

CHAPTER III.

OF REGULATING APPARATUS.

349. **Regulating Apparatus Classed—Brake—Fly—Governor.**—The effect of all regulating apparatus is to control the speed of machinery. A regulating instrument may act simply by consuming energy, so as to prevent acceleration, or produce retardation, or stop the machine if required; it is then called a *brake*; or it may act by storing surplus energy at one time, and giving it out at another time, when energy is deficient: in this case it is called a *fly*; or it may act by adjusting the power of the prime mover to the work to be done, when it is called a *governor*. The use of a brake involves waste of power. A fly and a governor, on the other hand, promote economy of power and economy of strength.

SECTION I.—*Of Brakes.*

350. **Brakes Defined and Classed.**—The contrivances here comprehended under the general title of *Brakes* are those by means of which friction, whether exerted amongst solid or fluid particles, is purposely opposed to the motion of a machine, in order either to stop it, to retard it, or to employ superfluous energy during uniform motion. The use of a brake involves waste of energy, which is in itself an evil, and is not to be incurred unless it is necessary to convenience or safety.

Brakes may be classed as follows:—

I. *Block-brakes*, in which one solid body is simply pressed against another, on which it rubs.

II. *Flexible brakes*, which embrace the periphery of a drum or pulley (as in Prony's Dynamometer, Article 341, page 383).

III. *Pump-brakes*, in which the resistance employed is the friction amongst the particles of a fluid forced through a narrow passage.

IV. *Fan-brakes*, in which the resistance employed is that of a fluid to a fan rotating in it.

351. **Action of Brakes in General.**—The work disposed of by a brake in a given time is the product of the resistance which it produces into the distance through which that resistance is overcome in a given time.

To *stop* a machine, the brake must employ work to the amount of the whole actual energy of the machine, as already stated in

Article 334. To *retard* a machine, the brake must employ work to an amount equal to the difference between the actual energies of the machine at the greater and less velocities respectively.

To *dispose of surplus energy*, the brake must employ work equal to that energy; that is, the resistance caused by the brake must balance the surplus effort to which the surplus energy is due; so that if n is the ratio which the velocity of rubbing of the brake bears to the velocity of the driving point, P , the *surplus effort* at the driving point, and R the resistance of the brake, we ought to have—

$$R = \frac{P}{n} \dots\dots\dots(1.)$$

It is obviously better, when practicable, to store surplus energy, or to prevent its exertion, than to dispose of it by means of a brake.

When the action of a brake composed of solid material is long-continued, a stream of water must be supplied to the rubbing surfaces, to abstract the heat that is produced by the friction, according to the law stated in Article 311, page 354.

352. Block-Brakes.—When the motion of a machine is to be controlled by pressing a block of solid material against the rim of a rotating drum, it is advisable, inasmuch as it is easier to renew the rubbing surface of the block than that of the drum, that the drum should be of the harder, and the block of the softer material—the drum, for example, being of iron, and the block of wood. The best kinds of wood for this purpose are those which have considerable strength to resist crushing, such as elm, oak, and beech. The wood forms a facing to a frame of iron, and can be renewed when worn.

When the brake is pressed against the rotating drum, the direction of the pressure between them is obliquely opposed to the motion of the drum, so as to make an angle with the radius of the drum equal to the *angle of repose* of the rubbing surfaces (denoted by ϕ ; see page 349). The component of that oblique pressure in the direction of a tangent to the rim of the drum is the friction (R); the component perpendicular to the rim of the drum is the normal pressure (N) required in order to produce that friction, and is given by the equation

$$N = \frac{R}{f}; \dots\dots\dots(1.)$$

f being the co-efficient of friction, and the proper value of R being determined by the principles stated in Article 351.

It is in general desirable that the brake should be capable of effecting its purpose when pressed against the drum by means of

the strength of one man, pulling or pushing a handle with one hand or one foot. As the required normal pressure N is usually considerably greater than the force which one man can exert, a lever, or screw, or a train of levers, screws, or other convenient mechanism, must be interposed between the brake block and the handle, so that when the block is moved towards the drum, the handle shall move at least through a distance as many times greater than the distance by which the block *directly* approaches the drum, as the required normal pressure is greater than the force which the man can exert.

Although a man may be able occasionally to exert with one hand a force of 100 lbs., or 150 lbs., for a short time, it is desirable that, in working a brake, he should not be required to exert a force greater than he can keep up for a considerable time, and exert repeatedly in the course of a day, without fatigue—that is to say, about 20 lbs. or 25 lbs.

353. The **Brakes of Carriages** are usually of the class just described, and are applied either to the wheels themselves or to drums rotating along with the wheels. Their effect is to stop or to retard the rotation of the wheels, and make them slip, instead of rolling on the road or railway. \sphericalangle The resistance to the motion of a carriage which is caused by its brake may be less, but cannot be greater, than the friction of the stopped or retarded wheels on the road or rails under the load which rests on those wheels. The distance which a carriage or train of carriages will run on a level line during the action of the brakes before stopping, is found by dividing the actual energy of the moving mass before the brakes are applied, by the sum of the ordinary resistance and of the additional resistance caused by the brakes; in other words, that distance is as many times greater than the height due to the speed as the weight of the moving mass is greater than the total resistance.

The *skid*, or *slipper-drag*, being placed under a wheel of a carriage, causes a resistance due to the friction of the skid upon the road or rail under the load that rests on the wheel.

