Integrating Rapid Product Development Methods in Engineering Technology

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Abstract – With increased competition through an ever growing global economy, engineering and engineering technology education have a renewed emphasis in teaching and implementing rapid product development and practice-oriented methodologies. Instructional methods must be more in line with current competitive practices in industry. To address this need, an integrated project was implemented at Western Carolina University that specifically focused on rapid product development. Students were required to develop mold designs in a parametric modeling class and build the mold in a rapid tooling and prototyping course. Students then brought forward the completed mold to a polymers class where the insert was mounted and injection molded. Finally, the data from the injection molding process were analyzed in a quality course, using individual and moving range control charts. This paper will present the approach taken at each level and discuss how rapid product development was demonstrated through hands-on student projects.

Keywords: Curriculum integration, Engineering Technology curriculum, rapid product development.

INTRODUCTION

Engineering Technology programs typically focus on applied scientific knowledge and engineering principles while engineering programs emphasize the theoretical aspects [1] [2]. Modern computer tools have become an integral component of engineering technology curricula and provide efficient methods of blending theory into practice. However, without adequate knowledge of application, this approach may give a false impression as to the ease of engineering design and product development. Application of basic engineering skills are often segregated and fragmented as students' progress through an engineering or technology program. As pointed out by Coe [3], many engineering curriculums do not require students to use these skills learned in the freshman year until the senior design course, three or more years later. In a report entitled "Making Quality Count in Undergraduate Education," the Education Commission of the States presented a number of characteristics related to a quality undergraduate experience [4]. One prevalent characteristic is the "ongoing practice of learned skills." The report makes a strong point that if opportunities to use basic skills are not continuously presented; those skills in many students erode quickly. Thus, for an undergraduate in a four-year program of study, many skills learned in the freshman year will likely be

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forgotten or at best seriously diminished by graduation unless those skills are applied in other courses [4]. Therefore, a strong case can be built for curriculum integration.

Research examining integration in practice is still relatively rare as pointed out by Wallace, et. al. [5]. However, Venville and Dawson [6] suggest that it is not an easy question to answer due to the diversity of approaches that currently exist. They do suggest that key features of a well planned integrated curriculum include investigations drawing on several discipline areas, flexible timetables, team teaching, student-centered learning and high levels of interaction between students, between students and teachers, and between teachers.

Using a curriculum integration approach to teach engineering applications focusing on design-build-test and analyze, provides an opportunity for students to gain a better understanding of modern manufacturing methods. This paper will present such an approach being implemented in the Engineering Technology program at Western Carolina University. A curriculum integration project involving the design and fabrication of machined aluminum mold inserts for injection molding is presented in the following section. A description of how the project is being implemented in multiple courses including Parametric Modeling, CAM, Polymers and Quality is explained.

CONSTRAINT-BASE 3D MODELING

Students enrolled in a sophomore-level Engineering Technology course entitled 3D Computer Modeling were responsible for supplying 3D constraint-based models of the mold cavity and core. The instructor coordinated and sequenced the lecture and laboratory activities to correspond with the progression of tasks necessary for student teams to complete their projects. Student teams, consisting of two members, worked collectively to produce constraint-based 3D solid computer models of the yoyo and pin. Students in each team made use of Pro/Engineer© features including revolved protrusions, ribs, coaxial-holes, shells, and extrusions. Additionally, each team was required to create an assembly of the yoyo and pin. Students were instructed in the use of Pro/Engineer Mold Cavity© where each team created 3D solid models of the mold cavity and core (Illustration 1). To verify their work, students teams created *stl* files of each 3D computer model and produced rapid prototypes using a Statasys FDM Titan© prototyping system.

