Industry Uses: CAM, RP, and CAE

Unit: CAD and CADD

Problem Area: Introduce CAD/CADD

Lesson: Industry Uses: CAM, RP, and CAE

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1 **Explain computer-aided manufacturing (CAM).**

2 **Explain computer-aided engineering (CAE).**

Resources. The following resources may be useful in teaching this lesson:

E-unit(s) corresponding to this lesson plan. CAERT, Inc. http://www.mycaert.com.

"Additive Manufacturing vs Subtractive Manufacturing," *Creative Mechanisms*. Accessed Dec. 22, 2018. https://www.creativemechanisms.com/blog/additive-manufacturing-vs-subtractive-manufacturing.

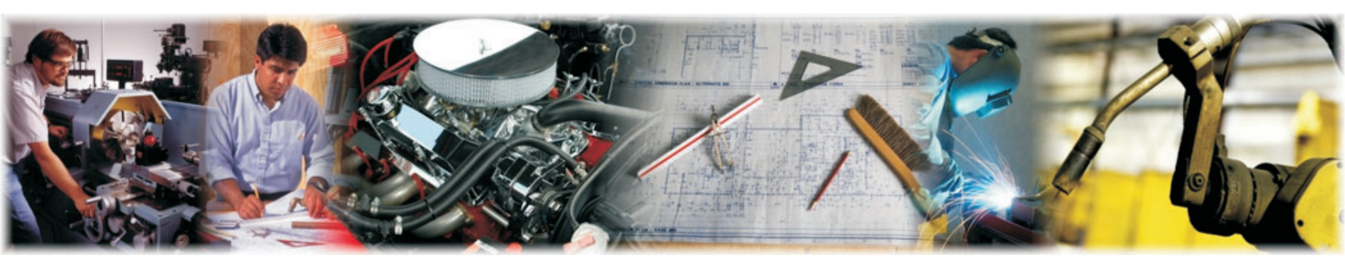
"Applications of Computer Aided Manufacturing," *Digital School Technical Design College*. Accessed Dec. 22, 2018. https://www.digitalschool.ca/applications-of-computer-aided-manufacturing/.

Brooks, Robert. "Autodesk, NIMS Developing First CAM Programming Standards," *AmericanMachinist*. Accessed Dec. 22, 2018. http://www.americanmachinist.com/cadcam-software/autodesk-nims-developing-first-cam-programming-standards.

"Computer-Aided Manufacturing," *Techopedia.* Accessed Dec. 22, 2018. https://www.techopedia.com/definition/4698/computer-aided-manufacturing-cam.

"Computer Aided Engineering (CAE) Explanatory Video," *YouTube.* Accessed Dec. 22, 2018. https://www.youtube.com/watch?v=xoVMQgH_qYc.

"Dartmouth Computer-Aided Mechanical Engineering Design Competition," *YouTube.* Accessed Dec. 22, 2018. https://www.youtube.com/watch?v=AGh4tCJOa-o.



“Directed Energy Deposition for MRO,” *YouTube*. Accessed Dec. 22, 2018. https://www.youtube.com/watch?v=YlHI-Bo2Elc.

“Electrical Discharge Machining,” *YouTube*. Accessed Dec.22, 2018. https://www.youtube.com/watch?v=L1D5DLWWMp8.

“Fused Deposition Modeling (FDM) Technology,” *YouTube*. Accessed Dec. 22, 2018. https://www.youtube.com/watch?v=WHO6G67GJbM.

“Getting Started with G-Code,” *Autodesk*. Accessed Dec. 22, 2018. https://www.autodesk.com/industry/manufacturing/resources/manufacturing-engineer/g-code.

“New Method of Manufacturing Using Powder Bed: Additive Manufacturing with Selective Laser Melting,” *YouTube*. Accessed Dec. 22, 2018. https://www.youtube.com/watch?v=te9OaSZ0kf8.

“Rapid Prototyping and Digital Sand Casting Services,” *YouTube*. Accessed Dec. 22, 2018. https://www.youtube.com/watch?v=Z8MaVaqNr3U.

“Understanding Computer-aided Manufacturing and its Benefits,” *BDE Manufacturing Technologies*. Accessed Dec. 22, 2018. http://www.bdeinc.com/blogs/understanding-computer-aided-manufacturing-benefits/.

Equipment, Tools, Supplies, and Facilities

- ✓ Overhead or PowerPoint projector
- ✓ Visual(s) from accompanying master(s)
- ✓ Copies of sample test, lab sheet(s), and/or other items designed for duplication
- ✓ Materials listed on duplicated items
- ✓ Computers with printers and Internet access
- ✓ Classroom resource and reference materials

Key Terms.

The following terms are presented in this lesson (shown in bold italics):

- additive manufacturing
- CNC laser cutter
- CNC lathe
- CNC machine
- CNC mill
- CNC plasma cutter
- CNC router
- computer-aided design (CAD)
- computer-aided design/computer-aided manufacturing (CAD/CAM)
- computer-aided engineering (CAE)
- computer-aided manufacturing (CAM)
- computer-aided process planning (CAPP)
- computer numerical control (CNC)
- computerized machinability data system

- coordinate-measuring machine (CMM)
- direct-shell production casting (DSPC)
- directed light fabrication (DLF)
- electric discharge machining (EDM)
- fused deposition modeling (FDM)
- fused filament fabrication (FFF)
- G-code
- inventory controlling
- kinematics
- laminated object manufacturing (LOM)
- machining
- manufacturing
- manufacturing control
- manufacturing planning
- M-code
- multi-body dynamics (MBD)
- near-net shape
- optimization
- process monitoring and controlling
- production delivery controlling
- rapid prototyping (RP)
- selective laser melting (SLM)
- separation process
- shape deposition manufacturing (SDM)
- shop floor controlling
- solid ground curing (SGC)
- stress analysis
- subtractive manufacturing
- T-code
- thermal and fluid flow analysis

Interest Approach. Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

> *Have students work to describe and define CAM and CAE. Make a list on the board of the information students delivered. Give the students a list of the Internet hyperlink resources included with this lesson to gather additional information about CAM and CAE. Have students use Microsoft Word or comparable word processing software to create a file containing the list and information they gathered about these CAD categories. Show students some of the online resources using the Internet and SchoolVue or comparable software.*

Students can also begin preparing an online ePortfolio (http://www.weebly.com) to display their body of work from the class.

