Learning Through Re-Engineering Historic Machinery

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Abstract

A common complaint of both graduating mechanical engineering students and their employers is that the graduates do not have a good understanding of actual machines and how they work. Another complaint is that, despite laboratories to study such concepts as material properties or fluid flow basics, the students do not have "hands-on" experience with complex integrated machines. A new three-credit elective course allows students to perform a complete machine disassembly and reassembly. The students determined whether the components need to be replaced to best perform their function. During this disassembly and reassembly, faculty judiciously interrupt to ask guiding questions. A once-a-week lecture provided background concepts and prepares the students for the design project part of the course. For example, when first offered in Summer 2016 the machine was a 1950 Ford 8N tractor. Unlike modern tractors, the drive, PTO, and hydraulics are all driven through one clutch. The design project for the students was to design a practical modification to the tractor so that the hydraulics were powered independently of the PTO. Faculty perceptions are that students who took this course increased their appreciation of the many implications of design choices and understanding of how machines work.

Keywords

Reengineering, historic, machinery, hands-on, disassembly

Introduction

Although the demographics of engineering students have always been somewhat diverse, there is a perception among some experienced engineering educators that previous generations of engineering students had more "hands-on" experience and more knowledge of how machines worked. It is often speculated that previously more students seemed to be children of parents who had jobs, such as factory workers and farmers, which had more involvement with machines. In addition, many of the machines (such as automobiles) were easier to work on as "shade tree mechanics".

Leading engineering programs include a variety of laboratories to give their students physical experiences. However, these tend to be designed to show physical principles or the use of instrumentation. The students do not gain a deep understanding of how machines work or have the "hands-on" experience of "turning wrenches", including machine disassembly and assembly.

Both graduating mechanical engineering students and their employers often perceive that graduates do not have a good understanding of actual machines and how they work. This affects their initial job performance, whether they are working in design, manufacturing, test, or other positions. Another complaint is that, despite the multiple laboratory courses in most

curriculums, student experiences focus on single fundamental concepts and not on dealing with complex integrated machines.

To remedy this perceived deficiency, the Mechanical and Aerospace Engineering Department at the University of Florida started an elective course for undergraduate mechanical engineering majors. The course was first offered in Summer 2016 with twenty students.

Course Description and Objectives

The course description for the university's undergraduate catalog is:

Study of a historic commercial machine or vehicle, including theory of operation, embedded engineering principles, and design. Re-engineering and design of enhancements. Laboratory includes disassembly, observation of characteristics and conditions, implementation of enhancements, and rebuilding.

The syllabus tells the students that the course objectives are:

Provide students with detailed understanding of machinery operation and design through hand-on disassembly and rebuild of historic machinery. Students will develop ability to measure and verify component design specifications. Custom design of replacement components and remanufacturing to bring components back to original design specifications may be required. Students will gain greater insight into manufacturing and maintenance aspects of machinery design.

Course Conduct

There was a once-per-week lecture meeting in which the students were given guidelines and background and technical information. For example, there were lectures on engine disassembly, power transmission, and painting. Three different instructors were used during the first offering of this course, each having extensive "hands-on" experience in the subjects of their lectures. This was to give the students enough technical background so that they could perform the laboratory tasks and gain maximum knowledge benefit from what they were seeing during disassembly. Although nominally a lecture, the periods were conducted with interaction between the instructors and the students, including frequent questions from the students and contributions from the peers with more experience.

The primary weekly activity was a multiple-hour laboratory meeting in which the students slowly disassembled the historic machinery. The instructors judiciously asked questions of the students as they disassembled the machine to prompt the students to investigate and understand characteristics of the machine and why certain design decisions had been made. The instructors did not direct the disassembly, but they did provide some suggestions when necessary to keep the students progressing. Of course, the instructors' prime objective was to make sure that safety was the first priority.

The disassembly and reassembly required that enough space be available for the machine and its components as it was disassembled. Of course, tools and equipment were needed, including

wrenches, a pressure washer, an engine stand, a spray painter system, etc. Storage bins and labelled bags were used to store the components.