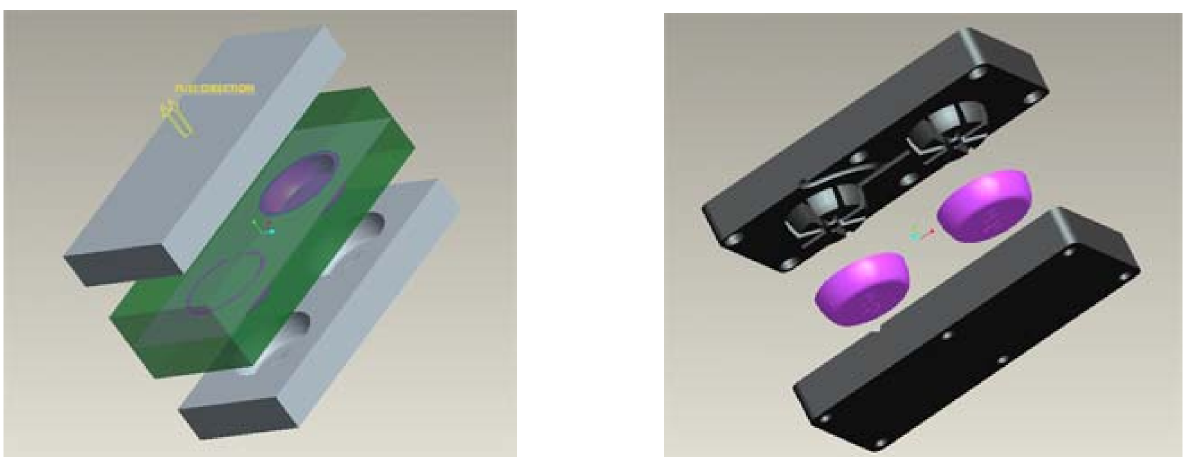

Illustration 1
3D Computer Model of Mold Core and Cavity with Yoyo Assembly

RAPID TOOLING AND PROTOTYPING

After students complete the mold design as part of the parametric modeling course, teams were formed to plan the fabrication phase of the mating mold inserts. Each team was responsible for machining two mating mold inserts (Illustration 2) in the Rapid Tooling and Prototyping course. This course focuses on using modern Computer Aided Manufacturing (CAM) techniques for rapid manufacturing including fixture design, machine set-up, tooling requirements, and process planning.

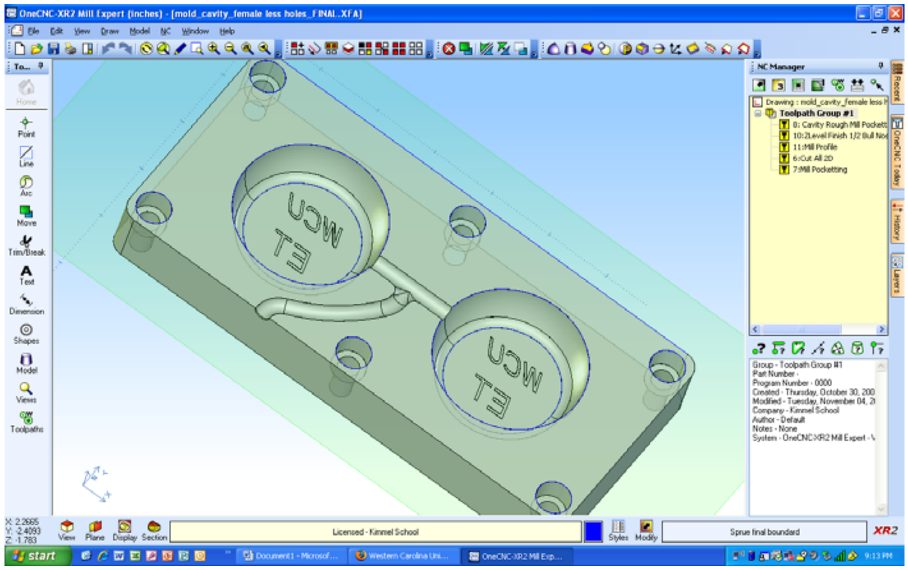

Illustration 2
Female Mold Half in OneCNC

For the mold insert project students were responsible for importing *iges* files from parametric models previously developed in Pro-Engineer, generating CNC tool paths in OneCNC CAM software, selecting appropriate tooling, and fabrication of prototypes using High Speed Machining (HSM) techniques. Examples of tool paths generated in OneCNC (Illustration 3), tooling requirements, and estimated cycle times (Illustration 4) are shown below for one of the mold inserts.

