LINCAGES 2000 Latest Developments and Case Study

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Abstract

This paper introduces the latest development of LINCAGES 2000, a mechanism design software package available on Windows 9x/NT and 2000. A case study of a motion generation mechanism design using LINCAGES 2000 is presented. Various design options are compared and their advantages and disadvantages are discussed. This software is proved to be a powerful tool for mechanism synthesis and analysis.

Introduction

A mechanism is a mechanical device that has the purpose of transferring motion and/or force from a source to an output [2]. Overall, the task of a mechanism falls into one of the following categories: motion, path and function generation. A multiple-stage process of mechanical design is required for mechanism design. Among these stages, synthesis and analysis are two of the key components. In short, synthesis generates the optimal dimensional parameters for the mechanism based on physical constrains and design specifications. Analysis evaluates the performance of the mechanism through kinematics and dynamics and makes changes to the mechanism as necessary. Traditionally, this design process is done by intuition, experience, and trial and error procedure. With the help of computer aided mechanism design packages, the work is greatly simplified and systemized. Various mechanism design packages like ADAMS [17], MINNSKETCH [12], AutoCAD [14], IDEAS [18], Pro/E [15] have been successfully used in academics and industry.

LINCAGES [6, 7, 8, 10, 11] developed in the University of Minnesota, is a powerful tool for the design of four-bar and six-bar planar mechanisms using dyad equations in complex number forms and Burmester theory [1, 2], LINCAGES 2000 provides three and four-precision-position motion, path and function synthesis. It also has basic analysis tools providing velocity, acceleration and transmission angle information simultaneously with the synthesis process, thus providing evaluation of the performance of ongoing designs. Users can interactively change design parameters by direct operation on the linkages or by using the Solution Map to achieve different mechanism types fulfilling the design specifications. Analysis results dynamically change as design parameters change. With the help of this software package, traditional trail and error effort in mechanism design process is greatly decreased.

Latest development of LINCAGES

LINCAGES was first developed in the mid 70's in the University of Minnesota. Through the past twenty years, LINCAGES has been ported to various computer platforms such as Macintosh, IRIX and DOS. New features have been added based on feedback from academic community and industry. The latest version is a windows based LINCAGES 2000. This version has a newly designed graphical user interface (GUI) and an object–oriented synthesis engine. It is developed using Visual C++ with MFC [16] for Windows 9x, NT and 2000. Source code control and bugs report systems with Perforce [19] were used during the development. Complete users help file and manual have been added.

New features of LINCAGES-2000

3-point motion generator solution map

For four prescribed positions, the solution map displays all the possible solutions in term of free choices (e.g. dyads) as opposed to x-y coordinates, as is done in the worksheet (the main window which displays the current

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linkage). Thus each axis of the map represents one dyad of the four- bar. All possible four bar mechanism that satisfy the design positions are displayed by way of a color code according to the type of four bar generated with those two dyads. The Solution Map allows user to see all the linkage solution possibilities at once, instead of having to search for all of them in the worksheet.

For a 3-point motion generator mechanism, the number of free choices is increased and thus the number of possible solutions is doubled. The result is that given a prescribed dyad, there is still a double infinity of solutions. These solutions can be represented by a solution map. The new version of LINCAGES 2000 displays the map in the x; y worksheet coordinates.

To activate the solution map, one clicks the solution map icon on the tool bar. User can drag the ground pivot or moving pivot around. When the left mouse button is pressed, LINCAGES 2000 will automatically generate a solution map in the worksheet as background like figure 1. In the figure, different regions with different colors show the mechanism type when the dragged pivot follow into them. User can use the analysis tools at the same time to estimate the performance of each design location simultaneously.

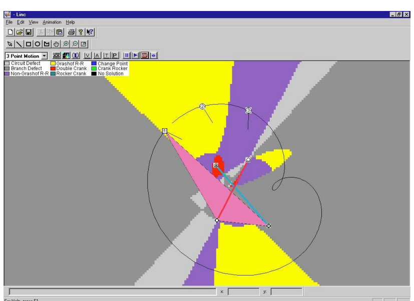
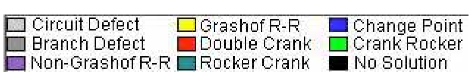


Figure 1: 3pt motion solution map



Ability to change synthesis precision

Base on the problem being solved, different design precision may be required. New release of LINCAGES 2000 enables user to specify synthesis precision by changing the number of points Burmester curve solutions displays and solution map resolution. This ability is especially usefully when doing 4-point synthesis.

Dynamic information display

When user moves mouse over objects such as precision positions or linkage pivots, its information is displayed at the bottom of the window. The x; y coordinates of the mouse cursor are also dynamically displayed.

Enhanced object operation

User can perform more operations on drawn objects. One can copy and delete imported Windows OLE objects. When zoom function is used, drawn/imported objects also zoom with the same ratio as linkage itself.

