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THE DESIGN OF A 10-BAR LINKAGE FOR FOUR FUNCTIONS USING SYMECH

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ABSTRACT

This paper describes a case-study which illustrates the capabilities of a commercially available software package called SyMech, which runs within Pro/ENGINEER. The software allows a designer to synthesize arbitrarily complex planar mechanisms by sequentially specifying one of three basic mechanism design functions: position, path, or angle. Because the software runs directly within Pro/ENGINEER, the designer can create the geometry of all of the parts during the mechanism synthesis process, greatly reducing the overall time and effort involved in the design process.

INTRODUCTION

The case-study begins by specifying a realistic (if not typical) industrial problem: create a mechanism that will move a finger (rigid body) inside a container to press a switch on the outside of the container, and then return to the inside of the container.¹ This finger mechanism will be a four-bar mechanism created with *position synthesis*. Next, another four-bar mechanism created with position synthesis will be designed to open the cover of the container. The two independently designed four-bar mechanisms will then be linked together using *angle synthesis*. Finally, *crank synthesis* will be used to design an input driver, so that the entire mechanism can be driven with a continuously rotating input.

¹ Two different solutions to this basic problem can be found in [Erdman and Sandor].

The complexity of this example not only highlights the utility and versatility of SyMech's synthesis and analysis capabilities, but clearly illustrates the importance of subdividing the overall requirements into a manageable sequence of discrete mechanism design functions. The completed Pro/ENGINEER model of the linkage is shown in Figure 1.

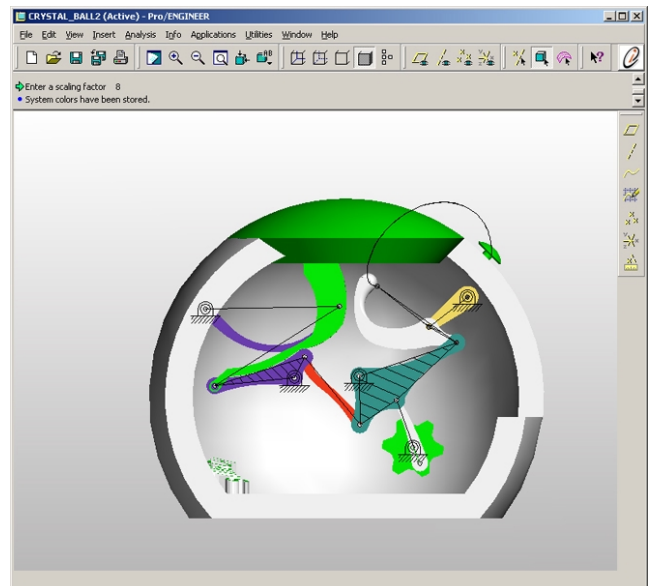


Figure 1. Completed ten-bar linkage.

DESIGN PROCEDURE

Step 1: Position synthesis of the “finger”

First, the basic geometry (the container and the finger in 3 positions) is created in Pro/ENGINEER as an *assembly*. This establishes the geometric constraints of the problem by showing the required positions of the linkage, and the acceptable locations for all of the links of the mechanism (within the container) as shown in Figure 2. After SyMech is selected from the assembly menu, a default four-bar linkage appears on the screen. Next, the default precision positions are mapped to the specified positions of the rigid body (finger), and then the linkage is interactively modified by dragging the ground pivots, so that the resulting linkage satisfies the geometric constraints, as shown in Figure 3. The linkage is guaranteed to *assemble* in each of the prescribed positions; because the coupler curve is continuously updated, the designer gets immediate feedback on whether or not the linkage can actually be *driven* through the 3 positions, and if it can do so in the correct order. The linkage can also be animated at this point to further ensure that the constraints are not violated.

Step 2: Position synthesis of the container cover

Figures 4 and 5 illustrate a similar procedure for designing a four-bar linkage to move the cover of the container from the closed to open position. At this stage of the design procedure, there are two independently designed, independently actuated four-bar linkages.