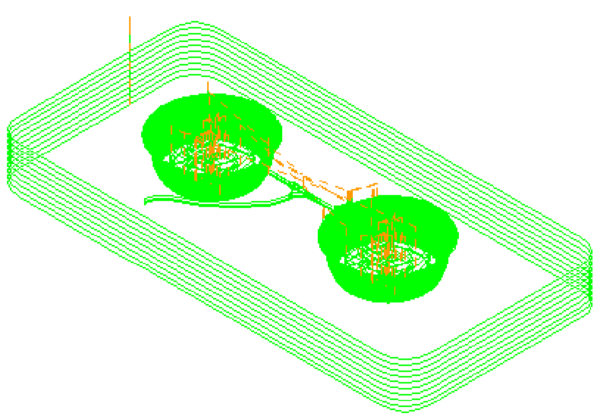

Illustration 3
Back Plot showing tool paths generated by OneCNC

OPERATIONS Total number of operations - 5
Operation #1 (8: Cavity Rough Mill Pocketing) Operation time - 4 minutes 17 seconds Tool - Station #3: .50 INCH 1/2 CARBIDE END MILL (End Mill, 0.5 Dia, 0 Tip, F25.0, S6921)
Operation #2 (10: ZLevel Finish 1/2 Bull Nose) Operation time - 22 minutes 23 seconds Tool - Station #4: BULLNOSE 1/2 Carbide (Bull nose, 0.5 Dia, 0.14 Tip, F120.0, S15000)
Operation #3 (11: Mill Profile) Operation time - 19 minutes 49 seconds Tool - Station #3: .50 INCH 1/2 CARBIDE END MILL (End Mill, 0.5 Dia, 0 Tip, F12.0, S6921)
Operation #4 (6: Cut All 2D) Operation time - 3 minutes 54 seconds Tool - Station #6: .062 INCH 1/16 HSS BALL MILL (Ball Mill, 0.062 Dia, 0.031 Tip, F8.0, S9500)
Operation #5 (7: Mill Pocketing) Operation time - 1 minutes 52 seconds Tool - Station #5: BALL MILL (Ball Mill, 0.249 Dia, 0.1245 Tip, F12.0, S9500)

Illustration 4
Back Plot showing tool paths generated by OneCNC

Upon generation of the tool paths a simulation was executed for verification of machining methods (Illustration 5). The next step involved machine set-up and fixture installation before producing the actual CNC code for a HAAS VF-3 machining center and transferring the code directly to the mill using Direct Numerical Control (DNC). This approach was required due to the large files generated due to HSM techniques. Finally, the mold inserts were machined from 6061-T6 aluminum billet, and actual dimensions were compared to the original parametric model. Photographs showing completed mold inserts are shown in Illustration 6.

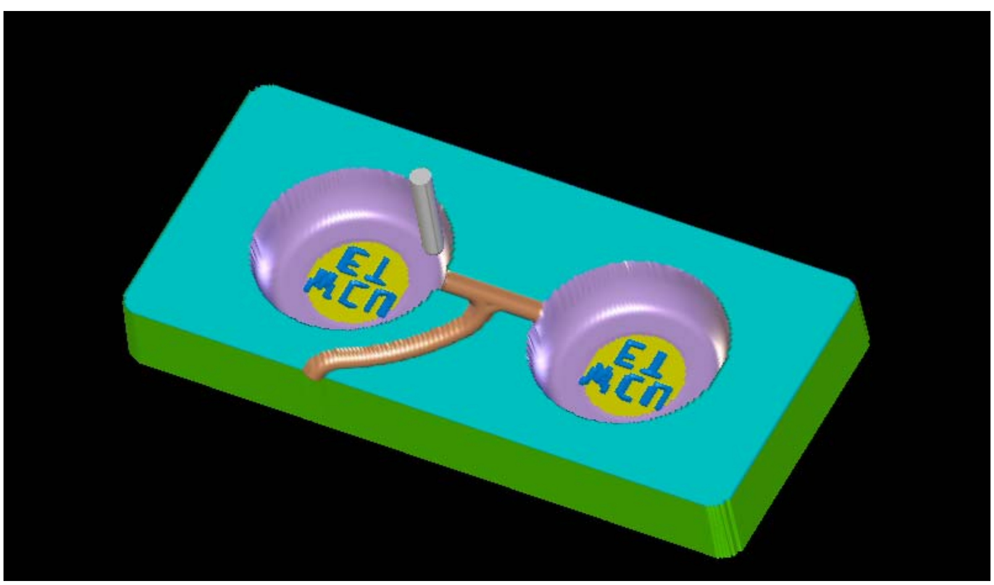

Illustration 5
Simulation showing completed operations

POLYMERS

Once the mold inserts were machined, they were sent to the Polymers area for molding (Illustration 6). Parts were molded on a Boy 30M injection molding machine (see Illustration 7). The Boy 30M machine is capable of 27 tons of maximum clamping force and has a two ounce shot size. For the purposes of rapid product realization, the mold base did not utilize the ejector pins or water cooling features of the machine, thus limiting the production capability. It was determined that the part would be molded in general purpose Polypropylene (PP) with purple color concentrate added for effect.

Illustration 6
Mold Inserts

The Polymers class was assembled into three teams; a mold set-up team, a molding team, and a spot-quality team. The mold set-up team attached the inserts to the mold base, insuring that the inserts were completely flush with the base. Shims were used to insure proper fit. The machine's clamp force was then adjusted for proper open/close. The screw retract was then set to allow a proper shot size of the PP to enter the plasticizing chamber. A number of shots were made to determine proper machine settings. Once the machine was operating at production level, the molding team and the spot-quality team carried out assigned responsibilities. The molding team was responsible for the operation of the molding machine and removal of the part from the mold (due to ejector pins not being used). The spot-quality team assessed the quality immediately out of the machine, discarded poor parts, and numbered good parts for further quality assessment.

Illustration 7
Boy 30M in operation

QUALITY

The next phase in the sequence of this project was to simulate a production process, and implement statistical process control. This step was implemented in Quality Systems, a junior-level required course, designed to teach the fundamentals of quality control, covering topics such as basic probability, gage repeatability and reproducibility, the standard normal distribution, and control charts. As a non-lab-based course, Quality Systems does not typically provide the hands-on exposure that many of the other courses in the curriculum do, so the work done in the Polymers lab became especially helpful.

