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Machine Tools

"**MACHINE TOOLS** 27.21). - The decade 1910-20 saw a noteworthy development in every branch of machine-tool engineering. In no branch was the progress more marked than in instruments for precise measurements. These include types employing both physical and optical means. Their perfection has made possible the production of interchangeable parts in commercial quantities. Without means of accurate gauging the making of cheap automobiles in great numbers would be impossible. This is also true of rifles, typewriters, sewing-machines and hundreds of other things made and used daily in great numbers. For accuracy and almost universal application, the gauge blocks shown on Plate I., fig. 1, made by C. E. Johansson, Eskilstuna, Sweden, stand high. The first combination set on his system was made in 1897, but not until 1911 was Johansson able to produce them in commercial quantities of a guaranteed quality. Subsequently these blocks became so recognized as standard that there is hardly a manufacturing plant in the world doing accurate or interchangeable metal work that has not one or more sets for reference purposes or actual use. They are also in constant use at the National Physical Laboratory, London; the National Bureau of Standards, Washington; the Bureau International des Poids et Mesures, Paris, and similar institutions of all the principal nations.

A full set consists of 81 blocks with surfaces flat and parallel within one hundred-thousandth of an inch. A standard set is made up of four series. The first series consists of nine blocks, the first o

Iooi in. wide, increasing by o

000t in. each to the ninth, 0.1009 in. wide. The second series consists of 49 blocks, the first o

IoI in. wide, increasing by o

ooi in. each to the 49th, 0.149 in. wide. The third series consists of 19 blocks from 0.050 in. to 0.950 in. wide, each increasing by 0.050 in. The fourth series consists of four blocks I, *2,* 3 and 4 in. wide respectively. These blocks may be stacked or" wrung "together to form an enormous number of very accurate" blocks "practically equal to a similar solid block. For instance, the blocks of the fourth series can be combined to give any size in even inches from one to ten. The blocks of the third series can be combined with those of the fourth so as to give any even multiple of 0.050 between o-050 and 10 in. The second series furnishes means of stacking the gauges to obtain dimensions varying by thousandths, and the first series gives variations by ten-thousandths of an inch. One stack of all the blocks wrung together gives accurate results.

That these blocks are held together by far more than atmospheric pressure is proved by a demonstration given Nov. to 1917 before the Stockholm Technical Institute. Two blocks were wrung together. The sizes of the two surfaces in contact were 0.49 sq. in. and they sustained a weight of 220 lb. The atmospheric pressure contributed about 6.6 lb., from which it will be seen that the adhesive power of the blocks was more than 30 times atmospheric pressure. In spite of this extraordinary adhesive power the blocks are easily separated by a simple sliding movement, and they are as easily" wrung "together in the same way if the surfaces are first wiped with the hand. The great advantage given by these blocks is that they furnish a practically universal standard of gauging, since parts, gauges, templets or tools, made in England and checked with reference to them, will check the same with a set in America, France or Japan. The composition of these gauging blocks is such that they are long-wearing and little affected by ordinary changes in temperature.

A gauge known as the Prestwich fluid micrometer is shown on Plate I., fig. 2. This is the invention of John Alfred Prestwich, of the English firm of John A. Prestwich & Co., Ltd. It was originally developed about 1910 for use in his own works, but later was put on the market.

The gauge is shown with a piston ring between the gauging points. The lower gauging point, or" anvil,"is a stationary block of hard steel set into the base of the instrument. The movable gauging point is set directly above the anvil and is attached to the lower side of a thin, springy diaphragm of metal which forms the bottom of a fluid container about 2} or 3 in. in diameter, and about; in. thick. A small glass tube leads upward from this container and a coloured liquid is put into the container and extends part way up into the glass tube. Pressure on the movable gauging point presses the diaphragm upward and causes the coloured liquid to rise higher in the glass tube, where it is plainly visible. A graduated scale at one side of the tube shows the amount of upward movement, and pointers at the left of the scale may be set to show the limits for various kinds of work. Owing to the size of the diaphragm and the small hole in the tube, any movement of the gauging point is greatly multiplied by the liquid in the tube, and in some of the instruments a variation of one thousandth of an inch between the gauging points will cause a difference of half an inch in the height of the liquid in the glass tube. This instrument is especially valuable for quickly inspecting machine products, as any variation is instantly visible.

