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Applying 3D Printing to Enhance Learning in Undergraduate Kinematic and Dynamic of Machinery Course

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Abstract

This paper presents the application of 3D printing to enhance the learning of undergraduate students about the mechanisms (linkage, Cam-Follower) on Kinematic and Dynamic of Machinery course. In this course, students will learn how a mechanical mechanism, including linkage and cam-follower mechanism, is working. They will learn how to analyze a mechanism or synthesis of a mechanism to provide a specified task. To enhance their understanding about the mechanism, the project was designed by the instructor for this course. The project has three phases. On phase I, each group, consisting of 4 to 5 students, should select a mechanism to design. They design the mechanism based on what they have learned in the class. On phase II, they make drawing on Solidworks. On phase III, they send the drawing file to the 3D printer facility to print the parts of the mechanism. They assemble the parts and come out with the real mechanism. This project will help them to see how their knowledge can help to build a real mechanical mechanism.

Introduction

The Kinematic and Dynamic Analysis of Machinery class, Mechanism Design, is one of the core courses taught in the mechanical engineering program for undergraduate students. This course is talking about the analysis and synthesis of different types of mechanism including Linkage Mechanism, Cam-Follower System, Gears and etc. They will learn how to do the displacement, velocity and acceleration analysis of a given mechanism. On the second part of the course, they will learn how to synthesis/design of a mechanism to provide the specific task/performance. They will see equations and methods for the analysis and synthesis of the mechanisms but they do not have much sense about the application of what they have learned in this class on the real engineering world.

The author of this paper has brought the project as a required part of this course. This idea for the first time was performed two years ago in the Kinematic and Dynamic Analysis of Machinery course. The instructor prepared 7 design projects. The students should perform their own group with 3 to 4 members on it. They could pick one project. The projects were about the design/synthesis of a linkage or cam follower mechanism to perform a specific task. They should do the project in three phases. Phase I: On this phase, they should do the calculation based on what they have learnt on this class and come out with the size of the links of the mechanism. They needed to check their calculations couple of times to make sure that everything is correct. Phase II: On this phase, they should use the solidworks to draw their designed mechanism based on the calculations and sizes that they got on phase I. They should use their creativity to have a nice and manufacturable design with minimum required material. Since the final drawing is going to be sent to the 3D printing facility, they need to talk with the operator of the machine to

make sure that their drawing does not have any conflict or other issues when it goes for the printing. Phase III: On this phase, they send the final drawing file to the printing machine. It may take couple of hours to couple of days depending on the size of the model to finish the production phase. The group should pick up their project and do the assembly the parts if it needs. In the rest of the paper, two sample projects will be shown.

Project I: Synthesize a Crank Shaper quick Return

The goal of this project is design a quick return mechanism with timing ratio of 1:2.5 for the cutting tool system. The cutting tool has a forward-backward motion. In forward motion, it removes the material from the surface and it should move slowly over the surface but in backward motion it can move back fast because the cutting tool does not do anything in backward motion. The speed ratio of forward motion to backward motion should be 1 over 2.5. Figure 1 shows the typical sketch of the quick-return mechanism with the design specification that should be met in the final design. The slider is the cutting tool which can be attached to the mechanism.

Length of Link 2 (Crank) = 2 inch

Length of Link 5 (coupler) = 6 inch

Length of Stroke (Difference between extreme positions of the slider (link 6)) =8 inch

