

## ROPE-POWER TRANSMISSION.

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BY JAMES M. DODGE.

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The lecturer was introduced by the Secretary and spoke as follows :

## MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN :

Rope-power transmission is comparatively a development of recent times. Although ropes were used in isolated cases for this purpose many years ago, it may be said, so far as this country is concerned, that the last ten years have seen the adoption of rope-power transmissions become more general and the system take a recognized place in the field of mechanical engineering.

There are two general systems in vogue, which may be designated as the "English" and the "American." The former employs one or more single ropes, whereas the latter uses one continuous rope and employs a tension carriage, operating on one of the turns of the rope, to insure a uniform amount of work being performed by each wrap around the wheels.

Wheels, or sheaves, used in connection with the rope for the purpose of transmitting power, are made with V-shaped grooves in the rims, the most commonly accepted angle being 45°. These grooves are made sufficiently deep to prevent the rope bottoming, or resting upon the bottom of the groove, the object of this being to increase the resistance to slipping and enable a moderate weight on the tension carriage to give sufficient driving force.

Sheaves used in conjunction with manila rope are made in two ways, the older method being to cast the sheaves with sufficient width of face for the number of grooves desired and to roughly core the grooves, so as to lessen the amount of iron to be removed by the turning tool in finish-

ing them. It is necessary to cast the wheels sufficiently heavy to resist the pressure of the turning tool, in order to have the finished wheels as round as possible. It is almost impossible, however, to avoid a small amount of spring between the arms, so that upon careful measurement the wheel is found to be polygonal. This is notably the case when the cut is heavy, it being necessary, in order to obtain a good result, to take a roughing cut, which releases the skin tension of the casting and permits it to take a modified shape, due to the internal strains ever present in cast-iron wheels designed to have the outer surface removed from them by turning. Then a second cut is taken, and finally a finishing cut is made with a tool ground to the exact shape of one of the finished grooves, this last cut, which is made more to true up the inequalities of the previous work, removing but very little metal. In the foundry work connected with the manufacture of these wheels, it is seldom that a wheel having two or more grooves in it is so perfect that upon turning imperfections are not discovered. These, of course, if too numerous, render the condemnation of the casting necessary. If, however, the sand holes, or blow holes, in the turned surface of the sheave are not too large, they are filled with babbitt metal, and the sheaves are put in use. The amount of metal turned from castings for rope sheaves is astonishingly large; for instance, in the case of a five-groove sheave of forty-eight inches diameter, for one and one-eighth inch rope, the rough weight before turning was 698 pounds, and after finishing the weight was 567 pounds, showing that 131 pounds had been turned off the original casting. This proportion would, of course, vary somewhat, dependent upon the care taken in the foundry, but at the same time it is always greater than would be supposed.

The second and newer method of manufacturing sheaves is that practised by the "Link-belt" companies and differs from the already described method in two very important features. In the first place, the sheaves are not turned after being cast, great care being taken in the proportioning of the hubs, arms and rims, so that the castings can be made of

extreme lightness, but being devoid of internal strain are very strong. The grooves are cast on green sand cores, a three-part flask being used. By this we mean the flask has a cope and a drag, as is common in all foundry work, but between them is placed what is known as the "third part" or "cheek piece," which holds the sand destined to form the grooves in the finished wheel. It has been found in practice that it is possible to cast sheaves in this manner that are fully as accurate as turned ones, and with an average saving in weight of 17.2 per cent. This saving in weight, of course, effecting a corresponding economy in the power required to operate a rope drive furnished with them.

The second radical difference between the "Link-belt" sheaves and the solid turned sheaves is, that the manufacture of multiple groove sheaves, or those having more than one groove, is effected by bolting together what are known as arm sections (which are really complete sheaves of one groove) and rim sections (which are simply grooved rims cast without arms or hubs). This plan makes it possible to vary the weight and strength of multiple groove sheaves by using a greater or less number of arm sections, dependent upon the size of the rope to be used and the varying conditions of their employment. After the sheaves are "built-up," as it is termed, they are bored out, and to show the trifling difference in weight between the rough and finished sheaves, I would state that a forty-eight inch five-groove sheave for one and one-eighth inch rope weighs in the rough 433 pounds, and when finished 423 pounds, or 144 pounds less than the finished solid-turned sheave referred to previously.