Explain some of the developments in additive manufacturing. Review the basic ideas behind CAM and CAE. [NOTE: This lesson was prepared assuming the use of the Autodesk product AutoCAD.]

CONTENT SUMMARY AND TEACHING STRATEGIES

Objective 1: Explain computer-aided manufacturing (CAM).

Anticipated Problem: What is CAM? What is CAD/CAM? What is a CNC machine?

I. Computer-aided manufacturing (CAM) processes

Manufacturing is the large-scale production of goods by using manual labor and machines to convert raw materials, parts, and components into finished merchandise. ***Computer numerical control (CNC)*** is a method for automating control of machine tools through the use of computer software that stands alone or is attached to the machine. CNC is commonly used in the manufacture of machined parts. A ***CNC machine*** is a device that manipulates factory tools and machinery according to preprogrammed computer commands. These software commands usually originate in a CAD file. ***Computer-aided design (CAD)*** is software used to create precision drawings, technical illustrations, or models according to specific industry or company standards.

A. CAM: ***Computer-aided manufacturing software (CAM)*** is technology that uses computer software and machinery to facilitate manufacturing processes. The CAD application software can be directly imported into computer-aided manufacturing software (CAM) to create products. Computer application software can be used to develop a manufacturing plan for tooling design, CAD model preparation, and numerical code (NC) programming. CAM software can coordinate CMM inspection programming, perform machine tool simulation, and engage in post-processing. The manufacturing plan is executed by direct numerical control (DNC), tool management, computer numerical control (CNC) machining, or CMM execution. A ***coordinate-measuring machine (CMM)*** is a device used to test components for quality by measuring the physical geometrical characteristics of the object against the design intent. CAM is divided into two main categories: manufacturing planning and manufacturing control.

B. MANUFACTURING PLANNING: ***Manufacturing planning*** is the computer-delivered information for production planning, as well as management of the system. The two main components of manufacturing planning are computer-aided process planning and a computerized machinability data system. Other aspects of planning are work standards development, line balancing, and inventory planning. Work standards development calculates the total time for a job by adding together the time for individual steps in the process. Computer-aided line balancing finds the best allocation of work elements among workstations. Inventory planning and production planning aid a manufacturer in the maintenance of inventory records, automatic reordering of stock as inventory is depleted, material requirement planning, etc.

1. <u>CAPP</u>: ***Computer-aided process planning (CAPP)*** is the connection between the CAD and the CAM module. It plans the process for producing a designed part. Process planning determines the sequence of individual manufacturing operations needed to produce a part or product. The resulting operation sequence is documented on a "route sheet" (a process sheet/a method sheet) that contains a list of production operations and associated machine tools for a part or assembly. Process planning in manufacturing also refers to planning the use of blanks, spare parts, packaging material, user instructions (manuals), etc.
   a. <u>Computerized Machinability Data System</u>: A ***computerized machinability data system*** is a computer system that selects cutting speed and feed rate based on the type of machining operation, the machine tool parameters, the cutting tool parameters, the work part, and operating parameters other than speed and feed.
      (1) Types of machining operations include boring, drilling, grinding, milling, etc.
      (2) Machine tool parameters include size and rigidity, horsepower, spindle speed and feed rate levels, convention or NC, accuracy and precision capabilities, and operating time data.
      (3) Cutting tool parameters include the tool material type (high speed steel, cemented carbide, ceramic, etc.), physical and mechanical properties (hardness, wear resistance, etc.). the tool type (single point, drill, milling, cutter, etc.), geometry (nose radius, rake angles, relief angles, number of teeth, etc.), and tool cost data.
      (4) Work part characteristics include material, hardness, geometric size and shape, tolerances, surface finish, and the initial surface condition of the workpiece.
      (5) Operating parameters other than feed and speed include the depth of the cut, the use of cutting fluid, the rigidity of the workpiece, fixtures and jigs used.

C. MANUFACTURING CONTROL: ***Manufacturing control*** is the use of a computer to manage and control the physical operations of the manufacturing plant. Those operations include:

1. <u>*Shop Floor Controlling*</u>: ***Shop floor controlling*** is the method used to prioritize, track, and report production orders and schedules.
   a. Tool management tracks the use and maintenance of production tools, and alerts when tools require maintenance or replacement, etc.
   b. Work center management establishes work centers for all production activities, defines the rate at which each work center can process its tasks, and defines days of the week when each work center is open, etc.
   c. Shop operations management defines required material, labor, and overhead for each work center, define number of splits per shift, including optional splits for overtime, and reserve labor, etc.
   d. Capacity management analyzes production efficiency for each manufacturing order operation and analyzes all work center conflicts for any date ranges, etc.
2. <u>*Process Monitoring and Controlling*</u>: ***Process monitoring and controlling*** is the process required to track, review, and orchestrate the progress and performance of a project. Specifically, it identifies any required changes to the plan, and then initiates those corresponding changes.
3. <u>*Inventory Controlling*</u>: ***Inventory controlling*** is the logistics of tracking materials, supply chain management, and the technological system and software needed to manage materials.
4. <u>*Production Delivery Controlling*</u>: ***Production delivery controlling*** is product distribution, packing, loading/unloading, shipping, storing, and any related communications required to supply adequate products to the customer.

D. CAD/CAM DEVELOPMENT: In the 1960's, General Motors Research Laboratories developed CAD to automate board (traditional) drafting. CAD was timesaving technology and that gave CAD a huge advantage over traditional drafting. With CAD, designs could be tested by simulation. The aerospace and semiconductor industries pioneered the use of computer modeling to test products. The development of mass-produced silicon chips and microprocessors made computers more powerful and more affordable. CAD/CAM software rapidly grew and its use broadened. Manufacturing firms of all sizes could now enjoy the benefits of CAD. Traditional machining equipment gave way to CNC machines.