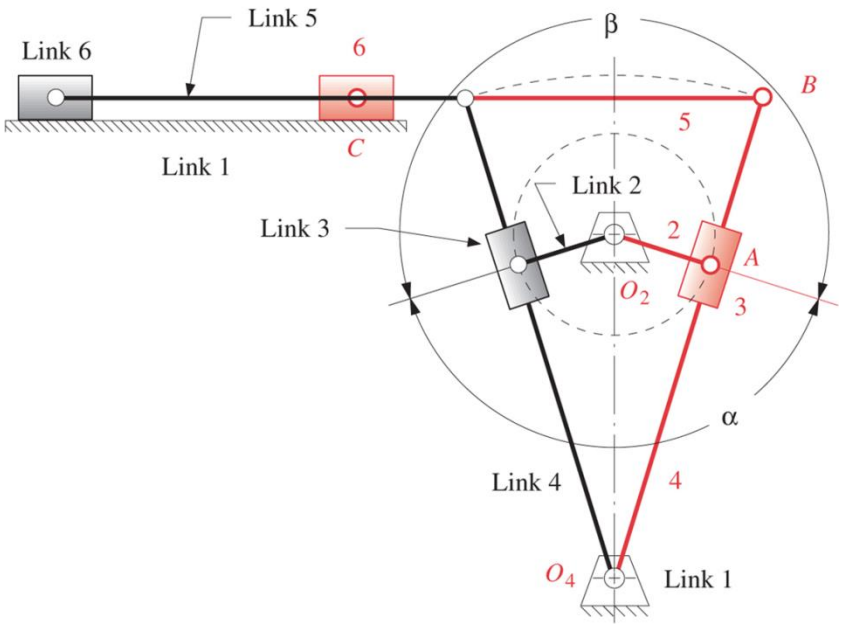

Fig 1. Crank Shaper quick Return Mechanism

On the phase I, the students should synthesis a quick return mechanism with timing ratio of 1/2.5. They should meet the given design requirement. They come out with the size of the links and location of the joints. Now based on these sizes, on phase II, they should come out with a nice and manufacturable design. They used Solidworks to draw their design. They should use their creativity to have a model with the minimum needed material. Figure 2 and 3 shows two views of the final design for this project.

