

## Simulation strategy in CAD/CAM programs as a method for teaching principals of material forming

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### **Abstract:**

The paper represents an investigation into suitable learning strategies to approach principals of material forming using CAD/CAM programs. Learning and teaching approaches needed to reach what a student deserves, and considerations that should be taken by teachers to decide on the proper learning style. Learning style depends on the individual's abilities, environment and learning history. Learners learn better when the subject is presented in a style that is consistent with their preferred learning style. Course specifications of a subject for principals of material forming using cad/cam programs, the intended learning outcomes for the subject and crosses contents of the subjects and software are listed. Focusing on teaching the learners CAD/CAM programs and their functions, the use of combination of CAD/CAM for CNC Machining in many program packages, Practice of simulation strategy in education to reach the toolpath simulation and machine. Tool controls simulate machining and the benefits of selecting simulation software are discussed. The assessment methods for the subject are mentioned.

### **Keywords:**

Simulation, teaching strategy, metal forming

### **Introduction:**

The use of traditional methods in teaching the rules of the material formation is very expensive due to the high prices of machines and materials as they are used for educational purposes only. In addition to danger the student is facing, especially in the early stage of learning. That is one of the reasons for using simulation strategy. Simulation strategy in learning is one of the educational methods recognized nearly, for teaching many crosses. This is due to great benefits gathered when using that strategy. The use of simulation software can change the way the student approach problems, also student find pleasure by making him active in computer exercises. Through using a cam program that contains simulation system as a package. To get the best benefit of the selected package of cam programs, it must be easy to learn and can be used for more than one course.

Furthermore, it must be widely used in the market in order to provide the student with vital skills at graduation. To simulate, essentially means to try

to duplicate a real world process or system over time. Whether done by hand or computer. The more we know about the system, better will be the simulation and more reliable the result from simulation. Simulation is defined as "the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time." (wikipedia)

It is an art of depicting the facts understood from the observations such that more experimentation can lead to better understanding of the phenomenon or the system being studied. Simulation models are "run" rather than solved, even through there may be a few exceptions. Given a set of inputs and model characteristics, the model is run for set of inputs and the simulated behavior observed. The process of changing inputs and model characteristics results

in a set of scenarios that are evaluated. A good solution, either in the analysis of the existing system or in the design of a new system is then recommended for implementation.

### Study Problem:

Due to lack of machinery, tools and materials in educational institutions, a proper simulation strategy is required as a method for teaching material forming principals in CAD/CAM programs. The suggested strategy is needed to be implemented in technology oriented courses to assist designers to improve their abilities in both understanding and practicing metal forming.

### Study Significance:

The study provides an enhanced simulation strategy to teach principals of material forming using CAD/CAM programs. It also boosts the ability of design student or trainee to learn the technique of materials forming. The introduced methodology assists a designer to accurately go for the right type of material forming according to the part shape.

## Methodology

### 1- Teaching and Learning Approaches:

Learning and teaching are at the spirit of a successful course. We now recognize more about how student learn and it's essential that we all realize that how we teach is as important as what we teach. Student deserve the very best in dominant learning experiences and in order to afford that we have to re-examine our methodologies and give greater scope to teachers to exercise their professional skill. Organization should discuss with all staff how best to capitalize on 'what we do well already' and how we can get better and be more resourceful in our learning and teaching.

There are considerations of Learning and teaching approaches should be taken by the teacher to select the suitable learning style:

- § Focused on the learner.
- § Well planned, considering outcomes, learner's interests and prior knowledge.
- § Enjoyable, relevant and inclusive – enhancing the experience, achievement and

attainment of our most vulnerable children and young people.

- § Active and fun, allowing young people to become problem solvers in a supportive and stimulating atmosphere.
- § Flexible and creative, allowing for personalization of learning.
- § Allow for choice, challenge and chances.
- § Based on up to date educational research.
- § Collaborative and co-operative, promoting quality social interaction between children and young people. (Glasgow City Council, 2009)

The learning style must fulfill all the aims of learner, teacher and help in achieving the intended learning outcomes for the subject.

### 2- Learning Styles:

There has been a cycle of debates about effective teaching that have taken place since the late 1960s, These have largely centered upon the efficiency of providing a wide range of teaching styles and strategies. This led to having variety of strategies, which can be choosing according to the subject. There has been a growing recognition that student learn in different ways, Finding out student learning preferences, and comparing those to the strategies they are offered in lessons, enables teachers to match teaching to learning.

Part of the effort to engage learner more in their learning has been to involve them in a conversation about how they learn, Engage more student in their learning; have led teachers to explore alternative ways of teaching, when teaching practical subjects. (John Beresford, 2011)

To select learning style depends on the individual's abilities, environment and learning history. Learners learn better when the subject matter is presented in a style consistent with their preferred learning style. Figure (1) present Kolb's four learning styles (adapted from Fielding, 1994)

#### 2.1 – Accommodators:

This learning style carry out plans and experiments and adapt to immediate circumstances, use the following strategies, Group work organized, Gut feelings asked for, Mistakes allowed, Reporting back methods varied,

Simulations and Variety of approaches. It is used when allowed to gain 'hands on' experience.

