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An Integrated Teaching Methodology for Manufacturing Processes

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An Integrated Teaching Methodology for Manufacturing Processes

Abstract

In this paper, we describe an integrated approach for promoting an effective education methodology for teaching manufacturing processes. In that regard, a three-faceted approach that incorporates providing opportunities for an active learning experience for manufacturing processes has been described. For demonstration cases, the course entitled as ENGR3600 Production Engineering has been chosen as the teaching medium. Three main aspects of the teaching methods include: 1) In-class teaching of lecture material (i.e., casting processes) 2) Hands-on sand casting laboratory where students are engaged in conducting and assisting in various steps of sand casting process (i.e., premixing, mold preparation, actual casting process, trimming sprues, runners, gates etc.) 3) Numerical and graphical analysis of the casting process through simulation. The integrated methodology would be comprised of classroom and lab activities, in which two sessions are conducted in the classroom environment, and one session is conducted in the casting lab. The first classroom lecture incorporates describing the various aspects of the casting processes such as the process description, capabilities, characteristics, design considerations, various types of casting processes with the corresponding variations. In the second classroom lecture, the students through the CastView™ software had the opportunity to analyze a casting process processes both visually and analytically. In the third step, the sand casting process is employed for casting aluminum for obtaining the final product. Students, using insights obtained from the classroom lectures have the opportunity to demonstrate their design skills in an engineering setting which involves mold design and preparation and actively participate in assisting in the subsequent operations. In overall sense, authors conclude that a three-faceted approach that integrates the elements of the theoretical classroom teaching with the computer assisted analysis along with actual laboratory implementation would significantly facilitate reaching the learning objectives associated with various manufacturing processes outlined in the Production Engineering class. It is worth mentioning that the suggested approach is not limited with a particular manufacturing process and might be adopted for different manufacturing processes which span a large spectrum of existing manufacturing technology (e.g., shaping processes for plastics, sheet metal forming and welding processes). As a future research direction, the guidelines that would help increasing the generality of the suggested approach for different manufacturing processes would be further proposed and detailed.

Background

Today's highly competitive environment requires careful consideration of the manufacturing process with respect to the lead time and resource requirements. In that regard, in order to increase the efficiency of the existing manufacturing operations, manufacturing processes should be designed accordingly. The design of the manufacturing processes along with the underlying manufacturing technology not only has an impact from the cost perspective, but also it has an important role based on the outcome of the process, the product and the associated quality.

Designing the manufacturing processes would require an integrated approach that takes into various aspects into the consideration. The approach should encompass various perspectives from an engineering standpoint. This is mandatory because in today's highly competitive environment, it is imperative to fine-tune the existing manufacturing processes to optimize the outcome. In order to provide the insights required for designing the manufacturing processes, various related courses are incorporated into this BS Manufacturing Engineering program.

Computer Aided Engineering (CAE) can be defined as employing relevant software for analysis of various engineering machines, products, or systems, and it has been widely implemented for different purposes in the literature[1]. It is crucial that manufacturing engineering students are exposed to CAE along with hands-on practical activities. The adaption of CAE based approaches eventually leads to the corresponding changes in the curriculum of engineering programs with the introduction of required software. Courses that feature introduction of various CAE tools have been developed. These courses are usually senior or graduate level courses featuring the part, tool, and manufacturing process design.

In this study, we develop a three-tiered approach for satisfying learning objectives for a specific course. The course is a junior level one, which aims to provide the students the fundamentals of the manufacturing processes, tooling, and part design. For this purpose, classroom teaching is augmented with the hands-on physical laboratory experience and the use of the CAE tools for simulating and visualization of the manufacturing process.

These three tiered approach supports all the functions of the learning process by providing the students hand-on experience for designing the actual process and the tool, and some insight on the computer simulation of the process for visualization. The laboratory experiments are classified into two categories. The first one is the computer simulation of the die casting process using manufacturing specific CAE software and the second one is the actual physical hands-on laboratory experiment where sand casting is performed. Using this approach, students find a chance of better visualizing and studying the underlying manufacturing process, and gain the required analytical and design skills. The positive reinforcement provided by those laboratory sessions enhances learning experience of the student. The CAE based approach not only promotes the visualization of the manufacturing process by providing the tools for corresponding analysis, but also constitutes to be a valuable tool for validating and verifying the existing manufacturing process, tooling, and part design in an integrated sense. Similarly, hands-on physical laboratory sessions provide a very valuable tool for giving an opportunity to students for designing and preparing the required sand molds for the casting process and assisting the subsequent stages of the casting operation.