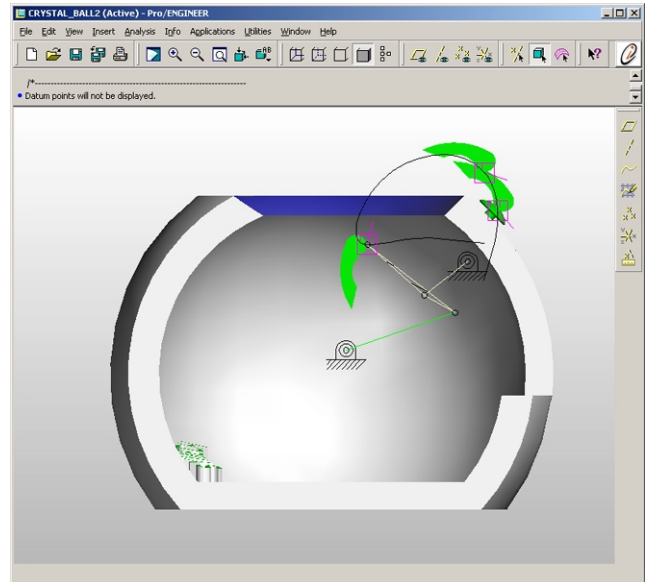


Figure 3: Four-bar linkage designed for position synthesis to position the finger in 3 prescribed positions.

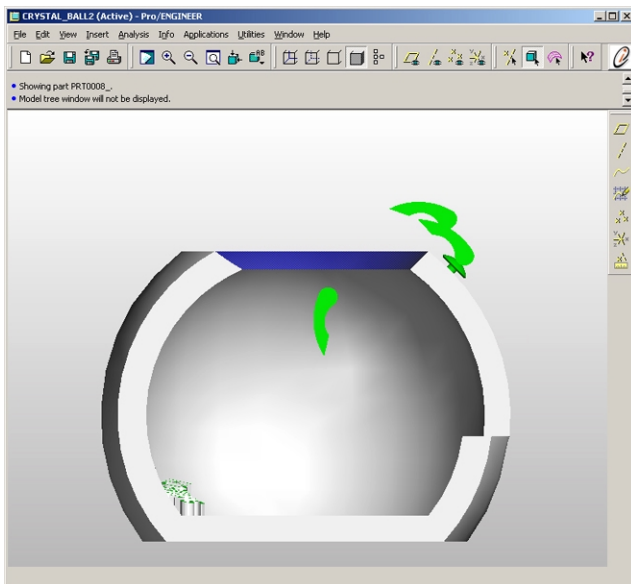


Figure 2: Three prescribed positions of the “finger” superimposed over the basic design geometry.

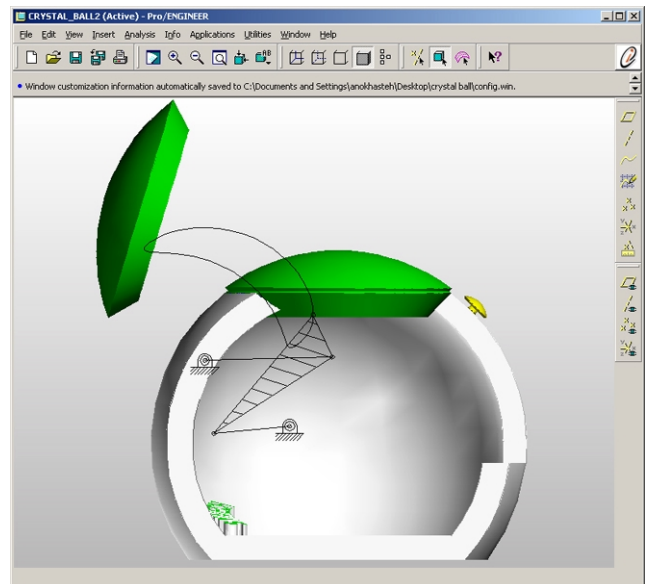


Figure 4: Four-bar linkage designed for position synthesis to position the cover in 3 prescribed positions (intermediate position not shown).

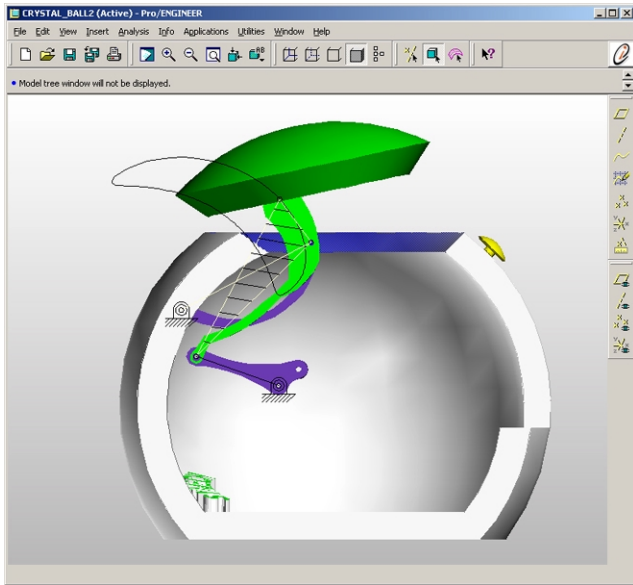


Figure 5: Four-bar linkage designed to position the cover with link geometry added.

