CHRONOGRAPHIC METHODS OF TAKING TRANSMISSION DYNAMOMETER MEASUREMENT.

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The chronographic drum apparatus in which an electromagnetically operated stylus traces a record on a revolving drum is extensively used for accurate physical measurements in which the readings can be converted into proportionate time intervals.

The object of the present paper is to describe the application of this principle to the measuring mechanism of transmission dynamometers. The majority of transmission dynamometers utilise the deformation of a spring as a means of indicating the transmitted torque, a typical design being that in which a helical spring connects a loose pulley to a fast one. The problem is how to indicate the amount of angular displacement between the pulleys while rapidly revolving.

Before describing the author's method it will be instructive to briefly consider other typical methods and their merits and limitations. In the Bailey Machine, a specimen of which may be seen in the Mechanical Laboratory of the University, a purely mechanical device is adopted. The boss of the loose pulley has a helical or diagonal slot in which slides a radially projecting pin attached to a rod lying axially along the centre of the main hollow shaft. The angular displacement of the loose pulley relatively to the shaft is thus converted into an axial movement of the rod, the motion being kinematically equivalent to the axial movement of a screw. By attaching a pencil to the rod projecting from the end of the hollow shaft an autographic record is taken on a drum driven by a worm gear from the main shaft. Since the axial travel of the pencil is small compared to the angular displacement to be measured, the sensibility of this method is low, and the accuracy is still further affected by a certain amount of play between the pin and slot and the friction of the various parts. A continuous record is however secured, and hence the instrument is well suited for the approximate measurement of fluctuating loads.

Another purely mechanical device is that described by Prof. Dalby in Proc. Inst. C.E., June, 1898, in which an arrangement somewhat resembling a differential pulley block is used. The fast and loose pulleys each bear a sprocket pulley, and an endless steel band with holes to mesh with the sprocket teeth passes first over one pulley then hangs in a loop and then encircles the other pulley and hangs in another loop to complete the circuit. So long as the two pulleys rotate together as much of the band is wound up on one as is unwound from the other, and the length of the loops is invariable, but any relative angular displacement of the two pulleys causes a corresponding increase in the length of one loop and a decrease of the other. The amount of this movement is observed by hanging a weighted pulley in each loop and observing the motion of a pointer attached to one weight, over a scale attached to the other. The main disadvantages of this mechanism appear to be friction duo to stiffness of the bands and oscillation of the latter at high speeds.

To come now to electrically operated devices: Fig. 5 illustrates a method due to Prof. Stroud, in which a wiper arm or brush attached to one pulley moves over a series of contacts attached to the other. Between successive contacts is included a certain resistance, and the angular displacement is indicated by measuring the total included resistance by means of a fall of potential method as shown in diagram fig. 6. In this arrangement the connection between dynamometer and indicating gear being only two conductors, the former can be located in any remote position. It is evident that the readings are given in steps, and that the load requires to be steady while the reading is being made.

Another very simple method is utilised in the instrument built by the Central Laboratory Supply Co., Lafayette, in which each pulley bears a metallic bar, which makes momentary contact with a brush once per revolution. One of these brushes is maintained in a fixed position while the other is mounted on a rocker arm, which is moved by the operator till both contacts are made simultaneously. This position is indicated by a click in a telephone, whose circuit contains a battery, and these two contacts in series so that the circuit is only complete when both contacts are simultaneous. In this way the angular displacement due to any load can be followed by the rocker arm. This arrangement is very satisfactory, as friction and lost motion are both practically eliminated, and the angular readings of the rocker are proportioned to the load, but the dynamometer cannot be situated in any position inaccessible to the operator, and a rapidly fluctuating load cannot be measured. Another very similar principle is that embodied in the Denny and Johnson Torsion Meter,* used for indicating the power developed by marine steam turbines, in which the shaft itself serves as the dynamometer spring.

Here instead of actually completing an electrical circuit by contact, a pointed permanent magnet at either end of the portion of shaft on which the torsion is to be observed, sweeps past a coil once per revolution and so induces a momentary current. At one end a number of these coils are wound side by side so that each coil occupies a different angular position. A telephone is placed in series with the single coil at the one end, and with one of the

*_Engineering_, April 7th, 1905.