Literature Review

In the literature, there is considerable effort on bringing different educational tools for the enhancing and augmenting the learning process. Ma and Nickerson[2] discuss about how the boundaries between the physical laboratories, simulated laboratories, and remote laboratories are blurring. The authors mention that there are proponents and opponents of these approaches, and call for additional research on how the technology can be incorporated for developing some solutions on how remote and simulated laboratories can immerse the students in an interactive teaching environment and might be used for mitigating the constraints related with access of the students on the physical laboratory sessions. Jong et al.[3] establish an integrated approach and discuss about combining the strengths of the simulated and the hands-on laboratories to enhance the teaching experience in engineering and science education. Corter et al.[4] compare the difference in terms of the motivation level and learning outcomes associated with different models of laboratory experiments (i.e., hands-on, simulated, and remotely operated). They conclude that the motivation level of the students is increased further, when they were working with the real data instead of the simulated data. Additionally, they also indicate that remotely operated and hands-on laboratory sessions increased the time spent in data analysis and writing. Klee and Dumas[5] discuss the integration of hands-on and simulation laboratories for the application of direct digital control (DDC) to an analog bench-scale system consisting of a direct Current motor and tachometer. The authors report that combination of hands-on experience and computer simulation coupled with theoretical knowledge better prepares the students to implement digital control systems in the real world. Abdulwahed and Nagy[6] have used the integrated approach for utilization of the remote, virtual, and hands-on laboratory sessions. The authors conclude that the developed program provides the first laboratory education model that builds thoroughly on Kolb's experiential learning theory that might be applied in the context of the Chemical Engineering Education.

Acknowledging the previous work in literature, we embark on an integrated approach on combining the simulated laboratories with hands-on laboratories to enhance the learning process. The contribution of our work is that it is one of the few if not the first study focusing on such an approach in Manufacturing Engineering Education. The education process of this specific discipline has improvement opportunities from analytical based approaches that are incorporated in the simulated laboratories. The manufacturing processes mainly rely on the physical laws that might be further visualized by conducting hands-on experience. This presents us unique approaches for bringing the strengths of these two types of environments, thus facilitating a better learning process. Additionally, the objective of the study is develop this approach for one of the introductory manufacturing engineering classes, and valuable lessons that are gained might be expanded for other courses to construct a more integrated approach for developing more active Manufacturing Engineering curriculum. Last, but not least, we discuss the logistics of developing such a methodology in this paper which might facilitate implementing such an approach.

The Production Engineering Course

The course, ENGR 3600-Production Engineering, is offered during fall semesters. The primary objectives of the course is providing the students the competency of the fundamental manufacturing processes, associated tooling and manufacturing materials, and provide them with understanding the concept of the productivity, metrology, quality, costing, safety, history, current status, and the future.

Both of the authors of this study were involved in teaching ENGR3600 in the recent past. The course spans a period of 16 weeks and makes use of various hands-on physical laboratory sessions as well as use of the CAE software in an integrated manner which facilitates the teaching process and enhances the student experience.

Various manufacturing processes are introduced within the context of the course. In that regard, casting, welding, sheet and bulk metal forming, machining, plastic injection molding, powder metallurgy processes, and various finishing operations (e.g. grinding) were introduced. In order to augment and reinforce the learning of the key manufacturing processes, CAE based approaches area also introduced. To simulate the casting process CastView^{TM} software is used. Figure 1 and Table 1 below present the related sections of the syllabus. Figure 1 demonstrates the key course information while Table 1 provides the laboratory sessions that are conducted. The size of the laboratory sessions depends on the nature of the manufacturing process in focus. It usually varies between 3 to 15 students. For example, the computer sessions are usually conducted in groups of 15, whereas welding laboratory sessions are conducted in groups of 3 and 4, where each student have an opportunity for practicing the welding process in concern. The individual student's effort and learning within the each laboratory session are assessed by assigning home-works and including relevant questions in the exams, and their participation in laboratory discussions with the faculty. Content related oral questions are directed to the students during the lectures and laboratory sessions, and instantaneous feedback regarding the level of understanding pertaining to the course material is obtained.