1. <u>*Manufacturing*</u>: By using numerical control (NC) technology, CAD facilitated the steps from design to manufacture and eventually resulted in the linkage between CAD and CAM. CAM software modeling, with CAD systems, offered a number of advantages over traditional board drafting methods. Designs are altered without erasing and redrawing. CAD software offered a "Zoom" feature that allowed the designer to magnify the drawing for easier creation and inspection. 3D models could be rotated on any of the three axes: X, Y, and Z. CAD software lent itself to 3D model cutaway drawings, revealing the internal shape of a part, and illustrating the spatial relationship among the parts. One

of the most important trends in CAD/CAM technologies is the ever-tightening integration between design and manufacturing stages of CAD/CAM-based production processes.

2. *Benefits of CAD/CAM*: CAD/CAM software benefits include:
   a. Improved Machining Capabilities: A CAD/CAM system enables the manufacturer to engage in complex multi-axis machining. CAD/CAM software creates a tool path for machining complex parts or systems. The CAM side of the system automates the process, and makes it easier for manufacturers to complete the project.
   b. Improved Client Accessibility: CAD/CAM software allows manufacturers to receive a CAD file from the customer. After receiving the customer file, the manufacturer can program the machining tool path and perform simulations that help calculate machining cycle times. The software allows manufacturers to minimize errors, perform projects easily, and deliver products to the market with a shorter turnaround time.
   c. Improved CNC Machine Productivity: CAD/CAM systems provide high-speed machine tool paths that minimize cycle times and reduce tool and machine wear. High-speed tool paths improve cutting quality and accuracy. CAD/CAM simulations enable visualization of the machining process, which helps eliminate mistakes and reduce material waste. Simulations contribute to the overall productivity of the manufacturing set-up. High-speed machining improves the productivity by more than 50%.

E. CAD/CAM MANUFACTURING: ***CAD/CAM (computer-aided design/computer-aided manufacturing)*** is computer system software used to design and manufacture prototypes and finished products, and to assist with production runs using CNC machines. CNC equipment is driven by CAD/CAM output known as G & M code. The linkage between CAD and CAM enables the design and manufacture of a part with one software system that is inexpensive, fast, and easy to use.

1. *History*: Some of the first CNC machines were developed in the 1940s and 50s and relied on a common telecommunication data storage technology known as “punched tape” or “perforated paper tape.” For example, a player piano is an early type of CNC machine running on paper tape. Punched tape technology became obsolete as the data medium transitioned to analog and then to digital computer processing in the 1950s and 1960s.
2. *Machining*: ***Machining*** is a way to transform a piece of material, such as plastic, metal, or wood, etc. into a finished product by means of a controlled material separation or additive process. Similar to other product development technologies, CNC relies on digital instructions from CAM software. A program called a “post-processor,” which is imbedded into the CAM software, looks at the tool paths created in the CAM software and creates numerical code (G & M code) that the CNC machine understands. The CNC machine is driven by the numeric code generated by the CAM software to perform the separation or additive process. Sometimes the geometry or model needs to be opened in the software separate from the CAM software and then the numerical code is written. The ability to program computer devices to control machine tools

increases shop productivity by automating these technical and labor intensive processes.

F. PROGRAMMING CODES: As with any computer program, CAD/CAM uses programming language, also known as coding. It is the alphanumeric coding that controls CNC machines during the manufacturing process. Codes order motion and function (G##). They declare a position (X##, Y##, Z##). Codes can select a tool (T##) and can set values for the speed of the tool (S##) and the feed rate (F##). Codes can switch something on and off (M##). Some of the more common codes are G, M, T, X, Y, and Z. Each block of NC programming resembles a line of text. That text contains a letter detailing the function to be performed, followed by a number that assigns value to the function. A line of code might look like G01 X01 Y02 F30 T01 M03 S500. A block of input is limited to a maximum of 256 characters.

1. <u>*G-code*</u>: ***G-code*** is the NC programming language that controls the motion of a computerized machine tool. This preparatory code is the most widely used numerical control (NC) programming language. A single word of G-code is a letter followed by a number. A few examples of G-codes are:

   G00-Positioning at rapid speed

   G01-Linear interpolation (machining a straight line)

   G02-Circular interpolation, clockwise (machining arcs)

   G03-Circular interpolation, counterclockwise

2. <u>*M-code*</u>: ***M-code*** (miscellaneous code) is programming language for a computerized machine tool that turns basic control functions (coolant, tool changes, safety circuits, etc.) on and off. A few examples of M-codes are:

   M00 - Program stop

   M02 - Program end

   M06 - Tool change

   M09 - Coolant off

3. <u>*T-code*</u>: ***T-code*** is NC programming language that orders the use of a specific tool. Examples of such tools are a flat end mill, a compression tool, a down spiral, and an up spiral. T-codes appear as T1, T2, T3, etc.

G. MANUFACTURING PROCESSES: A manufacturing process is either a subtractive process or an additive process.

1. <u>*Subtractive Manufacturing*</u>: ***Subtractive manufacturing*** (***separation process***) is the creation of a 3D object by removing material, layer by layer, from a solid block. Subtractive manufacturing can be done manually or with a CNC machine. Most CNC machines use between 3 and 18 axes. Common CNC separation process machines:

   a. A ***CNC plasma cutter*** is a machine that cuts metal by moving a plasma torch in a path directed by a computer.

   b. A ***CNC laser cutter*** is a computer-directed machine that focuses a laser beam to precisely cut or engrave various types of materials.

c. A ***CNC mill*** is a computer-directed machine that uses rotary cutters to remove material. The cutting tool can rotate in various directions and can create a wide variety of shapes and holes. CNC mills are used primarily on metal materials.
d. A ***CNC router*** is a computer-controlled machine used to dig or hollow out the face of a material, such as hardwoods or metal.
e. A ***CNC lathe*** is a computer-controlled machine that rotates a workpiece on a spindle while a cutting tool removes material from it. Cutting a workpiece on a lathe is known as turning. A lathe is capable of making a variety of shapes, cuts, and details.
f. ***Electric discharge machining (EDM)(spark machining)*** is a manufacturing process that uses a rapid series of electrical discharges (sparks) to remove metal from a workpiece. Repeated sparks create a series of deepening craters. The machining is done in a fluid bath. The fluid acts as an electrical conductor, serves as a coolant, and flushes away the eroded metal particles. This nontraditional process is best used for cutting intricate contours or delicate cavities into hard metals.