Individual halves of the yoyo were injection molded, generating a sequence of time-ordered data points. The data for 25 parts were collected and analyzed in the form of an *individuals and moving range* control chart, shown in Illustration 8. Using the computed values for central lines and control limits, the Western Electric Rules for control were applied, noting any out of control conditions. Students absorbed the importance of a control chart more readily when it was related to a hands-on example, which several of them had already worked on in their other courses.

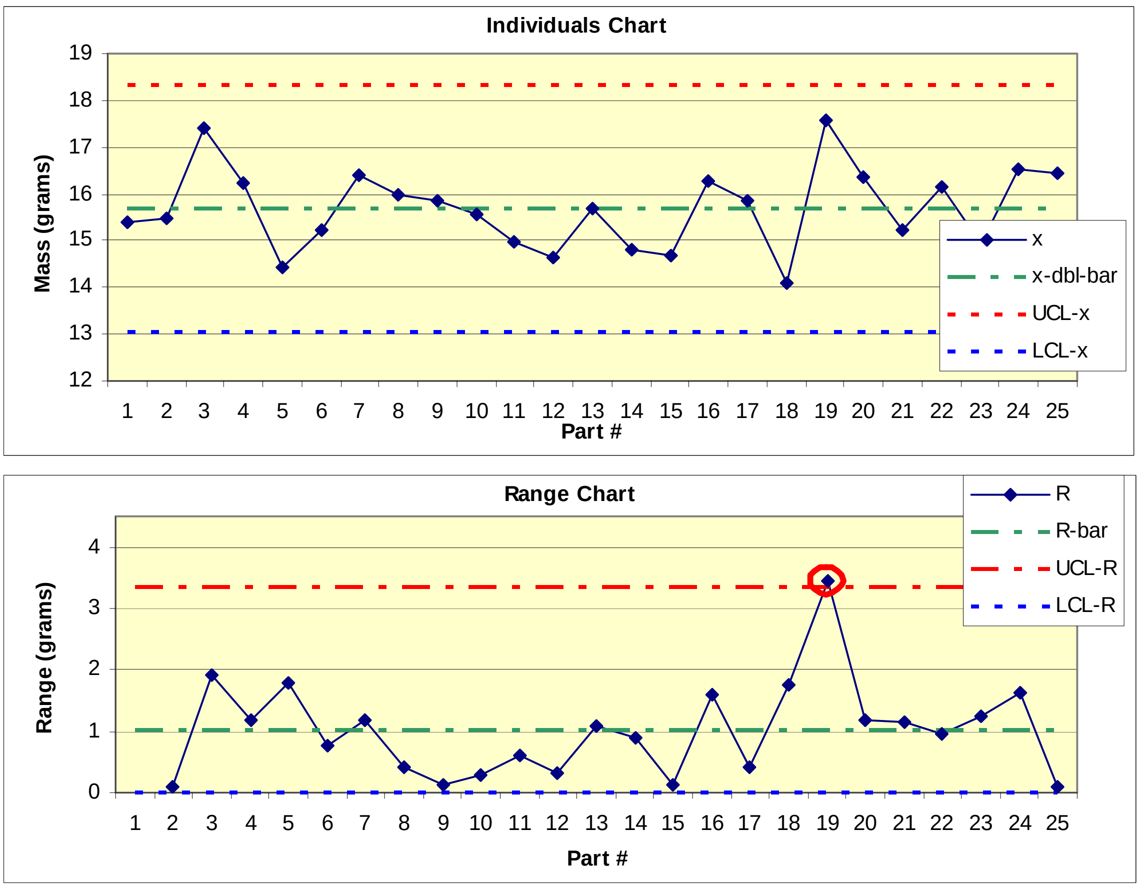

Illustration 8
Individuals and Moving Range Charts for Molded Part

SUMMARY AND CONCLUSION

Using the curriculum integration approach to teach engineering applications focusing on design-build-test and analyze provides an opportunity for students to gain a better understanding of modern manufacturing methods. Knowledge gained in individual courses are carried forward and applied in a logical sequence providing a more concrete understanding of building quality into the manufacturing cycle. Further, this approach should improve long term student learning. Specifically, the integrated approach provides opportunities for continuous improvement in the following areas:

- Ability to create more effective designs and build in quality
- Understanding of principles and concepts in mold design, materials, and polymer processing;
- Increased awareness of material selection, testing and physical properties;
- Understanding of applications of modern machining technology;
- Student retention (courses more enjoyable/rewarding; achieve better);
- Improve connection between classroom and workplace; and,
- Facilitate better student achievement in school and upon graduation.

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