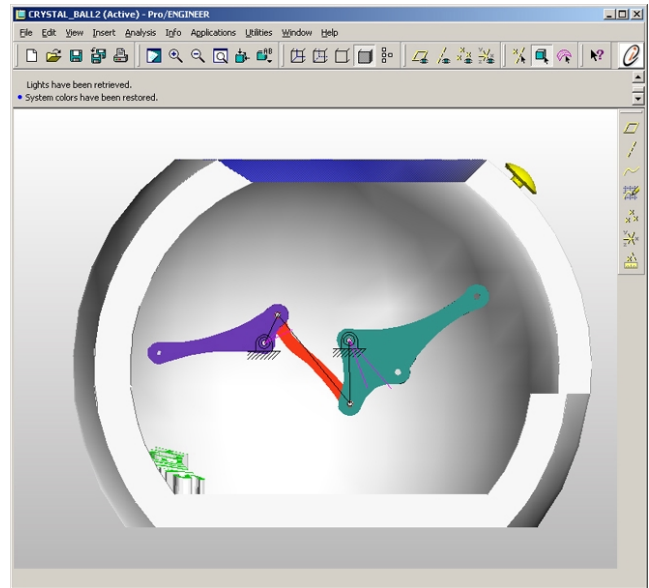


Figure 6: Creation of the link connecting the two four-bars.

Step 3: Angle synthesis to coordinate the 2 motion generators:

It is desired to combine the two four bar mechanisms by coordinating the angular positions of the input link of each mechanism, resulting in a single degree-of-freedom 8-bar linkage which performs the 2 separate position synthesis tasks. Figure 6 illustrates how SyMech can facilitate the synthesis of the function generator by specifying the angular rotation of each of the two four-bar input links. The resulting 8-bar linkage is shown in Figures 7-8.

Step 4: Crank synthesis

The final synthesis step is adding a crank input to drive the initial four-bar motion generator. First, an additional point on the four-bar driver is arbitrarily chosen in a convenient location (Figure 9). Next, the specialized design procedure for *crank* is selected from the SyMech menu. The default crank input is located anywhere along a line extending from the pivot location at the mid-point of the four-bar driver rotation, which is optimal in the sense that it maximizes the minimum transmission angle. It is also possible to design the driver dyad to provide for a quick-return, if so desired.

CONCLUSION

This mechanism example demonstrates a new method of designing mechanisms by incorporating sub-mechanisms or functions into a general mechanism. Two four-bar mechanisms

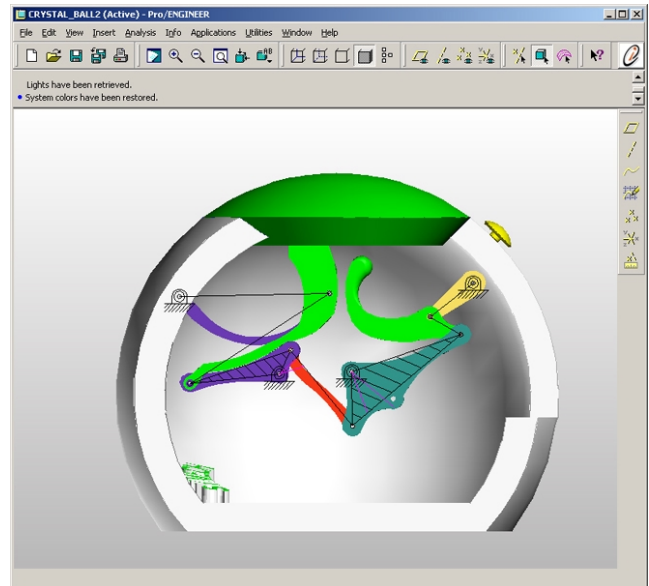


Figure 7: Completed eight-bar linkage.

were independently synthesized with motion synthesis to manipulate the finger and the cover. Once these mechanisms were created, a function generator was created to link the two four-bar mechanisms into one eight-bar mechanism. Finally, a

driving dyad was added to the mechanism to drive the completed mechanism. The ability to perform all of these synthesis steps directly within Pro/ENGINEER allows a designer to design an entire complex machine, complete with the geometry of all of the links, greatly increasing the designer's productivity and the quality of the solution.