2. <u>*Additive Manufacturing*</u>: ***Additive manufacturing*** is the creation of a 3D object by depositing material in successive layers. With a CNC machine, this process is performed according to alphanumeric code generated by computer software. A range of different metal, plastic, wood, and composite materials may be used in this process. Additive manufacturing usually creates a prototype as part of product development process with additional machining being done to the part to complete it. 3D printers are devices that appear to produce a finished part. ***Rapid prototyping*** is the use of a group of techniques to quickly produce a scale model or a physical part or assembly, using 3D CAD data. Despite these differences, the term "3D printing" is increasingly used as a synonym for additive manufacturing. Common CNC additive manufacturing machines:
   a. ***Selective laser melting (SLM)*** is a rapid prototyping technique that uses a highly powerful laser to melt and fuse metallic powders together. After powder material is placed on a build platform, a laser is directed onto the powder to selectively melt and fuse the metal particles together at specific points, according to a computer-aided design file. Once a layer is completed, the platform is lowered and more powder is rolled on. The process is repeated until the 3D object is completed.
   b. ***Directed light fabrication (DLF)*** is a direct metal deposition process in which metal powder is blown into the focal zone of a laser beam, to form a fully-dense metal deposit. The laser beam moves along/across the metal deposit to produce a fully dense, near-net shape, 3D metal component. ***Near-net shape*** is a term that means the shape of a part is as close to the finished (net) shape as possible. Computer-based design and numerical controls are used in conjunction with the metal deposition process to guide the laser in forming 3D parts.

c. ***Direct-shell production casting (DSPC)*** is a process that produces the ceramic molds for metal castings from 3D CAD designs by depositing a liquid binder onto a layer of ceramic powder. These ceramic molds are created in layers, three steps per layer. First, the ceramic shell model is "sliced" to yield a cross section of the ceramic mold. Second, a roller spreads a layer of fine powder. Third, a multi-jet print head sprays a binder in required spots of the cross-section. The binder is an adhesive that fills in the pores between the powder particles and fuses the particles together to form a rigid structure. Once a layer is completed, the process is repeated until all layers of the mold are formed. After it is cleaned, the DSPC mold is ready to be fired and poured with molten metal.

d. ***Fused deposition modeling (FDM)***, also known as ***fused filament fabrication (FFF)***, is a manufacturing process in which a nozzle uses melted plastic threads (filaments) to "draw" a cross-section of an object onto a build platform. The thin layer hardens and adheres to the layer beneath it. Once a layer is completed, the base (a build platform) is lowered and the process is repeated layer by layer, based on specific CAD/CAM design coordinates. These machines use a modeling material that becomes the finished plastic object and a support material, which acts as scaffolding to support the object as it is being formed. This technology is usually what the general public refers to as 3D printing.

e. ***Laminated object manufacturing (LOM)*** is an additive manufacturing process in which successive layers of paper or plastic are fused (laminated) together and then cut into a desired shape with a computer-controlled laser or blade. LOM makes it possible to build models quickly and inexpensively but LOM is limited in terms of what 3D geometrics can be created.

f. ***Shape deposition manufacturing (SDM)*** is a rapid prototyping process in which a near-net shape is created by material deposition and then machined into net shape by a CNC mill or router. The depositing and shaping continue, layer by layer, until the component is complete. The process combines additive manufacturing with subtractive manufacturing. SDM retains a 3D representation of the component and variable layers of thickness are created, as dictated by the geometry of the part.

g. ***Solid ground curing (SGC)*** is an additive manufacturing technology in which a thin layer of liquid resin is hardened (cured) by exposure to ultraviolet (UV) light, according to a photo model ("mask") of the desired shape. The holes in the resin are then filled with wax, turning the core material into a solid state. The process is repeated until the component is complete.

Teaching Strategy: *Many techniques can be used to help students master this objective. Use VM–A to review the advantages of CAD/CAM software. Use VM–B to review the CAM separation processes. Use VM–C to review additive manufacturing processes. Lead a discussion of the ways in which these processes are changing* *industry practices. If possible, relate how local companies are using CAM technologies. Assign LS–A.*

Objective 2: Explain computer-aided engineering (CAE).

Anticipated Problem: What is CAE? What are CAE tools?

II. Computer-aided engineering tools

Computer-aided engineering (CAE) is the use of computer software to create, simulate, validate, and optimize products, projects, or processes, for the purpose of resolving engineering problems.

A. CAE PROCESS: A typical CAE process consists of pre-processing, solving, and post-processing steps. In the pre-processing phase, engineers model the geometry (assembly), properties of the design, and the environment in the form of applied loads or constraints. Next, the model is solved using an appropriate mathematical formulation of the underlying physics. In the post-processing phase, the results are presented to the engineer for review.

B. CAE ANALYSIS: CAE tools are used to analyze CAD geometry, allowing product designers to simulate and study the expected behavior of the product in various environments. In order to optimize product performance, CAE analysis is performed during the development stage to study and predict mechanical, thermal, electrical, fatigue stresses, as well as characteristics related to fluid flow, heat transfer, and noise/vibration/harshness. There are different types of software tools for different analyses.

