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“Friction-Clutches.”

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THE passing of the Employers' Liability Act, and the rapid progress of electric-lighting, did much to stimulate a demand for improved methods of connecting or disconnecting machinery and its motive power whilst in motion, primarily with a view to avert the risk of accident; but on the grounds of convenience and economy alone, the merits of well-designed arrangements soon found recognition.

Friction-clutches, however, may be employed under all circumstances, and in contributing this brief outline to the present scanty literature on the subject, it has been the aim of the Author to give typical examples of successful application to dredging-vessels, electric installations, tram-cars, turbines, pile-drivers, or other machinery likely to come within the province of a civil engineer, which may be afterwards modified to meet almost any requirements of daily practice.

The principles observed in designing friction-clutches are founded on the ordinary laws of friction of solids, the coefficient 0·10, friction of quiescence, cast-iron on cast-iron with plain greasy surfaces being found to yield satisfactory results where there is little fluctuation of energy. In such cases the sizes of clutches are computed according to the HP. to be transmitted and the number of revolutions per minute, allowing a considerable margin for the inertia of the resisting medium whenever the clutch is put into action. But where the character of the strains is intermittent, violent, or irregular, the dimensions are regulated by the nature of the work, and have been determined by experiment for a variety of purposes.

In journals with lubricated surfaces there is a considerable variation in the friction under changes of temperature, the coefficient of friction at 120° Fahrenheit being only one-third of what it is at 60°, when lard oil is used,¹ and in practice it is found

¹ Institution of Mechanical Engineers. Proceedings. 1883. Report on Friction Experiments.

that a greater pressure is needed to keep the friction-surfaces of clutches with lubricated faces in proper connection under high temperatures than under low temperatures.

With dry surfaces, however, there is no reason to believe that much variation of friction occurs. Clutches, that have been neglected and allowed to get very hot when out of gear, transmit about the same power when put into gear as when they are cold. The following experiments were made to ascertain the difference in the angle of repose at temperatures up to 620° Fahrenheit.

Materials.	Temperature.	Surfaces.	Angle of Repose.
Cast-iron on cast-iron.	Both at 50° F. . . .	Plane surfaces	10°
	One piece at 50° F. on } one at 212° F. . . . }		9½°
	One piece at 50° F. on } one at 620° F. . . . }	dry and polished.	10½°
	Both at 620° F. . . .		11°

Thus with a difference of 570° in the temperature between the first and the last two experiments, there is only a difference of 1° in the angle of repose.

Efficient systematic lubrication doubtless exercises considerable influence on wear and tear, whilst, again, the form of friction surfaces affects the constancy of lubrication. Some clutches have been continuously at work for years without appreciable wear, though the velocity of the rubbing-surfaces in some instances exceeded 3,000 feet per minute, and the pressure per square inch was 500 lbs. at the moment of approach. Flat surfaces are better than curved or serrated surfaces. When the friction between the surfaces is sufficient to overcome the resistances, the only limit to the pressure that may be applied is the strength of the materials, because the rubbing-surfaces are relatively at rest. This pressure may be adjusted so that any increase of resistance shall cause the clutch to slip. Where power is sublet to several tenants, such an arrangement would prevent loss to the proprietor, and would make tenants careful not to overload their machinery.

Clutches may be divided into: Those capable of transmitting motion in either direction; and those capable of transmitting motion in one direction. And again into: Those in which the pressure applied to the friction-surfaces has to be maintained; and

those in which pressure on the friction-surfaces remains constant, without external assistance, after the external surfaces have been put in contact.

The cone-clutch is one of the most primitive, and at the same time most convenient, methods for the transmission of small powers. The male part slides on a feather-key lengthwise, and the female part may be either keyed on the continuing shaft or may run loose on the same shaft against a fast-collar as a pulley or wheel. The taper of the conical surfaces depends upon the materials of which they are made, and must be great enough to prevent jamming. Frequently one face is iron, whilst the corresponding face is lined with wood, leather, copper, or paper. The main objection to clutches constructed on this principle is that the manipulating lever has not only to put the friction-surfaces into contact, but to hold them there, the result of which is a tendency to work out of gear, and a loss of power through friction on the shipping arrangement and journals produced by end-pressure.

