

ments here except that it has been found by actual measurement that there is little to choose between group and individual driving as far as efficiency is concerned.

POSITIVE POWER.

7. The seventh and last point is the one on which the individual drive has its greatest claim to superiority, and which has done more for the individual drive than anything else. It was soon found that where motors were directly geared to the machine, a greater output was possible on account of the elimination of the slip in the belt, and the consequent driving of the work up to the limit of the cutting tool. This, of course, greatly reduces the time of the operation, and as the cost of the time is two-thirds the total cost of the product, it is easy to see what a saving could be affected. The introduction of the new high-speed steels added still more to the necessity of positive driving, and it has been well demonstrated that where heavy cuts are to be taken, the positively geared motor will show a great saving of time over the belt drive.

THE PLACE FOR BELTS.

Herein, also, lies the solution of the problem so confusing at present to the engineer who is trying to find out just how far he can carry the individual motor drive idea and make it pay. In the case of large tools, it will be seen at once that the solution is plain, and a careful consideration will show that the individual drive can be successfully used down to a point where a belt of convenient size will have no trouble in driving the cutting tool up to its limit. Rules which fix some particular limit to the minimum size of motor to be used, or the minimum size of machine to which a motor should be attached, are very misleading, as it depends entirely on what the tool is intended to do.

At present it will not pay, outside of the advantages of better light and cleaner surroundings, to drive very small tools individually; but the writer believes that cheaper motors and properly designed tools will make the size of tool smaller and smaller till eventually it will be the prevailing system. At present each case must be worked out on its merits along the lines suggested above.

INSTALLING MOTORS.

Having decided what tools to drive individually and what to group-drive, the next question is the matter of motors and the methods of connecting them to the machines. Here, again, a great difference of opinion exists, and conflicting literature has been written. In order to get a clear idea of what is needed in a motor for this work it will be well to look at the requirements of the tools themselves.

CLASSIFYING TOOL REQUIREMENTS.

Machine tools may for this purpose be classified into the following groups: a. Machines requiring a constant speed. The torque may vary with the demand for power. b. Variable speed machines requiring maximum power at minimum speed. In this class are most machine tools where automatic regulation is needed. Here the cutting speeds are practically constant for a given material, but the cuts are larger on the larger work. c. Variable speed tools requiring heavy starting torque, as cranes, etc., where regulation of speed is by hand. d. Machines requiring a torque increasing with the

speed, as blowers and fans which give variable blast. This class is rather unimportant, and will not be discussed.

SPEED-CHANGING DEVICES.

Of course there is no trouble in meeting the requirements of the constant speed machines, but the problem of variable speed is as old as the hills. If a good mechanical speed-changing device were to be had, the problem would be easy to solve. But so far none have been produced that will answer the purpose. Many have been made that will give any speed between the limits of the mechanism, but they all depend on friction, and hence to carry the work required must in most cases be very large and cumbersome; while those that are positive in their action give only special speeds between the limits, and hence are not all that is desired. Of the latter type a number are now on the market which can be used with success in many places.

A. C. OR D. C.

When the electrical side of the problem is considered a choice of two distinct systems of distribution is presented, namely, the alternating-current and the direct-current systems, both of which have a place under proper circumstances in this work.

It may be said at the outset that when the alternating-current system of distribution can be used it is preferable, as the wiring is smaller in a large system, the generators and motors simpler and more reliable. It has, however, its limitations, as will be seen, as far as machine-tool driving is concerned.

The alternating-current system offers two kinds of motors, the synchronous and the induction motor. The first is not self-starting, and, except in a few cases, has no place in machine-tool driving. Where heavy shafts, as test shafts, are to be run for some length of time, and provision can be made for starting, a synchronous motor is an excellent thing in connection with induction motors, as it tends to steady the line and help the power factor. In small sizes, however, it is not suitable for machine-tool driving.

INDUCTION MOTORS.

The induction motor is self-starting, and,

are now on the market controlled in this manner. One plant at least has been fitted out with induction motors, where several changes of speed were obtained by varying the frequency, with fair success. But as yet the induction motor cannot be considered as equal to the direct current motor for variable speed work, though considerable experimental work is now being done that may change the situation.

If the plant under consideration is to contain constant speed machines principally, the induction motor in connection with a mechanical speed changing device will generally prove to be the best, and where all the machinery is of constant speed type it is much preferable. Of course local conditions may affect this as, for instance, when the power is to be brought and only direct current is available.

DIRECT-CURRENT MOTORS.

The direct current system offers three kinds of motors, their combined characteristics covering much more closely the requirements of the case than do those of the alternating motor, and there is little doubt as to the greater adaptability of the system for general machine-tool driving. These motors are: 1. Series-wound motors; 2. Compound-wound motors; 3. Shunt-wound motors.

The series motor is a variable speed motor with great starting torque. It can be controlled throughout its whole range of speed, and would seem at first glance to be almost ideal for lathes and boring mills. It is, however, very uneconomical, as the control is obtained by resistance in its circuit. It also requires an expensive controller on account of the heavy current to be handled, and must be controlled by hand, as its speed varies inversely with the load, and under light loads it will run away. It is an excellent motor for cranes, elevators, etc., and occupies a very important place in the equipment. It therefore covers the requirements of the tools under class c.

The compound-wound motor is suitable where small variations of speed are needed, coupled with a large starting torque. It will, of course, give constant speed when set for any set of conditions within its range.

Class of Machine	A. C. Motors	D. C. Motors
Constant speed torque varying with load	Induction motor	Shunt or compound-wound motor
Variable $\frac{1}{2}$ speed, maximum work at minimum speed, automatic regulation	Synchronous motor	Shunt-wound motor with or without change gears
Variable speed. Heavy starting torque. Hand regulation	Induction motor with mechanical speed changing device	Series-wound motor
Variable speed, torque increasing with speed	Induction motor	Compound-wound motor

Table 1

like the synchronous motor, tends to run at constant speed. It is by its nature not a variable speed machine, although it can be made so in several ways, none of which, however, has so far proved adequate to the demands of the machine tool driving. It has been successfully used on cranes and similar devices, the speed variations being obtained by putting resistance in the secondary, and variable speed induction motors

SHUNT-WOUND MOTORS.

The shunt motor is, in its standard form, a constant speed motor. When set to run at a given speed it will not vary appreciably under varying load up to its capacity. It can be made to vary its speed in a number of ways, those which are most used being one of the following three: By varying the current in the armature; by varying the