Production Engineering
ENGR3600

Course Description

This course presents the techniques of production engineering, and fundamental manufacturing process concepts, at an introductory level. Methods of production are introduced, and productivity improvement methods are explored with an emphasis on quality, efficiency, and product cost. Basic manufacturing metrology principles are also introduced. Credits: 2 lecture, 1 lab

Course Objectives :

After completing this course, the student will be able to:

- Demonstrate competency of manufacturing processes used in making of consumer products and machine elements.
- Demonstrate competency in associated tooling and manufacturing materials.
- Understand the concepts of productivity, metrology, quality, costing, and safety as they relate to manufacturing processes.
- Understand the history, current status, and future of manufacturing processes and systems

Figure 1. Core Syllabus Information

Table 1.Laboratory Sessions for Manufacturing Processes and Computer Simulation

Lab 1	Sand Casting Laboratory
Lab 2	CastView^{TM} Computer Laboratory
Lab 2	Powder Metallurgy Laboratory
Lab 3	Welding Laboratory
Lab 4	Plasma Cutting Laboratory
Lab 5	Metal Cutting-Machining laboratory
Lab 6	Rapid Prototyping

Software Tools for Analyzing Casting Process

For simulating the casting process, various software tools are available. Some of the tools are general-purpose tools that might be used for simulating a range of manufacturing processes as well. In order to simulate those processes, usually Finite Element Method (FEM) and Computational Fluid Dynamics (CFD) based tools are employed.

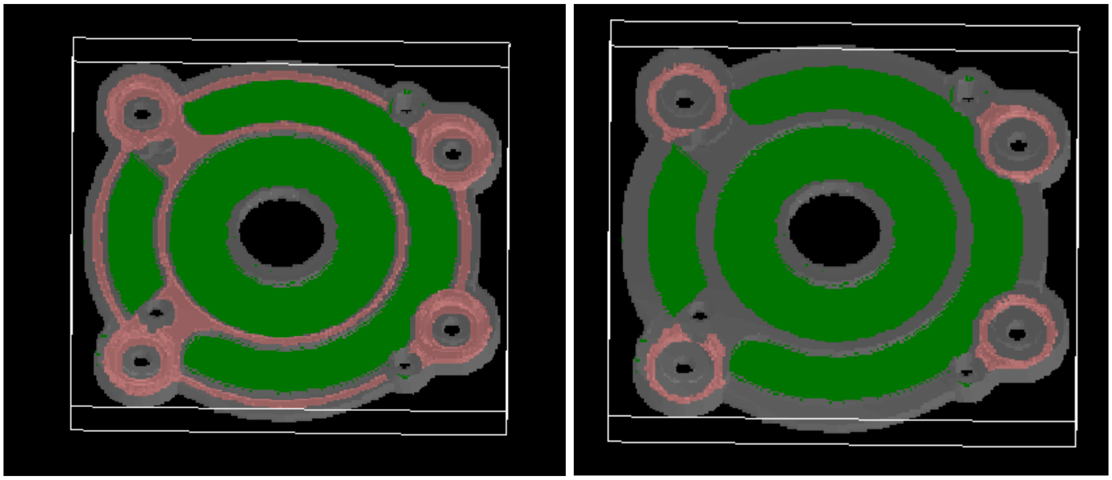
Software tools such as ABAQUS™ and ANSYS™, which are based on the use of FEM based methods, might be employed for the thermal and fluid analysis for the corresponding casting process. However, it should be mentioned that, using those software platforms require a thorough understanding of the related analytical models and extensive modeling requirements related to the process.

On the other hand, there are some other software which are suited for a specific manufacturing process. To cite an instance, ProCAST™, MAGMASOFT™, and the CastView™ are specifically designed for the simulating the casting process. Some of those software might use the analytical methods (i.e., FEM) for simulating the casting process whereas the others might use a combination of qualitative and quantitative approach which depends on part geometry (i.e., CastView™)

CastView™ Software and Geometric Analysis of Casting

As previously mentioned, CastView™ uses a simpler approach, and employ quantitative and qualitative approaches for the casting process in simulating the filling of die cavity. The thin/thick sections of the castings, filling patterns, and distances can be determined by using this software. One of the reasons why that particular software is selected as a laboratory example is the ease of the use. Through the simple yet useful graphical user interface, the software might provide the designer a good understanding of the part and process variables. It is possible to evaluate the various design alternatives in a short period of time, while using Castview™ as a pre-screening tool. Infeasible die and part designs might be eliminated before conducting a more detailed analysis. Moreover, due to the ease of using this software with steep learning curve, it constitutes a very useful candidate for the introductory level software for simulation and visualization of the process. At the same time, the students, with relative ease, can grasp the dynamics and modeling of the casting process with different part and process characteristics. The software can also be used to complement the numerical simulation. One of the advantages of the software is that it can pinpoint the existing thermal and flow processes in die casting with limited input and does not require the special expertise[7].