#### Learning styles

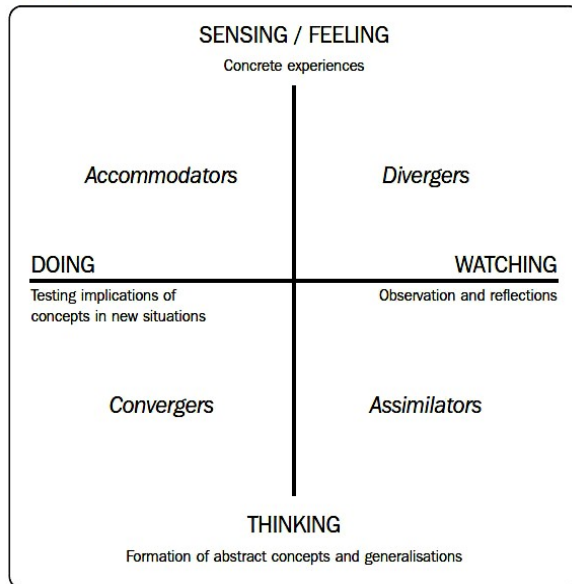


Figure 1: Kolb's four learning styles (adapted from Fielding, 1994)

#### 2.2 - Assimilators:

This learning style use inductive reasoning and have the ability to create theoretical models, use the following strategies, Accurate recall, Action planning, Case study, Class work, Data collection, Demonstrations, Hand-outs, Lecture, Specialism tapped, Video and Working alone. It is used when presented with sound logical theories to consider.

#### 2.3 - Convergers:

This learning style rely heavily on hypothetical-deductive reasoning, use the following strategies, Accuracy stressed, Choice of activities, Clear goals expressed, Comprehension, Note-taking, Planning of work by learner, Practicing skills, Problem-solving, Relevance of work explained, Scientific experiments, Testing, Thoroughness stressed, Working alone and Worksheets. It is used when provided with practical applications of concepts and theories.

#### 2.4 - Divergers:

This learning style view situations from many perspectives and rely heavily upon brainstorming and generation of ideas, use the following strategies, Brainstorming, Discussion, Group interaction, Investigations, Open-ended questions

asked, Paired work, Reflection on experience and Role play. It is used when allowed to observe and gather a wide range of information. After studying the learning styles, it show the importance of compatibility between the Syllabus, which is taught and education strategy used, and the attempt to change the strategy of traditional education strategy modern and applicable, is the simulation in order to bring the difficulties faced by the learner in the section on the formation of materials using the CAD/CAM.

So, we can start by the course specifications and by selecting the suitable course plan with the suitable learning styles, this will led to a complete education strategy to this subject.

### 3- A suggested course specifications of a subject for principals of material forming using CAD/CAM programs:

By the end of the course the students will be able to:

- § Compare between different techniques of effective using of CAD/CAM in manufacturing.
- § Use of modern tools and applications programs commonly used in CAM.
- § Enumerates the different CAD representation data.
- § Understand the fundamental concepts of computer assisted CNC programming.
- § Develop a process plan for a real case study.
- § Plan a production facility for a real case study.

#### 3.1 - The intended learning outcomes:

##### a- knowledge and understanding:

- a1 - List and describe the different applications of computers programs in industry.
- a2 - Identify the different CAD data representation and different file types.
- a3 - Explain the fundamental concepts of computer assisted CNC programming.
- a4 - Explain the concepts of computer aided process and production planning.
- a5 - List and describe the different sensors and transducer concepts.
- a6 - Explain the concept of rapid prototyping.

**b - Intellectual skills:**

b1 - Choose an appropriate CAD data representation for different applications.

b2 - Choose a suitable CAM program for different applications.

b3 - Establish a complete plan for a case study and simulate the case.

**c- Professional and practical skills**

c1 - Use appropriate steps for complete plan for a case study

c2 - Design and perform experiments using CAD/CAM programs

c3 - Use different CAM application software

**d - General and transferable skills**

d1 - Write technical report according the scientific standards guideline

d2 - Present the different knowledge concepts through a report in oral seminar

d3 - Work as a part of a team in production planning group for a real case Study

**3.2 - The main points of the crosses contents:**

What is CAD/CAM?

How to choose a CAD/CAM program?

The different types of CAD/CAM software.

What are tool paths and how do you create them?

The cam program steps: (As presented in Figure 2)

- § Define material
- § Define stock size
- § Define coordinates
- § Define tool
- § Define feeds and speeds
- § Simulate machining
- § Tool paths
- § Post process

Using cam software.

Example of some G-Code.

Machine controllers.