So great is the care taken in the casting of "built-up" sheaves, that the only finishing required in the grooves is that of smoothing the casting by holding a block of emery in the groove while revolving at a speed of about 120 revolutions per minute, the finishing of each groove in this way not occupying more than three or four minutes.

An incidental advantage of the multiple groove "built-up" sheave is, that after a rope drive is erected and the

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necessity arises for the transmission of more power than that for which it was originally designed, additional ring sections may be added to the sheaves, and by splicing in an additional piece of rope, the desired increased transmitting capacity may be secured.

It is obvious that in the use of a single rope making a number of wraps around two wheels, it is essential that the diameters of the grooves at the pitch line, which is the arc of contact of the ropes, must be uniform in all of the grooves in any one sheave; otherwise, there would be a tendency on the part of some of the wraps of the rope to travel faster than the others, which tendency must be counteracted by the slipping of the rope in some of the grooves, this, of course, resulting in a loss of power and also in the rapid wear of the rope. So important is this feature, that great care has to be taken in splicing the rope so that the diameter at the splice will be no larger than in the body of the rope. An increased diameter at the splice would, of course, make the splice travel around a larger circle on the sheave by its not being able to take as low a position in the V-shaped grooves.

It is impossible to splice a rope without impairing its strength at the splice, provided its diameter is not increased. What is ordinarily known as the "short splice," or the "long splice," as used by sailors, will not answer at all. It is essential that a splice (for instance, in a rope one inch in diameter) should be from ten to twelve feet long, and made with great care, so that after the splice is complete the tension to which the rope is subjected is evenly divided among the strands of the rope.

Durability of manila rope transmissions is dependent upon various conditions, the most important one probably being the quality of the rope. In order to make good rope it is necessary that the fibres employed in its manufacture should be long and of nearly uniform size. The fact that the fibres of manila have a rough interior and are of great strength in proportion to their weight, is an important factor in the strength of the rope when subjected to a tensile strain, but at the same time this very roughness becomes

an element of destruction when the ropes are passing around sheaves which cause the fibres to slide upon each other so that the internal wear of a rope becomes a most serious agent in destroying it. A worn-out rope untwisted so as to expose the strands, will show a fine powder which has been chafed off the fibres. Of course, after this has been detached from the fibres, it leaves them weaker than in their original condition. It is also noticeable that the fibres of manila, being composed of elongated cells, are not perfectly adapted to continued bending.

In order to counteract the destructive tendencies enumerated, it is essential that the rope should be lubricated. This is accomplished in two ways, the first being by the introduction of a lubricant in the manufacture of rope; notably, as in the case of what is known as the "Stevedore," into which tallow and graphite are introduced at the time the rope is made, the effect being to increase the flexibility of the rope, increase its life and to render it to a degree water-proof, and also in the ropes of some other makes, which are laid with tallow. The second method is to coat the outside of the rope with a mixture of lampblack or graphite and grease, relying upon the working of the strands of the rope with relation to each other to work the compound through it. This latter method is practised on the Continent, and is also being made use of in this country to a considerable extent.

Some of the larger constructors of rope transmissions in England claim that manila rope should never be used under any circumstances; that cotton is the only fibre that will give satisfactory results. I have seen samples of a rope one and three-eighth inches in diameter, which had been in constant use ten hours a day for nearly sixteen years. This was a cotton rope, known as the "Lambeth," the peculiarity of its construction being that it was primarily made of cotton, but each of the four strands of the rope was covered with a number of tightly twisted yarns, forming a protecting envelope, which prevented cutting or wearing of any of the strands proper of the rope. Of course, cotton ropes are much more expensive than manila ones, and a rope such as

the "Lambeth" must necessarily be the most expensive of those made of cotton.