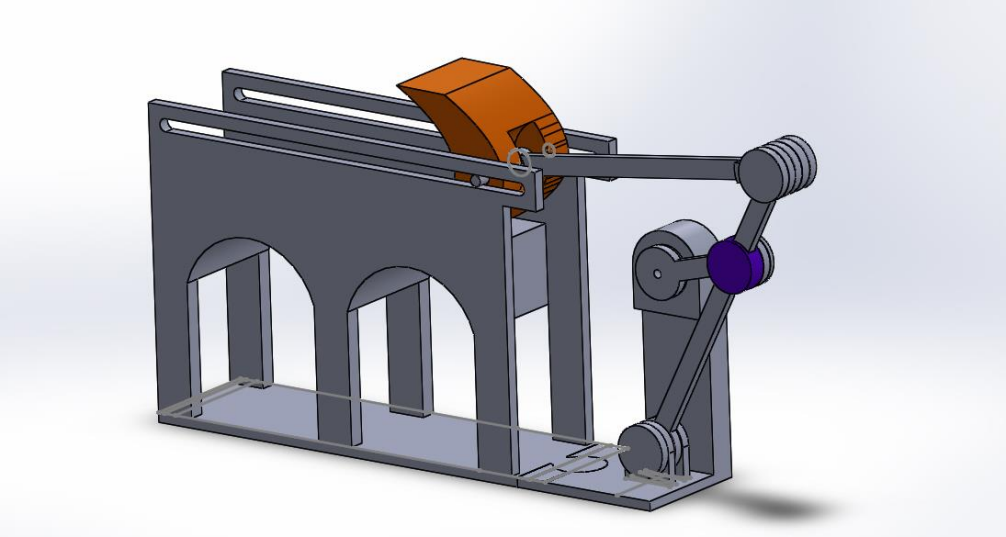

Fig 2. 3D view of the Quick Return Mechanism

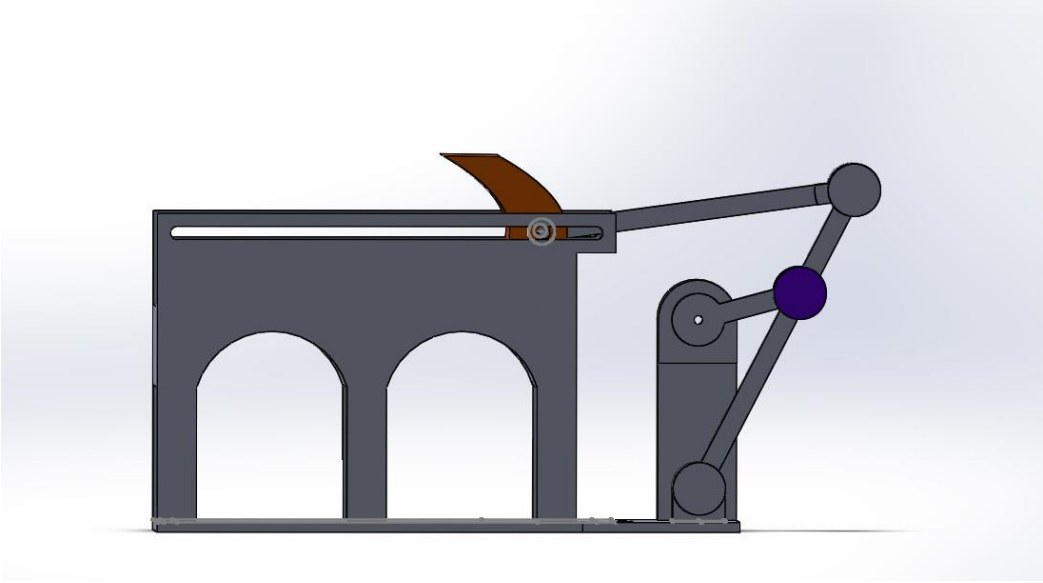

Fig 3. Front view of the Quick Return Mechanism

On the last phase of the project, the parts are printed out and they are assembled. Since the limitation of the printing machine was 8x8x12 in for the size, this project was needed to be divided by some parts to be printed individually and then the parts are assembled after had printed by the machine. Figs 3 and 4 are showing the final product. There is a motor running the cutting mechanism. The motor has 24 rpm speed.