ACKNOWLEDGEMENTS

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REFERENCES

Erdman and Sandor: "Advanced Mechanism Design, Volume 2, Prentice Hall, 1984.

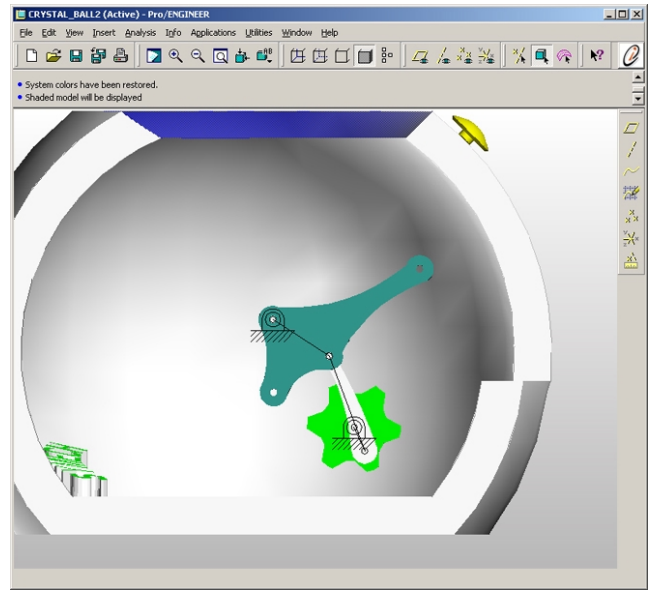


Figure 9: Addition of the crank input to the original four-bar to allow for continuous input rotation.

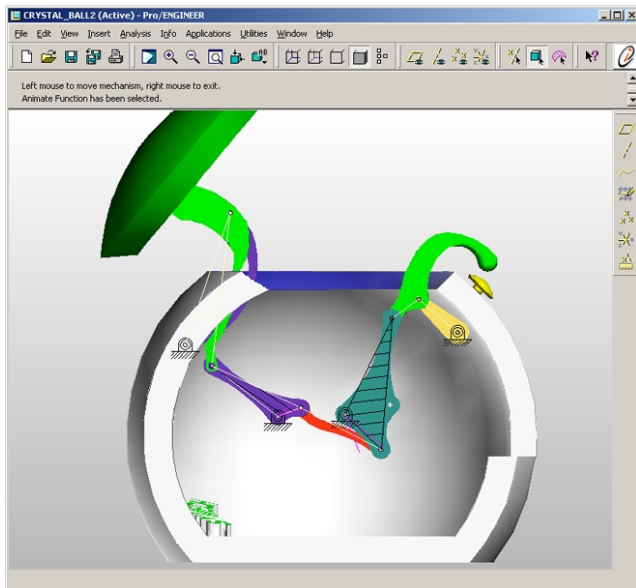


Figure 8: Completed 8-bar linkage in the open position.

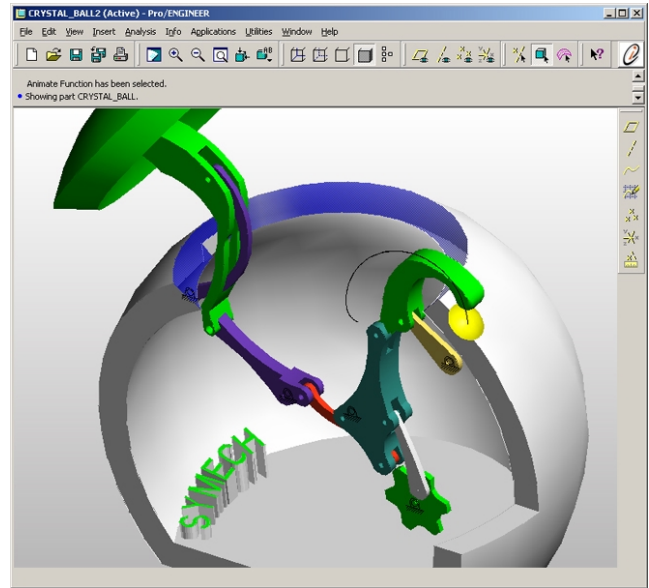


Figure 10: Completed ten-bar linkage.