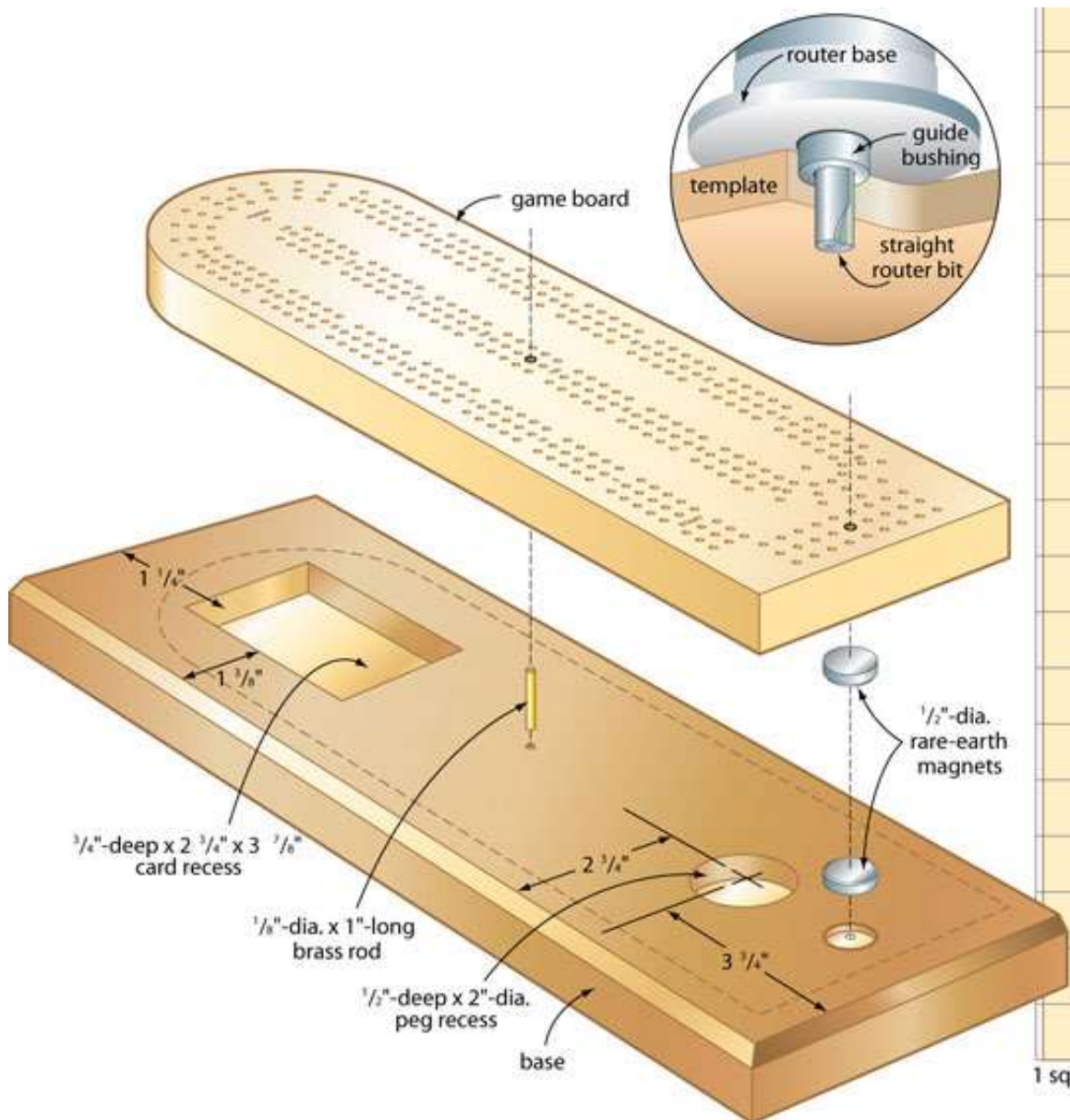
Learning Resources

(1)   SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

(2)   http://www.canadianhomeworkshop.com/weekend/cribbage_board.shtml, the Canadian Home Workshop magazine online.

Figure 5.3-1: Sample Crib board

Detailed dimensions for a crib board along with directions for manufacturing can be found at http://www.canadianhomeworkshop.com/weekend/cribbage_board.shtml, the Canadian Home Workshop magazine online.

Source: Canadian Home Workshop magazine online at http://www.canadianhomeworkshop.com/weekend/cribbage_board.shtml,

Lesson 5.4
Project #3 – #6 3D CAD

Suggested Duration: 8 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

5.4.1 Develop the 3D CAD model for a simple part for export to CAM [2.401,2.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
SolidWorks
SolidWorks Teacher Guide

Student Required Resources

Teacher Handouts
SolidWorks
SolidWorks Student Workbook

Teacher Preparation

(1)   Review the SolidWorks commands for 2D profiling and feature creation.

Refer to the SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational
Curriculum CD.

