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## GENERAL ADAPTATION OF ELECTRIC MOTORS TO MANUFACTURING PLANTS.

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(Read before the Electrical Section, January 10th, 1907.)

Motors in such continually increasing numbers are being used in our manufacturing establishments with such successful results, and have stood the test of practical working under so many different conditions, and for such long periods of time, that the trial stage is now past.

When power is transmitted by belts and shafts for industrial purposes, the percentage of the total horse power output of the engine which is actually useful at the productive machine (barring the limited use of ball-bearing line shafts), varies from 22% to 77%. It should be noted that these percentages are figured on the basis of horse power required to drive the shafting and belting when running light. There is good reason to believe that these losses increase with the increase of load.

As contrasted with these complications and losses, the electric drive offers numerous advantages. The system is easily installed and flexible and reliable. It is readily extended and maintained. Both generators and motors have a high efficiency, and most of the apparatus requiring skilled attention may be concentrated in the power plant.

The electric drive readily affords small sub-divisions of power so that it becomes practicable to use motors either for individual tools or for groups of tools. In either event, we arrive at a complete solution of the question of using power only when something is to be done with it, for even with group-driving, the groups may be made relatively small and of such a nature that it will rarely be necessary to drive a whole group in order to employ a single tool.

There are undoubtedly numerous special requirements which can best be fulfilled by use of the individual drive, but in the vast majority of cases the application of an individual motor to each tool carries the matter altogether too far. Small motors, like small engines, are less efficient than large ones, besides costing very much more in proportion to the power delivered. The general plan which meets with the approval of the best machine shop engineers, is to employ individual drives for tools which require variable speed drive. These conditions are most often met with on machines with direct application of a cutting tool to the rotating work, provision being made if the machine is to accommodate a work piece of large diameter. When cutting on the periphery of such a piece of work a slower speed of drive is necessary than when the cut is on a part near the centre of the work, the same maximum cutting speed of the tool being maintained in both instances. Even where these factors do not enter the calculation it is often desirable to drive individually on account of the comparatively large amount of power involved in a single machine, or where convenience of location of the machine is promoted by divorce from any relation to existing lines of shafting.

Probably the first application of electricity to machine shop needs was in the form of lighting. The second use was for the cranes, which are to-day in universal use in all large shops; and it is hardly an exaggeration to say that the existence of the great plants of the present time would be impossible without the electric crane.

The shop of the immediate past, with the hand or mechanical crane, and a Corliss engine driving a main shaft, which drives all the machine tools, is now being equipped with electric generators, delivering current to motors driving a group of machines or individual drives; and increased productive capacity and lower cost are resulting. At the present time, the travelling electric crane, with its flexibility of design, is really an indispensable power tool in a machine shop.

Until very recently the method of power transmission in general use in good shops consisted of a system of shafts and belting, taking power from the engine or turbine as a prime mover and transmitting it to individual tools. The application of this system was, of course, limited to the case of a single shop where the dimensions were not too great. In the case of such an establishment as a shipyard or great railroad shops, the system consisted either of a central boiler plant transmitting steam to engines located in various parts of the manufacturing area or, in some instances, of a number of boiler plants with large engines adjacent and smaller ones at considerable distances.

The disadvantages of long lines of shafting were realized long before electricity offered a way out of the difficulty. Unless the greatest care be used in keeping the shafting in alignment and the journals well oiled, the power wasted in the friction of bearings and belts becomes a very large percentage of the total power received from the prime mover. This friction loss is continuous even when, as is often the case in large shops, a single particular tool, like a large boring mill, has to run when all the rest of the shop is shut down.

The decided advantages of the application of motors to machine tools in industrial work has been thoroughly exemplified in machine shop practice to-day. The conditions under which machine tools operate are so varied that it is impossible to make any general statement covering all of the possible operating conditions, but some of the individual conditions are always important, as, for instance — the character of the work machined, kind of material cut, shape of the cutting tool, quality of tool steel, method of treating tool steel. All of these should be taken into account to intelligently fit a motor to any machine tool.