354. **Flexible Brakes.** (*A. M.*, 678.)—A flexible brake embraces a greater or less arc of the rim of a drum or pulley whose motion it resists. In some cases it consists of an iron strap, of a radius naturally a little greater than that of the drum; so that when left free, the strap remains out of contact with the drum, and does not resist its motion; but when tension is applied to the ends of the strap, it clasps the drum, and produces the required friction. The rim of the drum may be either of iron or of wood. In other cases the brake consists of a chain, or jointed series of iron bars, usually faced with wooden blocks on the side next the drum. When tension is applied to the ends of the chain, the blocks clasp the drum and produce friction; when that tension is removed, the blocks are

drawn back from the drum by springs to which they are attached, and the friction ceases.

The following formulæ are exact for perfectly flexible continuous bands, and approximate for elastic straps and for chains of blocks. Their demonstration has already been given in Article 310 A, page 354.

In fig. 254, let A B be the drum, and C its axis, and let the direction of rotation of the drum be indicated by the arrow. Let T_1 and T_2 represent the tensions at the two ends of the strap, which embraces the rim of the drum throughout the arc A B. The tension T_1 exceeds the tension T_2 by an amount equal to the friction between the strap and drum, R; that is,

$$R = T_1 - T_2.$$

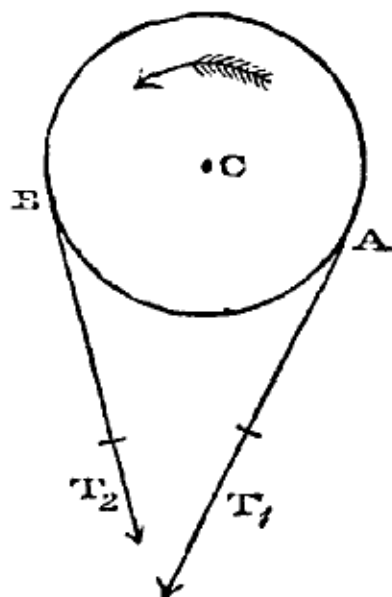


Fig. 254.

Let c denote the ratio which the arc of contact, A B, bears to the circumference of the drum; f , the co-efficient of friction between the strap and drum; then the ratio $T_1 : T_2$ is the number whose common logarithm is $2.7288 f c$, or

$$\frac{T_1}{T_2} = 10^{2.7288 f c} = N; \dots\dots\dots(1.)$$

which number having been found, is to be used in the following formulæ for finding the tensions, T_1, T_2 , required in order to produce a given resistance, R :—

Backward or greatest tension, $T_1 = R \cdot \frac{N}{N - 1}; \dots\dots\dots(2.)$

$$T_1 = N T_2$$

Forward or least tension, $T_2 = R \cdot \frac{1}{N - 1}. \dots\dots\dots(3.)$

The following cases occur in practice :—

I. When it is desired to produce a great resistance compared with the force applied to the brake, the backward end of the brake, where the tension is T_1 , is to be fixed to the framework of the machinery, and the forward end moved by means of a lever or other suitable mechanism; when the force to be applied by means of that mechanism will be T_2 , which, by making N sufficiently great, may be made small as compared with R.

II. When it is desired that the resistance shall always be less than a certain given force, the forward end of the brake is to be fixed, and the backward end pulled with a force not exceeding the given force. This will be T_1 ; and, as the equation 2 shows, how great

soever N may be, R will always be less than T_1 . This is the principle of the brake applied by Sir William Thomson to apparatus for paying out submarine telegraph cables, with a view to limiting the resistance within the amount which the cable can safely bear.

In any case in which it is desired to give a great value to the ratio N , the flexible brake may be coiled spirally round the drum, so as to make the arc of contact greater than one circumference.

355. Pump-Brakes.—The resistance of a fluid, forced by a pump through a narrow orifice, may be used to dispose of superfluous energy; as in the “cataract,” or “dash-pot.”

The energy which is expended in forcing a given weight of fluid through an orifice is found by multiplying that weight into the height due to the greatest velocity which its particles acquire in that process, and into a factor greater than unity, which for each kind of orifice is determined experimentally, and whose excess above unity expresses the proportion which the energy expended in overcoming the friction between the fluid and the orifice bears to the energy expended in giving velocity to the fluid.

The following are some of the values of that factor, which will be denoted by $1 + F$:—

For an orifice in a thin plate, $1 + F = 1.054$(1.)

For a straight uniform pipe of the length l , and whose *hydraulic mean depth*, that is, the area divided by the circumference of its cross-section, is m ,

$$1 + F = 1.505 + \frac{fl}{m}$$
(2.)

For cylindrical pipes, m is one-fourth of the diameter.

The factor f in the last formula is called the *co-efficient of friction* of the fluid. For *water in iron pipes*, the diameter d being expressed in feet, its value, according to Darcy, is

$$f = 0.005 \left(1 + \frac{1}{12d} \right)$$
(3.)

For *air*, $f = 0.006$ nearly.(4.)

The greatest velocity of the fluid particles is found by dividing the volume of fluid discharged in a second by the area of the outlet at its most contracted part. When the outlet is a cylindrical pipe, the sectional area of that pipe may be employed in this calculation; but when it is an orifice in a thin plate, there is a *contracted vein* of the issuing stream after passing the orifice, whose area is on an average about 0.62 of the area of the orifice itself; and that contracted area is to be employed in computing the