CHAPTER 10

Gears

It is difficult to generalize on intermittent motion gear systems because there are several basic types and they differ from each other in most characteristics. Some produce harsh impacts, some produce no impacts. Some characteristically produce only instantaneous dwell, others are used because they produce dwells of very long duration. Some are simple and cheap, others are complex and costly. All gear systems, however, require a continuous input rotation and, therefore, are probably never used with solenoid or fluid drivers.

Mutilated Gears

The easiest method of making an intermittent motion device from a pair of gears is to remove some of the teeth from the drive gear, as shown in Fig. 10–1. A gear with some of its teeth removed is sometimes called a mutilated gear, and if it is operated at high speeds or under high-load conditions, its name is well deserved! But if operated under a light load or at a reasonable speed, this is a very simple and versatile intermittent motion mechanism. Dwell and motion periods can be varied quite a bit depending upon the sizes of the two gears involved. The velocity ratio between input and output can easily be controlled by selection of the proper gear ratio. Nevertheless, this mechanism is an impact producer, as shown in Fig. 10–2. This is a simplified picture from that which would be obtained in most practical design situations where elasticity in the various parts of the system would result in multiple rather than single impacts.

The gear pair shown in Fig. 10–1 probably never would be found in practice. Some additional mechanism must be provided to hold the output gear during dwell periods to prevent the teeth of the two gears from "topping" as they re-engage. We will see some ways of accomplishing this in later illustrations.

Cycloidal Gearing

Another type of intermittent motion gearing is shown in Fig. 10–3. This is called a hypocycloidal gear train. A small "planet" gear runs around the inside of a fixed ring gear. A pin in the planet gear engages a slot in an output crank which rotates about the center of the ring gear, dwelling periodically as it rotates.

If the planet gear revolves around a fixed external or spur gear, as shown in Fig. 10–16, the system is called an epicycloidal gear train. The performance of these two types of cycloidal gear trains is similar. Anything we say about the hypocycloidal train is true or nearly true for the epicycloidal train, thus, we will discuss only the former.

The hypocycloidal gear train produces no impacts. It also produces only very short (theoretically only instantaneous) dwells. In these two characteristics, therefore, it differs significantly from the mutilated gear system considered earlier.

Figure 10–4 shows a schematic drawing of the gear train of Fig. 10–3. The dotted line represents the path taken by the drive pin as the planet gear moves around inside the ring gear. Since the diameter of the ring gear is an even multiple of the pitch

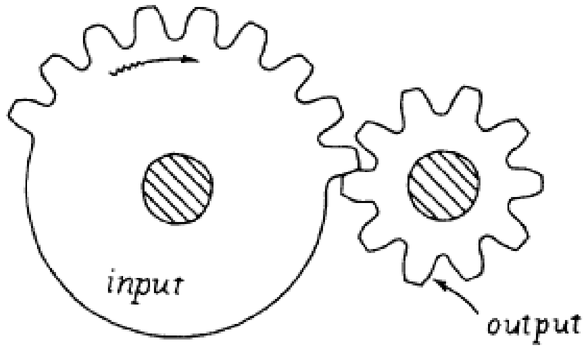

Fig. 10–1. Simple mutilated gear pair.

diameter of the planet gear (in the illustration, four to one) the drive pin will always follow the same path.

The instantaneous tangential velocity of the drive pin with respect to the center of the ring gear will vary as the rotational motion of the planet gear about its center is added to, and subtracted from, the rotational motion of the input arm about the center of the ring gear. (See Chapter 1 for the step-by-step procedure for determining the pin's tangential velocity.) The tangential velocity of the drive pin about the center of the system will be at a minimum in the position shown in Fig. 10–4 (and at the other three "corners" of the "square" being described by the pin). With the pin mounted about halfway between the center and pitch diameter of the planet gear, as shown in Fig. 10–4, the tangential velocity of the pin will never reach zero. If the pin were mounted on the pitch line of the planet gear, however, as shown in Fig. 10–5, it will describe a slightly different path, as shown, and there will be four times during each revolution of the input when