Broadly speaking, machine tools may be divided into two classes, first, those with direct rotary motion of work or cutter, and second, those with a reciprocating motion, either of work or cutter. Under the first classification come lathes, boring mills, milling machines, drill presses, and so forth. The second class includes planers, shapers, slotters, and machines of a similar character.

The factors which have had more to do with the recent impetus given to the study of rapid production than any others are the high speed steels and the variable speed electric motors. These agents have not only brought about conditions entirely new to the manufacturing fraternity at large, but their influence has extended further, having induced a complete study of manufacturing conditions, involving not only the rapid production of work, but also improved methods of handling work between operations.

It is to be noted here that whatever the class of machine tool, the variable speed motor generally offers decided advantages in the way of rapid and economical production. With the old method of speed variation, by means of cone pulleys or nests of gears, only large increments in speed are obtainable. This invariably means that tools cannot be worked up to their limit of productive capacity. With the new high speed steels requiring a greater pulling power in the belts, and an increased strength in the gears, reasonably fine increments in speed, by mechanical methods alone, are almost impossible, owing to the increased length of the cone pulley or the necessarily abnormal size of the change gears.

For this reason, the variable speed motor may, in some cases, actually decrease the cost of the machine tool by eliminating extremely bulky and expensive mechanical speed changing devices.

The electric motor has been most successfully applied to all classes of pumps and hoisting work. For the operation of fans and blowers it has unequalled advantages, due to the ease with which it can be controlled, and to the fact that an electric equipment requires little space and may be installed wherever needed.

The present advance in shop methods and increased economy are due to the increased use of portable tools, which means less work done by hand; therefore, the saving should be considerable. It frequently happens that it takes longer to set up a piece of work than it does to do it, hence the advantage of moving a portable tool to the part to be machined. Then there are certain classes and conditions of work for which small portable tools, such as grinders, are peculiarly adapted, and result in increased efficiency and economy.

Wherever electric energy is available, we find better heating and ventilating systems, with the exhausters for dust and shavings, and better illumination, due to the absence of belting, which obstructs the path of light and throws dust into the air, which is finally deposited on the windows and walls, giving them a dingy color. The absence of overhead shafting also gives a free space for the operation of the cranes so that they may be used to the best advantage.

Keeping a shop clean is not such a difficult matter as formerly. Sanitation and cleanliness are important questions in industrial plants, and are coming in for serious attention in connection with the improvement of shop production. The conditions under which employees of machine shops work have much to do with the output. With the electric drive, it is possible to maintain a clean shop, and the effect upon the character of the work cannot be otherwise than good.

Another sphere for the electric motor is in solving the transportation problems of industrial establishments. In addition to the crane and elevator service, the economical transportation of material about various parts of the plant is sometimes a formidable problem. With the electrically propelled locomotives, from either storage batteries or trolley, the transmission is economical, and these equipments have been found very serviceable, especially in the case of an establishment covering a wide area. Another valuable feature is the use of the hoisting derrick on car trucks. There are many other economies obtainable from electric haulage.

This paper will not attempt to discuss the relative merits of various systems. However, we can point out some valuable features of both the alternating current and direct current systems. These systems of power transmission have been explained so frequently that it seems scarcely necessary to touch upon them here, and it is sufficient to say that the variable speed system for direct current motors advocated by electrical manufacturers is becoming recognized as the only thoroughly satisfactory method of obtaining speed variation of motors used in connection with machine tools; namely, by means of shunt field control, either alone on single voltage systems by standard motors and the auxiliary pole motor, or the two voltage motors on the three-wire system of standard commercial voltages.