The principals of material forming:

- § Milling 2,5,3 axis
- § Milling 4, 5 axis
- § Turning
- § EDM

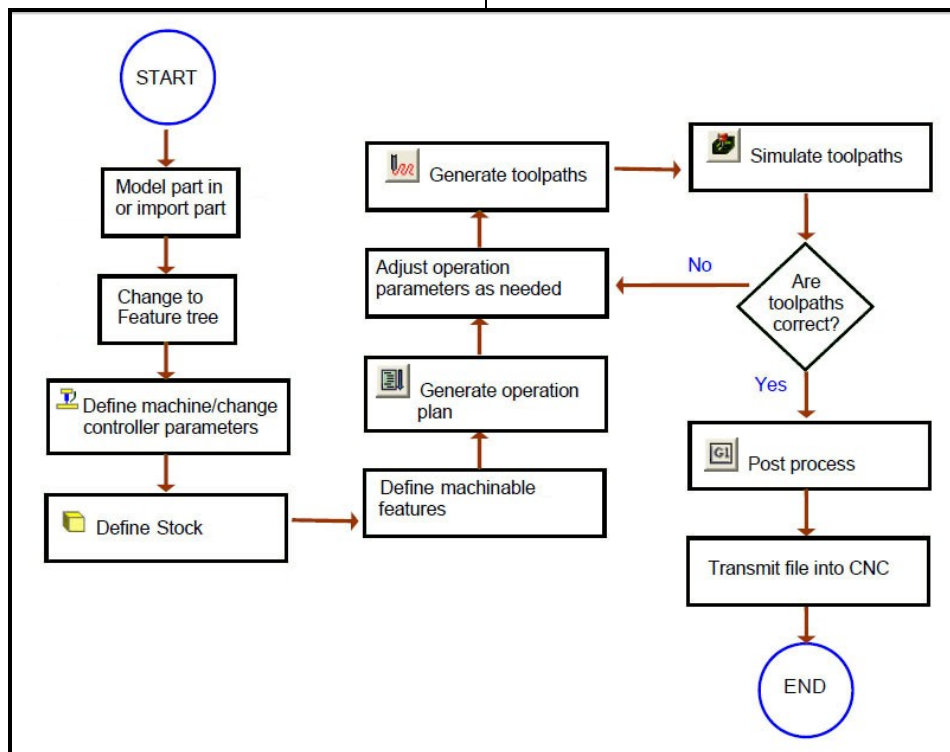


Figure 2: The cam program steps

#### 4- Subjects and Software:

Teaching method selected to teach courses like CAD/CAM program, material forming and theory of machines. Following Bloom's strategy, the acquaintance is achieved in the academic lecture with stress on practical examples (as shown in the Application at the end of the research). In order to increase student intellectual capacity simulating the case study, Excel sheet for recognizing the data needed to achieve the part properties and configurations and Working Model are used for revelation and visualization of the problem presented in the academic lecture. Selecting the software suitable for the subject needs great care and depends on some practical rules. It also, may led to choose a full package of software which is preferred than a single program. The full package of software gives the ability of starting any project from scratch till last machining stage.

Teaching subjects like dynamics, theory of machines and robotics with emphasis on the theoretical concept only is knowledge. In order to understand the function of a special mechanism, students are previously asked to build their own model in the workshop, or a laboratory setup is required to visualize and demonstrate the mechanism motion. A more viable option is to use the computer simulation to replace the workshop and Lab. Because of its extensive mathematical, simulation and graphical capabilities, simulation was selected to do the numeric and graphical job. Also, simulation has a wide number of toolboxes, which provide a graphical modeling environment. The ability of simulation to be interfaced with other dynamic simulation programs makes it a powerful tool for mechanical engineering educational. In the other hand, Working Model and simulation are becoming popular tools in education. The simulation packages allow one to quickly build and analyze a dynamic mechanical system. These packages are easily interfaced with simulation, which make it easier for the student to get the numeric data required for the simulation. (Allan Tubaileh, 2006)

The cam program in manufacturing process aims to successively reduce material from the stock

model until it reaches the final shape of the designed part.

To accomplish this, the typical machining strategy consists of:

- § Using initially large tools to perform bulk removal from the stock (roughing operations)
- § Using progressively smaller tools to remove smaller amounts of material (prefinished operations)
- § Using a small tool to remove the uniform stock layer achieved in previous operations (finish operations)

In addition, by simulating material removal the image of the stock mode at any time during the process can be visualized. This provides valuable feedback for choosing the most appropriate machining strategy. (Dinu Gubencu, 2009)

These are the steps that the student will pass by to reach the aim of the subject and the program.

#### 4.1 - CAD/CAM programs:

Computer-aided design is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. Computer-aided drafting describes the process of creating a technical drawing with the use of computer software. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print or machining operations. CAD software uses either vector based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects.

Computer-aided manufacturing is the use of computer software to control machine tools and related machinery in the manufacturing of work pieces. This is not the only definition for CAM, but it is the most common; CAM may also refer to the use of a computer to assist in all operations of a manufacturing plant, including planning, management, transportation and storage. Its primary purpose is to create a faster production process and components and tooling with more precise dimensions and material

consistency, which in some cases, uses only the required amount of raw material (thus minimizing waste), while simultaneously reducing energy consumption. (Wikipedia)

Detecting that definitions of CAD/CAM we have to discuss the function of their systems and how can the combination with CNC machining will be used in learning the course.

#### **4.1.1 There are several functions of CAD/CAM systems:**

1. To use CAD/CAM system can give a suitable solution in design and manufacturing products to teach the student, as most these programs are based on product design and manufacturing. Some of the CAD/CAM packages are for general products, and others are specialized in certain type of product.

2. A CAD/CAM system can generate manufacture information based on the numerical model contained in the CAD part. This information can be used in many ways during the manufacturing process. For example, it may assemble numerical control information for a part which is used in a diversity of ways by directing it to different numerically controlled equipment or systems, or it may be milling information to direct a machine to engrave a surface as described in the CAD part. This can play an important role in teaching the student how to deal with this information.