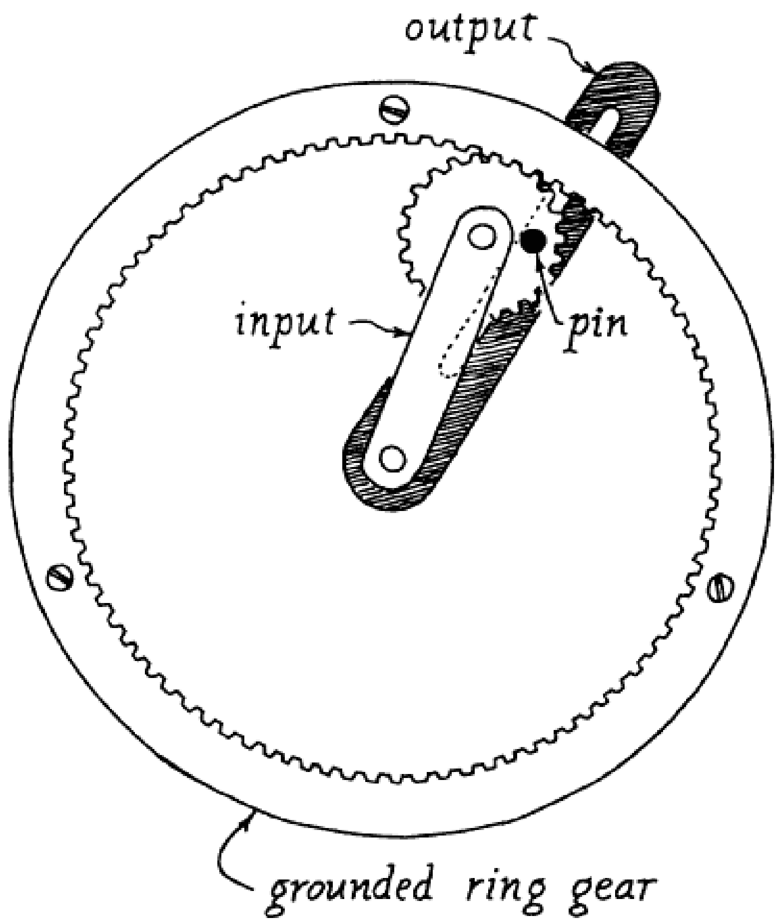

Fig. 10–3. Hypocycloidal gear train with a four-to-one ratio. The drive pin is located about halfway between the center and the pitch line of the planet gear.

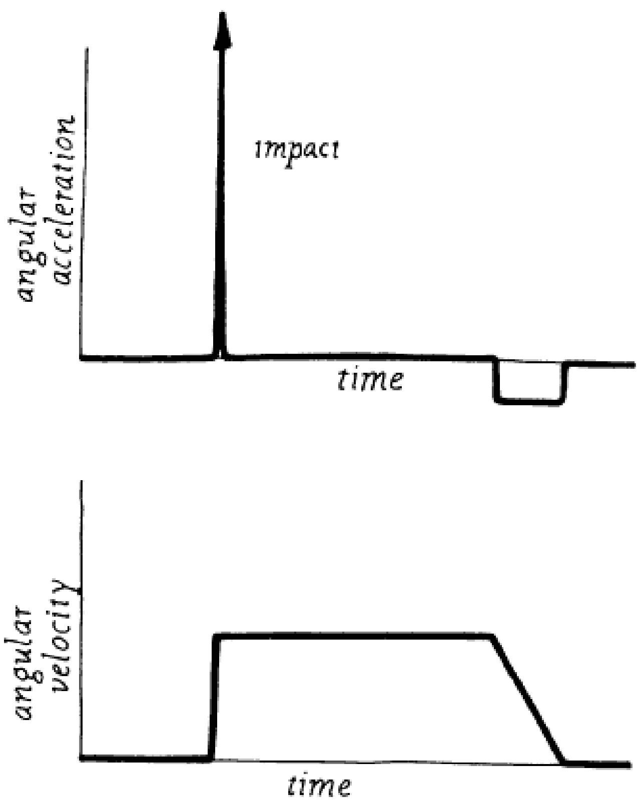

Fig. 10–2. Motion curves for the mutilated gears of Fig. 10–1.