Introduction

- Developing proficiency in 3D CAD requires time on task. In this sub-unit students will develop proficiency in 3D CAD model creation through completion of the 3D CAD models for Projects #3 - #6.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Review the commands used to create 3D CAD models using SolidWorks as required .**

This should be a student driven exercise that is directly monitored by the teacher to ensure progress and provide direction as required.

Suggested Student Activities

Students working in groups of 2 or 4 will complete development of the 3D CAD model necessary for export to CAM software for Projects #3 - #6.

Assessment and Evaluation

Student participation in the activity will be evaluated based on a rubric.

Wrap-up and Closing

- Review the commands for 3D CAD model creation in SolidWorks.

- Preview the next sub-unit in which students develop the 3D CAD part models for the major design project.

Learning Resources

(1)   SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Lesson 5.5
Design Project – 3D CAD Parts

Suggested Duration: 6 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

5.5.1 Develop the 3D CAD models for the design project components [2.401,2.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
SolidWorks
SolidWorks Teacher Guide
SolidWorks CO_2 Car Tutorial

Student Required Resources

Teacher Handouts
SolidWorks
SolidWorks Student Workbook
SolidWorks CO_2 Car Tutorial

Teacher Preparation

(1)   Review the SolidWorks commands for 2D drawing and feature creation.

Refer to the SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Introduction

- Using the knowledge acquired through the tutorial in sub-unit 5.5, students, working in groups of 2, will develop the necessary 3D part models for the major design project. Students will likely explore and share alternative construction techniques and this form of self-directed learning should be encouraged.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Review SolidWorks commands for 2D drawing and feature creation as required.**

Tthis should be a student driven exercise that is directly monitored by the teacher to ensure progress and provide direction as required.

Suggested Student Activities

Working in groups of 2, students will complete the 3D CAD models for each component of their major design project.

Assessment and Evaluation

Student participation in the activity will be evaluated based on a rubric.

Wrap-up and Closing

- Review the SolidWorks commands for 2D drawing and feature creation.

- Preview UNIT 6.0: Computer Aided Manufacturing (CAM) in which students are introduced to the use of CAM software in generating CNC programs.

Learning Resources

(1)   SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

UNIT 6.0

Computer Aided Manufacturing

Unit Overview

While CAM software is generally capable of both 3D model geometry creation and CNC program development, it is typically used for the latter with the 3D model geometry being imported from 3D CAD design software such as SolidWorks. This unit focuses on the use of CAM software in the development of CNC programs through completion of the following sub-units:

> 6.1 Overview of CAM Software and Features (1 hr)
> 6.2 CAD File Import, Defining Tools – Project #3 CAM (2 hrs)
> 6.3 Defining Toolpaths - Project #3 CAM (2 hrs)
> 6.4 Project #4 – #6 CAM (6 hrs)
> 6.5 Design Project – CAM (8 hrs)

In sub-unit 6.1, students are introduced to the general features and functionality of FeatureCAM, a CAM software for CNC program generation based on 2D and 3D CAD models . The commands required to import the Project #3 - Crib board 3D CAD files and define tools are presented in sub-unit 6.2. Next, in sub-unit 6.3, students are introduced to the commands used to define toolpaths for Project #3 - Crib board manufacture.   In sub-unit 6.4, students import the 3D CAD files and use CAM to generate the CNC program for manufacture for Projects #4 - #6. Finally, in sub-unit 6.5, students import the 3D CAD file for a main component of the major design project and use CAM to generate the CNC program for production using the shop CNC machine.

Lesson 6.1
Overview of CAM Software and Features

Suggested Duration: 1 hour
Suggested Format: Computer Lab Demonstration

Following completion of this lesson, students will be able to:

6.1.1 Identify the main areas of the CAM software user interface [2.404]
6.1.2 Identify the command tools available for file management, 3D CAD file import, tool definition, toolpath definition, post-processing and display manipulation [2.404]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
FeatureCAM
FeatureCAM User's Guide

Student Required Resources

Teacher Handouts
FeatureCAM
FeatureCAM User's Guide

Teacher Preparation

(1)   Review the FeatureCAM user interface and the steps for creating a part for manufacture.

Refer to the Getting Started with FeatureCAM Guide included with the software.

Introduction

- CAM software includes command tools for the creation of 3D model geometry, specification of the machining parameters such as tool paths, and the generation of a CNC program for operation of a CNC machine. The teacher should note how CAM software enables the generation of CNC programs and subsequent manufacture of parts for which developing the CNC program manually would be too complex. CAM also allows for a seamless transition from initial design concept to finished product since concept designs developed in 3D CAD design software can be imported, the CNC program then generated, and then posted to the CNC machine for automatic manufacture. There are a wide variety of CAM software packages available such as FeatureCAM and MasterCAM.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Overview the features and functionality of FeatureCAM through a demonstration of the software.**

This demonstration should identify the main areas of the CAM software user interface, and the command tools available for file management, 3D CAD file import, tool definition, toolpath definition, post-processing and display manipulation.

Suggested Student Activities

Following the teacher demonstration of the software capabilities, each student is required to complete a self-directed tutorial that provides an introduction to the common command tools used in CAM software. Chapters 2 and 3 in the Getting Started with FeatureCAM guide are recommended for this tutorial.