The disk or plate-clutch may consist of two or more disks. A very useful and common form is that applied to dye-vats, for alternately winding cloth through the liquid in one direction or the other. The two driving-disks, which are rigidly connected to the same boss or sleeve, are moved endwise on the shaft, so as to put either of them into contact with the plate, which is secured by a set-screw or key on a shaft at right-angles to the driver. Besides the facility with which the direction of motion may be reversed, a further advantage obtained with this arrangement is the variable speed of the driven-shaft with a constant speed of driver. By moving the driven-disk to or from the centre of the driving-shaft a slower or quicker speed will be given.

Weston's clutch or brake, Fig. 1 (p. 371), consists of a series of flat disks capable of being moved to a small extent longitudinally, and made to turn along with the shaft by means of grooves and feather-keys. Between each pair of the first set of disks *fff* is placed a disk *g*, belonging to a second set, fitting and turning with the shell A. The disks *fff* turn with the part B. When end-pressure is exerted, all the disks in the second set are gripped by the first set, and the two sets revolve together. It is a peculiar feature of this clutch that, with the same load, the frictional effect may be multiplied by increasing the number of disks in the two series. One of these clutches has been working in Paris on a guillotine, to catch twenty times per minute, at the bottom of a 3-foot drop, a blade weighing 5 tons. Clutches up to 1,000 HP. have also been applied

to rail-rolling mills, when the pressure on the disks has been applied by hydraulic power.

WESTON'S CLUTCH.

Robertson's grooved surface-clutch, Fig. 2, greatly reduces the pressure upon the bearings consequent upon plane surfaces. The grooves vary in pitch from $\frac{1}{8}$ -inch, for light work, to $\frac{3}{4}$ -inch

ROBERTSON'S CLUTCH.

A quick speed may be obtained by putting the pulley P into gear with the outer rim O, and a lower speed in reverse direction by putting it into gear with the inner rim I.

¹ Institution of Mechanical Engineers. Proceedings. 1853, p. 202.

Presbrey's clutch, Fig. 3, is a form of Robertson's clutch with appliances for locking the disks together without putting end-pressure upon the bearings of the shaft. B is a hollow shaft carrying a pinion, or pulley C and a disk D coinciding with the face of disk D', carried by a sleeve E. The sleeve E is threaded externally to receive a nut F, which takes its end-bearing against a fast collar *b*, and is provided with a flange *e*, which is overlapped by a flange ring *d* bolted to the collar *b*, and serving to connect the nut to the collar without interfering with the free rotation of the nut. By imparting to the nut a rotation at greater or less speed than that of the shaft carrying it, the nut is caused to turn upon the sleeve E, thereby carrying the latter and its disk by a powerful

PRESBREY'S CLUTCH.

pressure towards or from the opposite disk D. By proportioning the friction-disk J larger in diameter than the disk I, the nut may be made to travel faster than the shaft, whilst the motion of the nut may be retarded on application of a brake *f*.

Friskie's clutch, Fig. 4, is an ingenious combination with toggle-levers. The parts A and B are keyed fast upon their respective shafts, the levers EE having their fulcrums in wheel B, and their opposite ends attached by links to a sliding-piece G, which when moved, operates on the levers HH, turning them slightly on the knife-edges *hh*. Bolts from the levers HH are connected to dovetail pieces, II, faced with *lignum vitæ*, and put them in contact with the conical faces of the recess. Springs SS take up the lost motion of the parts.

Simons' clutch is a German invention, and consists of a modification of the so-called umbrella-clutch, in which the contact-surfaces are cylindrical and grooved, as in Robertson's arrangement, while the friction-blocks are connected to the sliding-sleeve by curved springs instead of by rigid arms, whereby the blocks may be brought into contact with the flange of the disk with an increasing elastic force. The pivots by which the arms are attached to the sleeve may be carried beyond the vertical line drawn through pivots at the other end of the arms, so that there shall

FIG. 4.

FRISBIE'S CLUTCH.

be no tendency for the sleeve to move backwards after it is once put into gear.

