Civil and Mechanical Engineering.

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

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Belts for Transmitting Power.

The traction of belts upon pulleys, like that of locomotive wheels upon railways, being incapable of demonstration except by experience, hindered for a long time the introduction of belts as a means of transmitting motion and power. I mention motion separately because with many kinds of machinery that involve high speed, such as wood machines, the transmission of rapid movement must be considered as well as power, and it is only by means of belts that such high speeds may be communicated from one shaft to another; so that at least in practice, belts alone are at this time employed for high speed.

The first principle I will point out in regard to belts, distinguishing them from shafts as a means of transmitting power, is that the power is communicated by means of tensile instead of torsional strain, the power during its transmission being represented in the difference of tension between the driving and the slack sides of the belts.

In the case of shafts, their length, or the distance to which they may be extended in transmitting power, is limited by torsional deflection, and as this torsional strain is avoided with belts, we may conclude that, unless there are other disqualifying conditions, belts are better than shafts for transmitting power through long distances.

Belts suffer resistance from the air and from the friction in the bearings of supporting pulleys, which are necessary in long horizontal belts. With these exceptions they are capable of moving at a high rate of speed and transmitting power without appreciable loss.

Following this proposition into modern engineering practice, we find how experience has gradually conformed to what these properties in belts would suggest; wire and other ropes with a diminished cross section to avoid air friction, and allowed to droop in low curves to avoid supporting pulleys, are now commonly employed for transmitting power through long distances. This system has been very successfully carried out in Germany and America, in some cases for distributing power in large manufacturing establishments.

Belts, among which are included all flexible bands, do not afford the same facilities for taking off power at different points that shafts do, but have advantages in transmitting power to portable machinery, or, in other words, when the power is to be taken off at movable points, as in the case of travelling cranes, hoists and so on.

An interesting example in the use of belts for communicating power to movable machinery is furnished in the travelling cranes of Mr. Ramsbottom, in the shops of the L. & N. W. Railway, at Crewe, England, where powerful travelling cranes receive both the lifting and traversing power by means of a cotton rope not more than one inch in diameter, which moves at a high velocity, the motion being reduced by means of tangent wheels and gearing to attain the force required in lifting heavy loads. In looking at this mechanism, those who had not their conceptions based on a true knowledge of power and the relations between power and speed, would see, in the effect of this small cotton rope, something marvellous.

Considered as means for transmitting power, the contrast as to advantages and disadvantages lies especially between belts and gearing instead of between belts and shafts. It is true in extreme cases, such as that cited at Crewe, or in conveying water power from inacessible places through long distances, and so on, the comparison lies between belts and shafts, but for ordinary practice, in three cases out of four, the problem as to mechanism for conveying power is between belts and gearing.

If experience in the use of belts was thorough, as it is in the case of gearing, and if the quality of belts did not form an important part in the estimates, there would not be much difficulty in determining where belts should be employed and where gearing would be preferable.

Belts are continually taking the place of gearing even in cases where they have been until very recently thought inadmissable; at least one of the largest rolling mills in Pittsburg, Pennsylvania, except a single pair of spur wheels as the last movers at each trains of rolls, is driven by belts throughout.

Leaving out the matter of a positive relative movement between shafts, which belts as a means of transmitting power cannot insure, there are the following conditions that must be considered in determining whether belts or other means should be employed in transmitting power :

1. The distance to which the power must be carried. 2. The speed at which the transmitting machinery must move. 3. The course or direction of transmission, whether in straight lines or at angles. 4. Durability and the cost of construction. 5. The loss of power during transmission. 6. Noise, vibration and jar.

In every case where there can be a question as to whether gearing shafts or belts will be the best means of transmitting power, the several conditions named will furnish a solution if properly investigated. Speed, noise or angles may become determinative conditions, and are such in a large number of cases; first cost and loss of power are generally secondary conditions.

Applying these tests to cases where belts, shafts, or wheels may be employed, and carefully considering the special conditions of any case, the apprentice will soon find himself in possession of knowledge to guide him in his own plans and enable him to judge of the correctness of examples that come under his notice.