Assessment and Evaluation

Student participation evaluated based on a rubric. Students may also be evaluated through a multiple choice test of their knowledge of the CAM software common command tools.

Wrap-up and Closing

- Review the general features and functionality of FeatureCAM.

- Preview the next lesson on CAD file importing and defining tools.

Learning Resources

(1)	Getting Started with FeatureCAM guide included with the software.

Lesson 6.2
CAD File Import, Defining Tools – Project #3 CAM

Suggested Duration: 2 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

6.2.1 Import the 3D CAD geometry for a simple 3D part [2.401]
6.2.2 Define the stock [2.401]
6.2.3 Define the tools [2.401]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
FeatureCAM
FeatureCAM User's Guide

Student Required Resources

Teacher Handouts
FeatureCAM
FeatureCAM User's Guide

Teacher Preparation

(1)   Review the FeatureCAM commands for 3D CAD file input, defining stock, and defining
         tools.

Refer to the Getting Started with FeatureCAM Guide included with the software.

Introduction

- As previously noted, CAM software is often used exclusively for specifying machining parameters and generating a CNC program based on the geometry of the part to be machined that has been created using 2D or 3D CAD software. 3D CAD models can be imported or the geometry created directly in the CAM software. Importing is more common in an integrated CAD/CAM process since the 3D CAD model has already been created using 3D CAD design software.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Using Project #3 – Crib board to demonstrate, overview the process for importing, feature recognition and CNC program generation using FeatureCAM.**

The teacher should demonstrate the commands used for CAD file import, stock definition and tool definitions for Project #3 – Crib board.

Suggested Student Activities

Following discussion and demonstration of the software, each student will complete a self-directed tutorial that provides an introduction to the software's command tools for 3D CAD model importing, stock definition and tool definition. Chapter 9 in the Getting Started with FeatureCAM guide is recommended for this tutorial.

Students will then import the 3D CAD model for Project #3 – Crib board, define the stock, and define the tools.

Assessment and Evaluation

Student participation evaluated based on a rubric. Students may also be evaluated through a multiple choice test of their knowledge of the CAM software common command tools.

Wrap-up and Closing

- Review the FeatureCAM commands for 3D CAD file import, stock definition, and tool definition.

- Preview the next sub-unit in which students define the toolpaths for Project #3 – Crib board.

Learning Resources

(1)   Getting Started with FeatureCAM Guide included with the software.

Lesson 6.3
Defining Toolpaths - Project #3 CAM

Suggested Duration: 2 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

6.3.1 Specify feeds and speeds [2.401]
6.3.2 Define toolpaths [2.401]
6.3.3 Verify toolpaths using machining simulation [2.401]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
FeatureCAM
FeatureCAM User's Guide

Student Required Resources

Teacher Handouts
FeatureCAM
FeatureCAM User's Guide

Teacher Preparation

(1)   Review the FeatureCAM commands for defining toolpaths and the automatic feature
         recognition utility included with the software.

Refer to the Getting Started with FeatureCAM Guide included with the software.

Introduction

- While CAM software and CNC machines permit the production of complex 3D shapes that would be impossible to produce manually, the basic tenants of machining must still be adhered to. The type of material used, for example, is an important consideration since it directly affects the speeds and feeds required for precision machining. The teacher should review the basic machining rules governing determination of feeds, speeds, and the selection of the appropriate cutting tools. The teacher should also discuss with students how references such as the Machinery's Handbook are available to assist with this task.

- Following this review of machining basics, the teacher should demonstrate, using the imported 3D CAD model for Project #3 – Crib board to illustrate, the options available for defining toolpaths or the motion the tool will follow in cutting the part from the stock. The teacher should also demonstrate how the integrity of the CNC program that is then generated based on these defined toolpaths can be checked using a graphical simulation of the machining process or what is typically referred to as machining verification.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Using Project #3 – Crib board to demonstrate, review the importance of feeds and speeds in machining and demonstrate the related FeatureCAM commands.**

The FeatureCAM command tools for customizing manufacturing parameters including speed and feed should be demonstrated.

- **Using Project #3 – Crib board to demonstrate, review the FeatureCAM commands for developing curves, defining features, generating toolpaths, and CNC program verification.**

Illustrate the process followed to develop the toolpaths, generate the subsequent CNC program, and verify the program using the graphical machining simulator. The automatic feature recognition utility should be used for this.

Suggested Student Activities

Following the teacher demonstration of the software capabilities, each student is required to complete a self-directed tutorial that requires students to define toolpaths, generate the CNC program, and verify. Chapter 4 in the Getting Started with FeatureCAM guide is recommended for this tutorial.

Students should then proceed to define the toolpaths using automatic feature recognition, generate the CNC program, and verify machining using the graphical simulator for Project #3 – Crib board.

Assessment and Evaluation

Student participation evaluated based on a rubric. Students may also be evaluated through a multiple choice test of their knowledge of the CAM software common command tools.