Machine for Initial Course Offering

The machine selected for the initial offering of this course in Summer 2016 was a 1950 Ford 8N agricultural tractor. The tractor was purchased from a local owner for $3000 and brought to the University of Florida campus. The Ford 8N is viewed by some experts as the best tractor made at its time and was a great technical and commercial success. In fact, the almost-identical 1948 Ford 8N still holds the record for the most sales of a single model in a year. Over sixty-five years later, many are still use productively on both hobby and commercial farms. Agricultural and mechanical engineering experts also tend to view the tractor and its engineering very favorably. Historical perspectives of the tractor can be found in books such as those by Williams (1987) and Gay (2001).

The tractor has a four cylinder, 120 cubic inch gasoline engine and a four-speed constant mesh transmission. Its drawbar power was 23 horsepower. The tractor was light and easy to operate, but powerful for its size. Its use of the famous Ferguson hydraulic system, including the innovative hydromechanical servo draft control, greatly contributed to its performance and popularity.

A drawback of the Ford 8N compared to later tractors is that the single clutch controls power transmission from the engine to the drive wheels, the power-take-off (PTO), and the hydraulic system simultaneously. Therefore, the open-ended design task given to the students for the reengineering aspects of this course was to design a tractor modification to allow the hydraulics to be operated independently. The need for this modification was demonstrated to the students by operating a post-hole-digger and showing that the rotation of the digger could not be stopped without also stopping the hydraulic lifting of the digger.

Disassembly, Inspection, and Reassembly

The students completely disassembled the tractor, including the engine, transmission, and rear axle housing. The students learned how the different assemblies interfaced and how they worked together. They learned how the individual components functioned within the assemblies. Although the instructors sometimes explained concepts and design choices, they often asked leading questions of the students, such as “Why is that designed that way?” or “What would be alternative designs?”. Figures 1 and 2 illustrate steps in the disassembly process.

As the students disassembled the tractor they had to take a systematic approach. They sorted and labelled the various parts so that they could later reassemble them properly. They also inspected the parts. As the tractor was sixty-six years old, there were parts which were worn or degraded. The students had to make holistic decisions about whether the parts should be replaced or not based upon the condition of the parts, the importance of their performance, and the cost of replacement. The exterior parts which were still adequate were sanded and repainted.

Figure 1: Students discover that historic machines are not clean and dry

Figure 2: Prof. Carroll and students discuss particulars of the partially-dissembled engine

Reengineering Design

The design problem of creating making the Ford 8N's hydraulic system independent of the PTO proved challenging to the students. This was an open-ended problem, not a textbook problem with a fixed procedure and a sole correct solution. Yet, the problem had many constraints as the system had to be practical and able to be installed on this particular tractor.

One potential solution is to move the hydraulic pump to the front of the tractor where it can be driven directly by the engine, a layout that is used on many more modern tractors. Figure 3 illustrates the proposal from one two-person student team. Of course, the students had to do detailed designs and analyses. Figure 4 shows the stress analysis for a bracket from this team.

