

AC 2007-204: INTEGRATING CAD/CAM AND COMPOSITE TOOLING TECHNOLOGIES IN A RESEARCH EXPERIENCE

Mean-Shang Chen, Central Michigan University

Dr. Mean-Shang Chen is currently a professor in the Department of Engineering & Technology at Central Michigan University. He completed his undergraduate studies in mechanical engineering at Taipei Institute of Technology. He also holds an M.S. from South Dakota School of Mines and Technology and a Ph.D. from Kansas State University in that same discipline. He is a licensed engineer in the State of Michigan. His current research interest is in computer-aided design (CAD) and computer-aided engineering (CAE). He offers a number of courses in these two areas.

Michael Chan, China Travel Ship Management Limited

Dru Wilson, Central Michigan University

Integrating CAD/CAM/CAE and Composite Molding Technologies in a Research Experience

Abstract

This paper discusses the research experience of a student who integrated design and manufacturing functions to improve a brake shoe used on a band saw. The CAD/CAM and composite tooling technologies selected for this project were primarily based on student's undergraduate and graduate course work. The scanning/digitizing and rapid prototyping technologies were also studied. This study shows the integration of these technologies could be successfully achieved.

Introduction

An Independent Research course (IET 791) in the Department of Engineering & Technology at Central Michigan University provides a venue for graduate students to showcase their comprehensive knowledge and skills. It serves as an important tool in evaluating their abilities in handling real world problems. This paper discusses the research experience of a student who integrated design and manufacturing functions to significantly improve a product.

A braking shoe used on a band saw was first selected for the project. This defective part, which was made of cast iron, was broken near the larger hole as depicted in Figure 1. The primary focus of this project was on developing an effective approach for producing a much stronger replacement.



Large lobe broken completely off

Figure 1. Broken braking shoe

An initial evaluation based on brake shoe design suggested a composite material would be preferred over a metal. A composite material was selected as the substitution for cast iron. This is because they have inherent properties that provide performance benefits over metals. It is well known that cast iron has built-in notches that can catastrophically fracture under impact. Composites are composed of a matrix material reinforced with fibers which are the primary load carriers of the material. The matrix component permits the load to be transferred from fiber to fiber providing good damping characteristics and high resistance to fatigue^{1,2}. In addition, a

composite provides better strength-to-weight ratio, stiffness-to-weight ratio, and excellent resistance to corrosion.

The process, which integrates CAD, CAM, scanning/digitizing, rapid prototyping and composite molding technologies, was recommended for making composite parts of braking shoe in this study. Table 1 provides a snapshot on how the process was designed based on the student's course work. Computer-Aided Design (IET 457) served as this sequence's core where the student learned to create 3D models and basic system assemblies using I-DEAS³. From there the student picked up various skills from different undergraduate and graduate courses. The student also learned how to interface I-DEAS further with other software/equipment in graduate-level independent study course. These include the interfacing of I-DEAS and MasterCAM⁴, I-DEAS and 3D Printer⁵, MasterCAM and CNC, 3D body scanner⁶ and I-DEAS, etc.

Course No.	Course Title	Software/Equipment
IET 457	Computer-Aided Design	I-DEAS
IET 377	Numerical Control Programming	CNC
IET 477	Computer-Assisted NC Program.	MasterCAM
IET 597	Composite Tooling	no additional equipment
IET 694	Independent Study	3 D printer, 3D body scanner, etc.

Table 1. The Software/equipment Used in Different Courses

Procedures for making both a composite mold and a composite part were also recommended based on an intensive hands-on experience from the laboratory. It proved in this study that the integration of these technologies provided a seamless transition from one technology to another. It showcased a very effective and efficient approach that is not difficult to follow.

Integration of Various Technologies

Figure 2 displays how various technologies were integrated in producing a stronger part. A strategy was developed based on the technologies available in house and student's course work in both graduate and undergraduate programs.