1. ***Stress analysis*** is an engineering discipline that determines the tensions and strains in and on materials and structures subject to external forces. This method is used in the aerospace industry (aircraft, rocket bodies), the field of civil engineering (tunnels, bridges, and dams), and the production of motorized vehicles (automobiles, boats, motorcycles).
2. ***Thermal and fluid flow analysis*** is the numeric analyses and data structures needed to analyze and solve problems with fluid flow. Computers are used to calculate and simulate how liquids and gases interact with surfaces. Among its many possible used, this method is used for wind tunnels (automobiles, aircraft, spacecraft), supercomputing (faster computing power), and propulsion systems (ships, aircraft, and spacecraft).
3. ***Multi-body dynamics (MBD)*** is the study of the behavior of interconnected rigid or flexible bodies undergoing translational or rotational displacement. Among other applications, this method is used in the aerospace industry (helicopter, landing gear, and gravity conditions), the auto industry (vehicle simulation, vehicle dynamics, stability control, comfort, and efficiency, gears, chain drive, and belt drive), the production of hoists (cranes, conveyors, and mills). MBD can simulate the movement of particles such as molecules, sand, and granular media. The field of biomechanics can use MBD analysis to study the

movement of cells and organs. Computer graphics and video games may contain elements that were subject to MBD simulation. MBD simulations are often coupled to other analyses.

4. ***Kinematics*** is the study of the motion of an object, without any consideration for the forces that may act on the object. The movement of an object is tracked using position, velocity, and acceleration. Among other applications, this analysis can be used in the automobile and aerospace industries, the development of biomechanics, the production of robotics (bomb detection, bio-robotics, and manufacturing), and the development of computer graphics and video games.
5. ***Optimization*** is the process of making something as perfect, functional, or effective as possible, given existing constraints. In the engineering field, this involves design, the systems in question, and decision making. Optimization is called for in many fields and industries, including architecture, aerospace, computing, electronics, electrical power, and shipbuilding.

Teaching Strategy: *Many techniques can be used to help students master this objective. Use VM–D to review CAE and selected analysis tools. Then, explain your view of the most beneficial uses of CAE. Lead a discussion of the ways in which CAE processes changed industry practices. When reviewing the purposes of CAE, relate how local companies are using CAM technologies.*

Review/Summary. Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different angle. If a textbook is being used, questions at the ends of chapters may also be included in the Review/Summary.

Application. Use the included visual master(s) and lab sheet(s) to apply the information presented in the lesson.

Evaluation. Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance on the application activities. Some of the assessment can be student driven to determine the level of performance and the grade applied to that performance. A sample written test is provided.

Answers to Sample Test:

Part One: Matching

1. c
2. d
3. a
4. f
5. h

6. e
7. g
8. b

Part Two: Completion

1. shop floor controlling
2. computer-aided process planning (CAPP)
3. manufacturing
4. T-code
5. electric discharge machining (EDM)
6. M-code
7. fused deposition modeling (FDM) or fused filament fabrication (FFF)
8. selective laser melting (SLM)

Part Three: Multiple Choice

1. a
2. c
3. d
4. b
5. c
6. d

Name ______________________________

Industry Uses: CAM, RP, and CAE

Part One: Matching

Instructions: **Match the term with the correct definition.**

a. additive manufacturing
b. computer-aided design/computer-aided manufacturing (CAD/CAM)
c. computer-aided engineering (CAE)
d. computer-aided manufacturing (CAM)
e. computer numerical control (CNC)
f. G-code
g. rapid prototyping
h. separation process

_____1. The use of computer software to create, simulate, validate, and optimize products, projects, or processes, for the purpose of resolving engineering problems

_____2. Technology that uses computer software and machinery to facilitate manufacturing processes

_____3. The creation of a 3D object by depositing material in successive layers

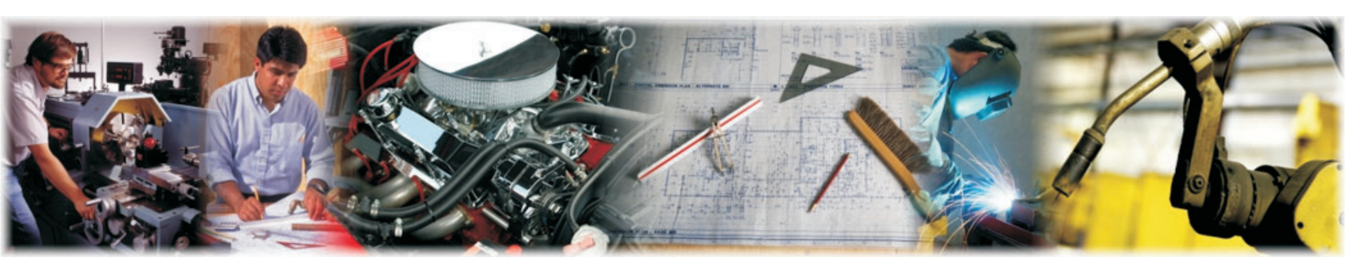
_____4. The NC programming language that controls the motion of a computerized machine tool

_____5. The creation of a 3D object by removing material, layer by layer, from a solid block

_____6. A method for automating control of machine tools through the use of computer software that stands alone or is attached to the machine

_____7. The use of a group of techniques to quickly produce a scale model or a physical part or assembly, using 3D CAD data

_____8. Computer system software used to design and manufacture prototypes and finished products, and to assist with production runs, using CNC machines



Part Two: Completion

Instructions: **Provide the word or words to complete the following statements.**

1. The method used to prioritize, track, and report production orders and schedules is called ________________________.
2. The connection between the CAD and the CAM module is ________________________.
3. The large-scale production of goods by using manual labor and machines to convert raw materials, parts, and components into finished merchandise is called ________________________.
4. NC programming language that orders the use of a specific tool is called a/an ________________________.
5. A manufacturing process that uses a rapid series of electrical discharges (sparks) to remove metal from a workpiece is called ________________________.
6. Programming language for a computerized machine tool that turns basic control functions (coolant, tool changes, safety circuits, etc.) on and off is called ________________________.
7. A manufacturing process in which a nozzle uses melted plastic threads to “draw” a cross-section of an object onto a build platform is called a/an ________________________.
8. A rapid prototyping technique that uses a highly powerful laser to melt and fuse metallic powders together is ________________________.