A case study of mechanism design using LINCAGES 2000

Dr Michael McCarthy from University of California, Irvine, proposed the following design challenge for software vendors. It's a motion generation problem with 11 prescribed precision positions (figure2).

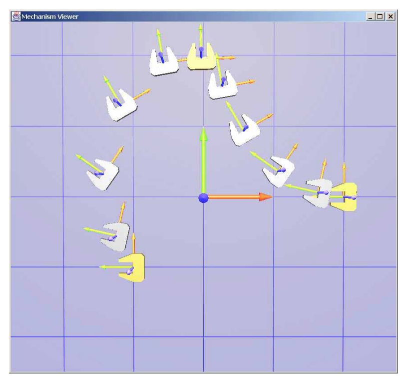


Figure 2: Design positions

Our goal is to design a simple 4 bar linkage to provide as close approximation to these positions as possible. With LINCAGES 2000, we can specify at most 4 precision positions, so we need to select the four precision positions from the 11 prescribed positions. It is decided the first position, the last position and the top most position are the most important positions (in yellow color in the design positions figure). The 4th precision positions will be chosen from the remaining ones. To start the solution process, one creates a new four-point motion design file, imports the design position graph (in BMP format), and adjusts the scale and location of the coordinate system to match the imported graph. Next, we drag the 4 precision position points (little box with numbers) to the specific design position and adjust the orientation of each position (the straight line attached to each little box). The solution map is opened by clicking the solution map icon. After a short investigation, the third position from the left is chosen as another precision position because it gives the solution map with the biggest solution area. The cross-hair in solution map (figure 3) is dragged while watching the change of mechanism in the main worksheet. When the solution is close to a local optimum (using measures like pivot locations, mechanism type, match of all non-specified positions), the pivots on the input or output link are dragged in the main window to fine-tune the path of tracer point on the couple until it reaches a "best" solution (figure 4).

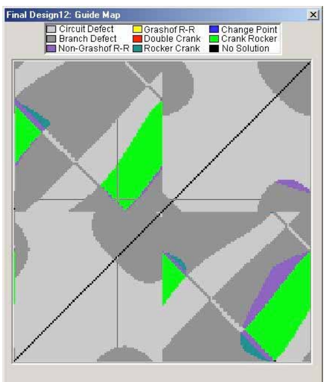


Figure 3: Solution map

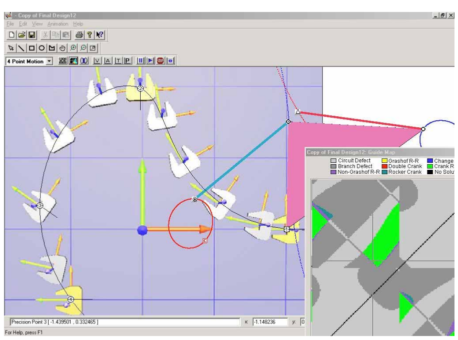


Figure 4: Solution to design positions

We can now reshape the coupler to include the moving object, and use animation to verify each design position. The solution was generated very quickly as a very good match for all the design positions (figure 4, 5). Is this the best design? Well, best depends on other considerations that were not specified! This design, however, very closely matches all 11 positions.

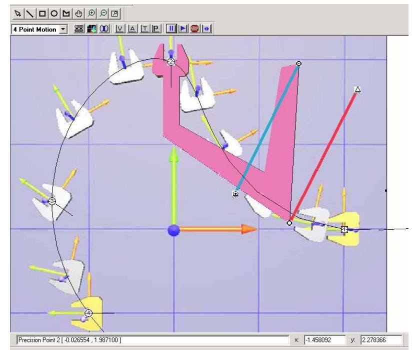


Figure 5: position checking

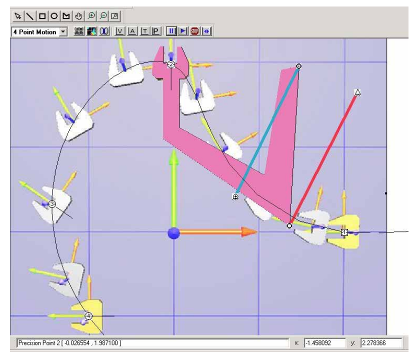


Figure 6: position checking

Linkage pivots location information is available by clicking the *linkage information* icon on the toolbar (figure 7). This linkage is a crank-rocker mechanism. (Input link has full rotation, which is desirable for using a motor as driver)

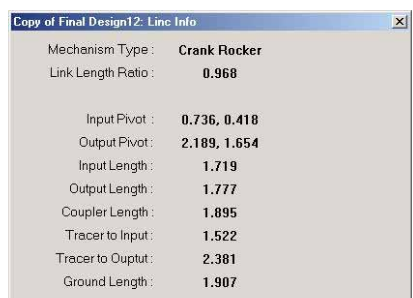


Figure 7: Linkage information

The transmission angle plot is shown in figure 8, which suggests a lower than desirable range between about 10 to 70 degree of input rotation.