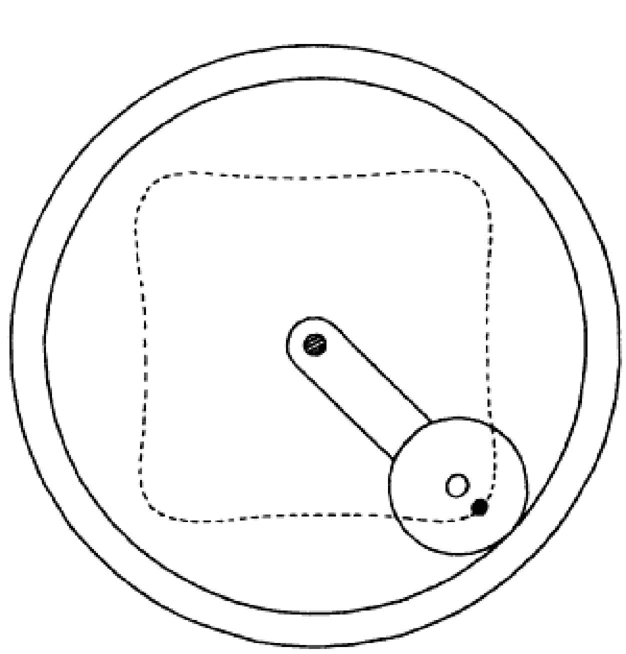

Fig. 10–4. Schematic illustration of the hypocycloidal gear train of Fig. 10–3.

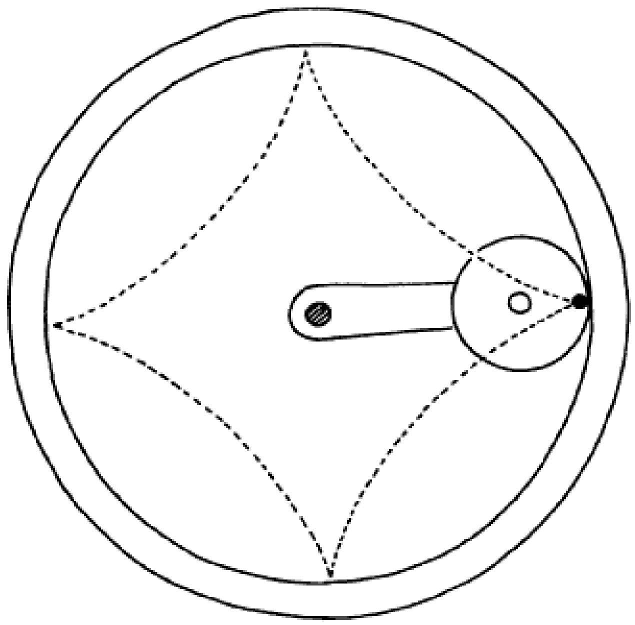

Fig. 10–5. Schematic representation of a four-to-one hypocycloidal gear train with the drive pin located on the pitch line of the planet and ring gears.

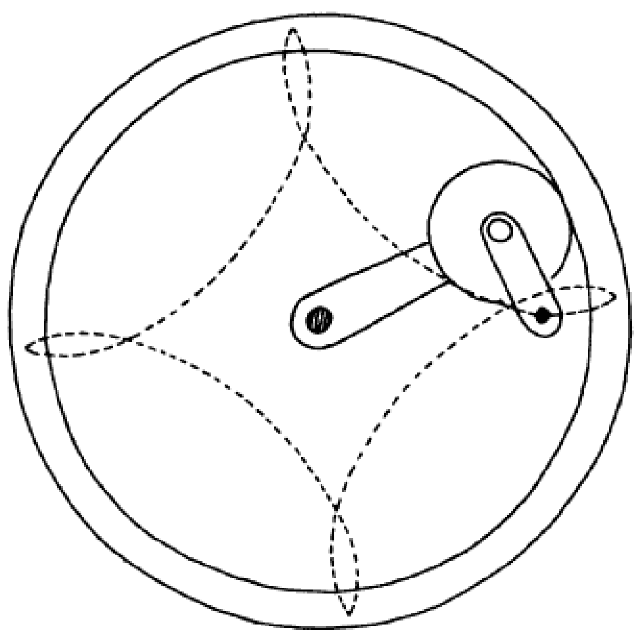

Fig. 10–6. Schematic representation of a four-to-one hypocycloidal gear train with the drive pin mounted beyond the pitch line of the planet gear.

the tangential velocity of the pin will be exactly zero. Theoretically, these are only instantaneous points but with backlash between planet gear and ring gear and/or backlash between the drive pin and the slot in the output crank, this instantaneous dwell period can be extended slightly. Of course, if it is extended too much by the introduction of backlash, impact can result when motion recommences.

