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ELECTRIC-DRIVEN ROLLING MILLS

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The first electric-driven steel rolling mill in the United States was installed about four years ago by the Carnegie Steel Company at its Edgar Thomson works. Since then a number of other electric mill drives have been installed and run with entire success, a noteworthy example being found at the steel plant at Gary, Indiana.

The introduction of the electric drive has made it possible to clear up many points in regard to the power required for rolling different shapes of steel, and moreover, the roller, or operator, is able to see at a glance the work done by each pass. The electric roll drive has also taught us how to get the best relation among rotating masses, speed, time, and horse power. It has helped the roll designer to calibrate rolls in such a manner that the power characteristic for all the passes is uniform, thereby avoiding high power peaks, decreasing the size of the prime-mover, and reducing first cost and fuel consumption.

The watt-hour meter warns the roller that bearings or rolls are becoming tight and hot, or that steel is causing excessive friction in the passes, often due to overfilling, cold steel or faulty calibration, thereby guarding against damage to the rolls and bearings. The meter indicates that lower heat, greater elongation, and especially change of profile in different directions, increase the power required at the rolls much more rapidly than do chemical hardness, high tensile strength, or larger draughts. The meter also shows that it is not the higher percentage of carbon in steel which requires more power in rolling but the lower temperatures at which this steel has to be rolled, and also that an increase in width of the steel shape requires more power than a decrease in height. By means of the meter too, it can readily be seen that rolling "squares" and "rounds" takes per square inch displacement much less power than that of shapes with large peripheries and many flanges, as the latter cool off quickly and cause much friction in the rolls.

Tests on rail-mills have shown that the foot-pounds per square inch of displacement gradually increase the nearer the rail is to the finishing pass. A 75-lb. rail required 1100 ft-lb. at the first pass on the first "rougher. On the same stand in the seventh pass it required 3000 ft-lb., in the first pass on the second roughing rolls 4800 ft-lb., in the fifth pass 8150 ft-lb.; 9500 ft-lb. were required for the last or finishing pass. The large increase in foot-pounds is partly due to the greater density and rapid cooling of the steel, especially at the thinner flanges near the finishing pass. For this reason, the flanges are rolled out as late as possible. Whenever required, exact power consumption can be given for each phase of rolling.

The ideal motive power for rolls should drive them slowly when the steel enters and should drive them faster as the piece lengthens. The reciprocating engine will do just the reverse; namely, run very fast without load and slow down as the load increases, finally stopping if the load becomes too great.

The maximum torque of reciprocating engines is fixed by the size of the cylinders and the pressure; it cannot be increased no matter how much steam or gas is available. For this reason most mill engines are made very large and often run with only half load, causing high steam consumption per horse power, their most economical cut-off being at full load.

For this work the characteristics of the electric motor are much better. Even with double its full torque, the efficiency is good and the motor will not stop, but will take more and more current, finally becoming overheated and burning unless properly protected. If desirable, its speed changes from no load to full load can be made small. The current can also be limited to a certain maximum, without stopping the motor. in this manner preventing excessive strains and probably serious breakdowns.

Where high speeds are necessary, motors can be direct connected to rolls, increasing the energy of the rotating parts and at the same time decreasing the size of motor, the power required and the fuel consumption. Heavy reciprocating engines cannot run at such high speeds, and must be connected to the rolls by means of gears, ropes or belts.

To obtain accurate information as to the exact power requirements for rolling steel, indicator diagrams were taken on reciprocating engines doing similar work, but these in many instances were misleading. The work of rolling steel is very changeable and intermittent. Engines often run with light loads, but at short intervals have their valves wide open. This, together with the work done due to the energy of the rotating parts, should be carefully observed. Although it probably is not difficult to get the maximum torque required to decide on the normal capacity of the motor, the above-mentioned points must be considered, together with the length and number of pieces in the rolls, and also time-intervals between passes. To be on the safe side it is advisable to follow standard mill practice and make motors of ample size and strength, in order to stand the severe service and overloads without injury.

In mentioning fly-wheels, the writer had only three high non-reversible mills in mind. As the weight of rotating parts is much greater in large motors than in reciprocating engines, and the energy of the rotating parts increases as the square of the speed, it is obvious that even a small change in speed is of great importance. As tests have shown that rotating masses are sometimes not only of no use but that they often prove a drag on the motor, careful study of this feature has to be made in each case.

While the steel is being rolled, both the motor and the fly-wheel should furnish the power, but as soon as the steel leaves the rolls the motor should accelerate the rotating masses to the same speed before rolling. The time available and the number of revolutions will determine the size of the motor more than anything else.

It has been observed that on blooming and roughing mills, where the pieces are very short and the intervals long, rotating masses supply the largest part of energy during the rolling period and should therefore be large. The reverse takes place at the finishing passes, where pieces are long and follow each other rapidly. Heavy rotating masses would in this case be useless, and would even require larger motors for their quick acceleration.

Where one motor drives roughing and finishing rolls, curves should be plotted showing the number of pieces in the rolls at the same time, the length of passes and intervals, the power required for each pass, etc. With the help of such curves, the best relation between the sizes and speed of the motor and fly-wheel, radius of gyration, and slip of motor can be easily determined.