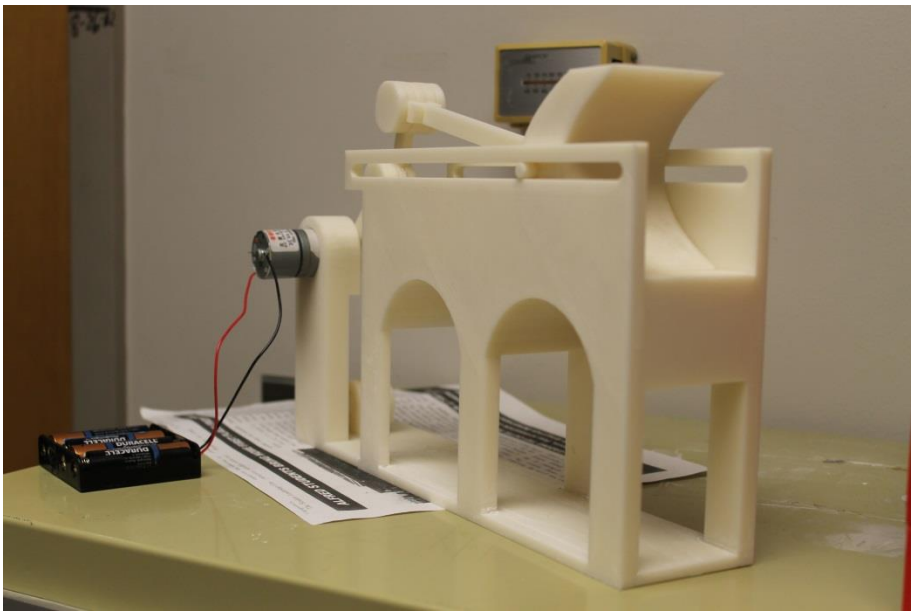

Fig 4. The 3D prototype of the Quick Return Mechanism

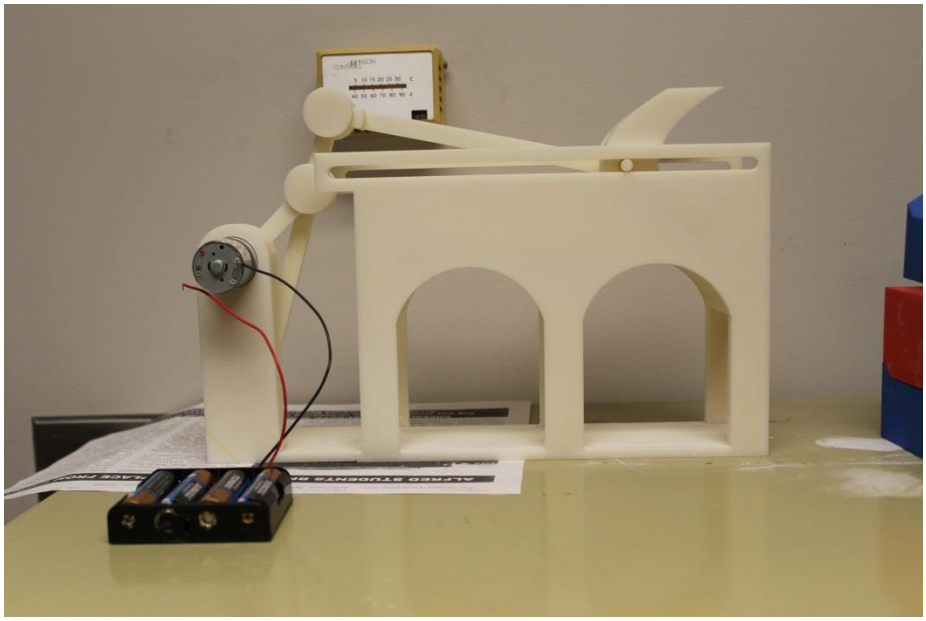

Fig 5. Front View of 3D prototype of the Quick Return Mechanism

Project II: Design a Foldable Picnic Table and Bench

This group of students would like to design a mechanism for the foldable picnic table. The picnic table could easily be converted to the bench. The group did the calculations and could size the links and table parts. On the drawing phase, they could use their creativity and their calculation to come out with a final drawing of the design. Figs 6 and 7 show their design. The designed mechanism for the table allows that it is converted to the bench. Fig 7 shows the bench.

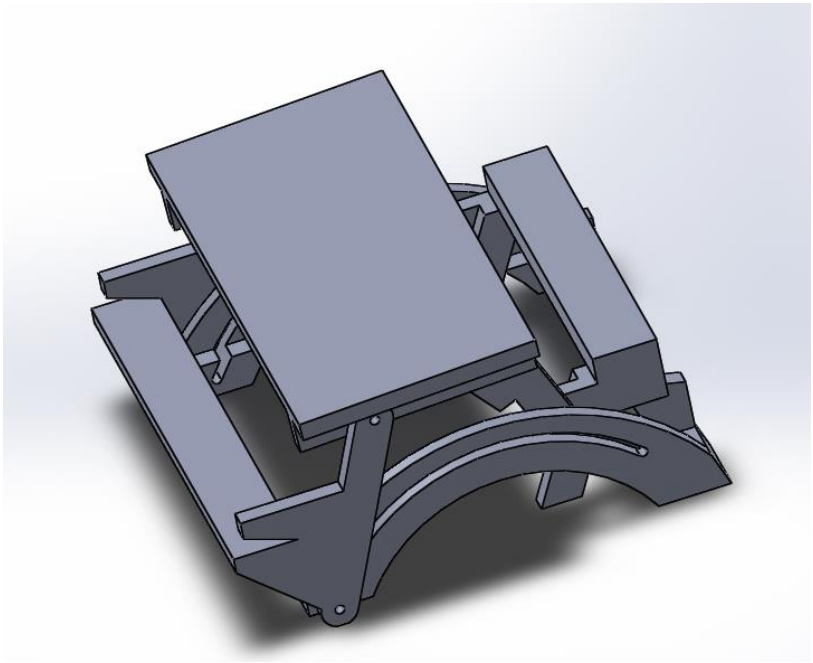

Fig 6. Picnic Table View

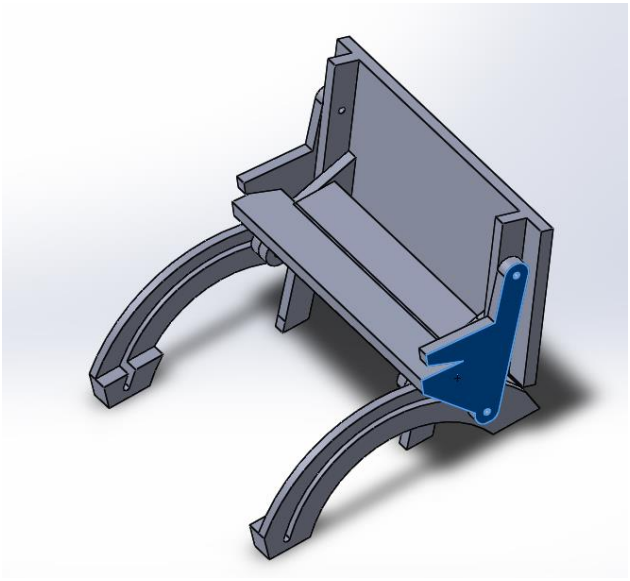

Fig 7. Picnic Table-Bench View

The final design file was sent to the 3D printing facility and the prototype was printed. Figs 8 and 9 show the final 3D printed prototype of this project.