If the drive pin is mounted on a small arm which is fixed to the planet gear so that the pin is operating on a radius that exceeds the pitch radius of the planet gear, then the pin will describe the motion path shown in Fig. 10–6. Under these conditions the tangential velocity of the pin around the center of the system actually reverses momentarily, four times during each drive cycle, as shown by the four cusps on the dotted-line path of Fig. 10–6.

Again, if backlash is purposely introduced into the system, perhaps between the pin and the slot in the output crank, then the entire period described by the cusps in the pin path can be converted to dwell in the output. Figure 10–7 shows the motion curves for the output crank of a hypocycloidal system (for 180 degrees of rotation of the input crank) when the drive pin is located on the pitch diameter of the planet gear. As can be seen from the velocity curve the dwells are only instantaneous, as explained above.

Cycloidal gear trains can be used alone to produce intermittent motion if short dwell periods are acceptable. They are frequently used, however, with other intermittent motion mechanisms such as Genevas or ratchets: in this case, the cycloidal gear is included to reduce impact velocities in the other mechanisms. With a Geneva, for example, the cycloidal gear train would be used to reduce the velocity of the Geneva drive pin at the moment the

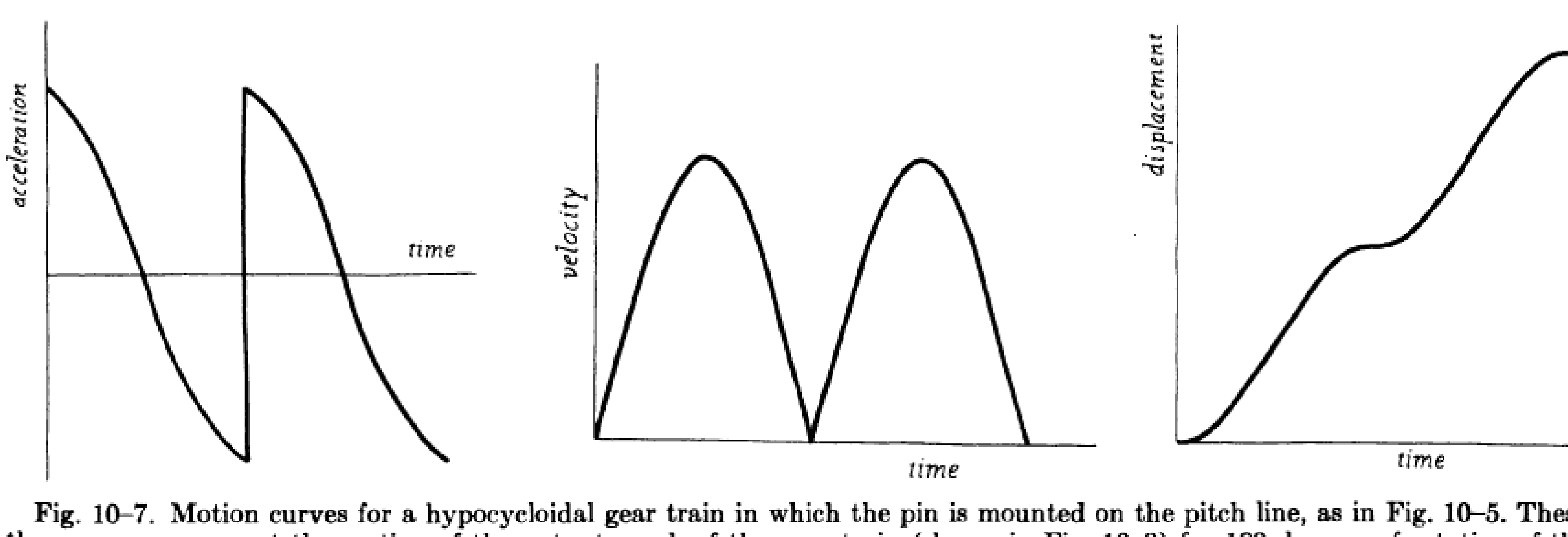

Fig. 10–7. Motion curves for a hypocycloidal gear train in which the pin is mounted on the pitch line, as in Fig. 10–5. These three curves represent the motion of the output crank of the gear train (shown in Fig. 10–3) for 180 degrees of rotation of the input crank.