As previously mentioned, computer simulation is a tool that might shed light into improving manufacturing processes, tooling and the part design. By using the geometric analysis provided by CastView™, it would be possible to conduct quick and reliable analysis for further increasing the efficiency of the simulation runs. The software can be used to pinpoint thermal and flow analysis in the die casting by pointing out thin and thick sections in the part and thin sections in the die. Generally speaking, thick sections of the casting indicate the locations/zones which will solidify latest, whereas the thin sections are to solidify sooner and might present premature solidification and fill problems. Detecting those problems might reduce the iterations for product redesign thus leading a more castable product[7,8]. Figure 2 provides the cross sectional view of thick section analysis of an adaptor. Figure 2(a) illustrates the sections that have the wall thickness of more than four voxels (indicated in pink) and Figure 2(b) provides the sections that have wall thickness more than five voxels.



(a) (b)

Figure 2. Thin Section analysis indicating fill regions more than (a) four voxels (b) five voxels

Hands-on Physical Laboratory Experiments

In order to augment and enhance the learning process, a hands-on experiment is conducted for sand casting of a specific pattern. The laboratory experiment is conducted in the Metal Shop.

Students have the chance to observe the actual sand casting process, participate in the mold making. The laboratory set-up is provided in Figures 3 and 4. Figure 3 depicts the bottom board, pattern board, cope and drag part of the flask while Figure 4 depicts the parts of the heating furnace (i.e., crucible) for melting the aluminum. The picture of the cast product is provided in Figure 5.

Figure 3. The Flask (cope and drag, bottom board, and pattern board)

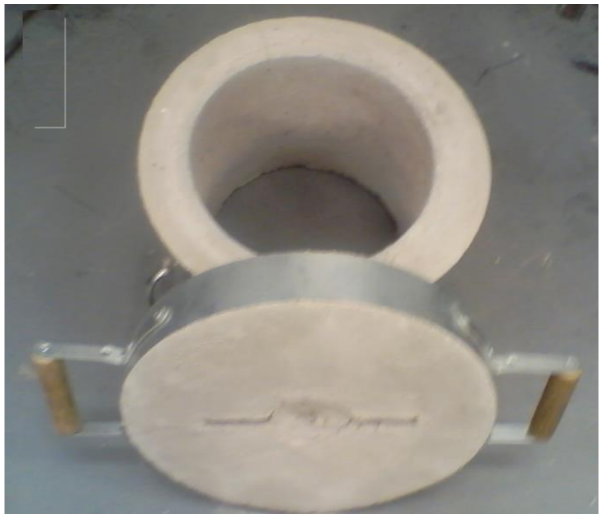


Figure 4. Crucible components for Melting Aluminum

Figure 5. Cast Indian Head

Following steps are taken for conducting the sand casting process

1. Premix the green sand with water to increase adhesion
2. Place the pattern board between the cope and drag part of the flask
3. Place the pattern with enough room for gating for the drag part of the flask
4. Dust the pattern with the parting dust. Parting dust is a hydrophobic material which repels the moisture.
5. Fill up the drag part of the flask with sand keeping the pattern at the bottom of the flask
6. Use a paddle to tuck the sides of the top part of the drag
7. Surface and compact the sand on the top part of the drag
8. Place the bottom board on the top of the mold
9. Flip over the drag part of the flask by holding the bottom board
10. Remove the cope and pattern board
11. Using the spoon, make the smooth *j* shaped gate and runner
12. Mark the location of the gate and cavity on the flask on *x* and *y* coordinates

