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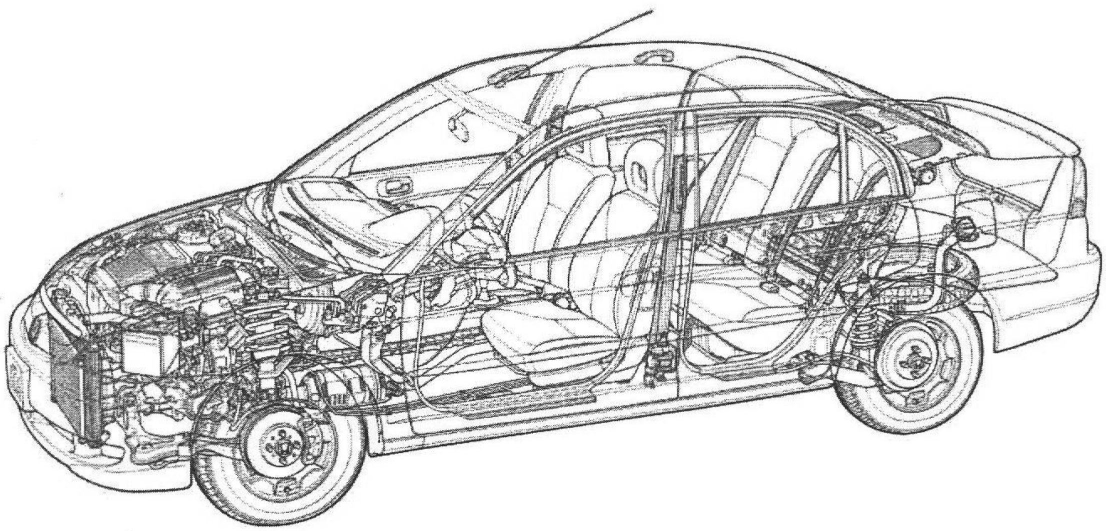
Fundamentals of MACHINE COMPONENT DESIGN



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Fundamentals of Machine Component Design

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CHAPTER 19

Miscellaneous Machine Components

19.1 *Introduction*

Power transmission between shafts can be accomplished in a variety of ways. In addition to gears (Chapters 15 and 16), *flexible elements* such as belts and chains are in common use. These permit power to be transmitted between shafts that are separated by a considerable distance, thus providing the engineer with greater flexibility in the relative placement of driving and driven machinery.

Belts are relatively quiet in operation. Except for timing belts (Figure 19.5), slippage between belt and pulleys causes speed ratios to be inexact. This slippage characteristic is sometimes used to advantage by permitting the pulleys to be moved closer together in order to disengage the drive, as in some snowblowers and self-propelled lawn mowers. This may save substantial cost, weight, and the bulk of providing a separate clutch. The flexibility and inherent damping in belts (and to a lesser extent in chains) serves to reduce the transmission of shock and vibration.

The design of chains illustrates the general proposition that if a component of desired characteristics is not already available, an engineer should consider the possibility of inventing something new. For example, the conventional roller and inverted-tooth chains discussed in Sections 19.5 and 19.6 require that all sprockets engaging a single chain lie in a common plane. Suppose a positive flexible drive is needed between sprockets lying in different planes. If little power is required, a "beaded chain" (similar to the pull cord on a plain light fixture) can be used. A stronger type of flexible chain incorporates parallel steel cables bonded to the sides of plastic cylindrical "buttons" that simulate the rollers of a conventional roller chain. A chain embodying this second concept was used between the pedal and propeller shafts of the Gossamer Albatross, the man-powered airplane that flew across the English Channel.

For transmitting small amounts of torque, flexible shafts often offer inexpensive solutions. The common automotive speedometer drive is a familiar example.

For transmitting power between nominally colinear shafts, flexible couplings, universal joints, and friction clutches have already been discussed. Another important general class of colinear members able to transmit power do so by *hydrodynamic* action. These are fluid couplings (also called fluid clutches) and hydrodynamic torque converters.

Other types of power transmission devices use rope or cable and move or lift a weight, using power delivered to a rotating shaft. Examples include hoists, elevator drives, and capstans. The site http://www.machinedesign.com on mechanical systems presents information on mechanical cable and wire rope, flat belts, V-belts, metal belts, and chains.

19.2 *Flat Belts*

A belt drive transmits power between shafts by means of a belt connecting pulleys on the shafts. Large flat leather belts were in common use a few decades ago when one large motor or engine was often used to drive several pieces of machinery. In today's more limited use, thin, light, flat belts usually drive high-speed machines. Often, the vibration-isolating capability of the belt is an important consideration.

The basic equations for the limiting torque that can be transmitted by a flat belt are the same as for band brake torque,

$$T = (P_1 - P_2)r \qquad \textbf{(18.24)}$$

and

$$P_1/P_2 = e^{f\phi} \qquad \textbf{(18.26)}$$

where P_1 and P_2 are the tight and slack side belt tensions, f is the coefficient of friction, and ϕ is the angle of contact with the pulley (see Figure 18.15). These two equations enable P_1 and P_2 to be determined for any combination of T, f, and ϕ. The required initial belt tension P_i depends on the elastic characteristics of the belt, but it is usually satisfactory to assume that

$$P_i = (P_1 + P_2)/2 \qquad \textbf{(19.1)}$$

Note that the capacity of the belt drive is determined by the angle of wrap ϕ on the *smaller* pulley and that this is particularly critical for drives in which pulleys of greatly differing size are spaced closely together. An important practical consideration is that the required initial tension of the belt not be lost when the belt stretches slightly over a period of time. Of course, one solution might be to make the initial installation with an excessive initial tension, but this would overload the bearings and shafts, as well as shorten belt life. Three methods of maintaining belt tension are illustrated in Figure 19.1. Note that all three show the slack side of the belt on top, so that its tendency to sag acts to increase the angle of wrap.

The coefficient of friction between belt and pulley varies with the usual list of environmental factors and with the extent of slippage. In addition to ordinary "torque transmission slippage," belts experience slip, commonly called "creep," through the slight stretch or contraction of the belt as its tension varies between P_1 and P_2 while going through angles ϕ in contact with the pulleys. For leather belting and cast-iron or steel pulleys, $f = 0.3$ is often used for design purposes. Rubber-coated belting usually gives a lower value (perhaps $f = 0.25$), whereas running on plastic pulleys usually

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