It is unquestionably true, that in time cotton ropes will be more extensively used in this country, crowding out the use of manila; but it is a fact that the introduction of any radical departures in the field of mechanical engineering are only possible by offering not only a more satisfactory article than has formerly been used, but also a cheaper one. This fact has aided in the introduction of the manila rope drive, as in many cases it is not only the best means of transmitting power, but also the cheapest. Ultimately, and as users of rope drives become more familiar with their intrinsic advantages, they will be more ready to increase the original outlay and put in the best rope that can be made.

If manila rope transmissions are designed with good judgment and are properly erected, there is no possible doubt of their giving satisfactory results. The prevailing notion is, however, that as rope is flexible in all directions, rope drives can be constructed in a haphazard manner, without special care being exercised in getting the sheaves in exact alignment, and considerable criticism has been engendered by lack of attention to the important details. When borne in mind that a rope used for the transmission of power runs at a speed as high as 5,000 feet per minute in many cases, and as a rule the rope is run in close proximity to the ceiling, which is the hottest part of a room, it is not surprising that the rope rapidly becomes dry and correspondingly brittle; hence, the importance of lubricating it in some way, to counteract the drying tendency. It is not uncommon to find rope transmissions erected so that the sway of the rope will occasionally bring it in contact with a beam, which, of course, results in extremely rapid wear of the outside of the rope. The fact that conditions of this kind exist is sometimes hard to discover, as when the rope is at rest it may apparently have abundant clearance throughout the path of its travel. One case brought to my attention, in which the rope was being rapidly worn out, resulted in the discovery of the fact that in its passage through the

wall of a building, the rope would sway and come in contact with the edge of a corrugated iron covering of the building. On calling this condition of affairs to the attention of the parties operating the drive they seemed quite surprised that such a trifling thing as an occasional touching of the rope on the corrugated iron should in any way impair the life and usefulness of the rope.

Manila rope is usually run under a working strain equal to three per cent. of its ultimate breaking strain and at velocities varying from 3,000 to 5,000 feet per minute.

To determine the power which any rope will transmit at a given speed, it is necessary to ascertain the nature and amount of the strains to which it is subjected while running, and then to find the exact part of the total working strain which is expended in performing useful work.

Generally speaking, ropes in the "American" system are subjected to three principal strains, viz: the strain due to the power transmitted; that due to centrifugal force; and that due to the tension carriage weight. Besides these three there are the minor strains, due to the weight of the rope, the internal resistance of the rope to bending and the strains required to make the rope enter and leave the wedge-shaped grooves. With good ropes, running in well-made grooves, the minor strains do not probably absorb more than five per cent. of the working strain of the rope.

As an illustration of the method of determining the horse-power of a rope in the American system, let us assume the case of a one-inch rope travelling at a speed of 4,500 feet per minute. The breaking strain of this rope, as given by the Plymouth Cordage Company, is 9,000 pounds, and according to the limitation imposed by good practice, the total working strain should not exceed three per cent. of this, or 270 pounds. Deducting five per cent. for the minor strains, we have 257 pounds, which represents the sum of the three principal forces.

In order to obtain the effective strain, or driving force, it is first necessary to find the strain due to centrifugal force. This force varies directly as the square of the speed, and may be found by multiplying the square of the speed

in feet per second by the weight of one foot of rope, and dividing the product by thirty-two.

Now, the weight of one-inch manila rope per foot is '33 pound, and the centrifugal force, therefore, equals

$$\frac{75^2 \times '33}{32} \text{ or about 56 pounds.}$$

Subtracting this from 257 pounds, we have 201 pounds as the sum of the strain due to the power transmitted and the strain due to the tension carriage weight.

