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Machine Design

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INTRODUCTION TO MECHANISMS AND KINEMATICS

INTRODUCTION

Imagine being on a design and development team. The team is responsible for the design of an automotive windshield wiper system. The proposed vehicle is a sports model with an aerodynamic look and a sloped windshield. Of course, the purpose of this wiper system is to clean water and debris from the windshield, giving clear vision to the driver. Typically, this is accomplished by sweeping a pair of wipers across the glass. One of the first design tasks is determining appropriate movements of the wipers. The movements must be sufficient to ensure that critical portions of the windshield are cleared. Exhaustive statistical studies reveal the view ranges of different drivers. This information sets guidelines for the required movement of the wipers. Fundamental decisions must be made on whether a tandem or opposed wipe pattern better fits the vehicle. Other decisions include the amount of driver- and passenger-side wipe angles and the location of pivots. illustrates a design concept, incorporating an opposed wiper movement pattern. Once the desired movement has been established, an assembly of components must be configured to move the wipers along that pattern. Subsequent tasks include analyzing other motion issues such as timing of the wipers and whipping tendencies. For this wiper system, like most machines, understanding and analyzing the motion is necessary for proper operation. These types of movement and motion analyses are the focus of this textbook. Another major task in designing machinery is determining the effect of the forces acting in the machine. These forces dictate the type of power source that is required to operate the machine. The forces also dictate the required strength of the components. For instance, the wiper system must withstand the friction created when the windshield is coated with sap after the car has been parked under a tree. This type of force analysis is a major topic in the latter portion of this text.

BUILDING COMPUTER MODELS OF MECHANISMS USING WORKING MODEL SOFTWARE

INTRODUCTION

The rapid development of computers and software has altered the manner in which many engineering tasks are completed. In the study of mechanisms, software packages have been developed that allow a designer to construct virtual models of a mechanism. These virtual models allow the designer to fully simulate a machine. Simulation enables engineers to create and test product prototypes on their own desktop computers. Design flaws can be quickly isolated and eliminated, reducing prototyping expenses and speeding the cycle of product development. Software packages can solve kinematic and dynamic equations, determine the motion, and force values of the mechanism during operation. In addition to numerical analysis, the software can animate the computer model of the mechanism, allowing visualization of the design in action.

VECTORS

INTRODUCTION

Mechanism analysis involves manipulating vector quantities. Displacement, velocity, acceleration, and force are the primary performance characteristics of a mechanism, and are all vectors. Prior to working with mechanisms, a thorough introduction to vectors and vector manipulation is in order. In this chapter, both graphical and analytical solution techniques are presented. Students who have completed a mechanics course may omit this chapter or use it as a reference to review vector manipulation.

MECHANISM DESIGN

INTRODUCTION

Up to this point in the text, an emphasis was placed on the analysis of existing mechanisms. The previous chapter explored methods to determine the displacement of a mechanism whose link lengths are given. Compared to this analysis, the design of a mechanism presents the opposite task: That is, given a desired motion, a mechanism form and dimensions must be determined. *Synthesis* is the term given to describe the process of designing a mechanism that produces a desired output motion for a given input motion. The selection of a particular mechanism capable of achieving the desired motion is termed type synthesis. A designer should attempt to use the simplest mechanism capable of performing the desired task. For this reason, slider-crank and four-bar mechanisms are the most widely used. This chapter focuses on these two mechanisms. After selecting a mechanism type, appropriate link lengths must be determined in a process called *dimensional synthesis*. This chapter focuses on dimensional synthesis. To design a mechanism, intuition can be used along with analysis methods described in the previous chapter. Often, this involves an iterate-and-analyze methodology, which can be an inefficient process, especially for inexperienced designers. However, this iteration process does have merit, especially in problems where synthesis procedures have not or cannot be developed. However, several methods for dimensional synthesis have been developed and can be quite helpful. This chapter serves as an introduction to these methods. Because analytical techniques can become quite complex, the focus is on graphical techniques. As stated throughout the text, employing graphical techniques on a CAD system produces accurate results.

VELOCITY ANALYSIS

INTRODUCTION

Velocity analysis involves determining “how fast” certain points on the links of a mechanism are traveling. Velocity is important because it associates the movement of a point on a mechanism with time. Often the timing in a machine is critical. For instance, the mechanism that “pulls” video film through a movie projector must advance the film at a rate of 30 frames per second. A mechanism that feeds packing material into a crate must operate in sequence with the conveyor that indexes the crates. A windshield wiper mechanism operating on high speed must sweep the wiper across the glass at least 45 times every minute. The determination of velocity in a linkage is the purpose of this chapter. Two common analysis procedures are examined: the relative velocity method and the instantaneous center method. Consistent with other chapters in this book, both graphical and analytical techniques are included.

ACCELERATION ANALYSIS

INTRODUCTION

Acceleration analysis involves determining the manner in which certain points on the links of a mechanism are either “speeding up” or “slowing down.” Acceleration is a critical property because of the inertial forces associated with it. In the study of forces, Sir Isaac Newton discovered that an inertial force is proportional to the acceleration imposed on a body. This phenomenon is witnessed anytime you lunge forward as the brakes are forcefully applied on your car. Of course, an important part of mechanism design is to ensure that the strength of the links and joints is sufficient to withstand the forces imposed on them. Understanding all forces, especially inertia, is important. Force analysis is introduced in Chapters 13 and 14. However, as a preliminary step, acceleration analysis of a mechanism's links must be performed. The determination of accelerations in a linkage is the purpose of this chapter. The primary procedure used in this analysis is the relative acceleration method, which utilizes the results of the relative velocity method introduced in. Consistent with other chapters in this book, both graphical and analytical techniques are utilized.