Part Three: Multiple Choice

Instructions: **Circle the letter of the correct answer.**

1. Stress analysis is an engineering discipline that determines the tensions and strains in and on materials and structures subject to _____.

   a. external forces
   b. additives
   c. prototyping
   d. constraints

2. In CAE, the study of the behavior of interconnected rigid or flexible bodies undergoing translational or rotational displacement is called _____.

   a. CAD/CAM
   b. kinematics
   c. multi-body dynamics (MBD)
   d. stress analysis

3. In CAE, optimization is the process of making something as perfect, functional, or effective as possible, given existing _____.

   a. G-code
   b. separations
   c. motion
   d. constraints

4. In CAE, kinematics is the study of the motion of an object, without any consideration for the _____ that may act on the object.

   a. flow
   b. forces
   c. acceleration
   d. velocity

5. In CAE, thermal and fluid flow is the numeric analysis and data structures needed to _____ and solve problems with fluid flow.

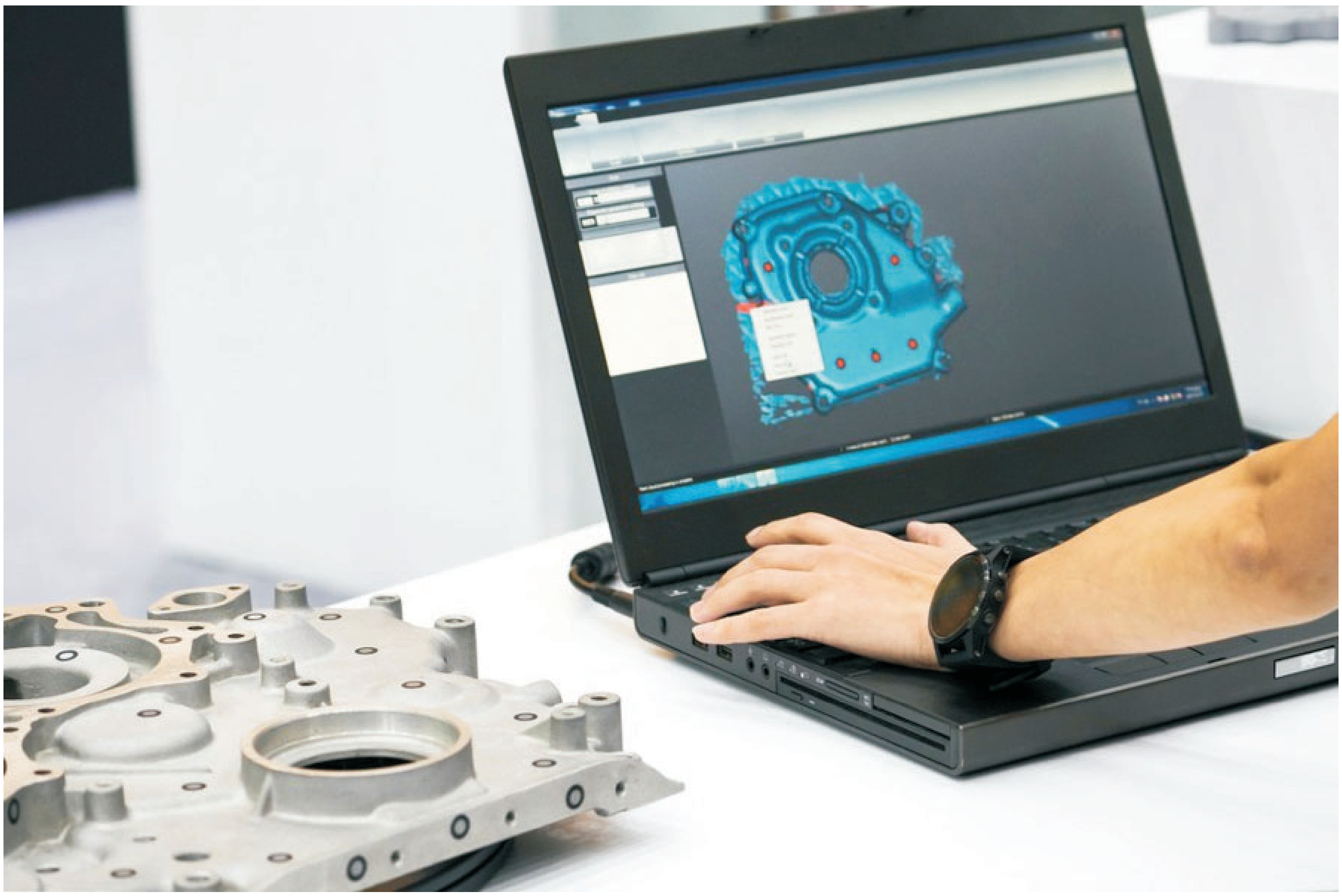
   a. add
   b. separate
   c. analyze
   d. remove