It is never enough to know that any piece of work is generally constructed in some particular manner, or that such a proposition is generally accepted as being correct; nothing is learned, in the true sense, until the reasons for it are understood, and it is by no means sufficient to know from observation alone that belts are best for high speeds, that gearing is best to form angles in transmitting power, or that gearing consumes more power, and that belts produce less jar and noise; the reasons for these things and the principles that lie at the bottom must be reached before it can be assumed that the subject is understood.

Gearing as a Means of Transmitting Power.

The term gearing, which was once applied to wheels, shafts and the general mechanism of mills and factories, has now in common use become restricted to tooth wheels, and is in this sense employed here.

Gearing as a means of transmitting motion is employed when the movement of parts of machinery must remain relatively the same —when a heavy force is transmitted between shafts that are near to each other, or when shafts are at angles to each other.

This rule is of course not constant, except as to cases where positive relative motion is essential; noise and the liability to sudden obstruction may be reasons for not employing tooth wheels when the distance apart and the position of shafts would render such connection the most durable and cheap.

Gearing under ordinary strain, within limited speed and when other conditions admit of its use, is the cheapest and most durable mechanism for transmitting power, yet the amount of gearing employed in machinery, especially in Europe, is no doubt far greater than it will be in future and as belts are better understood.

No subject belonging to mechanics has been more thoroughly investigated than that of gearing; text-books are replete with every kind of information pertaining to gearing, at least so far as the subject can be made a mathematical one, and to judge from the amount of matter, formulæ and diagrams relating to the form of teeth that the apprentice will meet with, he will no doubt be led to believe that the main object of modern mechanics is to generate the teeth of wheels. It must be admitted that the teeth of wheels and the proportions of wheels is a very important matter to understand, and should be studied with the greatest care, but it is equally important to know how to produce the teeth in metal after their configuration has been defined on paper; to understand the endurance of teeth under abrasive wear when made of wrought or cast iron, brass or steel; how patterns can be constructed from which correct wheels may be cast, and how the teeth of wheels can be cut by machinery, and so on.

The learner should, in fact, consider the application and operative conditions of gearing as the main part of the subject, and the geometry and construction of wheels as subsidiary, and based upon the operation of wheels.

Gearing consists of spur wheels, bevel wheels, tangent wheels, spiral wheels and chain wheels; the last I include among gearing because the nature of their operation is analogous to tooth wheels, although at first thought such chains seem to correspond to belts.

The motion imparted by chains that mesh over the teeth of wheels is positive, and not frictional as in belts. The speed at which gear chains may run, with other conditions, corresponds to gearing.

Tangent wheels as a name is certainly as applicable, and to be preferred to worm wheels, for the class of gearing to which it belongs. As all these forms of gearing can be seen in almost any engineering establishment, and in view of the amount of scientific information relating to wheels that is available to the apprentice, it will only be necessary here to point out some of the conditions that govern the use and operation of wheels.

The durability of gearing, aside from breaking, is dependent upon the amount of rubbing action that takes place between the teeth when in contact; spur wheels or bevel wheels, when the pitch is accurate and the teeth of the proper form, if kept clean and lubricated, wear but little, because the contact between the teeth is that of rolling instead of sliding.

Tangent wheels and spiral gearing have only what is termed line contact between the bearing surfaces, and as the action is a sliding one, such wheels are subject to rapid wear and are incapable of sustaining much pressure, or transmitting a great amount of power, except the surfaces be hard and lubrication constant.

In spiral gearing the line of force is at an angle of forty-five degrees, with the bearing faces of the teeth and the sliding movement equal to the speed of the wheels at their periphery; the bearing on the teeth, as before said, is one of line contact only; such wheels cannot be employed except in cases where an inconsiderable force is to be transmitted.

For communicating movement to the beds of planing machines, or to racks of any kind, the rack can be drawn to the wheel and a lifting action avoided by shortening the pitch of the rack, so that it will vary a little from the driving wheel; the rising or entering teeth in this case do not come in contact with those on the rack until they have attained a position normal to the rack.

Hydraulic Apparatus for Transmitting Power.

Although a system but recently invented, the use of hydraulic machinery for transmitting and applying power has reached an extended application to a variety of purposes, and gives promise of a still more extended use in future.

Considered as a means of transmitting regularly a constant amount of power, water apparatus is more expensive and inferior in every respect to belts or shafts, and its use must be traced to some special principles involved that adapt hydraulic apparatus for the performance of certain duties.