The wiring involved in the latter systems, however, is sometimes mentioned as objectionable, hence, the development of the direct current auxiliary pole type of motor, which presents the acme of simplicity, together with remarkable operating characteristics. The results obtained in this type of motor in eliminating sparking, and thus increasing the life of the commutator, are of direct benefit to every user of motors. The action of the auxiliary poles and windings in producing sparkless commutation is a matter, however, which will be of less interest to the user of motors than the question of how the development of the motor of this type makes a distinct saving in the layout and operation of the industrial plant. Up to the time when the auxiliary pole motor was commercially developed, there was no single voltage variable speed motor with suitable speed characteristics which could be built in all sizes required for machine tool operation, and for such speed variation as would give the best performance for each class of service. Wide speed variation, simplicity of control, and saving in wiring in the distribution system, make the handling of these motors easy for an inexperienced man, and insure a minimum amount of trouble and interruption of the work.

The characteristics of the alternating current motor are now quite generally known, and only the features which make a motor of this type desirable for machine shop or factory drive will be mentioned here. These motors are characterized by the absence of commutators, are built to withstand severe overloads, and, on account of their construction, are unaffected by dirt, iron fillings, and other foreign matter.

The alternating current motor is mechanically extremely simple. It only requires enough attention to keep the oil wells filled and to see that the oil rings are rotating properly. A number of successful installations, using alternating-current motors directly connected to machine tools are now in operation, and the maintenance account is extremely low.

The use of the alternating current motor is peculiarly adapted to planers, slotters, shapers, or tools of a similar nature, in which reciprocating motion is employed, provided variable cutting speed is not an object. It is obvious that on the quick reverse with machines of this character, unless the motor is abnormally large, or a fly wheel be employed, there is imposed a considerable momentary overload upon the motor. These overloads will be more readily taken care of by the alternating current motor than by the direct current motor, for the reason that overloads on direct current motors, if severe, will, if the overload capacity of the motor is not adequate, be accompanied by flashing at the brushes.

The alternating current motor, involving as it does, no commutator, which must be more or less accessible for cleaning and inspection, permits of a greater mechanical protection of the windings than is possible in the case of the direct current motor.

For group driving, the alternating current is specially desirable. For individual drive, where the conditions are of a definite character, and where the quality of the material operated upon and the tool steel are not liable to change, the alternating current motor furnishes an ideal drive so far as simplicity of construction and general reliability are concerned. In the case of the alternating current motor, speed changes must be made by means of some variable speed device other than the motor, as the motor itself is essentially a constant speed machine. Hence, it is peculiarly adapted to grinding operations and for the operation of certain classes of wood-working machinery, or tools situated in places that are not free from moisture, acid fumes or inflammable materials. It may be placed in the hands of unskilled operators and requires no skill or attention worth mentioning, and will bear overloading and abuse almost beyond belief—but the greatest advantage of the alternating current system is that it can be transformed either in voltage or phase and adapted for long distance transmission. The alternating current motors may be used in connection with direct current motors. Both alternating current and direct current systems have become quite common for industrial and railroad plants. In these installations, the main generators are of the polyphase alternating current type, direct current being obtained by means of rotary converters or motor generator sets.

So one might go on discussing the manifold advantages of the application of electrical energy in our industries. It is only necessary to assemble in one's mind the factors that have made possible such rapid advances in the past to appreciate the future conquests when our water powers are fully developed.

To intending purchasers of electric equipments, a number of considerations may be presented, as the customer, not always having the advantage of special knowledge or experience, may lack time and facilities for testing out before purchase; and works managers and superintendents may be in doubt as to the paying value or comparative merits of the machines and devices drawn to their attention by enterprising supply houses.

We might say first, that the motor should be of general adaptability. This is most important, as it largely governs the selection. It should be maintained and operated at low cost.

As is usually the case, the simplest and most compact motor, of light weight and of few parts, is at once the most adaptable, and easiest to maintain. Fewness of parts calls for less material. What is here said of manufacturing costs applies equally to repair expense; with fewer parts there is less liability for wear, for lost motion, for breakage; there are fewer "extra" pieces to carry in stock, and there is increased time service. The strongest motor is not the heaviest; the most powerful is not the largest.

In conclusion, the electric drive, whether individual or group, from present successful installations, greatly increases the general reliability of the plant.