In Rider's clutch, Figs. 5, a spiral spring B is bored to fit a projecting boss on the pulley A, and both boss and pulley are encased by a shell C having a slot through which a projection on the spring passes. The taper end of a lever D engages with this, and on movement of the sliding-piece E, tightens the grip of the spring, the opposite end of which is secured to the shell by a set-screw on the pulley boss, with a theoretical frictional effect equivalent to the number of coils raised to its own power.

Fisher's clutch, Figs. 6, has a disk-plate fixed to the wheel B and free to rotate on the shaft, or to remain stationary when out of gear. F is a wheel keyed fast on the shaft A, and clasped by four belts, centred on and carried by the disk-plate, connected at the ends by right- and left-hand screws, whereby the belts may

FIG. 5.

RIDER'S CLUTCH.

FIG. 6.

FISHER'S CLUTCH.

be closed or expanded. When closed upon the wheel F, the whole is locked together and revolves with the shaft.

The Bates clutch is a simple form of Rider's clutch. The hub of the pulley or wheel is surrounded by an annular spring severed transversely, the ring being such that after it has been contracted, it returns to its original size by elasticity.

The ring is contained within a casing, keyed to a shaft, in which casing is an opening for a wedge. By the insertion of this wedge the opposite ends of the spring are drawn together and carry the wheel round with it.

Figs. 7 represent Napier's differential-clutch. C is a disk forming part of the wheel A, and it carries the fulcrum of the differential-lever M, to the ends of which a brake-band is fixed. This band encircles a pulley D which is fast upon the shaft I. E is a boss which can both slide and turn upon the axis I; it has two arms K and L, the extremities of which pass through slotted plates, F and G. One plate is fixed on the disk C; the other plate is similar, but is fixed on the disk C; thus, by moving

NAPIER'S CLUTCH.

the boss E along the shaft, the lever M can be caused to rock on its fulcrum, and the brake-band can be tightened or slackened.

A good example of clutch, which acts in only one direction, is that applied to the vertical Otto gas-engine for the purpose of making a connection between the shaft and piston during the down-stroke. The wheel driven from the piston is made with inclined internal surfaces, against which sets of rollers travel, and press upon curved wedges, while the piston is descending. The opposite sides of the wedges are faced with leather and grip the driven-pulley. In the up-stroke no pressure is brought upon the wedges, and the wheel is free to revolve upon the shaft.

In Weston's clutch, Figs. 8, friction is set up or induced by the action of one pair of surfaces upon another or several other

pairs, their combined forces being exerted on the resisting load. On the shaft B is placed a loose disk C, next to which is keyed upon the shaft a brake-pulley D, having its side furthest from the disk made with an annular V groove for the corresponding projecting face of an adjacent loose disk F, capable of sliding laterally and rotating freely upon the shaft: a flexible brake-strap E extends from a pin X in the loose disk F, and passing round the pulley D terminates at its other end upon a pin *y* fixed in the loose disk C. A spring G is used to quicken the release of the strap. The action is as follows:—When the disk F is pressed laterally, against D, it receives rotary motion and exerts a tensional strain upon the brake-strap, wrapping it tightly around the brake-

FIG. 8.

WESTON'S CLUTCH.

pulley under the resistance furnished at the other end of the strap by its attachment to the pin *y*. The pull upon the strap E, due to the action of the first pair of V faces, thus induces frictional action of the strap and pulley, and the combined force is exerted on the resisting load on the wheel keyed upon the disk C. Instead of a single strap, a compound strap, passing twice or three times round the pulley, may be used.

The working of Braun's coupling, Figs. 9 (p. 377), is as follows:—If the coupling is to be put into gear, the casing H is held stationary by the brake-block W. As the lever G is fixed on the shaft A, the casing F will move in advance of the shaft A to the same extent to which the casing H remains behind, as the proportion of the toothed rings (not shown) to their pinions O N is the

same. As the cross-piece D makes the same number of revolutions as the shaft A, the spiral M will turn the two pinions E E in the direction towards the periphery of the casing, whereby the screws X will be rotated so as to cause the brake-blocks P to be pressed against the casing C. The brake-block W being released, the parts will remain in this position until the part F is held stationary by the application of the brake-block V, when a reverse action will take place causing the shafts to be uncoupled.