13. Smooth edges with finger if necessary
14. Tap on the pattern to loosen and use a screw to gently take the pattern out, make sure that the cavity is not disturbed during this process
15. Place the cope and pattern board on the top of the drag
16. Open the sprue vent hole with hole cutter. While opening, twist the cutter slightly to ensure the smoothness of the hole. During this process, pay attention to the location of the gate and cavity that is marked in Step 12
17. Similarly open the vent hole with the hole cutter having a smaller diameter
18. Lift the cope part of the flask slightly to remove the pattern board
19. Pour the metal
20. Let the molten metal solidify and release the snap clips
21. Disperse the sand for having the casted product
22. Trim the sprue, gate, and runners for obtaining the final product

Due to the relatively low melting temperature, and ease of casting, aluminum is used for the casting process in the laboratory. Using a crucible, the temperature of the aluminum is raised above melting temperature, and poured into the mold. After a relatively short solidification time (e.g., usually less than 30 seconds), the cast part is retrieved from sand mold.

Integration of Physical Laboratory Experiments, Classroom Instruction and Simulation Software

As previously mentioned, a three-tiered approach is developed that incorporates various elements to reinforce the learning process, accomplishing its objectives.

During the lectures, various aspects of the casting process are introduced including underlying laws of physics. Chvorinov's rule, which under basic assumptions estimate the solidification time, is introduced to the students. Additionally, the part defects and the associated root-causes are discussed in detail.

The computer simulation is the second tier that has been added to reinforce the actively engaging learning process. CastView™ software is used for simulating the casting process based on the part geometry. Students having different design alternatives employ the software to evaluate and decide on the suitable gate locations to improve the product quality and ensure the smooth flow during the casting process. The thin and thick section analyses are used for anticipating the potential problems. Additionally, simulation helps to visualize the existing process which constitutes a cue for understanding the casting process dynamics. During the laboratory sessions, the students are directed questions that would encourage them to link their theoretical knowledge obtained from the classroom instruction with the actual computer implementation of the casting process.

As previously mentioned, the third tier constitutes the hands-on laboratory experience. For this purpose, sand casting process is selected. The students are asked to actively participate in the stages of the mold making process and are encouraged to provide the feedback on the process. To cite an instance, the following questions are directed regarding the sandcasting process and mold preparation.

1. What are the primary differences between the sandcasting process and die casting process that we are simulating using CastView™ software?
2. In what way, the mold design is important for the sandcasting process? What are the effects of the mold design for the final part quality?
3. According to Chvorinov's rule, and your judgment, how long do you think the solidification time would be?
4. Why do we have geometric differences between
   a. Runners and gate,
   b. Sprues and vent hole?
5. Why is the sand used as molding material in sandcasting process?
6. Why is aluminum used as casting metal?

The students are separated into two groups and physical laboratory exercise is replicated for each student group. These questions are directed to the student and ideas and thoughts are exchanged during the laboratory session. Detailed answers are provided to above questions after students have the chance to express their point of view on the dynamics of the process. Additional questions coming from students are answered as well. One of the questions for example was "How can we retrieve the final product from the mold, do we use any chemicals?" This was answered verbally and through the demonstration on how the cast product is obtained from the mold. The answers obtained from the student provide the instructor good feedback on the level of understanding of the students.

The overall objective of directing those questions were helping them establish the link between process parameter, process set-up and final product quality. Students learn the design of the sprues, runners, gates, and the vent holes, and their impact on the final product quality by embarking on the hands-on experience. Potential problems are also identified. To cite an instance, the effect of the cross-sectional area of the runner on complete filling is discussed.

After conducting the laboratory, the cast product is closely inspected, and product defects are highlighted. The potential issues during the design, mold making, and casting process that might lead to those particular defects are discussed in more detail, and references are made to the previous sessions to promote a coherent and integrated approach. The cause of flash formation is discussed in reference to the cope and drag portions of the mold.

Figure 6 summarizes the framework of the proposed integrated approach.

ABET Student Outcomes and Grading Scheme

In line with ABET specifications, following student outcomes are identified with the ENGR3600 Production Engineering Course.

• The student outcome M2: Manufacturing Engineering Graduates have proficiency in process, assembly and product engineering and understand the design of products and the equipment, tooling, and environment necessary for their manufacture.