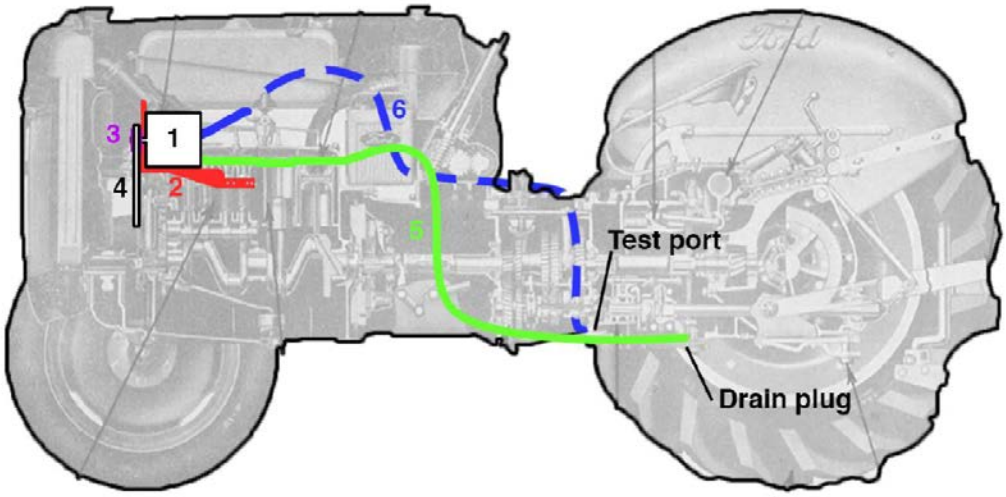

Figure 3: One student team's solution to move hydraulic pump to front of tractor

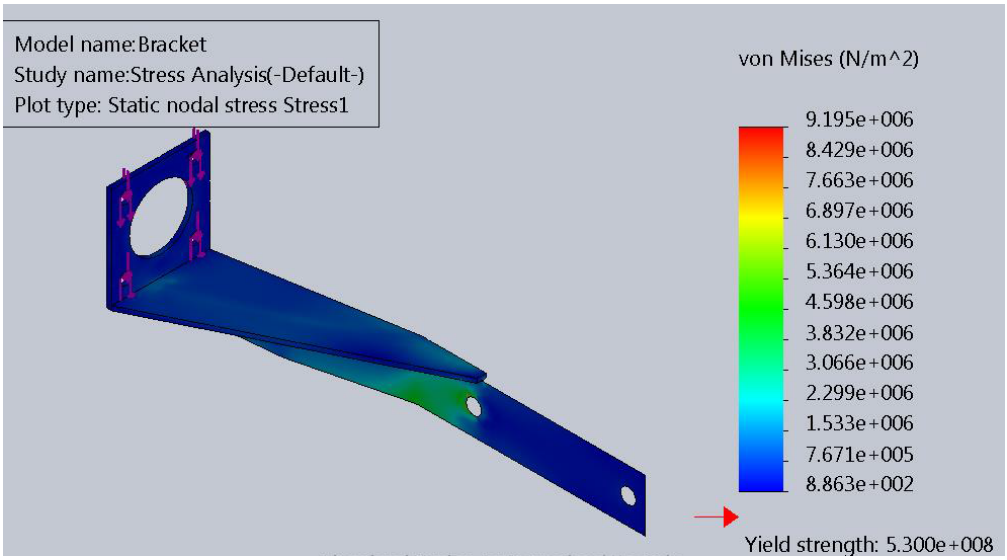

Figure 4: Stress analysis of pump mounting bracket.

Another potential design solution was to add a clutch to the PTO. Figure 5 shows one group's solution. Besides the analytical and computation analyses, the students had to prepare complete design reports, including costing analysis.