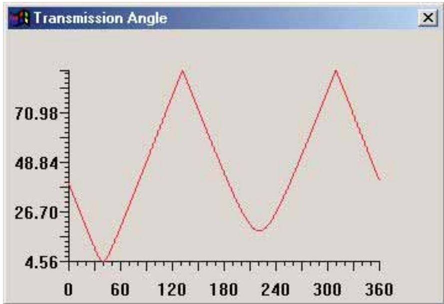


Figure 8: Transmission angle

It is found transmission angles fall under 20 degrees. This is usually not acceptable because small transmission angle will affect the smooth operation of the mechanism.

Angular velocity and acceleration are shown in figure 9 and 10.

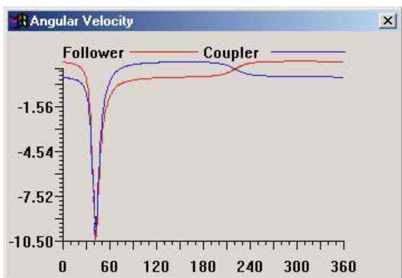


Figure 9: Angular velocity

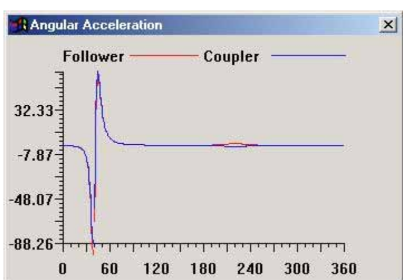


Figure 10: Angular acceleration

If we desire to have a design with better transmission angles, we can have transmission angle graph open, while synthesizing the mechanism. One design with minimum transmission angle greater than 20 degree is shown in figure 11. The tracer point curve of this design doesn't match all the design positions as well as the other solution. It is found the design positions on the left side causes the transmission angle problem. As usual, there is some trade off to make in satisfying multiple design constrains.

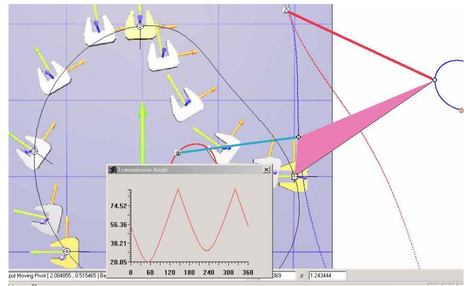


Figure 11: Alternative solution with better transmission angle

The three-position motion generation option is another design strategy available in the software. Since the real goal is to match 11 positions, we would tend to first use the four-position option as was done above.

Figure 12 shows a solution that resulted in a short design exercise with 3 prescribed positions. The advantage here of many more available solutions is over shadowed by the performance of the mechanism being further away from matching all 11 positions.

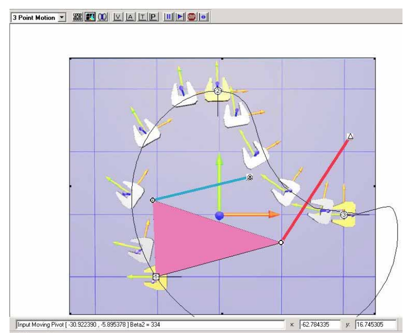


Figure 12: 3-position motion generation

Figure 13 shows the solution map superimposed on the 3 specified design positions. This is a different solution than shown in figure 12. For one fixed dyad position (upper right), the map is generated for the other (input) dyad. Notice that the ground pivot had been placed in the green region, which guarantees a crank-rocker solution.

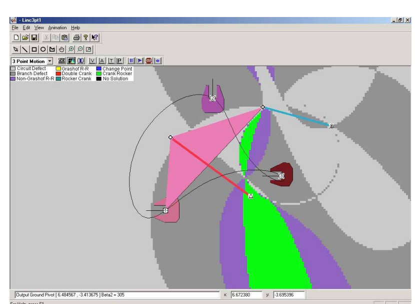


Figure 13:Solution Map for 3-position option

Scope for Future Work

The current LINCAGES 2000 release saves documents in a standard binary format for Microsoft Foundation Classes documents. Changing to STEP standard compatible format is under consideration. This will enable LINCAGES to exchange files with other CAD software package like ADAMS. This will greatly expand the use of LINCAGES 2000 in other domains.

Kinetostatic and dynamic analysis may be also the future feature of LINCAGES.

Conclusions

This paper introduced the latest development of LINCAGES 2000 and some of its new features. A case study of designing a motion generation mechanism using LINCAGES 2000 is presented. Even though the four-position option was preferred here, other problems may be easier to solve in the three-position or sketch option. The power of the software is proved by its quick solution to synthesis problems and its analysis functions. Once the precision positions were imported into the software, the solution shown in figure 4 took about 10 minutes.

Acknowledgement

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