• The student outcome M3: Manufacturing Graduates have an ability to design manufacturing systems through the analysis, synthesis and control of manufacturing operations using statistical or calculus based methods, simulation and information technology

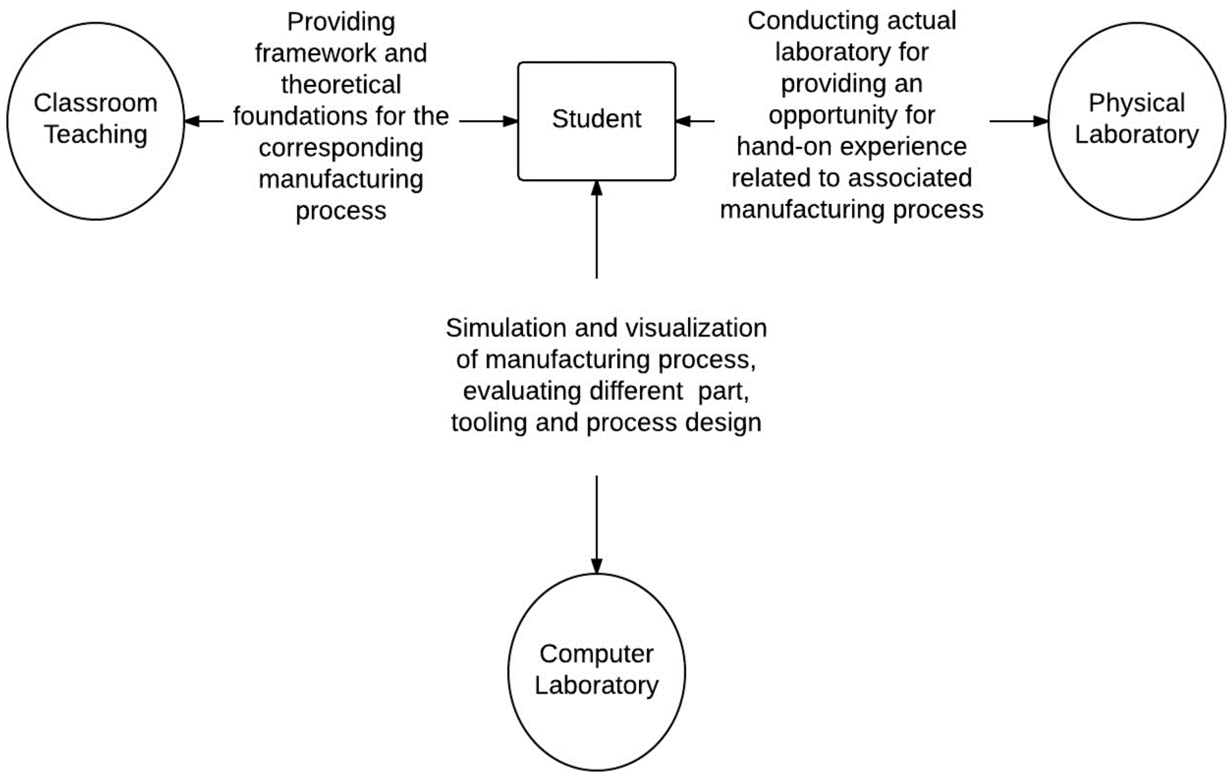


Figure 6 Framework of the three-tiered approach

The assessment of the course based on the homeworks, midterm and final examinations indicate that 86% of the students have obtained 80% (B- letter grade) or more in assessment of the related work on the outcome M2. Similarly, when evaluated based on the student outcome M3, results indicate that 91% of the students have exceeded the level of 80% (B- letter grade).

For grading laboratory work, we loosely follow the rubric proposed by Stevens and Writing at Colorado State University[9,10]. For the laboratory experiments, especially for hands-on physical laboratories that are participated by the students such as sand casting and welding, the student attention to the laboratory session is evaluated. Primary points that worth attention are whether the student is not wasteful of the materials, while conducting the experiments, the student is tidy, respectful of others, mindful of safety precautions, and leave the area clean for subsequent repetitions of the experiment with other student groups. Additionally, as previously mentioned, during the laboratory experiment, students are questioned on how well they understand the dynamics of the manufacturing process in focus. To cite an instance, during the actual hands-on physical experience, they were asked about the primary differences between manufacturing process simulated by CastView™ software, and the sand-casting process that has been performed during the physical lab. For the laboratory related homework that is provided in

Appendix 1, the main emphasis for the evaluation is whether the student understand the concepts associated with the casting process, especially with the thin and thick section analysis. As previously mentioned, relevant questions are also included as short essay type of questions in the midterm and final examinations. For the sand-casting process, two questions cited below are included in the Midterm and one in the Final Examination.