Wrap-up and Closing

- Review the commands for defining toolpaths and the automatic feature recognition utility in FeatureCAM.

- Preview the next sub-unit in which students use CAM to generate the CNC program for Project #4 - #6.

Learning Resources

(1)   Getting Started with FeatureCAM Guide included with the software.

| Lesson 6.4 |
| Project #4 – #6 CAM |

Suggested Duration: 6 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

6.4.1 Generate NC code for machining of a simple 3D part using CAM software [2.401]
6.4.2 Specify feeds and speeds [2.401]
6.4.3 Define toolpaths [2.401]
6.4.4 Verify toolpaths using machining simulation [2.401]
6.4.5 Post-process NC part file for the shop CNC machine [2.401]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
FeatureCAM
FeatureCAM User's Guide

Student Required Resources

Teacher Handouts
FeatureCAM
FeatureCAM User's Guide

Teacher Preparation

(1)   Review the FeatureCAM NC code generation commands and the post-processing utility.

Refer to Getting Started with FeatureCAM Guide included with the software.

Introduction

- After the CNC program has been graphically verified, the CNC program can be viewed for editing. The teacher should demonstrate the command tools required for this, identify some of the common G and M codes that appear in the CNC program, and relate this to the basics of CNC programming covered in UNIT 3.0. The complexity of the CNC program generated using CAM should be compared to the basic program developed manually in UNIT 3.0 with a view to illustrating the advantage of using CAM to develop more complex CNC programs. The need for post-processing or translating the CNC program to a form acceptable by the shop CNC machine should be discussed as well.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Explain post-processing of CNC programs and why it is necessary.**

The notion of a "universal" CNC programming language consisting of G codes and M codes should be discussed and it should be noted that the initial output from CAM software must be translated to the particular "language" that the shop CNC machine controller understands.

Suggested Student Activities

For Project #4 - #6, students use CAM to generate the CNC programs and post-process for the shop CNC machine .

Assessment and Evaluation

Student participation evaluated based on a rubric. Students may also be evaluated through a multiple choice test of their knowledge of the CAM software common command tools.

Wrap-up and Closing

- Review the need for post-processing and the related FeatureCAM commands.

- Preview the next sub-unit in which students use CAM to develop the CNC program for a main component of the major design project.

Learning Resources

(1)   Getting Started with FeatureCAM Guide included with the software.

| Lesson 6.5 |
| 6.5 Design Project – CAM |

Suggested Duration: 8 hours
Suggested Format: Computer Lab/Shop

Following completion of this lesson, students will be able to:

6.5.1 Generate NC code for machining of a design project component using CAM software [2.401]
6.5.2 Specify feeds and speeds [2.401]
6.5.3 Define toolpaths [2.401]
6.5.4 Verify toolpaths using machining simulation [2.401]
6.5.5 Post-process NC part file for the shop CNC machine [2.401]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
FeatureCAM
FeatureCAM User's Guide

Student Required Resources

Teacher Handouts
FeatureCAM
FeatureCAM User's Guide

Teacher Preparation

(1)   Review the FeatureCAM commands for 3D CAD import and CNC program generation.

Refer to the Getting Started with FeatureCAM Guide included with the software.

Introduction

- Student knowledge of CAM software and operation of the shop CNC machine is applied to the Design Project in this sub-unit.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Briefly review the requirements for this lesson.**

This should be a student driven exercise that is monitored by the teacher to provide direction as required.

Suggested Student Activities

In groups of 2 or 4, students use CAM to develop the CNC program for manufacture of a main component of the major design project using the shop CNC machine.

Assessment and Evaluation

Student participation evaluated based on a rubric.

Wrap-up and Closing

- Review the use of CAM to develop CNC programs.

- Preview UNIT 7.0: 3D CAD Design Software Intermediate.

Learning Resources

(1)   Getting Started with FeatureCAM Guide included with the software.

UNIT 7.0

3D CAD Design Software Intermediate

Unit Overview

After the 3D CAD models of components are created, they can be assembled using assembly constraints to produce a working virtual prototype. These 3D CAD assemblies can also be rendered for realistic presentation of the physical model and animated to test functionality. These virtual prototypes can also be analysed for strength and aerodynamics using the engineering analysis utilities included with the 3D CAD design software. UNIT 7.0 includes the following sub-units:

>7.1 Assembly, Render and Animate Overview (1 hr)
>7.2 Creating Assemblies – Design Project (2 hrs)
>7.3 Rendering and Animation – Design Project (2 hrs)
>7.4 Major Tutorial #1 and #2 (10 hrs)
>7.5 Reverse Engineering Project (5 hrs)
>7.6 Computer Aided Engineering (5 hrs)
>7.7 Design Project – 3D CAD Assemble, Render, Animate and Present (10 hrs)

In sub-unit 7.1, the SolidWorks command tools for assembly, rendering and animation are introduced. Students then build a virtual prototype of their major design project by assembling the various components created previously in UNIT 5.0. The assembly is then rendered and animated in sub-unit 7.3. Next, in sub-unit 7.4, students complete two extensive SolidWorks tutorials in which they develop a mountain skateboard and a trebuchet. Knowledge acquired through these tutorials is then applied in a reverse engineering project in sub-unit 7.5 is which they reverse engineer a skateboard. The engineering analysis capabilities of SolidWorks COSMOS utility are then overviewed through completion of an extensive SolidWorks tutorial in which students develop and analyse a CO_2 car design in sub-unit 7.6. Finally, in sub-unit 7.7, students complete the assembly, rendering, animation and presentation of their major design project.