3. The connections capabilities which offer a system for exchanging information with other computers using conventional telecommunications networks are also used in CAD/CAM system. This information may be numerical control information, CAD drawing information, or any other type of information. The integration of CAD/CAM is not only based on the material part of creation being produced, but also on the data that define and direct each step in the manufacturing process. This can help in teaching the student how to deal with different kind of information and to select the best according to the situation.

#### **4.1.2 - Computer-Aided Manufacturing (CAM):**

The number of Computer-Aided Manufacturing (CAM) applications is growing rapidly after the development of Computer-Aided Design (CAD).

CAM depends mainly on the CAD data, using special type of file (extensions), such as STL, IGES, VRML, DXF, and DWG, also file types belonging to the programs, and graphics of the designed projects, and so on. The students have to study the different between the file extensions, and what type can be used in which machine and why. Answering this is the first point in the manufacturing plan. Therefore, the connection between computer aided design and manufacturing processes is closely attached. It is the relationship that provides the design of tooling, parts, assemblies and fixtures and the generation of machine information for manufacturing and examination.

The range of CAM applications differ greatly from highly programmed tools which are mainly graphics determined to pure language based tools where machine tool, and other programming languages to control the machines. Modern technology provides the combination of both graphics and language in an application to take full advantage of the efficiency.

#### **4.1.3 - Combination of CAD/CAM for CNC Machining:**

CAD/CAM combination means performance interfaces between these systems as long as internal or external announcement of item for consumption data. It is acknowledged that different steps in the development of a manufactured product are interrelated and can be accomplished more successfully and professionally with computers. Programs as Solidworks, Parasolid, Catia, ProE, Inventor, Solidedge, and some other programs specialized in certain product as jewelry design as Rhino, Artcam, and Matrix, all this packages work on combining CAD and CAM programs. Both types can be studied by student to increase general knowledge about the subject, but only one program will be used in simulating the final project.

The combination is not typical in all programs, but nearly the same main steps or topics. The CAD/CAM applications submit starting manufacturing analyses to manufacturing controls. In general, the relationship that CAD/CAM provides between geometric models and the quantity crunching power of computers allows it to offer huge efficiency improvements

in numerical control (NC) system. Largely, CAD/CAM integration is a solution to the industrialized which improves the productivity, efficiency, and profitability in existing production.

#### **4.1.4 - Simulation of CAD/CAM system in CNC Machining:**

After a NC programmer finishes programming, and before an operator begins to manufacture the geometry part, it is very helpful for them to watch a graphic representation of the path superimposed on the geometry part. A CAD/CAM system can be developed to generate automatically the optimal cutter path, to move from one machining feature to the next. This is simulation.

Current research focuses on the NC tool path simulation with the ability to display the cutter path superimposed on the geometry part. CAD system displays cutter location on a color screen rather than in black and white screen. Additionally, the CAD/CAM system suggests that the geometry as a shaded image is in one set of color, and then the tool path is in a contrasting color. Cutting paths are as solid lines and rapid movements in air are seen as dotted lines. Therefore, CAD/CAM system makes CNC manufacturing process simulation more powerful and clear than any other simulations. (Shanshan Chen, 1995)

Generally, when multimedia for education is used, there is a trend to consider it the ideal system for educating while presenting material which can be understood easily, by using a computer simulation. This simulation is very important because there are some cases where even very common words, when they do not appear in written form often, are missed totally, even by academic students. Not only in the vocabulary as verbal communication, but also existing activities. Generally, multimedia comprises all of the information of images, voices and others, and gives an impressive feeling. Conversely, considering the students who entertain advanced education as easy information is not inputted only because trial information is lacking, and for aiming at social self-determination, they apply very much to rise above the gap of thinking as well as wide-ranging common sense, the fear that the sense of

accumulating the creative experiences to make by themselves as physically emotion drops out becomes very large. It is considered that students who are departing to start an engineering career in the future, that multimedia education through physical feeling to learn through whole senses may be essential by all means. The development advances toward the basic education for machine design by teaching through practical approach. The simulation of machinery and equipment being used which are related to multimedia and networks are enumerated. They are used for teaching, mainly centering on the operation for CAD/CAM, and by transmitting CAD data. This at last generates a well educated graduated student.

#### **5- Practice of simulation strategy education:**

The experiential practice of drawing education aided by multimedia and network is introduced. The teaching of CAD in which drawing is performed by using computers has been carried out for students in CAD/CAM practice so far. However, the special training for doing the practice in companies has been performed, and the number of the students who are assigned as the type of occupation suitable to the persons who have auditory defects increased, thus those results became experientially remarkable, and it was decided to strengthen the teaching. At present, from the third term of graphics exercise which is performed in first year, the teaching of the basic operation of CAD is begun. However at this stage, students scarcely learn special subjects, and it is too difficult to do machine drawing including machine elements for them, therefore, the drawing education in which the experiential multimedia through bodily feeling is taken so as to be able to learn the sense of using CAD begins. (Tsutomu Araki, 1998)

#### **5.1- Toolpath Simulation and Machine Tool Control:**

Simulation provided a basic toolpath simulation and a 2D simulation are available as internally developed software. In addition, Machine Works for 3D simulation. It performs solid toolpath verification and simulation and is the primary simulation capability employed by users.