1. What kind of safety precautions are taken during conducting sandcastinglaboratory?
2. Please provide the list of the main steps that were followed during the sand casting process.

Student Feedback

Based on the Educational Testing Service (ETS) SIR II™ Student Instructional Reports, 20 returns are obtained from the students at the end of the semester. In Table II, we present the results in terms of percentages on the corresponding course and instructional items of interest. The positive student reaction varies between 40 – 80% throughout the survey. As the approach is repeated, we expect that student feedback on individual items will improve. On the contrary, three important questions on active learning, thinking independently, and making progress towards course objectives indicate 80% positive feedback. Small group discussions also show 60% positive feedback.

Table II: Student Evaluations on Selected Items based on SIRII™ (Student Instructional Reports)

Item	5-Very Effective	4-Somewhat effective)	3-Moderately Effective	2-Somewhat ineffective	1-Ineffective	Other (Omitted etc.)
Problems or questions presented by the instructor for small group discussions	20%	40%				40%
Laboratory exercises for understanding the important course concepts		20%	20%			60%
Assigned projects in which students worked together	20%	20%				60%
Case studies, simulations or role playing	40%		20%%			40%
This course actively involved me in what I was learning	20%	20%	40%	20%		
The course helped me to think independently about the subject matter		40%	40%		20%	
I made progress achieving the course objective		60%	20%		20%	

Further Discussion

In this paper, we follow a multi-faceted integrated teaching approach. Students having the classroom lectures, engaging in process related activities through hands-on laboratory experiments, and running computer simulations and analyzing results find ample opportunities to enhance their learning processes.

With regard to the systems thinking, the approach that is taken has additional benefits. To cite an instance, finishing operations are performed to obtain the final product. Sprues, runners, and gates of the cast product are trimmed in the subsequent laboratory sessions. The primary objective of this approach is facilitating the development of systems thinking perspective for the students, where different manufacturing processes are deployed concurrently for obtaining the final product with the desired quality level. Moreover, during the physical laboratory sessions, the importance of taking necessary safety precautions is emphasized. The personal protective equipment such as a fire retardant suit is introduced and worn during the laboratory sessions. During the selection of sand casting process and accompanying simulation software for visualization and analysis purposes, the level of the course is considered. Since the course is an introductory level course, selection of the sand casting process and CastView™ software was a logical choice. Instant feedback obtained from the students during the laboratory sessions, homework, examination, questions. Replies exchanged during the laboratory sessions, and classroom teaching are used for assessment of the level of understanding. This feedback is also used to evaluate whether the course learning objectives are reached. Based on student performance and feedback, it is concluded that the learning outcomes and course are reached and students have a fairly good understanding of the course materials. Moreover, further communication with the students reveal that the suggested teaching methodology increase the satisfaction from the course and promote the active learning process.

Conclusions

Developing multi-faceted approaches is an important mean for presenting effective learning environments. In this paper, we have used different approaches for augmenting and supporting classroom teaching activities of the manufacturing process in focus. The tools that are described in this paper are used as the instructional tools for teaching an introductory level production engineering course. Based on the personal communication, course assessment and feedback obtained from students, it has been indicated that the suggested tools promote the learning process. The tools for accompanying the classroom teaching are the physical hands-on laboratory sessions in which the actual manufacturing process is conducted and accompanying simulation software.

Due to the simplicity of the set-up, sand casting process is selected. Sand- casting does not require the complex procedure or expensive machinery, and implementing in the lab environment is fairly easy, apart from the process of melting the aluminum. The students prepare the molds for the sand-casting process; provide suggestions and recommendations for improving the design of the process and actual implementation of the process in focus. An interactive learning environment is generated by exchanging comments and suggestions.

Moreover, in order to provide a platform for the visualization of the die casting process, CastView™ software is introduced to the students, and a homework is assigned for the students to simulate the die-casting process. . The homework is provided in Appendix 1. As compared to similar software tools, CastView™ is fairly easy to use, and does not require expertise and detailed knowledge about the software, tool and part design, and process parameters.

In the future, additional process simulation software such as DEFORM™ and Moldflow™ (Figure 7) would be incorporated into the course material gradually. However, one of the challenges associated with this approach might be the time commitment required for introducing new software and providing the technical and analysis skills required for using it. For the introductory course such as ENGR3600, this might be time prohibitive; however, some portion of the class time might be allocated for introducing those software to enhance learning process.

