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The American Machine Shop.

A thorough and exhaustive treatment of this subject in all its details would require a work of several volumes. It can not be expected then, that in a paper of a few thousand words more than a rapid sketch covering the main features of the general machine shop and a few words upon some of the special machines can be given.

Modern Machine shop practice shows fully as well as any other field the wonderful development of the nineteenth century in industrial life. Machines that were up to date ten years ago are obsolete now. The machinist of all men must be ever on the alert for all the new devices for reducing labor cost of his product, or else find himself undersold by his more enterprising neighbor. The tendency of the present is toward the developement of special machines - machines designed to do a special kind of work and to do that work with a precision and rapidity far surpassing the ordinary work of planer lathe and vice. One exception to this is the milling machine. The thousands of ways in which it may be applied to the making of small parts of form other than plane and cylindrical outline make it one of the most important machines of the modern shop.

Every tool for cutting metal into the shape desired uses the primary principle of the wedge. Before the days of modern machinery the wedge consisted of a cold chisell driven into the work by a hammer and the good right arm of the workman or the fine teeth of a file drawn repeatedly over the surface. A step in advance of this was to fasten the ~~work~~ wedge firmly and rotate the work, the point of the tool turning off the metal very much as the coulter of a plow turns the soil. From this has developed the modern lathe. Its work is limited to cylindrical or at most elliptical surfaces. To work down a plane surface it was only necessary that the tool be fastened firmly as before, and the work traversed by it in parallel lines, the tool turning off its furrow of metal at every forward movement of the traversing table. This is the principle of the modern planer. The next great advance is the use of a rotating cutter, bringing into action many cutting edges successively as the work is traversed. From this has developed the modern milling machine. Last but not least is that the cutting shall be done by the innumerable fine points of the grains of an emery wheel, revolved at high speed and properly presented to the work. All the many kinds of grinding machines that are very recently being introduced into the general machine shop employ this principle. In all these forms the cutting edge is forced between the particles ~~w~~edging them off. All the complications of shafting, belting, pulley, gearing, and frame-work are but the means of accomplishing this end.

The lathe is the most important of all metal cutting machines. Not only because it keeps the cutting tool in operation continuously, but because of the great variety of duty it will perform to advantage. The general operations of turning, drilling, boring, and reaming are done on many kinds of work. The lathe is the form from which the planer, shaper, and boring machines have been developed. Lathes were in use as early as 1680 but their real importance began with the invention of the slide rest by Maudslay in 1794. Concerning the importance of the slide rest as one of the factors of machine development Jas. Nysmith, inventor of the steam hammer, says: "It is not saying to much to state that its influence in improving machin-ery has been as great as that produced by the development of the steam engine." It is one of the fundamental features of all metal cutting machinery. By means of it, movement in two directions are given to the cutting tool of the lathe, the planer and the shaper. Upon it depends the traversing of the work in the planer and the milling machine. In fact it is universally employed in metal cutting machinery.

Lathes are of many kinds, but the important one of the shops and the one which combines the various types is the engine lathe. Power is communicated to it from an over head cone pulley, connecting with the main line shaft, to a similar cone pulley on the lathe head. These cone pulleys give as many changes of speed as there are steps on the cone. The lathe head pulley turns what is known as the live spindle. Back gears are so arranged that by unclamping the cone pulley from this spindle it is made to communicate with it again at a reduced rate, thus giving double the number of changes of speed. The work is fastened between centres on the head and tail stock, the line connecting these centres becoming the axis of the work to be turned. The tail stock traverses the lathe bed on V-shaped rails and may be clamped at any point length of work requires. The cutting tool is carried back and forth between the head and tail stock by means of a slide rest on rails parallel to the line of work. It is traversed at right angles to this, enabling the tool to be set at any required depth.