Fig 1

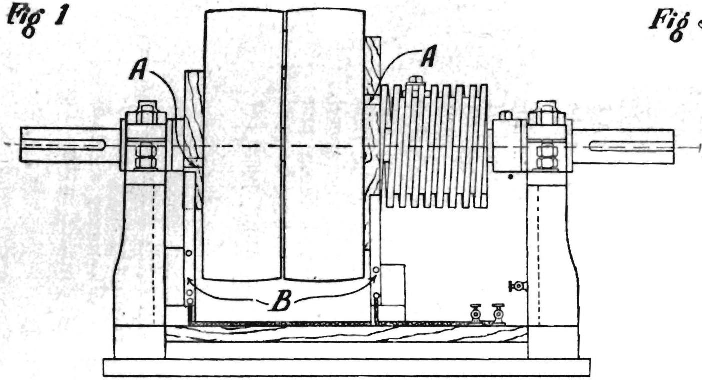


Fig 2

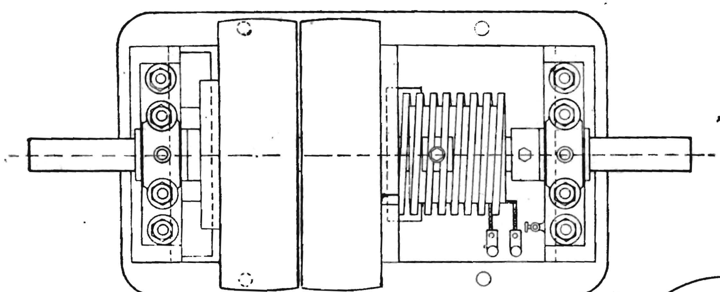


Fig 3

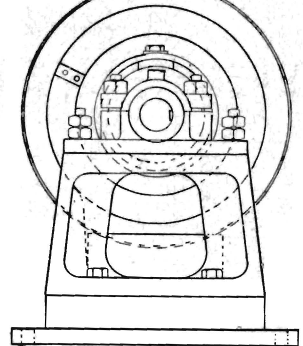


Fig 4

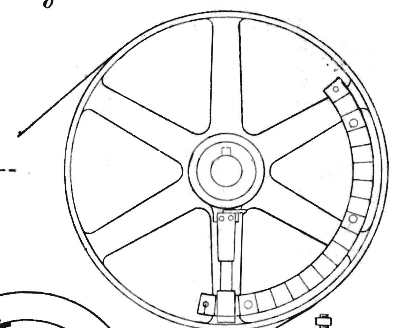


Fig 6.

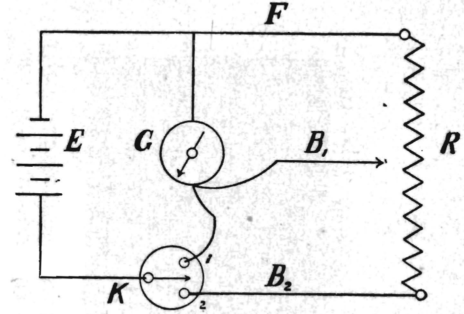
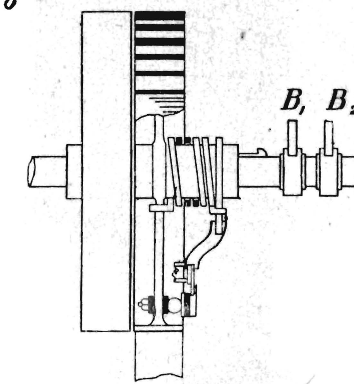


Fig 5



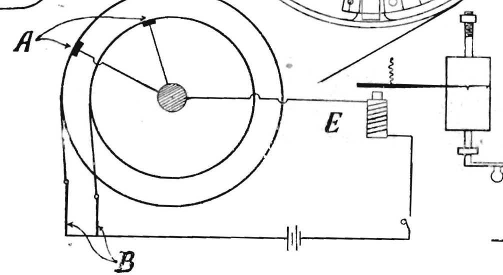
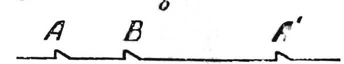


Fig. 7

Fig 8



group of coils at the other end connected in opposition to it. When the magnets simultaneously sweep by the two coils included in the telephone circuit, the inductive effects counteract each other; so that to take a reading the various coils of the group are successively thrown into circuit until the sound of the 'phone is a minimum.

Of course in this method instead of using a number of coils one only need be used and rocked mechanically, but the advantage of taking the readings at a distance would be lost.

To come now to the method forming the subject of this paper. The dynamometer itself is provided with a contact on each pulley engaging with a fixed brush. These two contacts are connected in parallel with a battery and an electromagnetically controlled stylus, so that the latter is drawn aside at each contact, or twice per revolution. See fig. 7.

By uniformly rotating a smoked paper drum past the stylus a record like fig. 8 is obtained, in which AA^1 represent successive contacts of the fast pulley, and B that of the loose pulley. If the speed of the dynamometer shaft and recording drum are both uniform, then AA will represent one complete revolution, or 360 degrees, and AB will represent to the same scale the angular displacement of the two contacts. The reading then expressed in

$$\text{degrees is } \frac{\text{Length AB}}{\text{Length AA}^1} \times 360$$

The actual length AA^1 being dependent on the relative speeds of drum and dynamometer can be made of any desired length according to the accuracy required, but generally a length of from two to five inches will be found satisfactory.

Several arrangements of the drum may be used according to the requirements of the work, but for work with high dynamometer speeds such as 500 R.P.M. and over, if a simple hand drum mounted on a screw be used and given a single sweep or turn when a reading is desired, the most open part of the record will generally show a portion where two or more adjacent lengths, AA^1 are equal, and the measurements at this point will give accurate results.

For slow speed work, or where a continuous record for an appreciable time is required, the hand drum can still be used if a tuning fork with a stylus attached to one prong is use to give an undulating record alongside the contact record. The lengths AA^1 and AB are then measured, not as absolute lengths, but in terms of the number of undulations they subtend on the accompanying fork record. There is also another gain in this arrangement in that, as the period of the fork is known, the speed of revolution of the dynamometer can be ascertained from the lengths AA^1. In this way a continuous record can be secured, showing the instantaneous values of both torque and speed at every revolution.