The total motive power required in a steel plant is changeable and fluctuates continuously, the average in many plants being often below one-fourth of the total horse power installed in motors. The electric-driven rolling mills will, however, demand considerably larger power-stations to take care of the large currents, especially when all the motors happen to be overloaded at one time, as for instance when rolling cold steel. It is very important to find out beforehand how much of this fluctuating load the power house may have to supply, assuming the worst conditions, as the shut-down of the electric power station for even a very short time, will stop the operation of a large number of machines and cause enormous losses. This is the one very objectionable feature of making such a great number of prime movers entirely dependent on one power station, and, therefore, some means should be taken to prevent this disturbance.

With steam engines and boilers the liability of a complete shutdown is not so great, but the delays and annnoyances caused by low steam-pressure are of daily occurrence in many plants. In such cases not only will all the steam-driven prime movers be unable to develop the required power, but also in trying to develop this power, they will use more and more steam, thus making it difficult to raise the steam pressure without increasing the number of boilers, or decreasing for a while the load and consequently the production.

The short, high-peaked current demands should be kept off the power station as much as possible and only the average current be supplied. The least number of units can then be kept running under nearly full load with the most economical fuel consumption and the least wear and tear of moving parts. As before mentioned, the average current consumption in a steel plant is always small in comparison with motor capacity, on account of the intermittent work and large amount of inertia of the rotating parts. By means of storage-batteries or fly-wheel sub-stations the occasional large demands for current can be taken off the station and supplied from these two sources, where it is stored up when the current demand is below the average.

The exchange of current from one motor to another, in connection with electric roll-drives, is often considerable and should not be overlooked.

With regard to the electric reversing mill, it is a fact that soon after its first appearance the use of reversing rolls became more general, especially in England and Germany. In those countries, small quantities of one kind and shape of material are rolled, and the cost of the large number of rolls required and the saving of time in changing rolls are probably the chief reasons for using the reversing mill, where many different sections can be worked with the same rolls. The absence of the heavy and troublesome lifting tables is also a welcome feature, especially when pieces rolled are very long.

The first installation in this country of an electric reversing mill, at the Illinois Steel Company's works at South Chicago, has given entire satisfaction from the start, and has demonstrated that the electric motor is much better adapted for this kind of work than the reciprocating engine. Although the first cost was high, its lower depreciation, better operation and lower cost of maintenance should justify its installation.

In a reversing mill the operator is able to draw steel slowly into the rolls and " speed up " while the piece lengthens, making a great advantage in rolling steel. In order to obtain perfect speed regulation, no use can be made of steam expansion, but admission continues during nearly full stroke. Even then much depends on the skill of the operator, who can subject the engine and the mill to very severe shocks and cause serious breakdowns if he is not careful. Reversing mills are therefore made heavy and strong.

If too much steam is admitted, it is difficult to prevent such large engines from racing without load. It is also wasteful, as both the time of actual rolling and the speed of the rolls are limited, most of the power being consumed in the rapid starting and stopping of the heavy rotating parts, without making any use of their fly-wheel energy.

With the use of electric motors in place of reciprocating engines, the problem of reversing rolls becomes much simpler and better, in regard to manipulation, fuel consumption, and cost of maintenance. Operation of electric-driven reversing mills is nearly automatic; no skilled operator is required and all danger to the motor and the mill is eliminated. The speed of acceleration is prearranged, and no matter how fast the operator moves his levers, the maximum current and the speed are limited.

Reversing is done with the least shocks in rolls and couplings and the danger of overstraining machinery is done away with. It is important to be able to reverse the motor just as rapidly as the engine. Special care should therefore be taken to have a motor-generator that will give large currents with very low excitation, and one that will be quickly magnetized and demagnetized.

It has been observed that only one-fourth of the power required at the reversing-roll motor is the average supplied from the power station. The large current demands are furnished by the motor-generator through the energy of the high-speed fly-wheel, and a considerable amount of current is sometimes sent back into the line.

As for all other mill work where power and speed variation are considerable, the direct-current motor, on account of its load and speed characteristics, is better adapted for driving rolls than the alternating-current motor. For reversible roll drives it is used exclusively.

There is no reason why the direct-current motor should give any more trouble than the direct-current generator at the power station. Four years' experience has shown that the wear of the commutator and the cost of maintenance amount to practically nothing. The transmission of large low-tension currents is much more serious, especially when tens of thousands of horsepower have to be supplied and the distance of the motors from the station is considerable.

The use of higher direct-current voltages in connection with large rolling mill motors should be satisfactory; but no doubt high-tension alternating-current transmission and induction motors direct on the line will be generally employed, especially in new installations. Where conditions demand it, the induction motor characteristics can now be made nearly similar to those of the compound-wound, direct-current motor. However, much of its simplicity and efficiency will be sacrificed in doing this.

Among some of the earlier disadvantages of the induction motor were: very large current required for starting under heavy load; one speed fixed by the number of poles and the tendency always to run at synchronous speed; low power-factor with light loads; small air gaps; impracticability of reversing large units; and inability to change speed to fly-wheel requirements.

In the design of the modern rolling-mill motor, most of these objectionable points have been remedied by different means such as wound rotors, the introduction of variable resistance, changing the number of poles, shifting the phases, slip-rings, etc.

Whether direct-current power stations and direct-current motors are used, or alternating-current stations are installed for high-tension transmission with alternating-current motors directly on the line or fed through transformers, or direct-current motors are supplied from an alternating-current station through converters, or motor-generators, batteries or fly-wheel substations, is a matter of detail. No doubt any one of these systems will give satisfaction if properly designed and installed.