Session 1268

Design Using Spread Sheets

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Abstract

Design is an important factor in Mechanical Engineering and Technology programs. The more realistic the design project, the better the learning experience is for the students. Often, design requires many iterative calculations and “what if” parametric studies. For these types of processes, spread sheets have been useful in eliminating the routine and repetitive calculations. This paper will explain the design projects given in four mechanics courses where spread sheets were used for the calculations. These courses were Statics, Dynamics, Applied Mechanisms Kinematics and Dynamics, and a combined Statics/Strengths/Dynamics course. For some of the design projects, the students created their own spread sheets to do the calculations; in other cases the instructor gave the spread sheet preprogrammed to the students. The author will relate his success in using spread sheets in design projects and the impact they had on the design project and the learning process. In addition, student opinion as to the benefits of using spread sheets will be discussed.

Introduction

Design is an important factor in Mechanical Engineering and Technology. Industry needs engineers and technologists that have a design background in their formal education. At Purdue University at Kokomo, the Mechanical Engineering Technology program exposes students to design by incorporating design projects in many of the required courses. Good design projects often have many possible solutions and/or the design process is not a straightforward procedure of choosing the correct equations and crunching the numbers in a one pass solution. Instead the design process involves logical choices in concert with iterative calculations. With some design projects, the calculation aspects overwhelm the design process to the point of either discouraging the students because of the workload or taking the attention away from the design process and concentrating the work on the calculations. Spread sheets can be used to avoid both of these problems. Spread sheets are an excellent tool for complex, repetitive and iterative calculations. What follows are four examples of how spread sheets were used in mechanics courses to focus the attention on the design process and away from the calculational process.

Four Design Projects in Mechanics

Over the past, design projects have been assigned in four courses in mechanics. These courses were Statics, Dynamics, Applied Mechanisms Kinematics and Dynamics, and a combined Statics/Strengths/Dynamics course. For some of the design projects, the students created their own spread sheets to do the calculations; in other cases the instructor gave the spread sheet preprogrammed to the students. In all cases the project stressed the design aspect and the calculation aspect was to be minimized. One advantage the Purdue University Mechanical Engineering Technology program has is that the first required course for entering freshman is a computer tools course that introduces spread sheets, spread sheet “programming” and graphing. This is a prerequisite for all the courses in the rest of the program. Therefore, all the students in the following mechanics courses are capable of creating their own spread sheets to do engineering calculations and graphs.

In Statics, shear and moment diagrams are covered near the end of the course. The design project given in Statics was to find the optimal placement of the strut for the main spar of a light aircraft as diagrammed in figure 1. The design criteria was to locate the strut so that the maximum bending moment on the spar would be the minimum value possible. The spread sheet calculated and graphed the shear and moment along the beam using the method of singularities[1]. In this case, the spread sheet for the analysis and calculations was created by the instructor and given to the students on disk. Since the project was given near the end of the term it was unreasonable for the students to create their own spread sheets and do the design within the time constraint. The spread sheet did the repetitive calculations and displayed the results as shear and moment graphs. The students were to specify the parameters of the spar and iteratively locate the strut to meet the design criteria. After a solution was found, the students were to verify the results by determining the shear and moment diagrams using another method.

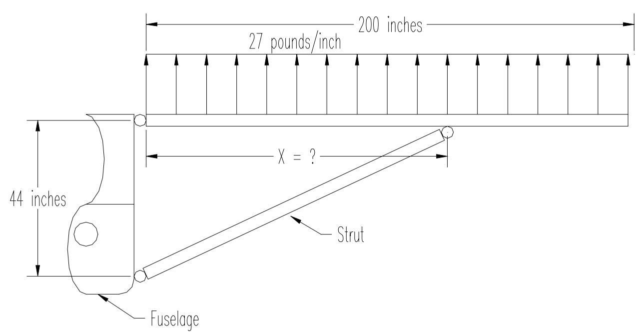

Figure 1. Aircraft Wing/Strut Design Projects

In a combined Statics/Strengths/Dynamics course for non-Mechanical Engineering Technology majors, a similar project to the Statics course was given. The students were to design the wing spar for a light aircraft and locate the strut. The spar was to be a solid rectangular shape and only the lift forces were to be considered on the wing as diagrammed in figure 1. The design criteria included both stress and wing deflection limitations. Due to the fast pace of this course, five weeks on each topic of statics, dynamics and strength of materials, the spread sheet for the analysis and calculations was created by the instructor and given to the students on disk. The spread sheet did the repetitive calculations and displayed the results as shear, moment and deflection graphs again using the method of singularities[1]. The students were to specify the parameters of the spar and iteratively locate the strut to meet the design criteria and do a verification of the final solution using a manual analysis method.