6. The term "3D printing" is increasingly used as a synonym for _____ manufacturing.

   a. multi-axis
   b. high-speed
   c. separation
   d. additive

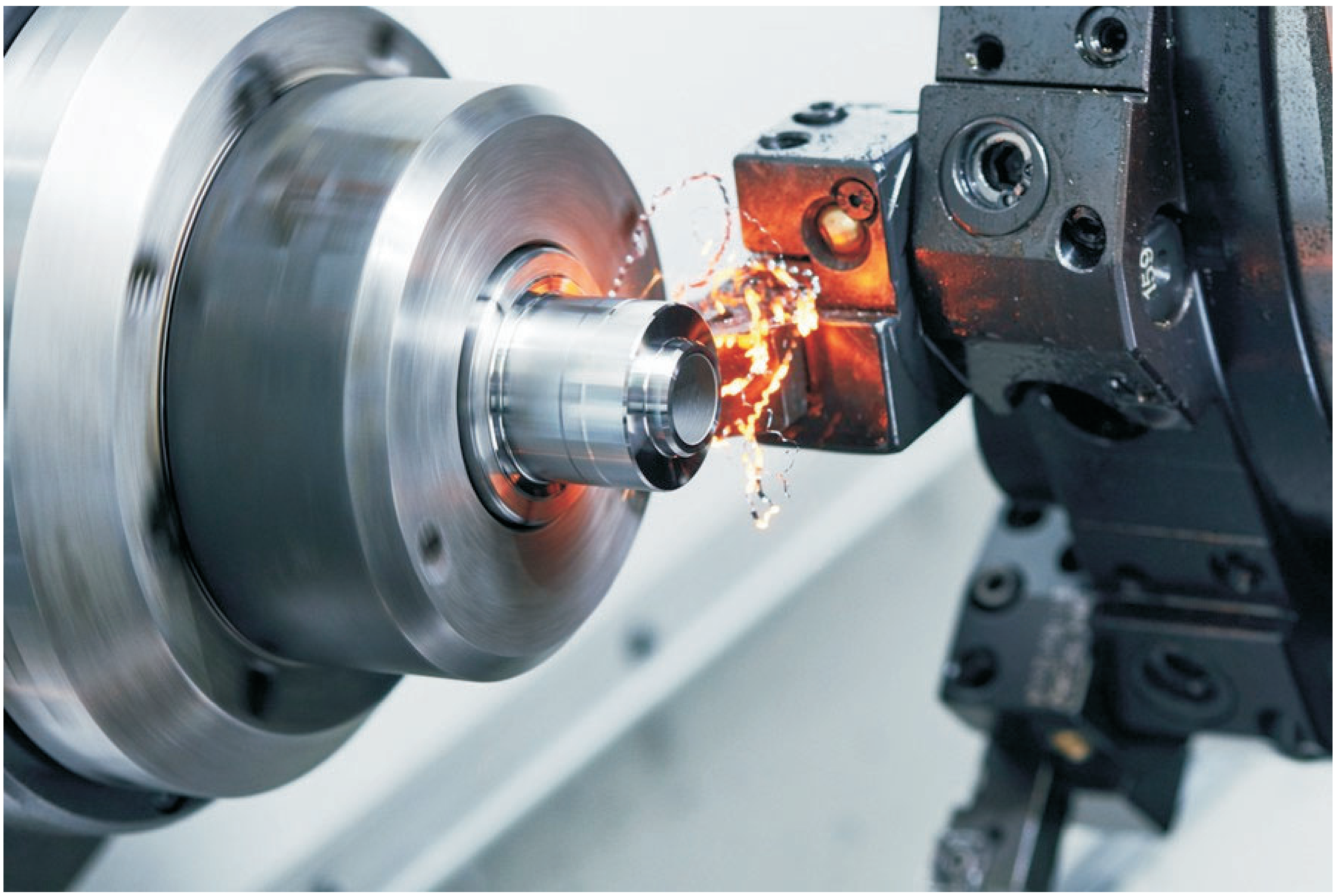
CAD/CAM SOFTWARE

CAD/CAM software enables an engineer to design a product in the virtual environment.



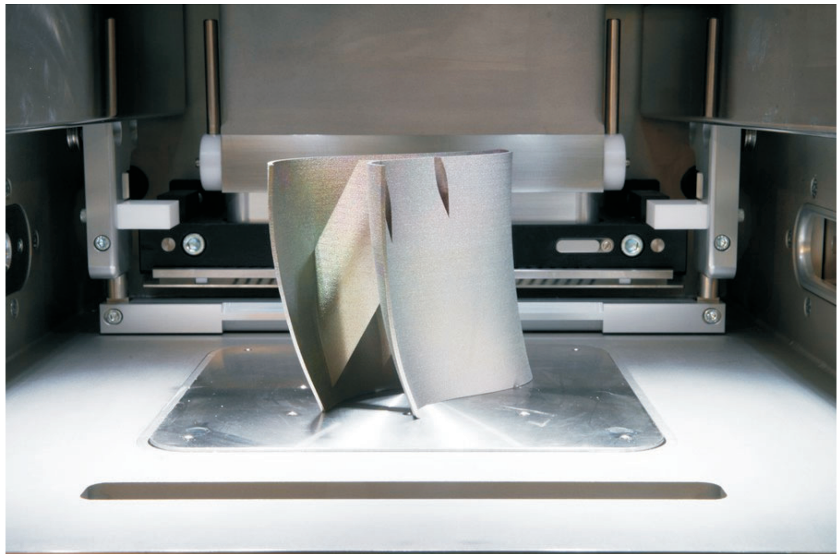
CAM SUBTRACTIVE MANUFACTURING: CNC

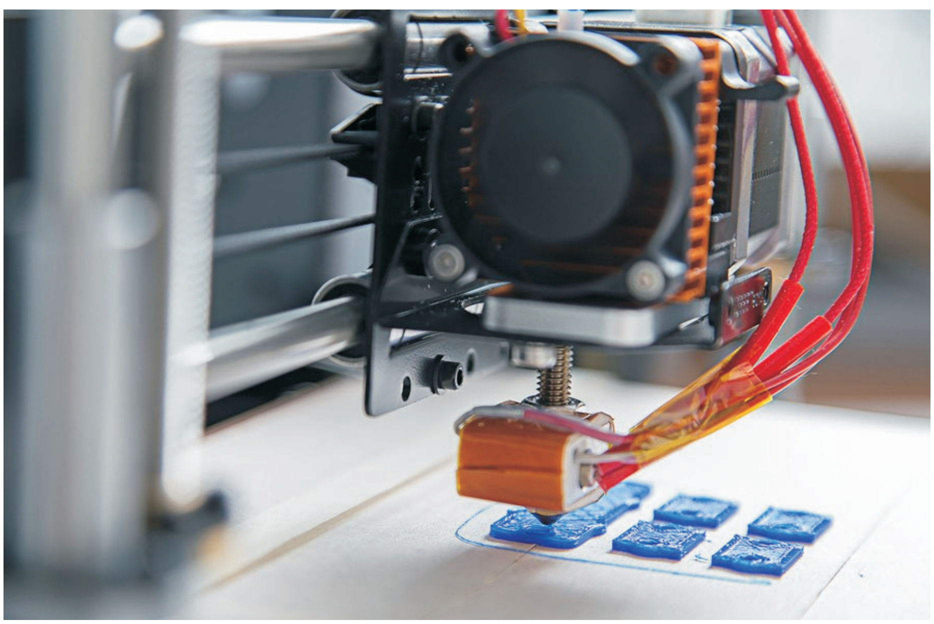
A CNC lathe is a type of CNC machine that performs subtractive manufacturing.