The simulation software also provides graphical tool path simulation in CAD environment to

prevent the machine tool damage. Three views are available in the graphical tool path, such as top view, front view and right view. Therefore, students or other users can generate the machine tool path in CAD before actually machining of the part. The graphical tool path simulation uses different line types and colors to distinguish between the cutting operation and rapid travel operation. This makes this tool path clear and powerful as present in Figure (3).

The geometry data of the cutters must be provided before the simulation. A developed tool path should show the length and the diameter of the cutter, plus the depth and width of the cutting path. Turning operation is used widely in NC technology. This is another feature suggested to be added in future research. It will make this simulation software more versatile and more applicable.

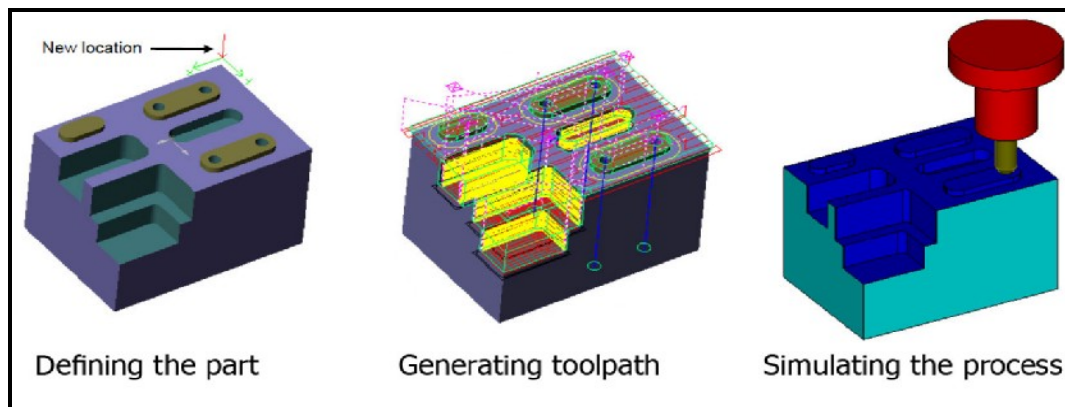


Figure 3: The toolpath in different line colors

### 5.2- Simulate machining:

- § Simulation occurs before posting and before the G-codes are computed in the post-processor.
- § Parts can be rotated during verification. The entire machine tool including fixtures and the part are simulated in 5-axis operations. In 2- and 3-axis operations the entire machine tool is not simulated.
- § CAM maintains greater control over the process. The CAM post generator is language based; the language being similar to Basic. There is neither a Wizard nor graphics to aid the user when developing posts.
- § From a large library of post-processors, the specific posts required by a customer are provided with the system.
- § Post-processors can be and are often customized by a CAM reseller. Additional posts can be generated by the CAM reseller and there is usually a charge for this service. Only a few users create their own post-processor. When the G-code is created in the post, there is no need for further editing before it is sent directly to a machine. It can be generated from a Post-processor.
- § CAM employs its own internal code that is unique to CAM. It is referred to as parameter code or P code. CAM believes that their P code

is more efficient than use of a CL-file. Sub-routines are built into the P code. If an operation is to take place at multiple levels the commands are only created once, as compared to being generated for each level.

- § The CAM program output is efficient. If the same operation is performed several times the commands are only recorded once in the output, there by minimizing the program length. In other systems the commands are often repeated. (Allan Christman, 2005)

### 5.3- Benefits of selecting Simulation software:

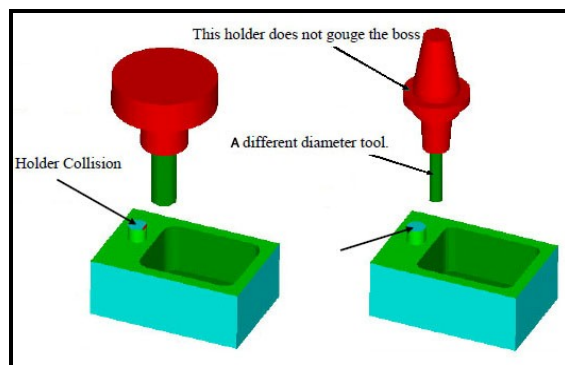
Simulation software can be used for vertical milling machine. It is known that NC programs containing errors can cause serious problems during the communication and the machining. For instance, if the dimension of the drill operation is too deep, the cutter may drill into a clamp or a fixture. That can cause breakage of the tool and damage to the clamp or fixture. Therefore, the benefits of graphical simulation software package are:

1. The software package gives the students all the benefits of CAD/CAM without the complicated steps of generating NC codes, such as G40, G41. That is complicated to



student with lack in engineering background.

2. The software packages provides NC code inspection functions, and help the students and other user to verify their NC programs correctness during the programming process.
3. When the error occurs, the software will stop converting NC codes into script file, and display an alarm message to tell user which part of the NC program is wrong and how to correct it as present in Figure (4). Some programs may give hints to the solution of the error or hints to the cause of error.