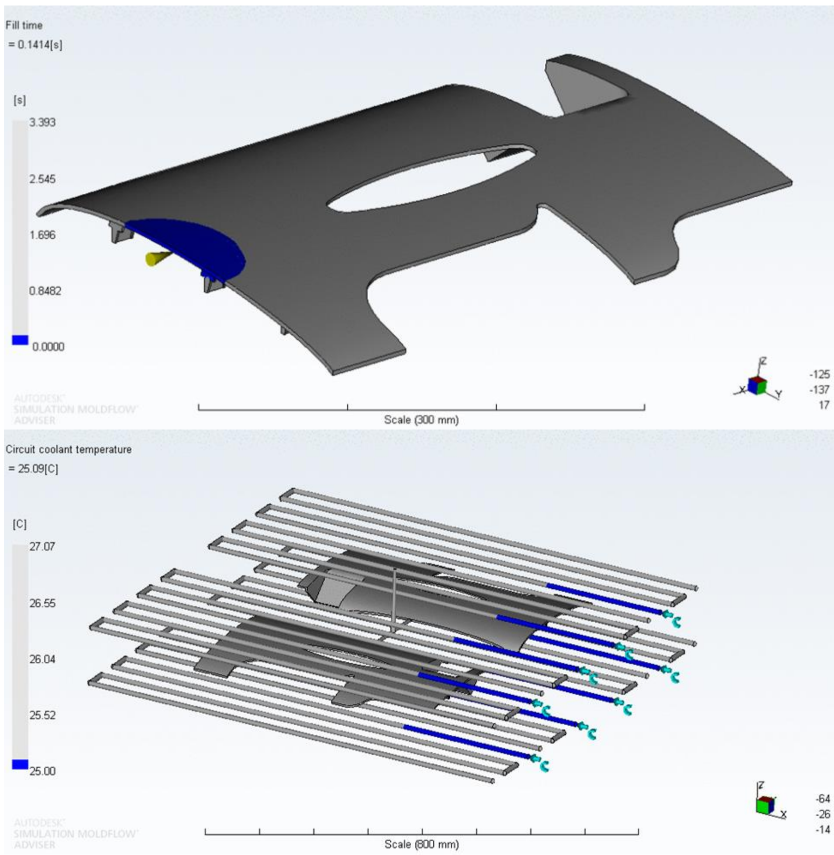


Figure 7. Moldflow Analysis (a) Fill time (b) Circuit Coolant Temperature – Preparation in rogress for the next semester

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Appendix 1-CastView™ Homework

ENGR3600 Production Engineering
Fall 2014
Production Engineering
Homework
Die Casting Simulation Using CastView™

Introduction

There are a lot of variables to be considered in the die casting process. For example, the variables of importance are melt temperature, dissolved gas content, die temperature and its distribution, plunger velocity and its variation during the stroke, chamber pressure, cavity pressure, and gas composition. These are the just a few of many that need to be considered.

In this lab, you are asked to use CastView™ software to simulate the die casting process. You will be given the part geometry and the location of the gates, so you don't have to generate your own.

Using the CastView™: You need to answer those questions using adapter.stl and adapter.gat files.

Requirement

1. Where are the first and the last places you would expect to see the solidification taking place? How can you improve the process condition (as long as the part geometry is not changed) so that the difference of solidification time can be minimized?
2. What is the difference between the "fill pattern" and "fill distance" approaches in the filling analysis?
3. Conduct the fill analysis using "fill pattern" and send the snapshot of the fill pattern at seq<130
4. What is the difference between "part and die skeleton" and "fast thinning of die"?
5. What is the difference between the "Euclidean", "City Block" and "Chamfer approaches"?
6. Conduct thin section analysis and indicate the sections that are thinner than 5 voxels on the part, and attach the snapshot. (Hint: Make sure that you select "part" or "part&die") Why do the thin section and thick section analysis are important?

Brief Reminder Instructions:

1. Install CastView™. Open the attached file
2. Using File →open load adapter.stl file.
3. Using Tool →Design-→Gate→Load Gate, load adapter.gat file
4. Go Analysis →Filling for filling analysis
5. Go Analysis →Thin section analysis for thin section analysis.

Important Hint: In the Help section, you can find the answers of some of the questions above, and this section provides lots of information on how you use the software.