ADDITIVE MANUFACTURING PROCESSES

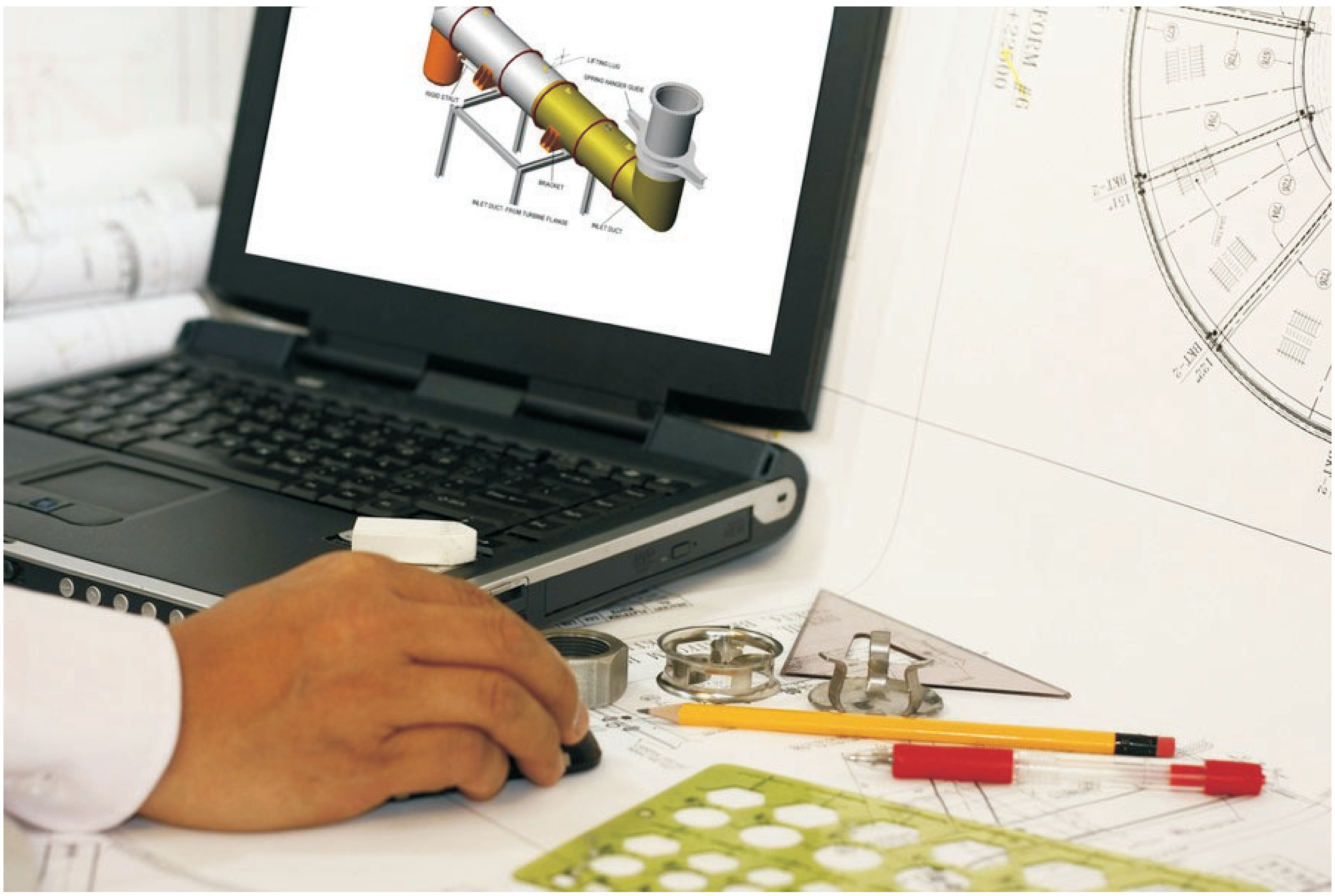
Selective laser melting (SLM) is a rapid prototyping technique that uses a highly powerful laser to melt and fuse metallic powders together. 3D printers are devices that appear to produce a finished part.





COMPUTER-AIDED ENGINEERING (CAE)

In the pre-processing phase of computer-aided engineering (CAE), engineers model the geometry (assembly), properties of the design, and the environment in the form of applied loads or constraints.



LS–A

Name ______________________________

Additive Process Technologies

Purpose

The purpose of this lab activity is to research an additive manufacturing process.

Objectives

1. Research one additive manufacturing process.
2. Write a one-page paper, explaining the additive process that you researched.
3. Present a 5-minute talk about the additive process, enhanced with key screen captures and a video clip.

Materials

- lab sheet
- device with Internet access, word processing software, and printer

Procedure

1. Select one additive manufacturing process to research.
2. Conduct the research to prepare a one-page report explaining the additive process.
   a. Create screen captures with a “Snipping Tool” to enhance your report.
   b. Find one video that demonstrates the additive process you chose.
3. Make a five-minute presentation to class that includes screen captures and a short video clip.
4. Turn in your completed lab sheet report to your instructor.