Design Class Projects in Fluid Power

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1. Introduction

Class projects offer many opportunities for students to learn by doing. A design class project completed recently in fluid power area at Purdue University is presented. They provide opportunities for students to solve problems and boost their competency level. The project presented in this paper involved design and manufacture of a hydraulic pump by applying a rapid prototyping technology. Examples of solved problems are presented. The project offered an excellent opportunity for students to implement their ideas in praxis, and gave the instructor a very useful feedback in the form of an activity log.

Students used a rapid prototyping machine to manufacture the housing of a fluid power component. The housing was made out of a clear epoxy, so there is an additional educational benefit from the project: The fluid power component can be used later for demonstration purposes. It is possible to buy a complete line of clear plastic components[1,2], but they do not give the opportunity for students to gain hands-on experience from building them.

2. Rapid prototyping of a hydraulic pump

2.1. Project assignment

MET 499 Independent Study Project is an elective three-credit-hour course. Two students signed up to design and manufacture a hydraulic gear pump that could be used in MET Fluid Power Laboratory for demonstration purposes. Existing Danfoss 36194-136 365A DL gear pump was selected for the project, see Fig. 1. Students could use parts from this pump to avoid manufacturing all of the necessary components. The major part to be manufactured was the pump housing, consisting of two halves bolted together. The housing was to be made out of clear epoxy resin, so that the internal parts of the pump could be seen.

Our MET stereolithography (SLA) rapid prototyping machine uses epoxy resin, which is hardened by a laser, layer by layer. The thickness of one layer is 0.006 in. The resolution of the laser is about 0.002 in. Students had to create a solid model of the pump housing, which would be manufactured on the SLA machine, taking into consideration the resolution of the machine. This proved to be quite a challenge due to several dimensions requiring tight tolerances. In order to create the solid model, students needed to disassemble the Danfoss pump, and take the measurements first. Removing the needle bearings for the pump gears from the aluminum housing created additional problems, as these bearings were difficult to remove.

Figure 1. A Danfoss hydraulic gear pump was used for the project

Some machining still was required to fit the metal parts into the epoxy housing. Students had to develop a technology to create a smooth and lustrous surface on the outside of the housing. The housing had to be mounted on a small stand, which could be used to display the pump, or operate it by using a small handle. Las, but not least, students were requested to keep a log of their activities, and submit it to the instructor weekly. The log was part of the project documentation, and was an important part of the final presentation of the project.

2.2. Log of the activities

Both students assigned to the project were asked to keep a current log of their individual activities. It took several weeks of instructor's demands to keep the log in greater detail. Both students finally updated their logs and kept them as requested. The logs were submitted to the instructor weekly by email. The instructor responded my email or during meetings. Each student sent every week the latest version of the log file. This requirement of keeping the log was new in MET in 2002, and, at first, met with some resistance from students. Overall, it greatly helped keep both students on track, and the instructor well informed about the progress of the project. As predicted, preparing the final report and the final presentation was much easier by using the log.

Table 1 contains the log of activities of one of the students. The other student submitted a similar report describing his work on the project. The table was edited by removing several weeks' worth of activities, to make it less overwhelming. The instructor allowed students to pursue their ideas. He suggested solutions when asked, or suspected problems. As can be seen from the log below, both students were able to find the solutions themselves, in very capable ways. The log can be used as a starting point in other class projects.

Table1. Excerpts from a student's log of activities[3]