Lesson 7.1
Assembly, Render and Animate Overview

Suggested Duration: 1 hour
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

7.1.1 Identify the command tools available for assembly, render, and animation [2.404]
7.1.2 List two advantages of using assembly constraints to build 3D CAD assemblies [2.404]
7.1.3 List two advantages of animation in engineering design [2.404]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
SolidWorks Teachers Guide

Student Required Resources

Teacher Handouts
SolidWorks Student Workbook

Teacher Preparation

(1)   Review the SolidWorks command tools for assembly, rendering and animation.

Refer to the SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Introduction

- Once the 3D CAD models for each component of an assembly are created, they can be put together using assembly constraints. Assembly constraints define how two parts mate or fit together. For example, an INSERT constraint may be used to define how a bolt fits into or mates with a hole. If part design changes, the assembly constraints adapt to maintain the mate condition. Assembly constraints also control how a part is permitted to move in relation to its mating part when animated. For example, a TANGENT assembly constraint may limit the motion of a moving part to a path that remains tangential to the edge of a mating part.

- Rendering allows for a realistic representation of the physical prototype as it will appear in real life. Rendered 3D CAD assemblies can be used by marketers, engineering managers, and industrial designers in presentations.

- Animation permits analysis of the geometry of motion for an assembly. The actual motion the assembly will follow in operation can be simulated using animation. This can be used to help engineers determine motion paths, possible collisions, work envelopes, and necessary part geometry.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Using a simple assembly to illustrate, review the SolidWorks commands used for assembly of components.**

The MATE, INSERT, ANGLE and TANGENT constraints should be demonstrated.

- **Introduce how materials can be assigned and demonstrate basic rendering.**

- **Manually animate the assembly with the cursor to demonstrate how assembly constraints control motion.**

  Note the possible application of this capability in engineering design.

- **Animate the assembly by "driving" an assembly constraint.**

Suggested Student Activities

Students complete a self-directed tutorial that introduces the basics of assembly and assembly constraints in SolidWorks. Lesson 4 in the SolidWorks Student Workbook is recommended for this tutorial.

Assessment and Evaluation

Students evaluated based on recall of assembly constraints, rendering and animation in a multiple choice test.

Wrap-up and Closing

- Review the basics of assembly, render, and animate in SolidWorks.

- Preview the next sub-unit in which students assemble their major design project components.

Learning Resources

(1)   SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

<table>
<tr><td colspan="2" align="center">Lesson 7.2
Creating Assemblies – Design Project</td></tr>
</table>

Suggested Duration: 2 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

7.2.1 Assemble the design project components [2.401, 2.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
SolidWorks Teachers Guide

Student Required Resources

Teacher Handouts
SolidWorks Student Workbook

Teacher Preparation

(1)   Review the SolidWorks command tools for assembly.

Refer to the SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Introduction

- An important component of the major design project is the creation of a virtual prototype. Using the 3D CAD models for each component of the design project created in UNIT 5.0, students must assemble the final design in preparation for rendering, animation and presentation to the class.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Briefly review the assembly constraints and SolidWorks command tools for building assemblies.**

Following this brief overview, this should be a student driven exercise.

Suggested Student Activities

Student groups begin the assembly of their major design project 3D CAD models for each component to form the virtual prototype of their design.

Assessment and Evaluation

Students evaluated based on completed assembly in accordance with a rubric.

Wrap-up and Closing

- Review the basics of assembly in SolidWorks.

- Preview the next sub-unit in which students render and animate their major design project.

Learning Resources

(1)   SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational
         Curriculum CD.

Lesson 7.3
Rendering and Animation – Design Project

Suggested Duration: 2 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

7.3.1 Render the design project assembly [2.401, 2.403]
7.3.2 Manually animate the design project assembly to simulate operation [2.401, 2.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
SolidWorks Teachers Guide

Student Required Resources

Teacher Handouts
SolidWorks Student Workbook

Teacher Preparation

(1)   Review the SolidWorks command tools for rendering and animation.

Refer to the SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Introduction

- After the assembly is created, materials can be assigned to each component to generate a rendered image that realistically represents the physical prototype as it will appear in real life. This image can be used for presentation purposes by engineers, marketers, and industrial designers. 3D CAD assemblies can also be animated to simulate geometry of motion and aid in engineering analysis.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Briefly review the assignment of materials, render tools and animation in SolidWorks.**

Following this brief overview, this should be a student driven exercise.

Suggested Student Activities

Student groups begin the rendering and animation of their major design project assembly.