Scanning/Digitizing

A 3D solid model of the brake shoe was to be created in I-DEAS as the first step of this integration process. Ideally, a reverse engineering tool such as digitizing laser scanner should be utilized to capture the 3D geometry of the part with speed and accuracy. This type of equipment can gather measurement data of a part in form of Cartesian coordinate points referred to as a point cloud. The point cloud is then used to re-construct surfaces with every feature and all the details of a part. Figure 3 illustrates a point cloud captured from the brake shoe using a 3D body scanner. However, the thicknesses were not used, because the resolution provided by the scanner was not fine enough for this particular application. A number of features on the upper surface of the base were also lost. The point cloud was primarily used to digitize only the contour of the part. The attempt of this approach was eventually abandoned, because there were no other reverse engineering tools with a finer resolution available at the time.

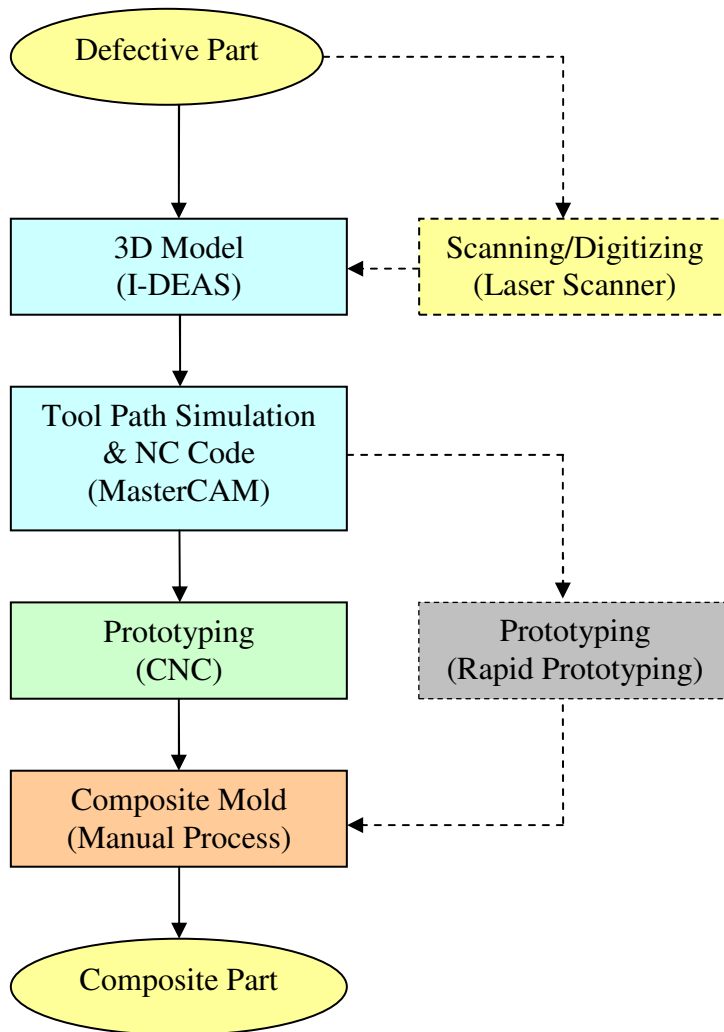


Figure 2. Integration of Various Technologies

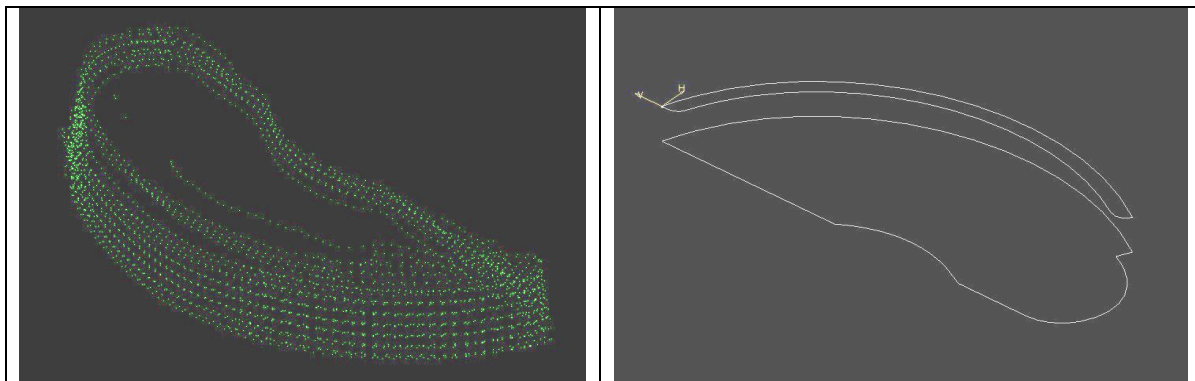


Figure 3. Point cloud of brake shoe and profile extracted for 3D model construction.