These principles will be found to consist in storing up power in such a manner that it may be used with great force at intervals, and, secondly, in the facilities afforded for multiplying motion or force by the use of pumps.

An engine of ten horse-power, that is connected with machinery by hydraulic apparatus, may exert a force equal to one hundred horse-power for one tenth of the time, the power being stored up by accumulators in the interval, or, in other words, the motive power acting continuously can be accumulated or stored up and applied at intervals as it may be required for raising weights, operating punches, compressive forging, or other work of an intermittent character. Hydraulic machinery employed for such purposes is more simple and inexpensive than gearing and shafts, especially in the application of a great force acting for a considerable distance, and where a cylinder and piston represent an amount of strength that could not be gained with twice the amount of detail if screws, levers, or other devices were employed instead.

Motion or power is varied to almost any degree by the ratio between the pistons of the pumps and the pistons that give off the power; the same general arrangement of machinery answering in all cases, whereas with gearing the quantity of machinery has to be increased as the difference between the motive power and the applied power increases; this recommends hydraulic apparatus where a great force is required at intervals, and it is in such cases that it was first applied, and is yet for the most part used. In the use of hydraulic apparatus for transmitting and applying power there is, however, this difficulty to be contended with: water is inelastic and non-yielding, and, in the ordinary machinery for performing irregular duty, there is a loss of power equal to the difference between what a piston can perform and what it does perform, that is, the amount of water, and consequently the amount of power given off, is as the movement, instead of as the work that is performed. This applies to cases where accumulators that store up the power by lifting weights, are used but not to accumulators where the power is stored by compressing air, or in cases where steam pressure acts directly against the water that performs the work; in such cases the consumption of steam is in proportion to the amount of force employed. In the latter case the water in its relations to the motive power and the work is the same as shafts or gearing, merely a medium of regular transmission, The application of hydraulic force to the lifting and handling of weights will be noticed under another head.

Pneumatic Machinery for Transmitting Power.

Pneumatic machinery, aside from the subtlety and elasticity of air as compared with water, is analogous in operation to hydraulic machinery.

Water may be considered as a rigid medium for transmitting power, and air as a flexible or yielding one, the first corresponding in some respects to gearing and the latter to belts.

There is at this time but a limited use of pneumatic apparatus for transmitting power, but its application is rapidly extending, especially in the way of transporting materials by means of air current and in conveying power to mining machinery.

The successful application of the pneumatic system at the Mont Cenis tunnel in Italy, and at the Hoosac tunnel in America, has demonstrated its value in such operations, where the air not only serves to transmit power to operate the machinery but to ventilate the mines at the same time.

Pneumatic force is also used for sinking foundations, and in some cases for lifts and hoists. Presuming that the flow of air in pipes is not materially impeded by friction or angles, and that there will be no difficulty in maintaining lubrication in pistons or other machinery driven by air, there seems to be many reasons in favor of its use as a means of distributing power in manufacturing districts.

The diminished cost of power when generated on a large scale, and the expense and danger of maintaining a steam power for each establishment, especially in cities, points to many advantages in generating and distributing power as gas and water are now supplied.

Air seems to be the most natural and available medium for transmitting and distributing power upon any general system like water or gas, and there is every probability of such a system existing at some future time. There is no subject more interesting, and perhaps none more important for an engineering student to study at this time, than the transmission of power and transport of material by pneumatic means. The power given out by the expansion of air is not equal to the power consumed in compressing it, but the loss is but insignificant compared with the advantages that may be gained by its use in many cases.

In considering pneumatic machinery there are the following points to which the attention of the apprentice is directed:

The value of pneumatic apparatus in reaching places where steam furnaces cannot be used.

The use that may be made of the exhausted air after it has been applied as a motive agent.

The saving from condensation, to which steam is exposed, avoidance of heat, and the consequent contraction and expansion of conducting pipes.

The loss of power by friction and angles in the flow of air through pipes when carried to long distances.

The lubrication of surfaces working under air pressure, such as the pistons and valves of engines.

The diminished cost of generating power, on a large scale, compared with a number of separate steam engines distributed over manufacturing districts.

The effect of pneumatic machinery in reducing insurance rates and dangers of fire, as compared with steam machinery.

The investment in the appliances of distribution and their maintenance.