Assessment and Evaluation

Students evaluated based on completed assembly in accordance with a rubric.

Wrap-up and Closing

- Review the basics of rendering and animation in SolidWorks.

- Preview the next sub-unit, two extensive tutorials in which students build a virtual prototype of a mountain skateboard and a functioning model of a trebuchet.

Learning Resources

(1)   SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

| Lesson 7.4 |
| Major Tutorial #1 and #2 |

Suggested Duration: 10 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

7.4.1 Identify the advanced command tools for 3D part feature creation, parts assembly, rendering, and animation.

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
SolidWorks Teachers Guide
SolidWorks Mountain Skateboard Tutorial
SolidWorks Trebuchet Tutorial

Student Required Resources

Teacher Handouts
SolidWorks Student Workbook
SolidWorks Mountain Skateboard Tutorial
SolidWorks Trebuchet Tutorial

Teacher Preparation

(1)   Review the SolidWorks Mountain Skateboard Tutorial and SolidWorks Trebuchet Tutorial.

Refer to the SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Introduction

- Developing proficiency in the use of 3D CAD design software requires "hands-on" time. This sub-unit provides a comprehensive overview of the capabilities of this software through two self-directed tutorials by SolidWorks: The Mountain Skateboard Tutorial and the Trebuchet Tutorial. Each tutorial overviews the key capabilities of the software through a review of the 2D sketching and 3D feature tools, an introduction to building part assemblies, an introduction to developing exploded assemblies, an introduction to animating assemblies, and an introduction to the creation of 2D working drawings from the 3D model.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Briefly review the purpose of the tutorials and the expected learning outcomes.**

Following this brief overview, this should be a student driven exercise.

Suggested Student Activities

Students complete the Mountain Skateboard tutorial and the Trebuchet tutorial.

Assessment and Evaluation

Students evaluated based on participation.

Wrap-up and Closing

- Review the key concepts covered in the two tutorials.

- Preview the next sub-unit in which students reverse engineer a skateboard.

Learning Resources

(1)   SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Lesson 7.5
Reverse Engineering Project

Suggested Duration: 5 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

7.5.1 Following disassembly, determine the critical dimensions for the components of a common product assembly using conventional shop metrology tools [2.401, 2.403]
7.5.2 Develop the 3D CAD part models for each component of the product assembly based on field measurements of critical dimensions using conventional shop metrology tools [2.401, 2.403]
7.5.3 Develop the rendered 3D CAD exploded assembly of the product [2.401, 2.403]
7.5.4 Animate the assembled virtual prototype of the product [2.401, 2.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
SolidWorks Teachers Guide
Skateboard (dis-asembled)
Calipers
Micrometer
Protractor
Steel rule

Student Required Resources

Teacher Handouts
SolidWorks Student Workbook
SolidWorks Mountain Skateboard Tutorial
SolidWorks Trebuchet Tutorial
Skateboard (dis-assembled)
Calipers
Micrometer
Protractor
Steel rule

Teacher Preparation

(1)   Review the use of standard metrology tools including calipers, micrometers, protractors, and steel rules.

Introduction

- One means by which students can learn to appreciate the complexity of engineering design, manufacturing and their interdependence is to reverse engineer a common product.   Reverse engineering is used in industry to develop engineering drawings or CAD files for parts that must be replaced but must be custom manufactured. A major challenge in reverse engineering is determining the part measurements needed to accurately model the part in CAD. This challenge will help students appreciate the importance of good dimensioning practice when developing engineering drawings and the relationship between design and manufacturing.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Briefly review the purpose of the sub-unit and the expected learning outcomes.**

The use of the metrology tools should also be reviewed. Following this brief overview, this should be a student driven exercise.

Suggested Student Activities

Students are required to reverse engineer a skateboard. This should include: (1) Measurement of critical dimensions for each main component; (2) Development of the 3D CAD model for each main component, (3) Development of the rendered assembly (4) Animation of the rendered assembly, and (5) Generation of the 2D engineering drawings required for the manufacture of one of the main components.

Assessment and Evaluation

Students evaluated based on 3D CAD assembly and 2D engineering drawings in accordance with a rubric.

Wrap-up and Closing

- Review the key concepts addressed in the reverse engineering project.

- Preview the next sub-unit in which complete an extensive SolidWorks tutorial that introduces the engineering analysis tools available in the COSMOS utility.

Learning Resources

(1)   SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Lesson 7.6
Computer Aided Engineering

Suggested Duration: 5 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

7.6.1 Explain the purpose of engineering analysis in design [1.403]
7.6.2 Identify the engineering analysis tools available in 3D CAD Design software [2.404]
7.6.3 Perform a basic bending stress analysis on a simply supported beam using 3D CAD Design software [2.401]
7.6.4 Perform basic hydrodynamic flow analysis on a simple 3D part using 3D CAD Design software [2.401]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
SolidWorks Teachers Guide
SolidWorks Building a CO_2 Powered Car Tutorial

Student Required Resources

Teacher Handouts
SolidWorks Student Workbook
SolidWorks Building a CO_2 Powered Car Tutorial

Teacher Preparation

(1)   Review the SolidWorks tutorial Building a CO_2 Powered Car.