Week/Plan	Completed
Jan 7: Initial meeting with instructor to discuss details of course work	Met with Professor Lugowski regarding Independent Study for spring semester. Discussed different candidates for our rapid prototyping. We discussed how our part could fit into future projects with fluid power and how it could be a part of teaching equipment used in fluid power classes. We scheduled another appointment for Tuesday Jan. 11, 2002. 1 hr.
Jan 14: More meetings with instructor to receive part and to discuss requirements for course. Also initial pump work to be performed	Met with Prof. Lugowski to receive Danfoss gear pump. We discussed different design ideas that need to be taken into consideration when drawing and design the part. Also strategies regarding the mounting of the pump were also discussed. We also discussed making an agenda for the coursework. I also met with Mike to disassemble the pump given us. We met at length to brainstorm ideas. This brainstorming session included discussion about how to approach measurement, how to approach design, what needed to be taken into account when designing the part, what measurements were going to be most critical to the functionality of our part and what our schedule for the semester should be. (3 hrs.)
Feb 25: Rapid Prototype Part.	1. STL outputting. I attempted to output the parts suing AutoCAD as an .stl file. I used the export part, and saved it as an stl file. Prof. Lugowski in his office using 3D Lightyear software then opened this file. It stated that the file was missing all of the triangles needed to make the part. I then used AutoCAD help to determine the appropriate way to export the part. I used the STLOUT command to export it. Also I determined that the part needed to be in the positive X-Y-Z quadrant. When exporting the part I was given the option of exporting it in Binary or ASCII. I chose the default of binary. Prof. Lugowski was then able to open both parts successfully in 3D Lightyear. (1.5 hrs.) 2. Drawing Modification When I met with Prof. Lugowski and he viewed my part we decided that it would be in our best interest to not have the part designed with a round external surface. This then led me to change my drawing so that it was in the shape of a box and remove all of the rounded portions making my part with all flat faces. (2hrs.)

Apr 15: Prepare for presentation and finish final report.	1. Final report work Worked on final paper, researched, developed and wrote about what we did (5 hrs.) 2. Video Tutorial Worked on learning how to edit crop and paste the video to put a whole presentation together. (1hr) 3. Meeting Met with Prof. Lugowski, we talked about ho to mount a pump handle to turn the crank as well as how to mount the part for display (45 min) 4. Editing Our film editing film- this consisted of cropping and deleting footage we did not need (2.5 hrs.) 5. Final Report work We worked on typing more of the final report up. We also edited and proofread part of the report.(1hr) 6. Updated Log (30 min)

3. Lessons learned

1. Requesting a log of activities being kept current and submitted weekly proved to be very helpful to both students and the instructor during the project. The instructor provided the template of the log to students, with the tasks to be completed, along with deadlines. Filling it out was the job left to students.
2. Equally important is the selection of a component to be manufactured. Start with a simple component, as described here, and shown in Fig. 2, and then move to more challenging tasks. In such projects, there is never a shortage of problems to be solved by students.

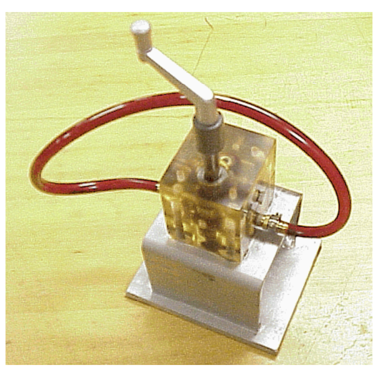

Figure 2. The Danfoss hydraulic gear pump in the epoxy housing as built by students

3. By selecting a component, the instructor provides students with specific opportunities to learn. This is an excellent addition to a course material. Students can acquire skills they would not otherwise learn. Technologies other than rapid prototyping, that lead to a clear and smooth plastic component are also possible.[4]

4. As is the case with other design project, students gain confidence in their skills. The instructor can facilitate this process by avoiding solving problems for students. Actually, the instructor should make it clear right at the start of the project, that it would be done by the students themselves. It helps to involve student in the planning of the project, and the selection of the component to be manufactured. It is then only natural that the students take the ownership of the project.
5. At first, students tend to avoid recording all of their work in the log of activities. Instructor should insist that they pay detailed attention to the log. It took several weeks of rejecting the submitted early logs for students to change their approach. They benefited greatly at the end of the project by using excerpts from the log to prepare their final presentation. The quality of the log, the final presentation, and the completed part were used to assess the students' performance.

4. Conclusion

The presented project enriched students' learning experiences. They encountered problems and took initiative to solve them. Both students showed more of their individual strengths than would be possible in a lecture-style approach. They needed only a very limited amount of instructions in order to solve problems, to which the students were exposed for the first time. Students still encountered numerous problems as they proceeded with their assignments and developed skills from identifying and solving them.

The students responded positively to the project. They demonstrated satisfaction from problem solving and the opportunity to develop their own solutions. And they valued the opportunity to apply previously gained knowledge of fluid power fundamentals and analytical skills to solve real-life problems.

Bibliography

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4. Fluid Handling and Fluid power, Bonding Plastics without Crazing, at http://www.memagazine.org/backissues/dec00/departments/tech_focus/techfocus1.html

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