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Impact of commercially popular machine mechanisms using simulation tool in computer-aided design for improvements in mechanical engineering curriculum

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Abstract. The main content in the kinematics of machinery course includes kinematic analysis of machines and mechanisms and forms an integral part of the mechanical engineering curriculum. The conventional way of teaching students about the machine mechanisms is either by lecture notes/PowerPoint presentations/blackboard sketches finds it challenging to get an overall concept. Students find it challenging to understand the movements of machine parts due to a lack of visualization. The course can be taught in much lucidly and persuasively way by physical models or virtual mechanisms in a software ecosystem. There are several commercial and free software exists that can be used to complement the teaching and learning. In this paper, more straightforward, and more intuitive CAD software is reported, which has a very simple to use interface and a swift learning curve. A user can appreciate why and how the mechanism works by simulation of various mechanisms through CAD software.

1. Introduction

Mechanisms and linkages are the crucial components of a machine that move in a wholly determined way to execute a task. Thus learning mechanisms is an essential step in designing a machine. Without any course related to machines or mechanisms in mechanical engineering would be baseless because of its vast demand in industry and research without a course on mechanisms and linkages. However, the visualization of a mechanism is a big obstacle for students and teachers [1]. Visualizing various links that move relative to each other is a challenging task for a student to study mechanism-related courses. The instructor can reduce this obstacle by introducing working of fabricated models of mechanisms, but this would be an inconvenient approach and restrict the analysis to a few mechanisms. But then, how does one comply with the interest of a student who needs to examine with different input parameters applicable to the mechanism? It would be a lot easier if computer resources

can simulate mechanisms through a fusion of graphical and analytical method. Using computer resources will make the full learning experience lucrative and rewarding [2].

At present, there are commercially available software tools that can model and simulate mechanisms. For instance, it can be carried in 3D CAD tools such as MSC. ADAMS, RecurDyn, COMSOL Multiphysics, IDEAS, ANSYS Motion multibody dynamics, Dynamic Designer, LMS Virtual.Lab, Analytix, Autodesk Inventor, SolidWorks, Solid Edge, PTC Creo, by creating the mechanism, establishing constraints and thus simulating the mechanism. Moreover, the output parameters can be interpreted by plotting the graph after the simulation. Unique software for mechanism visualization has been built up by commercial software vendors and universities. Working Model 2D, Universal Mechanisms, SAM etc. are such freely available commercial software tools.

However, many universities and research organizations have also created free software and services such as MMTool, Lincages 2000, GIM, MechAnalyzer, MBDyn [3]. In Working Model 2D, where mechanisms can be built from the base by choosing links and joints and attaching them to grant relative motion between them. It also has some preloaded example mechanisms so that a user can load and simulate. The Working Model 2D has an option to import 2D parts from other CAD packages. MechAnalyzer is another interesting software developed by the authors. The user can select a pre-built mechanism and enter the dimensions of the mechanisms. Velocity and acceleration study can be carried out in MechAnalyzer. It has an option to plot kinematic or dynamic analyses data. Motion analysis is an add-in option available in SolidWorks CAD package [4]. The motion analysis is capable of performing both kinematic and dynamic analyses of planar and spatial mechanisms. It could perform analysis, and then display the results in a graphical format where it can be exported to a workbook or excel format for further analysis.

The SolidWorks package also allows exporting the mechanism to various software packages such as MATLAB Simscape Multibody [5] and LabVIEW SoftMotion [6] for co-simulation. The GUI of the software is easy to use and has a swift learning curve. A user needs to get familiar with the basics of CAD modelling commands before implementing the motion analysis module. Hence the paper aims to highlight the integration of such tools in the commercially accessible machine mechanisms using simulation tool in computer-aided design—Thereby enhancing the mechanical engineering curriculum.