Screws are cut by means of a lead screw. The slide rest is clamped to the lead screw by means of a sectional nut, and carries a thread-cutting tool. The number of threads per inch to be cut is obtained by two gear wheels, the ratio of the number of teeth in one, to that in the other giving the desired relation between the longitudinal feed of the tool and the rotation of the work. For example: suppose it is required to cut eighteen threads per inch and the lead screw has six threads per inch. A gear wheel having 72 teeth would be put on the end of the lead screw and one having 24 teeth on a spindle having the same rate of rotation as the work. For every three revolutions of the work, the lead screw would revolve once. Six revolutions of the lead screw would carry the tool through one inch and the work would have revolved 6 x 3 = 18 times.

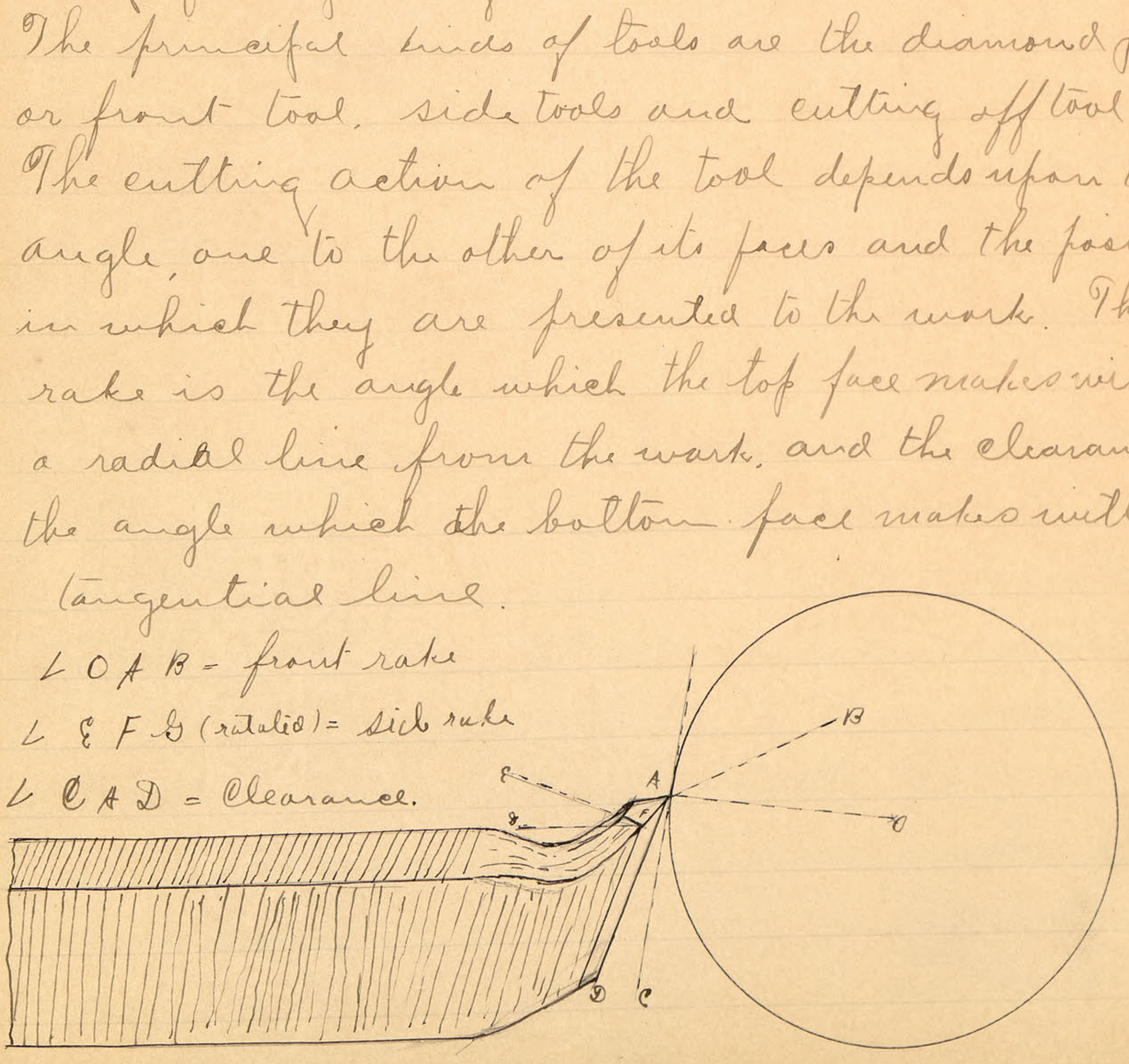
Taper work is done in the lathe by two methods. One, by setting over the tail stock moving the work either to or from the cutting tool and giving it eith a less or greater diameter at that end, respectively. The other method is by means of a taper attachment which draws the tool either into or out of the work, as it is traversed.