Refer to the SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Introduction

- COSMOS is a finite elemental analysis (FEA) utility included with SolidWorks that allows for the basic engineering stress and hydrodynamic analysis of 3D CAD models. Stress analysis helps determine if a design has adequate strength to withstand loads, has stress concentration features that should be eliminated, or has excess material that can be removed to minimize weight. Hydrodynamic analysis relates to the flow of fluids over structures such as airflow over a car body. It can be used to help refine a car body design in order to minimize drag on the vehicle.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Briefly review the purpose of the sub-unit and the expected learning outcomes.**

Following this brief overview, this should be a student driven exercise.

Suggested Student Activities

Students are required to complete the SolidWorks tutorial Building a CO_2 Powered Car with a focus on the use of COSMOS to assess the aerodynamics of the car body and subsequent improvements. This will help prepare students for completion of similar CAD activities for their major design projects.

Assessment and Evaluation

Students evaluated based on participation.

Wrap-up and Closing

- Review the key engineering analysis concepts addressed in the tutorial.

- Preview the next sub-unit in which students complete the 3D CAD requirements of the major design project.

Learning Resources

(1)   SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Lesson 7.7
Design Project – 3D CAD Assemble, Render, Animate and Present

Suggested Duration: 10 hours
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

7.7.1 Develop an exploded assembly of the design project [2.401, 2.403]
7.7.2 Render an exploded assembly of the design project [2.401, 2.403]
7.7.3 Record an animation of the design project [2.401, 2.403]
7.7.4 Deliver a Powerpoint presentation describing their final design [2.401, 2.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide
SolidWorks Teachers Guide

Student Required Resources

Teacher Handouts
SolidWorks Student Workbook

Teacher Preparation

(1)   Review the SolidWorks commands for exploding assemblies and recording animations.

Refer to the SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

Introduction

- Once students complete the rendered assembly and animate using cursor control, they will need to generate an exploded assembly and record an animation in AVI (or other Windows compatible media format) of their final design. These will be used along with the physical prototype to help present their final design to the class during the last week of the course.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Briefly review the purpose of the sub-unit and the expected learning outcomes.**

Following this brief overview, this should be a student driven exercise.

Suggested Student Activities

Students are required to develop an exploded assembly and record an animation simulating motion of the prototype design in preparation for their presentation of their final design to the class during the last week of classes. Students are also expected to use PowerPoint for the final design presentation.

Assessment and Evaluation

Student group presentation of their final design evaluated based on a rubric.

Wrap-up and Closing

- Review the concepts addressed in the major design project.

- Preview UNIT 8.0 on Careers in CAD/CAM/CNC.

Learning Resources

(1)   SolidWorks Teacher Guide and Student Courseware on the SolidWorks Educational Curriculum CD.

UNIT 8.0

Careers in CAD/CAM/CNC

Unit Overview

UNIT 8.0 introduces students to the wide variety of challenging and rewarding career options related to CAD/CAM/CNC. CAD/CAM/CNC is an exciting dynamic field of study that seamlessly integrates knowledge of both engineering design and manufacturing in the production of a part. CAD/CAM/CNC software and CNC machines are continuously evolving and this requires the CAD/CAM/CNC practitioner to become a lifelong learner. The dynamic nature of this career field is a constant motivator for the CAD/CAM/CNC practitioner to upgrade skills and knowledge. This UNIT requires students to identify the available job roles in the CAD/CAM/CNC field, research related employment statistics and future prospects, and determine the educational qualifications needed to work in this area. An industry case study is also used to help illustrate the various job functions that are performed in support of CAD/CAM/CNC.Typical roles performed during the CAD/CAM/CNC process are overviewed and students explore the related employment statistics and educational requirements through completion of the following sub-units:

> 7.1 Overview Careers in CAD/CAM/CNC
> 7.2 Research Careers and Employment Statistics
> 7.3 Identify Education Programs and Entry Pre-requisites

In sub-unit 8.1, students are introduced to the wide variety of career roles that are available in the CAD/CAM/CNC filed. This is followed by sub-unit 8.2 in which students explore these various careers and the related employment statistics. Finally, in sub-unit 8.3, students are required to identify education programs in support of employment in this field and to determine the entrance requirements for such programs.

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Lesson 8.1
Overview of Careers in CAD/CAM/CNC

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Suggested Duration: 1 hour
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

8.1.1 Identify the various career roles in CAD, CAM, CNC, and CAE [4.401, 4.403]
8.1.2 Summarize the primary duties and responsibilities associated with each of the primary career roles in CAD, CAM, CNC, and CAM [4.401, 4.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide

Student Required Resources

Teacher Handouts

Teacher Preparation

(1)   Review the various career roles in the CAD/CAM/CNC field.

Refer to the JobFutures website of Services Canada at http://www.jobfutures.ca.