**Figure 4: Solving the errors that appear by simulation**

4. The stock size control function in this simulation software uses CAD basic commands to generate an original stock drawing with three different views.
5. After simulating in some complicated cases manufacturing start machining by wooden, wax, or foam as prototypes, for verifying the toolpath and examining it, this step was usual before simulation was added to CAD/CAM packages. Discrepancies between the prototypes and the intended design specifications are corrected by editing the program and the entire process is repeated until an acceptable part is produced.
6. This kind of process requires a lot of machine setup time, and multiple manufacture time on prototypes. Moreover, it is even founded to be costly because of the largely unavoidable expenses associated with the overall manufacturing process cycle. Hence, this graphical simulation software automates the NC verification on the computer, avoids

many of the hard testing process for the prototype, and reduces the cost.

7. Without simulation software, milling machine is almost useless in education. Due to the high cost of materials when examining every step in machining process. Right now, it can be used to fulfill the education requirements and saves unnecessary costs.

#### **6- Assessment methods for the subject:**

The exercises are designed to present more compelling questions to be answered via simulation. In the traditional course, development of a model that properly given real-problem situation is often seen as an end in itself. In the revised course, model development is just the starting point for experimentation and analysis, drawing of conclusions, and reporting results. Students thus have greater exposure to the entire process of simulation modeling and analysis.

For example, the theoretical concept of cam design which includes selection of displacement curves of the follower and the parametric equations of the cam profile is presented in the class. For better understanding of the theory, each student is asked to design his own cam. Then, the data is exported to simulation to model the cam geometry using the geometry window. The rest of linkages are easily modeled by simulation, and the mechanism is animated to analyze its motions. The motions parameters can be easily changed to visualize the output motion like displacement, velocity and acceleration in a form of easily to read and understand graphs. (John Beresford, 2011)

Finally, the design of the course lends itself to active experiential learning, as students experiment with and “discover” the principles being demonstrated, rather than simply being “told”.

#### **7- Application:**

The application depends on parts designed by the student or selected from brakeage of examples introduced in the crosses for them.

##### **7.1- Case study A:**

A part selected from an assembly introduced to explain 2.5 and 3 axis milling.

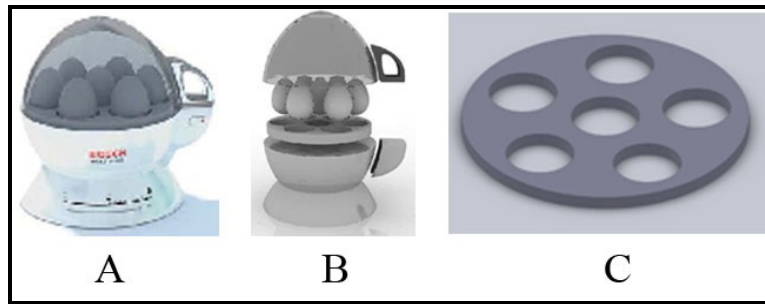
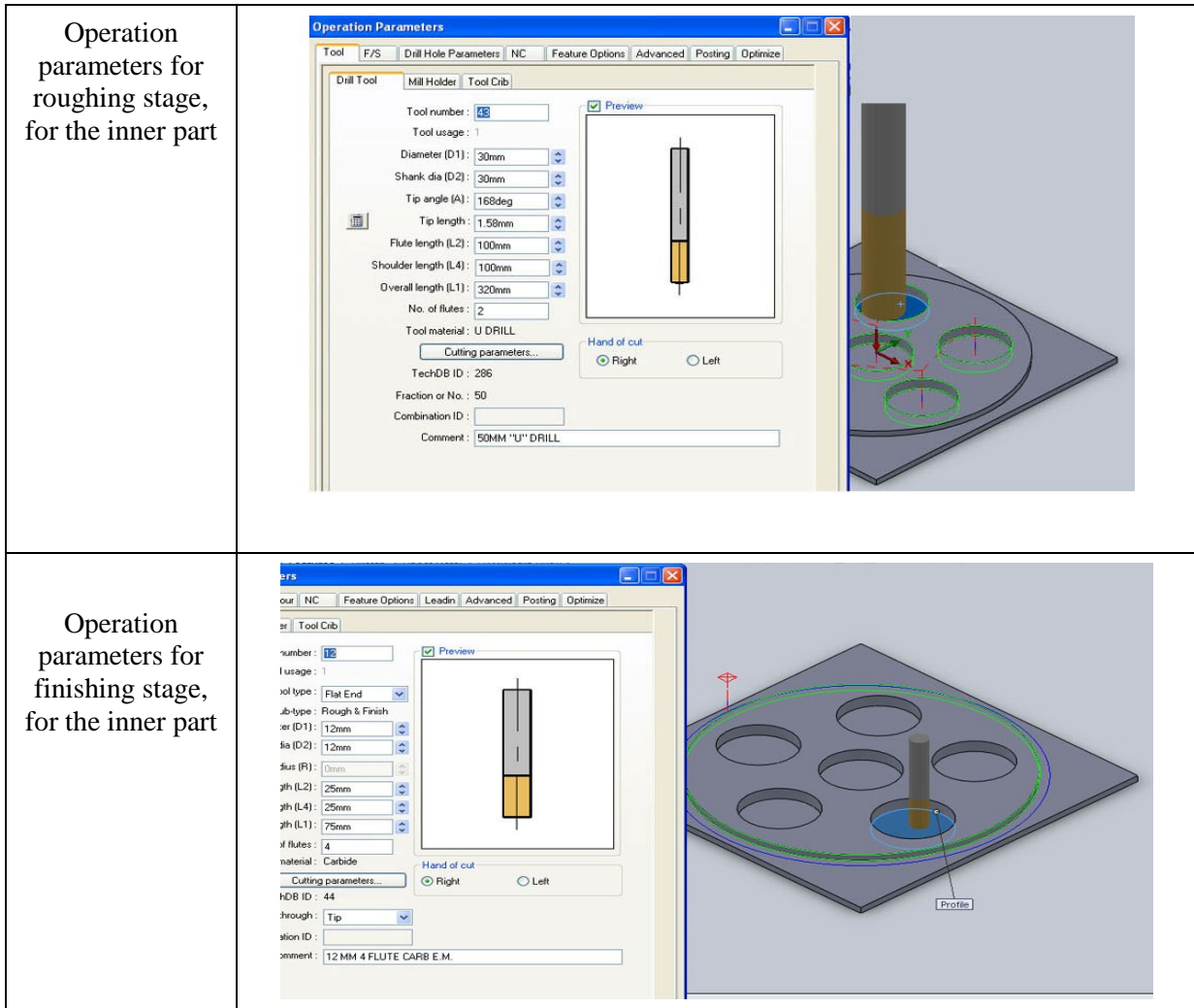