The cutting tools for a lathe are made of a very fine grade of cast steel termed "tool steel." The principal kinds of tools are the diamond point or front tool, side tools and cutting off tool. The cutting action of the tool depends upon the angle, one to the other of its faces and the position in which they are presented to the work. The rake is the angle which the top face makes with a radial line from the work, and the clearance the angle which the bottom face makes with a tangential line.

∠ O A B = front rake

∠ E F G (rotated) = side rake

∠ C A D = Clearance.



Pressure of the work falls upon the top face and has a tendency to spring the tool into the work. As soon as the tool is given a side motion a second stress appears and the cutting action is altered. Tools for traversing should be given a side rake also. Roughing out tools are frequently all side rake, but in work where it is desired to leave the surface as smooth as possible a minimum of side rake is given. Keenness of the cutting edge is almost wholly dependent upon the rake while the strength of the tool depends upon the amount of clearance. Very soft metals (except brass) require a maximum rake, and the rake diminishes with the hardness of the metal.

A special form of the lathe is the screw-machine. In this the live spindle is made hollow and the work is passed through it and held in a chuck. In place of the ordinary tail stock is a slide rest upon which is mounted a turret, containing seven holes for inserting tools. This turret is rotated automatically through one-seventh of its circumference at every return motion of the slide bringing the next tool in line with the work for the next operation. After the tools are once set, seven operations can be given the work without changing a tool. Besides this the ordinary side tool can be used for cutting off, etc.

Important as the lathe is in machine shop equipment, a revolution was effected by the introduction of planers. When these were introduced in 1825 they were mobbed and broken by the workmen thrown out of employment. The immense amount of work necessary to secure plane surfaces by means of the chisel and file had given employment to thousands who were now thrown out. Planers are comparatively simple in their construction, the essential features being given above under principles of cutting tools. A table rests on V-shaped groves, and is T-slotted ~~for bolting~~ to receive bolts for bolting down the work. This table is traversed by means of a rack underneath driven by a worm gear (in latest forms). Reciprocating motion is given by an automatic shifting of ~~pulleys~~ two belts on three pulleys. The belts run in opposite directions and are alternately shifted to the middle pulley which drives the rack. A recent improvement is in the high return speeds, these being in some instances as high as eight to one. The cutting tool is suspended above the work by a cross rail between the vertical frame work. It is traversed from side to side by a feed screw and is given a vertical feed by a second feed screw in the planer head which carries the tool. A ratchet is provided on the sides of the frame for elevating the cross rail. Planers are not so universally used now since the advent of the milling machine and special machines for slotting, key way seating, etc.

The milling machine is at once the most complicated, and - in piece work - the easiest of operation of all machines in the general machine shop. Nine-tenths of the milling machines used, however, are employed on job work, and this requires great skill in the operator. For duplicating of parts as in piece work most of its operations may be automatic, requiring only the services of a comparatively unskilled attendant.