Introduction

- There are a variety of available career roles related to CAD, CAM, CNC, and Computer Aided Engineering (CAE) ranging from 2D CAD drafter to professional engineers. While the teacher should provide students with direction on potential sources of career related information for this field, such as Internet sources, government departments, and local industry, this sub-unit should be a student driven exercise.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Briefly review the lesson requirements.**

This lesson should be a student-directed activity. Following completion of the student group activity, the teacher should query the groups in an effort to develop a "master" list of potential career paths in this field.

Suggested Student Activities

In groups of 2 or 4, students research the various career roles related to the CAD/CAM field with a view to identifying the primary duties and responsibilities. Group results are then compiled, through an interactive discussion with the teacher, into one "master" list.

Assessment and Evaluation

Student participation in the group activity will be evaluated based on a rubric.

Wrap-up and Closing

- Review the master list of CAD/CAM/CNC career roles.

- Preview the next sub-unit on related career statistics.

Learning Resources

(1)   http://www.jobfutures.ca, the JobFutures website of Services Canada.

Lesson 8.2
Research Careers and Employment Statistics

Suggested Duration: 1 hour
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

8.2.1 Retrieve career descriptions for each of the primary career roles in CAD, CAM, CNC, and CAM [4.401, 4.403]
8.2.2 Retrieve employment statistics for each of the primary career roles in CAD, CAM, CNC, and CAM [4.401, 4.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide

Student Required Resources

Teacher Handouts

Teacher Preparation

(1)   Review the various career statistics in the CAD/CAM/CNC field.

Refer to the JobFutures website of Services Canada at http://www.jobfutures.ca.

(2)   Review some of the employment opportunities in the CAD/CAM/CNC field.

Refer to www.monster.com or other reputable employment recruitment site.

Introduction

- This sub-unit extends on sub-unit 8.1 by requiring students to retrieve actual samples of job ads recruiting candidates to work in CAD/CAM/CNC related fields. Students are also required to obtain employment related statistics for related career roles. While the teacher should provide students with direction on potential sources of this information, this sub-unit should be a student driven exercise.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Briefly review the lesson requirements.**

This lesson should be a student-directed activity. Following completion of the student group activity, the teacher should query the groups in an effort to develop a "master" list of job ads and employment statistics.

Suggested Student Activities

In groups of 2 or 4, students research job ads and employment statistics related to the CAD/CAM/CNC field. Group results are then compiled, through an interactive discussion with the teacher, into one "master" list.

Assessment and Evaluation

Student participation in the group activity will be evaluated based on a rubric.

Wrap-up and Closing

- Review the master list of CAD/CAM/CNC employment opportunities.

- Preview the next sub-unit on related career statistics.

Learning Resources

(1)   http://www.jobfutures.ca, the JobFutures website of Services Canada.

(2)   http://www.monster.com or similar employment recruitment site.

Lesson 8.3
Identify Education Programs/ Entry Pre-requisites

Suggested Duration: 1 hour
Suggested Format: Computer Lab

Following completion of this lesson, students will be able to:

8.3.1 Determine the entrance requirements for enrollment in post-secondary studies in a CAD, CAM, CNC, or CAE related field [4.401, 4.403]
8.3.2 Summarize the key topics of study in a post-secondary program of study aimed at a career in CAD, CAM, CNC, and CAE related field [4.401, 4.403]

Teacher Required Resources

Design and Fabrication 2212 Teacher Resource Guide

Student Required Resources

Teacher Handouts

Teacher Preparation

(1)   Review the various education programs available locally, nationally, and internationally in support of CAD/CAM/CAE education.

Refer to http://www.a2zcolleges.com/, a privately owned website, or similar website for an extensive list of links to colleges and universities.

Introduction

- One of the intended outcomes of completion of Design and Fabrication 2212 is for students to acquire an awareness of related careers and insight into the post-secondary educational path that will best prepare them to work in the CAD/CAM/CNC field. In this sub-unit, students, once again through self-directed study, are required to identify and briefly describe post-secondary programs of study that will prepare them for a career in this field. Students are also required to determine the entrance requirements for these post-secondary programs, and subsequently identify the high school courses that must be completed in order to meet these entrance requirements.

- State the purpose of this lesson and the expected learning outcomes

- State how this lesson relates to other topics in Design and Fabrication 2212

- Summarize what will be covered in this lesson and the related student activity

Presentation

- **Briefly review the lesson requirements.**

While the teacher should provide students with direction on potential sources of this information, this sub-unit should be a student driven exercise. Following completion of the student group activity, the teacher should query the groups in an effort to develop a "master" list of post-secondary programs and related entrance requirements.

Suggested Student Activities

In groups of 2 or 4, students research post-secondary programs along with the entrance requirements related to the CAD/CAM/CNC field. Each group will compile these results through an interactive discussion with the teacher into one "master" list.

Assessment and Evaluation

Student participation in the group activity will be evaluated based on a rubric.

Wrap-up and Closing

- Review the master list of CAD/CAM/CNC education programs.

Learning Resources

(1)   http://www.a2zcolleges.com/, a privately owned website, or similar website for an extensive list of links to colleges and universities.