The arrangement most to be recommended however, is to provide some means of revolving the drum at a constant speed, such as by clockwork or a small motor. In the apparatus with which the record fig. 9 was taken, the drum was driven through worm-gearing from a belted constant-speed motor. Whenever a reading was required the stylus was lowered into contact with the

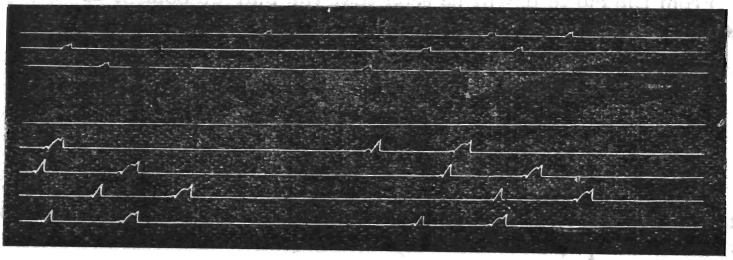
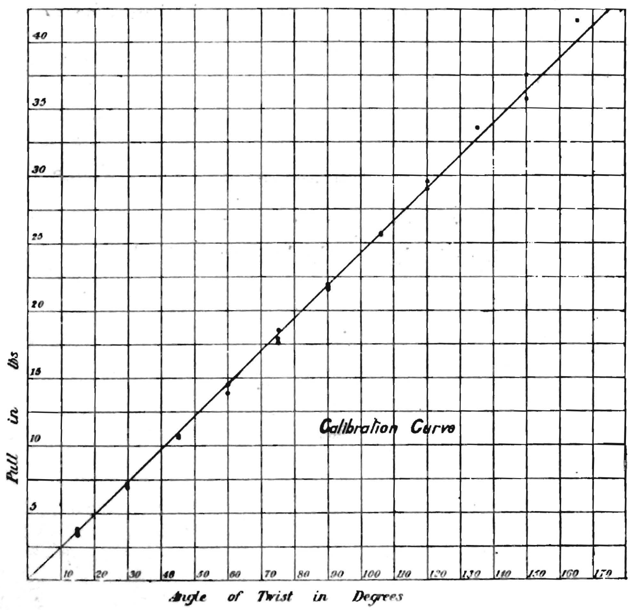


FIG. 9

paper and moved axially to prevent superimposing the various portions of the record. If the speed of the drum is known the dynamometer speed can also be calculated. The dynamometer portion itself with which the tests were made is illustrated in design Figs. 1, 2 and 3, and had pulleys 1 foot in diameter and a $\frac{1}{4}$ inch x $\frac{1}{4}$ inch spring, which could be clamped at various points so that any number of turns up to about nine could be used. In several tests it was found that when running at a high speed the presence of a certain amount of oscillation in the spring, probably due to the joint of the belt, was clearly shown in the readings, so that it was necessary to take the average of three or four consecutive revolutions.

The calibration of the spring was effected by measuring the deflecting produced by deadweights hung from a cord, equal in thickness to the belt, and wrapped round the loose pulley, and the deflection proved to be strictly proportional to the load throughout the range of 165 degrees.



From the curve it will be seen that the pull in pounds = ·233 × deflection in degrees or P = ·233D°

$$\text{The HP} = \frac{2\pi\, n\, r\, P}{33000} \quad \text{where } n = \text{revs. per minute}$$
$$r = \text{radius of pulley} = \tfrac{1}{2}\text{ ft.}$$
$$p = \text{pull in pounds}$$

$$\therefore\ \text{HP} = \frac{2\pi\, n \times \cdot 233\text{D}}{33000 \times 2} = \cdot 0000221\text{D}n$$

or to find the HP, the product of reading in degrees is multiplied by the revolutions per minute and by the constant ·0000221.

The authors are indebted to Messrs. S. W. Jones and J. P. Tivey, B.A., for the following data pertaining to the test of a 1 H.P. Heyland single-phase motor, driving through the dynamometer a direct currect dynamo.

Watts input to Motor.	E.H.P.	Speed of Dynamometer.	Angular Displacement.		H.P. Transmitted.
			As Measured.	From No Load Reading	
275	·37	565	51·7°	0	Belt off.
575	·77	540	77·7	26	·31
750	1·01	520	93·7	42	·48
875	1·17	510	99·1	47·4	·53
975	1·3	500	104·3	52·6	·58

The record was rendered permanent by dipping it into a weak alcoholic solution of shellac and allowing to dry. The average of several successive intervals on the record was taken, the measurements being made with a pair of dividers.

The advantages of this Chronographic method may be summarised as follows :

The readings are of the nature of records, which are taken to cover any period, and may be taken with any desired interval between readings which are instantaneous. From direct linear measurement this record will give accurate values of simultaneous torque and speed. The recording apparatus can be located at any desired distance from the dynamometer portion.

These features render this method capable of dealing with work for which the majority of other methods are unsuited.