3D Model

A 3D model was created from scratch in I-DEAS based on the manually measured dimensions, due to the failure of an attempt in digitizing the part as previously described. I-DEAS is composed of a number of software modules called ‘applications’, each subdivided further into ‘tasks’. Each application or task can be used by itself, though they could also be used together as integrated tools for a full design cycle. The 3D model in this study was created in the task of ‘Master Modeler’ in the application of ‘Design’. Applications and tasks are executed from a common user interface and sharing a common database³. They employ the concept of 3D master model that shares an information source containing the geometric definition of the parts and assemblies across different applications and tasks, which also makes the interfacing with the downstream design and manufacturing functions possible.

Tool Path Simulation & NC Codes

MasterCAM was utilized to simulate the tool path and generate the NC code required for machining in this study. The part profile was first imported from I-DEAS to MasterCAM in IGES format. In the manufacturing environment, the process planning must be fast, flexible and easy to change for the benefit of a mass production. Two separate NC codes, which were created based on different tool paths in this study, can significantly reduce if not completely eliminate the changeover/setup time. The first NC code was used to cut the brake shoe profile that include all the round fillet corners and draft angles. Figure 4 illustrates this process that produces a very smooth surface that is ideal for composite mold making. The second NC code was used for the depth of cut, which was basically a 2D path, on the flat surface of the part. It could be easily revised without changing the features on the original part. For example, if the thickness of the part must be changed, one does not have to reprogram the entire NC code. The user just needs to revise the depth of the cut in the second portion of the code.

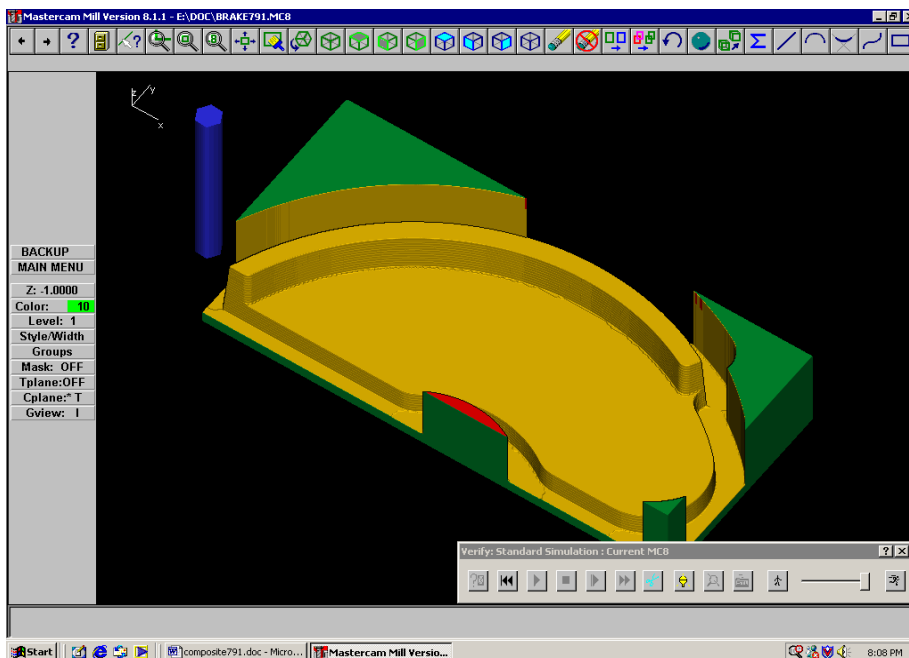


Figure 4. Tool path simulation in MasterCAM.