In passing thus rapidly over so important a subject, and one that admits so extended a consideration as machinery of transmission, the reader can see that the purpose has been to touch only upon such points as will lead to thought and investigation, and especially to meet the queries that arise in the mind of a learner.

In arranging and erecting machinery of transmission, obviously the first problem must be, what kind of machinery should be employed? And, secondly, what are the conditions that should determine the selection and arrangemeut? What has been written has, so far as possible, been directed to the proper means of solving these questions.

Machinery of Application.

The term application, has been selected as a proper one to distinguish machines that expend and apply power from those that are employed in generating or transmitting power. Machines of application expend their action on material, and are directed to certain operations, which I will term processes, such as cutting, compressing, grinding, separating and disintegrating.

By classifying these processes, it will be seen that, after all, but a few functions are to be performed by machines, and that they all act upon a few general principles.

For instance, all engineering tools used in fitting are directed to the process of cutting. Planing machines, lathes, drilling machines, and shaping machines are all cutting machines, acting upon the same general principles.

Confining what is said, for the present, to machines of application that have cutting action, it may be assumed that the operation of such machines is governed by certain principles or laws, and that the most thorough manner of studying and understanding the nature operation and best mode of their operation, manner of constructing such machines, is by a study of these laws or principles.

Cutting, as an operation, includes the force to propel cutting edges, and means to guide and control their action. In cutting with hand tools, the operator performs these functions of propelling and guiding the tools with his hands, and in power operations the machines do the same; but to be of value, machines must either employ more force than a man can exert, or must guide the tools with greater accuracy than is attainable by hand.

Increased speed may also be an object in the employment of machinery, as well as the guidance of cutting edges, or increased force in propelling them; in other words, the hands of an operator are not only limited as to the power that may be exerted, but also as to the rate of movement, which becomes a highly important consideration in many operations where neither the force or guidance of tools are wanting.

There is nothing more interesting, nor at the same time more useful, in the whole study of mechanics, than to analyze the action of cutting machines or other machinery of application, to ascertain whether the main object of a machine is increased force, more accurate guidance, or greater speed than is attainable by hand operations. Cutting machines may be directed to either of these objects singly, or to all of them together, or these objects may vary in their relative importance in different operations, but in all cases the general principles remain the same.

To follow this matter further, we find in such machines as are directed mainly to augmenting force or increasing the amount of power that may be applied to any operation, such as sawing wood or stone, the effect produced when compared to hand labor, is nearly as the difference in the power applied, and the saving that such machines effect is generally in the same proportion. A machine that can expend ten horse-power in performing its work, will save ten times as much as a machine that expends but one horse-power, provided the purpose of the machine is to perform operations in which hand labor lacks power.

In other machines of application, where they are directed mainly to guidance or speed of action, such as sewing machines, dove-tailing machines, gear cutting machines, and so on, there is no relation whatever between the advantages gained and the amount of power expended.

The difference between hand and machine operations and the labor saving effect of machines, will be treated in another place ; the subject is alluded to here, only to enable the reader to more fully distinguish between machinery of transmission and machinery of application.

Machinery of application directed to what has been termed compression processes, such as steam hammers, drops, presses, rolling mills, and so on, act upon material that is naturally soft and ductile, or when it is softened by heat, as in the case of forging.

The nature of compressive operations of all kinds is distinguished from cutting and abrading, in the fact that no material is cut away, the mass being forced into shape by dies or forms that give the required configuration.

The action of compressing machines may be either intermittent, as in the case of rolling iron, or percussive, as in steam hammers, where a great force acts throughout a limited distance.

Machines for abrading or grinding are common among machinery of application, their main purpose being to cut or shape material that cannot be heated, and is too hard to be acted upon by compression or by cutting processes.

Separating machines, although forming a distinct class, such as bolting and screening machines for grain, are not complex enough to require explanation.

Grinding, no doubt, if traced to the principles that lie at the bottom, is nothing more than a cutting process, in which the edges employed are harder than any material that can be made into cutters, and in which these edges are firmly supported by being imbedded into a mass like the particles of sand in grindstones, or the particles of emery in emery wheels.

Disintegrating machinery, as a class, includes machines directed to grinding grain, or separating the fibres of textile material, such as grinding mills, pulp machines, cotton and wool machinery.

The principle of action in machines of this class requires no special explanation here ; the process is one of crushing, tearing and macerating.

To be continued.