Figure 2

The stage	Simulation graphics
Toolpath for milling stages	
Operation parameters for roughing stage, for the outer part	



**7.2- Case study B:**

A part selected to explain milling stages, and the operation parameters.

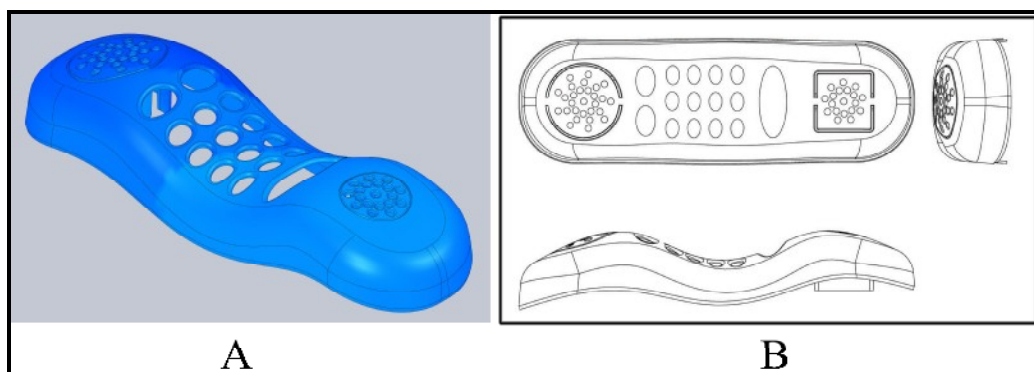
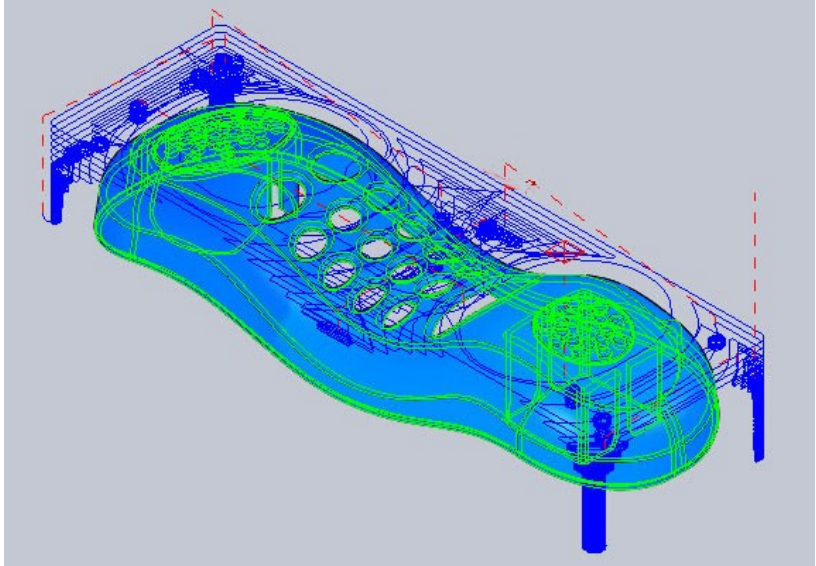
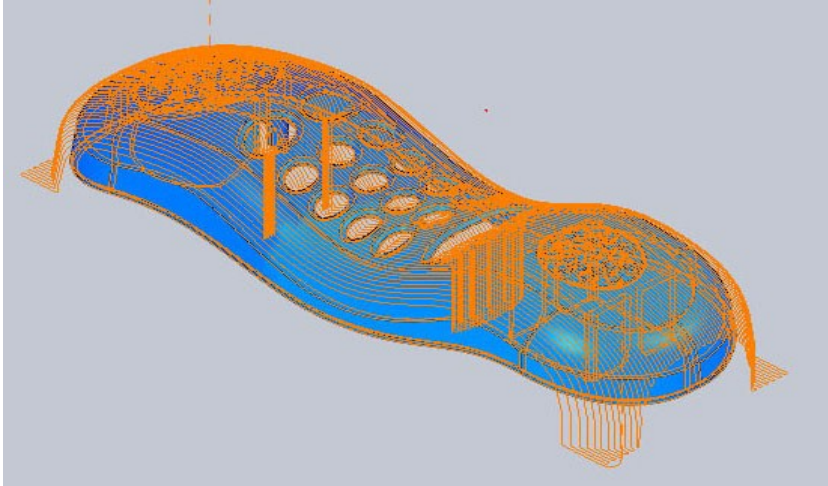
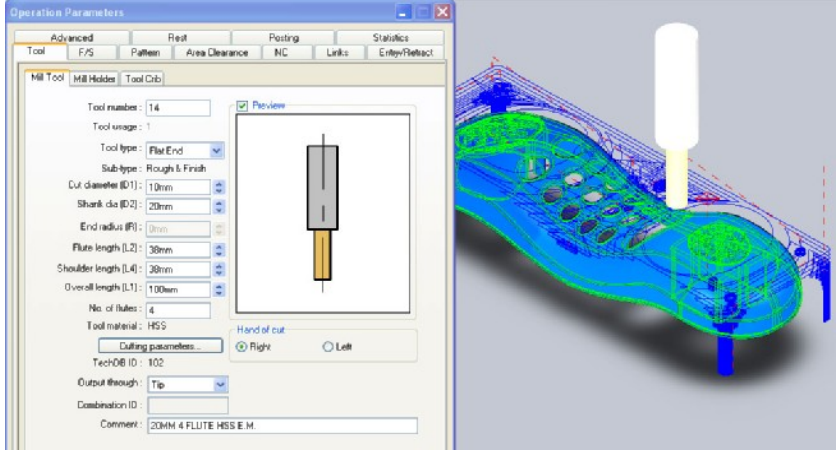
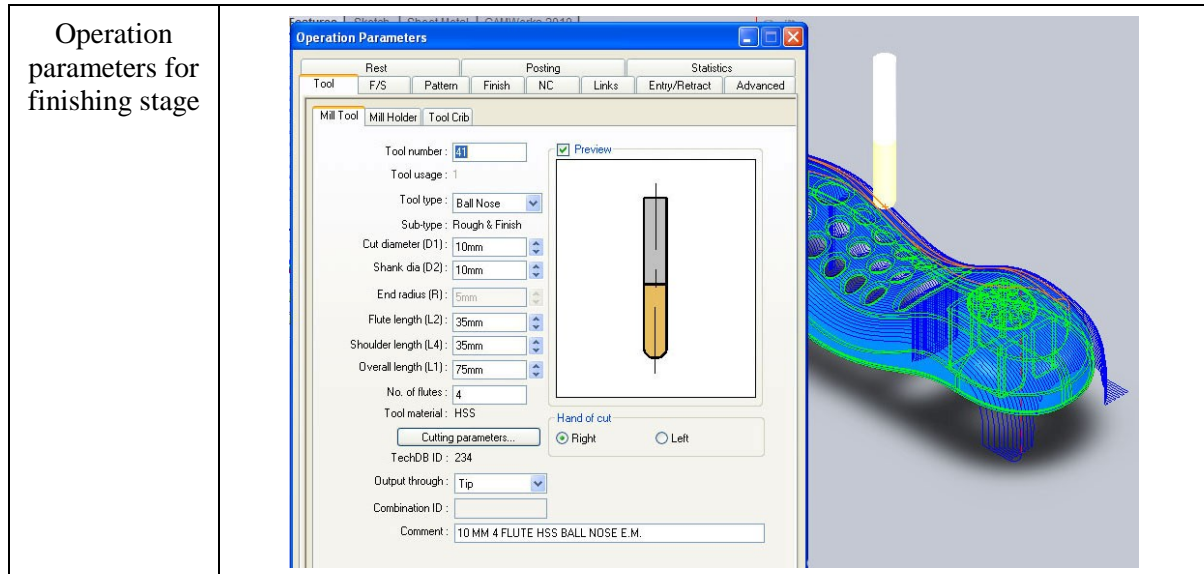


Figure 3

<p>The stage</p>	<p>Simulation graphics</p>
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<p>Toolpath for roughing stage</p>	
<p>Toolpath for finishing stage</p>	
<p>Operation parameters for roughing stage</p>	



### Discussion:

- § Simulation strategy in education can be made convenient for design and manufacturing issues, and give the student easier way in complicated manufacturing problems. It reduces the time it takes to teach the implement of new CNC machines.
- § Simulation prevents the danger that faces the students when they deal with the CAM steps and CNC machine crashes and near-misses, that may happened in early stages. That increase safety aimed to the student.
- § Simulation strategy in education shows machinists what to expect from new NC programs, also improve process efficiency.
- § Simulation provides the student train programmers and machinists without using production time or risking a crash, Enhance presentations and documentation.

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