COMPUTER AIDED MECHANISM ANALYSIS

dynamic analysis software was introduced. This chapter focuses on other forms of computer approaches to mechanism analysis. These other forms include using spreadsheets and creating routines using programming languages. dynamic analysis software was introduced. This chapter focuses on other forms of computer approaches to mechanism analysis. These other forms include using spreadsheets and creating routines using programming languages.

GEARS: KINEMATIC ANALYSIS AND SELECTION

INTRODUCTION

Gears are an extremely common component used in many machines. illustrates the drive mechanism for the paper feed rollers of a scanner. In this application, an electric motor drives a small gear that drives larger gears to turn the feed rollers. The feed rollers then draw the document into the machine's scanning device. In general, the function of a gear is to transmit motion from one rotating shaft to another. In the case of the feed drive of Figure 10.1, the motion of the motor must be transmitted to the shafts carrying the rollers. In addition to transmitting the motion, gears are often used to increase or reduce speed, or change the direction of motion from one shaft to the other. It is extremely common for the output of mechanical power sources, such as electric motors and engines, to be rotating at much greater speeds than the application requires. The fax machine requires that the rollers feed the document through the machine at a rate compatible with the scanning device. However, a typical electric motor rotates at greater speeds than are needed at the rollers. Therefore, the speed of the motor must be reduced as it is transmitted to the feed roller shafts. Also the upper rollers must rotate in the direction opposite to that of the lower rollers. Thus, gears are a natural choice for this application. aillustrates two mating spur gears designed to transmit motion between their respective shafts. Figure 10.2b shows two friction rollers or disks that are also designed to transmit motion between the shafts. Such disks are obviously less costly than complex gear configurations. However, the disks rely on friction to transmit forces that may accompany the motion. Because many applications require the transmission of power (both motion and forces), smooth disk surfaces may not be able to generate sufficient frictional forces and thus will slip under larger loads. To remedy the possibility of slipping, a gear is formed such that the smooth surfaces of the disks are replaced by teeth. The teeth provide a positive engagement and eliminate slipping. From a kinematic viewpoint, the gear pair in would replace the disks of because the effective diameters are identical. The principles of general gearing and the associated kinematic relations are presented in this chapter. The focus of this book is on the analysis and design of mechanisms that are necessary to provide the motion required of machinery. Consistent with this mission, the focus of this chapter is on the selection of standard gears to produce the motion required in industrial machinery. Because they are the most widely used and least complicated gear, spur gears are emphasized. The reader is referred to other sources for further detail on gear tooth profiles, manufacture, quality, design for strength, and more complex gears

BELT AND CHAIN DRIVES

INTRODUCTION

The primary function of a belt or chain drive is identical to that of a gear drive. All three of these mechanisms are used to transfer power between rotating shafts. However, the use of gears becomes impractical when the distance between the shafts is large. Both belt and chain drives offer the flexibility of efficient operation at large and small center distances. Consider the chain on a bicycle. This mechanism is used to transfer the motion and forces of the rotating pedal assembly to the rear wheel. The distance between these two rotating components is considerable, and a gear drive would be unreasonable. Additionally, the velocity ratio of the chain drive can be readily altered by relocating the chain to an alternate set of sprockets. Thus, a slower pedal rotation but greater forces are needed to maintain the identical rotation of the rear wheel. The velocity ratio of a belt drive can be similarly altered. Changing a velocity ratio on a gear drive is a much more complex process, as in an automotive transmission. Belt and chain drives are commonly referred to asvflexible connectors. These two types of mechanisms can be “lumped together” because the kinematics are identical. The determination of the kinematics and forces in belt and chain drives is the purpose of this chapter. Because the primary motion of the shafts is pure rotation, graphical solutions do not provide any insight. Therefore, only analytical techniques are practical and are introduced in this chapter.

SCREW MECHANISMS

INTRODUCTION

In general, screw mechanisms are designed to convert rotary motion to linear motion. Consider a package for a stick deodorant. As the knob turns, the deodorant stick either extends or retracts into the package. Inside the package, a screw turns, which pushes a nut and the deodorant stick along the thread. Thus, a “disposable” screw mechanism is used in the deodorant package. This same concept is commonly used in automotive jacks, some garage door openers, automotive seat adjustment mechanisms, and milling machine tables. The determination of the kinematics and forces in a screw mechanism is the purpose of this chapter. Because the motion of a nut on a thread is strictly linear, graphical solutions do not provide any insight. Therefore, only analytical techniques are practical and are introduced in this chapter. movement are gradual or the mass of the components is negligible. These include clamps, latches, support linkages, and many hand-operated tools, such as pliers and cutters. The following chapter deals with force analysis in mechanisms with significant accelerations. In many high-speed machines, the inertial forces created by the motion of a machine exceed the forces required to perform the intended task.