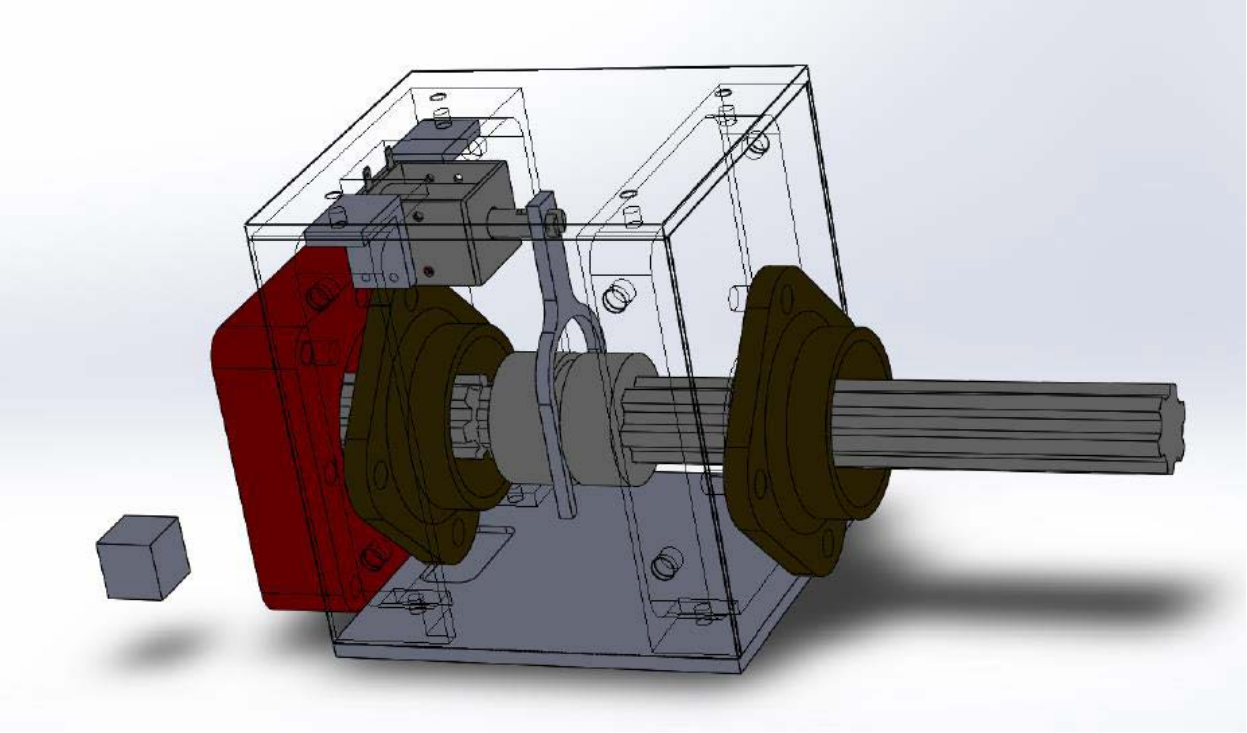

Figure 5: One student team's solution to add a clutch to the PTO

Results and Discussion

The students came into this course with diverse backgrounds. Some of the students had very little "hands-on" experience and were very tentative in disassembly. Others had extensive experience, some working as professional mechanics. There was a large amount of peer-to-peer learning where the experienced students shared their knowledge. But even the experienced students learned substantial amounts as the faculty and fellow students asked them probing questions which forced them to think and make engineering observations. The students who took this course are now not afraid to disassemble or reassemble and to investigate how machines work.

The reengineering portion of the course challenged the students. Being open-ended and yet constrained forced them to higher-level thinking. The students generally produced designs which are feasible in concept and their analytical and finite-element analyses were reasonable. However, the designs were definitely sub-optimal and in need of changes and further refinements. But this was expected from inexperienced undergraduate students. Unfortunately, there was insufficient time to manufacture and test these designs or even to iteratively improve the design.

The choice of the Ford 8N tractor for the project was very appropriate as there were many interesting concepts of machine design embedded in the tractor, including structural, thermal, engine, power transmission, hydraulics, and human factors design decisions. The assembly and disassembly was profitable to the students. The reengineering to get hydraulic independence from the PTO was a reasonable and profitable project. However, scheduling both of these tasks (with the necessity of supporting lectures and learning) was too much for one semester. So the students did not get to build and test.

It is anticipated that other machines will be used in subsequent offerings of this course. For example, a watercraft ("jet ski") is planned to be the next machine. This rotation between types of machines will keep the course fresh and help prevent students from being robbed of the educational experience of exploring new topics by the passing of information and biases from previous classes.

Conclusion

A new elective course was developed for mechanical engineering students which utilizes historic machinery to develop "hands-on" experience with machines and to practice machine design. The first offering of this course in Summer 2016 involved the complete disassembly, inspection, and reassembly of a 1950 Ford 8N tractor. Students also designed and engineered a modification to the tractor to make the powering of the hydraulics independent of the PTO.

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