Now a series of carefully conducted tests have established the fact that a weight of (say) fifty pounds on one end of a rope wrapped half way round a sheave having a 45° V-groove, will sustain, without slippage, about three and one-half times its weight at the other end of the rope. Assuming, for the sake of safety, that this ratio is as 1 : 3, it is evident, that to sustain a strain of 201 pounds on the tight side without slippage, it is necessary to maintain a tension of one-third this amount, or sixty-seven pounds, on the slack side. The effective strain, or driving force, will, therefore, be equal to the difference of these strains, or 134 pounds, which at 4,500 feet per minute will transmit

$$\frac{4,500 \times 134}{33,000} \text{ or } 18\cdot4 \text{ horse-power.}$$

In the same manner we find, that at a speed of 1,800 feet per minute, the centrifugal force is only nine pounds, and the effective strain is 166 pounds, transmitting nine horse-power; while at a speed of 6,600 feet per minute, the centrifugal force is 125 pounds and the driving force only eighty-eight pounds, transmitting 17·6 horse-power.

On reflection it is evident, that as the speeds are increased the centrifugal force increases, and the effective tension must be reduced to avoid overstraining the ropes. At a speed of about 4,800 feet per minute the ropes attain their greatest efficiency, *i. e.*, they will transmit more power with the assumed working strain than at any other speed, either higher or lower, although there is but little variation in the power transmitted at that speed and



the power transmitted at either 4,200 feet per minute or 5,400 feet per minute, thus giving a wide range from which to choose. It is well to bear in mind, however, that the higher the speed the greater the wear of the rope, and that for this reason the slower speed is the more economical. All things considered, speeds of from 3,600 to 4,200 feet per minute are best.

It may be well to note, that for the working strain assumed, viz: Three per cent. of the ultimate breaking strain, forty diameters should be regarded as the minimum size of sheaves to be used. If it is necessary to use sheaves of smaller diameter, the working strain should be proportionately reduced; thus in the case previously considered, an inch rope at a speed of 4,500 feet per minute transmitted 18.4 horse-power; now if it is desired to use a 30-inch wheel as a driver, it is advisable to reduce the power transmitted to three-quarters of 18.4, or 13.8 horse-power. This rule does not only apply to the driving and driven wheels, but also to any intermediate idlers around which the rope may be called upon to bend.

The idlers of rope transmissions have usually been made with semi-circular grooves, permitting the ropes to rest upon the bottoms of them. It has been found better, however, in practice to use the V-shaped groove for all purposes, as it insures a revolution of the idlers at the same speed at which the rope is travelling, and thus prevents the wear due to the slipping of the rope in the grooves of the wheel. It has been shown, that idlers having semi-circular grooves in them become highly polished, while those having V-shaped grooves do not. Thus the demonstration that the ropes slip to a certain extent in passing over idlers with the semi-circular grooves, is complete.

The use of the tension carriage in the "American" system of rope transmissions is twofold. In the first place where a continuous rope is used passing over the grooves of two sheaves, it is obvious that the rope must be wound spirally around the two wheels, and that unless the rope in passing off the last groove of one of the wheels is not conducted back again to the first groove of the wheel, the drive would

become inoperative, from the fact that all of the wraps of the rope would soon run off and leave the wheels without connection between them. In order to make this return, the wheel of the tension carriage is set at an angle so as to enable it to make the proper return of the rope. Secondly, the tension carriage is weighted so as to give the proper tension to the rope and serve as a corrective agent to the trifling inequalities that may exist in the sheaves or in the rope. It is by the weighting of the tension carriage that we are enabled to tell the exact amount of strain to which we are subjecting a rope. I might add, that the tension carriage being mounted on guides, it is capable of maintaining the proper tension of the rope even if the latter becomes considerably elongated by the strain put upon it or is variable in its length, due to atmospheric changes. This latter is especially noticeable in rope transmissions which are used wholly, or in part, out of doors, they being subjected to the action of rainy and dry weather.

The use of wire rope for the transmission of power I will only briefly touch upon, by stating that the economic use of it seems to be confined to transmissions of great length between centres. The sheaves employed have to be of very large diameter; otherwise the rope becomes crystallized and is of short life.

With reference to raw hide I might say, that its cost has prevented its general adoption, as it is cheaper to use an increased number of strands of manila rope to accomplish the desired result, though it has one marked advantage, inasmuch as it is possible to use it on sheaves of smaller relative diameter than in cases where manila rope is employed.

If possible, in running the rope care should be taken to have the bends all in one direction; as a rope bent in opposite directions will wear with much greater rapidity.