CHAPTER 7

Transmissions and mechanisms

Sometimes solid parts are assembled to cause force or torque in one place when a different force or torque is applied at another place. Such assemblies include levers, gear boxes, presses, pliers, clippers, chain drives, and crank-drives. Besides solid parts connected by pins, a few special-purpose parts are commonly used, including springs, strings and gears. Tricks for amplifying force are usually based on principles idealized by pulleys, levers, wedges and toggles. Force-analysis of transmissions and mechanisms is done by drawing free-body diagrams of the parts, writing equilibrium equations for these, and solving the equations for desired unknowns.

Here we consider collections of parts assembled to transmit motion or force. We are not going to address the conversion of thermal, chemical (or biological) or electrical source to a useful force. Rather we discuss the transmission of that force. We are concerned with the passive parts of machines, or with passive machines that have no energy source within them. Most often there is an input force or torque and a desired output which does the machine's job.

The categorization of an assembly of parts as a structure or as a ma-

chine is mostly a matter of intent. Is the main job to hold or support something still (a structure) or to move something. Besides its intended use, there is no way to look at an assembly of parts and assuredly characterize it as a structure or a machine①. So the statics analysis of mechanisms and transmissions is the same as for frames. Our main concern, as in the rest of statics, is:

> Given some information about the forces on or in a mechanism, find out more about the forces.

The practice of mechanism-design is often dominated by kinematic analysis, the study of the geometry of the interacting motions of the parts as the mechanism configuration changes. Such is not our concern here. Rather we focus on the relations between the various forces in a given configuration of the mechanism②.

Building blocks

In the same way that machines and buildings are built from bricks, gears, beams, bolts and other standard pieces, elementary mechanics models of the world are made from a few elementary building blocks. Conspicuous so far, roughly categorized, are:

- Special objects:
  - Point masses.
  - Rigid bodies:
    - Two-force bodies,
    - Three-force bodies,
    - Springs,
    - Pulleys, and
    - Wheels.
- Special connections:
  - Hinges,
  - Welds,
  - Sliding contacts, and
  - Rolling contacts.

Products and models Some of these things have dual lives, as products and as models. On the one hand, a mechanical hinge corresponds to a product you can buy in a hardware store called, naturally, a hinge. On the other hand a hinge in mechanics represents a constraint that restricts certain motions and freely allows others. A hinge in a mechanics model may or may not correspond to hardware called a hinge. For example, when considering a box balanced on an edge, we may *model* the contact as a hinge meaning we would use the same equations for the forces of contact as we would use for a hinge. Although you can buy a pulley, you might model a rope sliding around a post as a rope on a pulley even though there was no literal pulley in sight.

The relation between product and model can even sound contradictory. Although 'like a rock' means 'solid' in English, one may model a

①A candidate delineation between machine and structure might be whether the assembly allows any motion (mechanism) or not (structure). Even that concept is ambiguous. Common machines, like presses, wrenches and clamps, are as motion-restricted in their end-use as many structures. And, conversely, many structures are adjustable and thus are designed to move.

②The dynamics portion of this book is largely an introduction to the kinematics of mechanisms.

rock as a spring (which is done for foundation engineering, understanding waves in rocks, and calculating the energy of earthquakes). A coil spring may be modeled as a rigid rod for a simple structure-like study of a machine. And a hinge might be modeled as a spring if its deformation is important. That is, the appropriate mechanics model for a thing and its common name don't always agree.

What's new in this chapter The new content in this chapter is

- Detailed discussion of a few components used in mechanisms and transmissions that are not used commonly in simple 'structures'. These include springs, pulleys, wheels, and gears.
- Introduction to a variety of design tricks to, say, cause a big force when only a small force is available.

We start the chapter by discussing a few special parts and assemblies of those parts. Then we consider more general assemblies.