In Dynamics, the students created their own spread sheet to do the repetitive calculations and display the results in a graphical form. The design project was to determine the ratio of crank length to connecting rod length for a sliding crank mechanism to obtain certain specified velocity and acceleration characteristics of the slide. An Example of the criteria is shown in figure 2. The analysis and calculations involved determining the position, velocity and acceleration of the slide in 2.5° increments for the full cycle of the system and creating graphs of these values. The students were to vary the connecting rod length to obtain the desired characteristics. Because of the full cycle aspect of the problem and the resulting voluminous and repetitive calculations, spread sheets were the logical calculational tool to use to solve the problem.

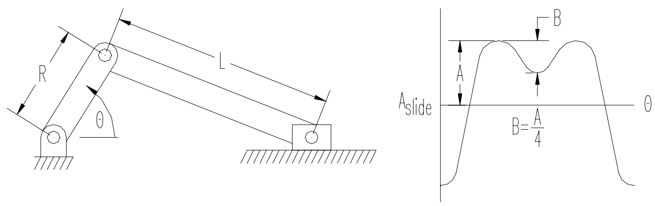

Figure 2. Sliding Crank Design Project

A much more comprehensive design project was given in a junior level Applied Mechanisms Kinematics and Dynamics course. The students were to create a spread sheet that would perform calculations to simulate a Rotax 277 two cycle internal combustion engine for both the mechanical and thermodynamic aspects. The simulation was to obtain the power output of the engine and determine mechanical and thermodynamic efficiencies given a known fuel burn rate. In addition, the design aspect was to determine the balance masses needed to be used to minimize the overall full cycle shaking forces of the engine and design a proper flywheel for the engine. The volume of calculations for finding case and cylinder pressures, resulting gas forces, dynamic forces, output torque, shaking forces and graphing these parameters over a full cycle suggested that spread sheets would be the best calculational tool. The same spread sheet could be altered to do the design aspect of finding the best balance mass.

Goals and Results of Projects

All the design projects described had a common set of goals. The main goal was to give the students a realistic design experience within the limitations of the course topic and the students' knowledge. A second goal for all the projects was to give the students an understanding of the way mechanical systems respond, in loads, stresses, deflection, movement etc., as the parameters of the devices change. Through the observation of the system response to changing conditions, it was hoped the students would gain a better global understanding of mechanics and the interaction of mechanical systems. The third goal was for students to gain an appreciation that the computer is a useful tool but that results should be verified by alternate calculation or testing wherever possible.

Using spread sheets to do the calculations and graphing of numerical results was successful in all the projects. For cases where the instructor provided the spread sheet, the design and design process was the main focus of the exercise. In those cases where the students generated their own spread sheets, there was a distinct separation of the two major aspects of completing the projects. Initially, students concentrated on writing and debugging the spread sheet so that the calculational and graphical results were correct. Once that phase was completed, the students' attention was focused on the design process and meeting the design criteria. Although the students were initially distracted from the design aspect of the project, the focus did return and the major concentration was on the design aspect of the project. So in all respects, the use of spread sheets did succeed in keeping the primary focus on the design process.

The other two goals were also served well by using spread sheets. Using spread sheets to do the repetitive calculations allowed the students to vary the system parameters and easily observe the impact through a graphical presentation of the results. By using spread sheets, the students could concentrate on the cause and effect aspect of the mechanical system interactions instead of going through many manual calculations and the frustrations of inevitable errors. In addition, the students realized the need to make sure the spread sheet was performing the calculations correctly. This was more evident with the projects that required the students to write their own spread sheet. However, in the cases where the instructor provided the spread sheet, the students were told to check the results to verify that the spread sheet was doing the calculations correctly and that any assumptions used in the creating of the spread sheet were not violated.

Conclusion

From an instructor's perspective the projects were a successful exercise in all respects. From a student's perspective, using spread sheets was also a worthwhile activity. In all the projects the students realized that doing the projects with paper, pencil and calculator would be prohibitive because of the time involved and the problems of finding and correcting potential errors. Spread sheets were a familiar computer tool and unlike standard programming languages, the graphs were easily obtained. Students generally felt that the projects were useful in seeing and understanding trends as parameters changed and allowing them to do many "what if" trials to investigate the system's behavior and come to a quick and successful solution to the problem. The realistic nature of the projects kept the students' interest and often resulted in good discussions of the design of real products in industry.

References

1. Shigley & Mitchell (1983) Mechanical engineering design (4^{th} ed.),(pp. 45-48) New York, McGraw-Hill.

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