Rapid Prototyping

These NC codes were then downloaded on to the control panel of a HASS CNC milling machine to machine a wax block into a prototype of the brake shoe as displayed in Figure 5. Wax was used in this case to save time required for machining. As illustrated in Figure 2, the alternative of using a Dimension 3 D Printer for rapid prototyping was also considered at the time. This type of rapid prototyping machines use a STL file converted from a CAD file to produce plastic prototypes. This idea was discarded primarily due to the following two considerations: (1) both material cost and machine time of utilizing a 3D printer for a prototype are much greater than that of utilizing a CNC, and (2) a finer finish for the prototype surface was much more challenging and time-consuming to obtain from a 3D Printer than from a CNC.

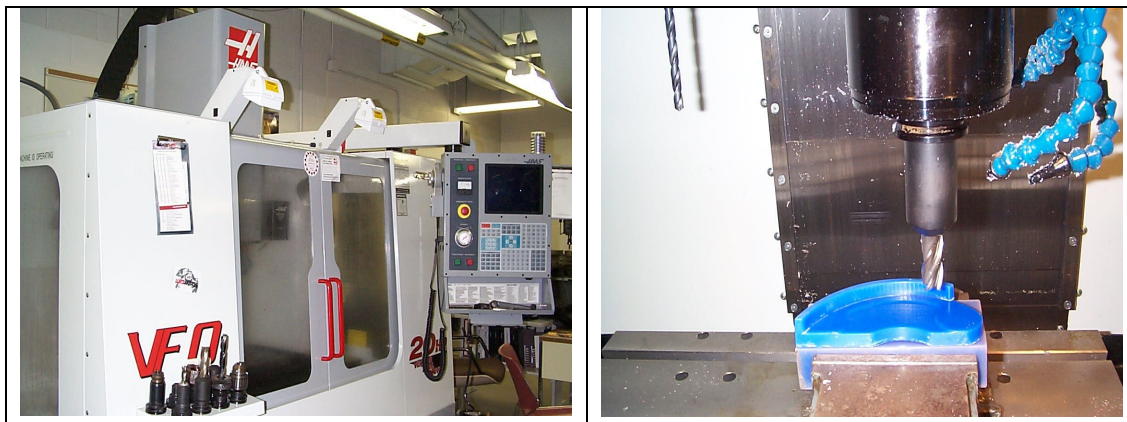


Figure 5. CNC milling machine and milling process.

Composite Mold

The process utilized for composite mold making in this study was a method called ‘hand lay-up’. This method uses a single, inexpensive, open-faced mold. The reinforcement mat or fabric is placed in the mold and saturated with resin by brush and/or squeegee. Plies of reinforcement are built up to the desired thickness to form a laminate that is cured at room temperature. The following is a list of steps applied for making a composite mold in this study:

1. Laid the master model (prototype brake shoe) on a sheet of wax paper.
2. Applied wax mold release on the parting surfaces of the master model. Hint: more coats of wax will be needed if the surface is porous. These layers of wax will fill the tiny surface imperfections keeping the epoxy resin from locking into these imperfections.
3. Applied two layers of gel coat to entire parting surface of the master model and onto the wax paper. Waited 45 minutes between coats.
4. Cut fiberglass cloth to small pieces, up to three or four plies, to cover up the part. The cloth was stretched and distorted as needed to follow the surface, because the mold had a somewhat complex shape.
5. Applied epoxy resin (such as WB-400 from Resin Services, Inc.⁷) to the gel coat and fiberglass reinforcement one ply at a time. This will wet out the glass from the bottom

displacing the air in the fabric with less chance of trapping air under the ply of reinforcement.

6. Set the mold aside and let it cure at least 24 hours.
7. Removed the new mold with the master model from the wax paper.
8. Used a band saw to trim all the rough edges off the molds.
9. Carefully separated the prototype brake shoe from the mold. The mold was now completed as shown in Figure 6.