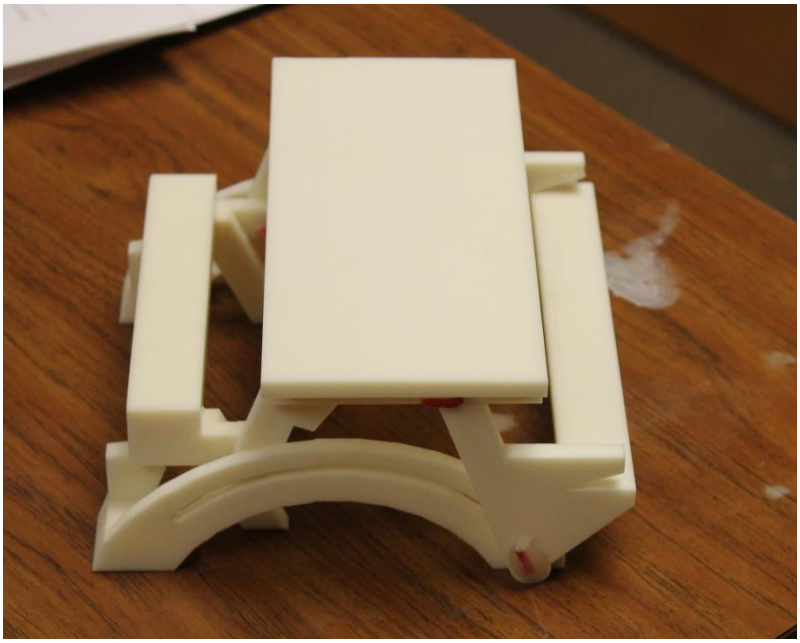

Fig 8. 3D Prototype Picnic Table

Fig 9. 3D Prototype Picnic Table-Bench

There are 10 to 12 projects done on every class of Kinematic and Dynamic Analysis of Machinery. These two projects are just two samples of them to be shown in this paper.

Learning Experience:

The students learned how to apply the materials covered in the class in the real mechanism. They had experience of making a product from scratch to final stage. They started from brain storming to come out with a mechanism to design then they designed the mechanism for sizing the links and joints. The drawing will be done based on their design. They could see that how the real manufacturing might be different than perfect world on drawing. They will learn how to optimize their design to save material. They will learn how to work at a group.

Conclusion:

Having the hands on project on the mechanism design class will help the students in different ways. First, they will apply the materials that they have learned in this class to design and build a real mechanism. They will see how their knowledge can help them to build a real mechanism. Second, they will see three phases needed to build a product. Design phase, Drawing Phase and Production. They will see how it could be difference between the Solidwork files that they send to the 3D printing machine and the real product that they will get it from it. Their mechanism is working perfectly on the Solidwork but it has some problems when it goes for the production. Third, they used their creativity to have a nice and optimum design. They should use their skills on drawing with Solidworks to complete the project.

The material cost was the main part of the cost for the projects. The cost of material was 9 $\$/in^2$ .The total cost for 12 projects was around twelve hundred dollars.

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References:

[1] Kroll, Ehud, and Dror Artzi. "Enhancing aerospace engineering students' learning with 3D printing wind-tunnel models." *Rapid Prototyping Journal* 17.5 (2011): 393-402.

[2] Sven G. Bilen, Timothy Wheeler and Randall Bock. "Applying 3D Printing to Model Rocketry to Enhance Learning in Undergraduate Engineering Design Projects." *2015 ASEE annual conference and Exposition.*

[3] Chris Pung. and Debbie Mlis. "A Practical Approach to Student Use of University Owned Rapid Prototype Machines." *2015 ASEE annual conference and Exposition.*

[4] Rodney Boehm, and Magdalini Lagoudas. "48-hour Rapid Prototype Development." *2015 ASEE annual conference and Exposition.*