The advantages of the milling machine lie in its capacity to do work as true as the wear of cutting edges will permit, in the number of cutting edges that may be employed in a single tool, and in its adaptability to a very wide range of work. The essential features are as follows: a vertical frame-work supports at its upper end an arbor or overhanging arm, and also a cone pulley with its live spindle as in the lathe. Between centres on the arbor and live spindle is supported the rotating cutter. To the side of the frame work is attached a slide rest termed the knee. On the knee is a slide rest which may be traversed in line with the centres of the milling cutter. On this slide is a plate which may be rotated, carrying with it the table. The table has a longitudinal traverse provided with suitable automatic feed arrangements and stops. The work is held between centres on a head and tail stock, or clamped in a vice bolted ~~to it~~ on the table. Bearing in mind then that the work may be elevated to any desired height by the knee, given a transverse movement by the slide rest on top of it, rotated at any angle to the milling cutter by means of the graduated plate, given a longitudinal traverse by the table, ~~and~~ rotated ~~upon~~ the centres of the head and tail stock bolted upon it, that the milling cutter may be of such a shape as to leave almost any shape of cut desired, and the dizzying possibilities of the milling machine will begin to appear.

Milling machines are now largely used in the manufacture of light machinery. Through their use it is now possible to make a sewing machine at a labor cost of from \$5.00 to \$10.00. A workman at lathe and bench could not make it for \$200.00. Few have been built as yet for heavy work but that they will ultimately largely displace the planer there is little reason to doubt. The Ingersoll Milling Machine Co. make one now that takes a 30" cut with a feed of 4" per minute. Such a rate far exceeds the work of the fastest planer.

Grinding machines are coming to be largely used in American practice. Their chief advantages lie in the finishing of work after it is tempered thus obviating the difficulty of warping, and in the delicate accuracy that may be obtained with them. Fits to one-ten thousandth of an inch are obtained in common practice. They are built mostly for special work, the tool grinder having a wider range than any other. Browne and Sharpe build one for surface grinding which finishes surfaces far smoother than any planer tool could do it. Wm Sellers & Co. build one especially for drill grinding.

Emery wheels for grinding machines are made by crushing and grinding corundum till the particles are of the desired fineness, and then cementing them together into a solid wheel. A distinctive feature is the character of the cement. It must bind the particles together with sufficient strength to resist the centrifugal force. It must neither soften by heat nor become brittle by cold. It must wear away as fast as the emery. It must mix uniformly with the emery so that the wheel may be of uniform strength, texture, and density. It must not combine with the cuttings to form a glaze over the wheel. The search for a cement possessing these qualities has led to much scientific investigation which is still in progress. Emery wheels are run at very high speeds, as high as 5000 or even 6000 circumferential feet per minute. The fineness of the cutting teeth and this high speed enables a rapid removal of metal without the spring of the work incident to the use of a cutting tool.

Gear cutting machines have reached a high state of development within recent years.

The automatic gear cutter needs only that the man fix the work and start the machine and it does the rest. They are somewhat complicated machines that have greatly reduced the cost of gear cutting.

A recent element for the cheapening of work has been in the introduction of hoisting machinery, quick acting cranes, electric traveling cranes etc. The use of electrical aparatus is steadily increasing in the machine shop. A radical change to be expected in the future is the independent driving of machines by small motors, replacing the elaborate system of belting and shafting that we now have. The saving in power and noise, the increased light and other conveniences are quite appreciable factors.

American machine manufacture is rapidly taking a formost place in the world. American machinery is now sold in large quantities even in Great Britain itself. The endless ingenuity that has constructed so many special machines, and the distinctively American practice of so arranging machines that one man can tend several, makes the American product cheaper despite the higher cost of labor. American machinery is coming to be a successful competitor in the South American countries. It is every where favorably regarded as to excellence of quality and construction although there are poor machines as there must ever be so long as there is a demand for them.

In the manufacture of machinery as well as in other lines America will come out ahead.