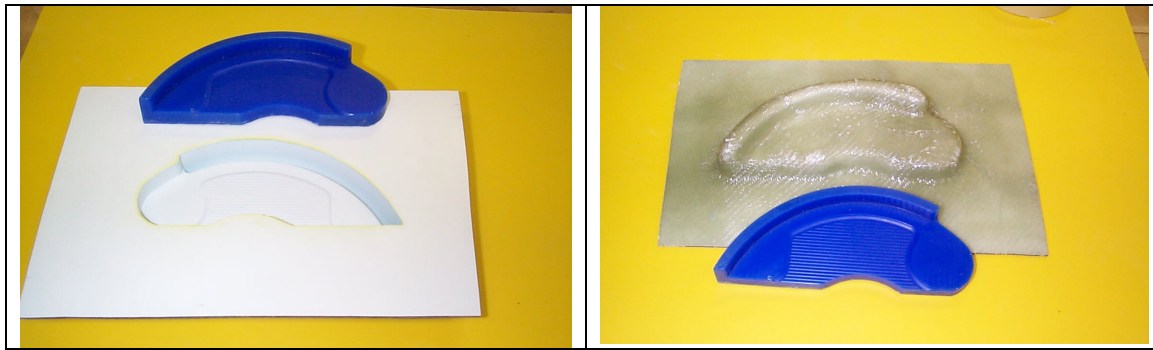


Figure 6. Wax prototype and composite mold (front side & back side).

Composite Part

1. Prepped the composite mold for making a part. The mold was cleaned, sealed, and a release agent was applied to the mold (Waterclean®, Sealproof®, and Watershield® were used⁸).
2. Applied multiple coats of mold release wax to all surfaces of the mold. This step is critical - if any spot is missed, the mold will bond to the final part and would not release when the composite part is removed.
3. Cut several pieces of fiberglass reinforcement at different fiber orientations (0° , 90° , + 45° - 45°) to distribute part strength as required.
4. Applied a thin coat of epoxy resin (the same resin used to make the mold), over the entire mold surface with a brush and/or squeegee.
5. Applied each ply of fiberglass reinforcement with epoxy resin. Care was taken to eliminate all air bubbles from each ply of reinforcement. Air bubbles will cause weak spots and potential part delamination.
6. Allowed the part to cure 24 hours before it was removed from the mold.
7. Used a band saw to trim the edge of the part. A fiberglass part of the brake shoe was now completed as illustrated in Figure 7. This process could be repeated to duplicate additional fiberglass parts if necessary.

Hints:

If the final part is completely solid, another option is to make the part with only a few plies of fiberglass reinforcement. Remove the part from the mold (after 24 hours) and then add the rest of the plies of fiberglass to the back side of the part. If the part has any small radii corners in the mold, mix small cut fiberglass strands in to a cup of epoxy resin the produce a

extremely thick reinforced resin. Apply this thick reinforced resin in to all of the detailed corners and angles.



Figure 7. Composite part vs. wax prototype.

Conclusion

This research experience provided a venue for the graduate student to showcase his comprehensive knowledge and skills. It met the expectation of serving as a tool in evaluating his abilities of dealing with real-world problems. The goal of designing an effective and efficient process using the integrated CAD/CAM and composite tooling technologies was also successfully achieved. The process as designed was based on different topics the student learned from various undergraduate and graduate courses. This study provided a very valuable experience for the faculty advisor. As a result, the following curriculum changes were incorporated:

- IET 458 Advanced Computer-Aided Design was implemented to cover the topic of reverse engineering in addition to surfacing techniques. Students learn how to remodel products via digitizing models into a CAD system.
- IET 477 Computer-Assisted Numerical Control Programming was updated, so it now makes a better connection with the CAD classes which include IET 457 and 458. Students learn how to transfer CAD files (created in I-DEAS or CATIA) to MasterCAM for CAM applications.
- IET 597 Composite Tooling and Prototyping was expanded to overlap with IET 477. Students apply the knowledge/skills learned from IET 477 to provide master prototypes for composite molds with the NC codes generated from MasterCAM on a CNC machine.

The focus was on how to streamline various technologies in the curriculum to greatly enhance learning in different classes. In addition, students would be capable of taking advantage of the knowledge and skills acquired from using these technologies in different courses for an independent research as the capstone course.

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