2. Methodology

Motion Analysis aims to be a platform that can be adopted to demonstrate and understand the concepts associated with the kinematic and dynamic analyses of the mechanisms and machines [7]. An overview of the module is presented in this part. As illustrated in Figure 1, a user can create individual parts in part modelling module of SolidWorks. After creating the components of mechanisms, the same can be imported in the assembly module of the software package. The rigid links are constrained by applying mates to allow the relative motion. At the same time, motion analysis add-in can be activated from setting option or add-in option provided in the menu bar of the software package. There are three types of analysis options available in the software package, such as animation, basic motion, and motion analysis. The animation option is the most basic level analysis which does not consider physics while simulation and does not provide and any result [8]. The basic motion is an intermediate level of study involving some physics such as gravity but does not offer support for analysis. The motion analysis module of the software package provides the most versatile platform for kinematic and dynamic analyses for machines and mechanisms. The module includes options such as motor, force, spring, gravity, solid contact. The motion analysis allows to plot the graph and animate the mechanisms as per the input parameters. The graphical plots can be saved and exported in the form of clipboard or excel sheet for more data analysis. The module also provides an option known as event-based motion analysis for the time based or event-based simulation. Event-based motion analysis option can be used for massive industrial simulation similar to Delmia software package. The result, such as displacement, velocity, acceleration, power consumption, and torque can be plotted in graphical format[8]. The simulation can be directly saved in standard .avi or .mp4 format for the

presentation purpose. Also, different views such as top view, front view, right view, zoom in, zoom out options are given for better viewing of simulation.

3. Discussions

Four bar mechanism is the simplest and widely used in many applications [9]. The mechanism comprises four rigid links and four revolute joints. The revolute joint allows rotary motion and has one degree of freedom (DOF) or mobility. This is accomplished by applying concentric mate available in the SolidWorks. With respect to Figure 1, it can be noted that one of the links out of four-link is grounded or fixed, and the remaining links will be free to move relative to each other. It can be noted that the yellow colour link is fixed or grounded, the red colour link acts as a crank and green, blue colour link acts as a rocker and moves relative to each other due to revolute joint.

(a)	(b)
(c)	(d)
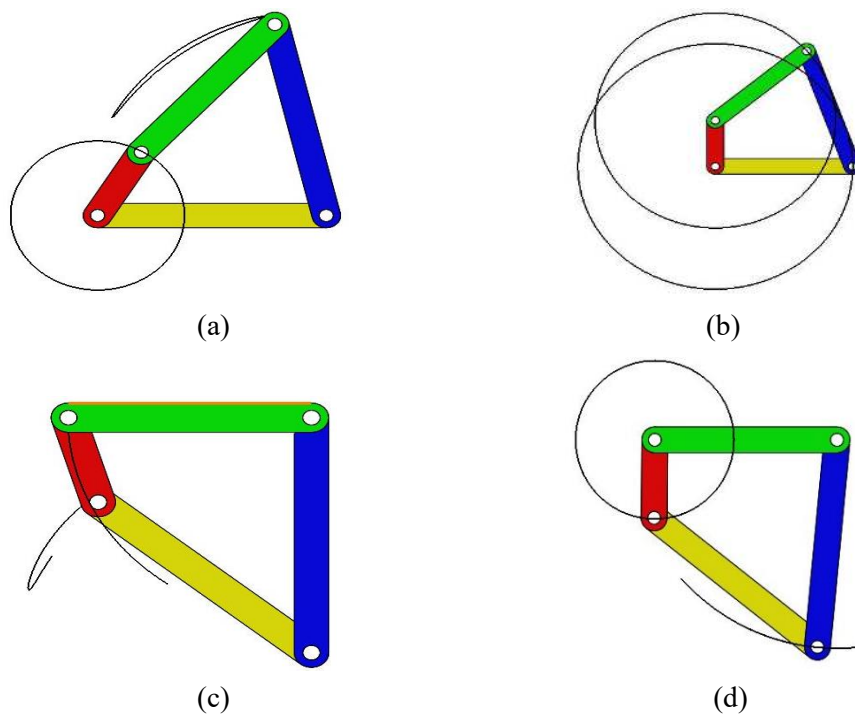
Figure 1. Inversions of four-bar mechanism: (a) First Inversion, (b) Second Inversion, (c) Third Inversion, and (d) Fourth Inversion.