BRAUN'S COUPLING.

ADDYMAN'S CLUTCH.

Figs. 10 represent Addyman's clutch. A is a hollow shell bored out to the same diameter as the friction-ring H, and keyed fast on the driving-shaft B. On the driven-shaft E a disk D is secured, having a crank-pin or driver C, to which is attached the friction-ring H, and on the same shaft the wedge-piece F slides over a feather-key. The taper of the wedge is made to correspond with the angle of repose, whereby it has no

tendency to work out of gear. The end of one shaft projects into the boss of the piece on the continuing shaft. When the wedge K is moved forwards, it opens out the levers L L, and thereby expands the friction-ring H, thus causing it to grip the whole interior surface of the shell A, and to transmit power from one shaft to the other. As the pressure is first applied at right-angles to the movement of approach of the friction-surfaces, all end-thrust is removed, and only a small effort is required to make the connection. A clutch transmitting 100 indicated HP may be thrown in or out of gear with no more power than can be exerted by the finger and thumb during a few seconds. It is immaterial whether the pulley drive the shaft, or the shaft the pulley; nor does change of direction in the motion make any difference. This clutch is working up to 1,000 revolutions per minute, and in some

BAGSHAW'S CLUTCH.

of the Birmingham stamping-machines is brought into use as often as 1,000 times per hour.

In a clutch devised by the Author, Figs. 11, as a driving-pulley for broad belts, the weight of the pulley and the tension of the belt are taken off the shaft and borne by independent bearings, so that when the clutch is out of gear there is no wear and tear. The ends of the friction-ring A are connected by the right- and left-handed screw C, and to this screw is affixed an arm D, connected with the sliding-piece E by links. By moving this sliding-piece in one direction or the other, the screw is turned, and is caused to either force the ends of the friction-ring apart to expand it, or to pull them together and allow the internal parts to revolve independently of the outward shell and pulley. A direct and firm connection is thus maintained at all times, and there is no liability of

the friction-surfaces putting themselves into action by centrifugal force when not required. A clutch on this principle has been working for three years at Tadcaster flour-mills, during which time it has had the severe duty of coupling a turbine to a steam-engine of 150 HP. In connecting the two at variable speeds no backlash nor other detrimental effect has been experienced; but rather a steady, smooth action free from biting or jerk, whilst slipping or breakage of belts has been entirely prevented.

Wrigley's friction-coupling consists of two segmental friction-blocks, connected by toggle-joints which put them into contact with the internal face of a shell. Adjusting screws take up the wear as required.

Figs. 12 represent Davison's brake-clutch. The disk A is formed with openings in which bevel-wheels B turn freely on spindles

DAVISON'S CLUTCH.

C, and both disk and wheels are free to revolve on the driving-shaft D. A brake-strap E clasps the outside rim and is fixed to timber framework. The bevel-wheels B gear on one side with a bevel-wheel H keyed on the driving-shaft, and on the opposite side with the bevel-wheel J bolted to a loose pulley or winding drum K, or on a line of shafting to be driven. By tightening the brake-strap the disk is held stationary, and the pinions B transmit motion from the wheel H on the driving-shaft to the wheel J on the pulley K, at the same speed as the motor-shaft, but in a contrary direction. When the brake-strap is released it is evident that the wheels B will simply roll round the wheel J without transmitting motion.

Probably no single clutch is capable under all circumstances of fulfilling such essential conditions as the following:—Positive reliance at all speeds and under severe and sudden strains; ease

in throwing in or out of gear whilst in motion, and freedom from shocks; non-liability to wear or derangement; no tendency to work out of gear; and last, but not least, moderate price. In all cases experience must guide the engineer in his selection.

Some time ago in Germany a law was proposed, to make it compulsory that the main shaft in every separate room should be arranged for disconnection from the motive power in case of accident; but prudential reasons prevailed over the humanitarian, and the law did not pass. It is beyond doubt, however, that in multitudes of instances if friction-clutches were applied to the various departments of a workshop, or to separate machines, it would result in a saving of time, power, wear and tear, and oil, and would prevent accidents.

The Paper is accompanied by tracings, from which the Figs. in the text have been prepared.