Motion Analysis also has an option to trace the point of a vertex located on any link, as. It can be noted that different configurations or inversions of the four-bar mechanism by fixing different link one at a time. The straight-line mechanism is special-purpose mechanisms meant to deliver a straight-line motion [10]. In earlier days, manufacturing quality prismatic joints that permits smooth, straight-line motion without backlash was difficult. To overcome the difficulty, revolute joints were implemented to achieve a nearly straight-line motion mechanism. Figure 2 shows different configurations of straight-line motion mechanism. The straight line can be verified by using a trace path option on the vertex of the link.
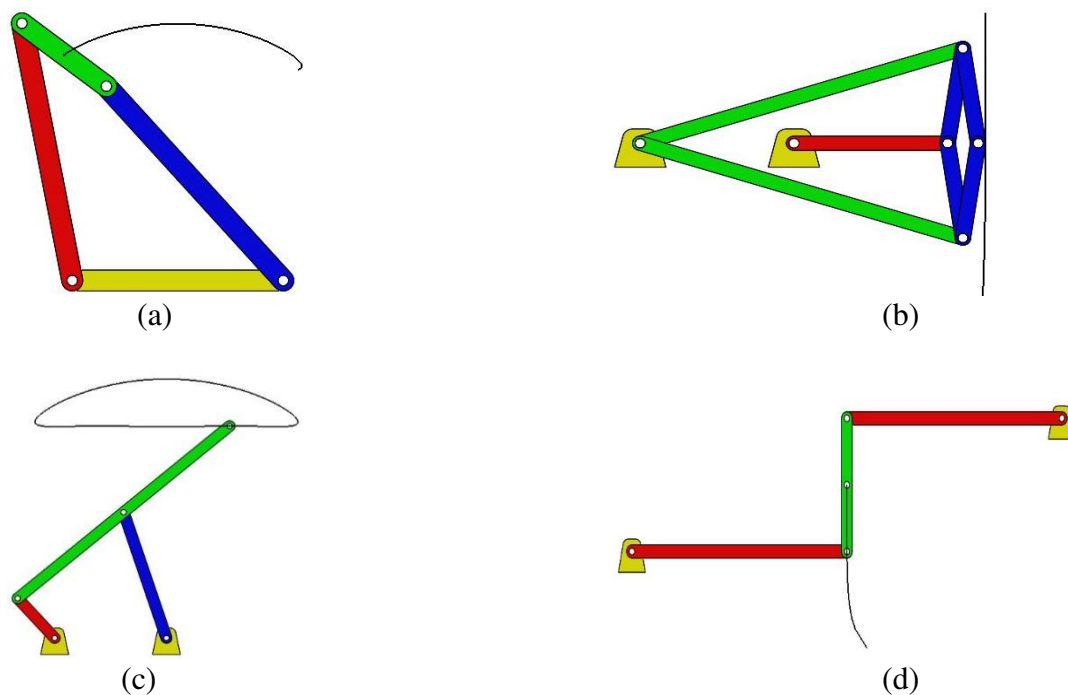
Figure 2. Inversions of four-bar mechanism: (a) First Inversion, (b) Second Inversion, (c) Third Inversion, and (d) Fourth Inversion.

4. Conclusion

A simulation environment with a swift learning curve is required for the active learning of concepts in the kinematics of machinery. In this paper, a CAD package is used to demonstrate the motion analysis of the mechanisms. Teachers can implement the CAD package for encouraging the students by showing them the animation of the model. This approach will not only motivate the user but also will deepen their understanding of mechanics. It is expected, that experience with CAD package will help the user to tackle similar such packages (like creo, COMSOL) and so the work though refers to a specific package has a broad point of view in mind.

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