During the World War considerable difficulty was experienced in finding a satisfactory method of quickly inspecting screw threads for size, shape and lead. This was solved in 1916 by the National Physical Laboratory in England, under the direction of Sir R. T. Glazebrook, by means of a projection lantern. The general principle of this lantern is along the lines of the stereopticon or the motion-picture machine, as the threaded (screwed) piece to be inspected is placed in the path of a powerful beam of light which projects a greatly enlarged image of the object upon a screen. An accurate drawing of the screw is previously imprinted on the screen, and the faithfulness with which the projected image conforms to the lines of the drawing instantly determines the accuracy or inaccuracy of the screw or any part of it. Building on this original idea, a number of concerns have placed on the market" comparators,"projectoscopes," projection lanterns "and similar instruments under various names.

A measuring machine sufficiently accurate for all ordinary shop purposes is illustrated on Plate fig. 3. It consists of a bed with a sliding work-table and a microscope mounted on a compound slide. The latter is furnished with a large dial micrometer reading to o 000r in. In addition the microscope is fitted with two hair-lines, one rotating with the eyepiece and one with the outside tube. This is fitted with a dial reading to half degrees, while the eyepiece carries a vernier reading to one minute.

The accuracy of measurements depends upon standard rods inserted between blocks at the left-hand end, one block being on the bed and the other on the work-table. The work-table is provided with centres, one of which has cross adjustment for alignment. The method of using this machine will be evident in the case of limit gauges and the like, having plain length measurements, since the selection of suitable measuring rods, the setting of the hair-lines and the reading of the traversing micrometers present no difficulties. With little additional trouble the machine may be used for contour work, while the two hair-lines enable the operator to measure the pitch and angle of screw threads as well as the depth. The table will accommodate work 12 in. long and up to 3 in. in diameter. A lamp and mirror are set as shown in the illustration to give clear projection.

For testing the flatness of a lapped steel surface of a gauge, or other polished surface, the U.S. Bureau of Standards has developed a tool known as the" optical flat."This consists of a polished piece of flat, clear glass, one surface of which is very accurately flat. The principle is, that if a piece of clear glass with an optically flat surface is laid on another more or less flat surface, and is illumined by monochromatic light, dark and light bands will be observed on the lower surface. If these bands are parallel and equally spaced the surface under inspection is flat. If the bands are curved, then the surface below the glass is curved, the reason being that a difference in the thickness of the film of air between the adjacent surfaces causes a variation in the direction and spacing of the light bands. By observing certain conditions of light and position, flatness to within one millionth of an inch may be plainly observed with the naked eye.

The diagrams shown on Plate I. fig. 4, indicate how light bands, or" interference fringes,"look when an optical flat is laid on surfaces of different degrees of flatness. The optical flat may be used for comparing the height of two pieces laid side by side. If one is higher than the other the arrangement of the light bands will instantly indicate it. Curved surfaces may also be as easily inspected and the amount of error estimated. Complete apparatus for accurately measuring with optical flats is made by H. L. Van Keuren, Boston, Mass.

Among recent developments in the small-tool field, those of importance in lathe and planer cutting tools have been slight, apart from the research work of the late Frederick Taylor, of Philadelphia, and the advances in steel making and treating which make the tools more durable. Taylor spent many years and much money investigating the proper shape, clearance and cutting angles for lathe and planer tools. He also designed and built for the market a machine for grinding these tools according to the shapes outlined in his charts. He also did a share of the work in evolving the Taylor-White process of hardening highspeed steel, which made possible higher speeds and heavier cuts than had previously been imagined. This discovery profoundly affected machine design as well as production methods, since it compelled the building of heavier, speedier and more powerful machine tools to meet the severe demands placed upon them by properly hardened high-speed steel. Except for this strengthening, standard lathes, planers and shapers have really advanced but little. One feature, however, may be noted, and that is the increasing use of air-operated chucks on turret lathes (monitors) and chucking-machines.

An unusual type of single-purpose lathe was designed by Lucien I. Yeomans, of the Amalgamated Machinery Co., Chicago, for which he was awarded a medal by the Franklin Institute of Philadelphia. This type of lathe was intended for making large shell of from 6 to 16 in. in diameter. The head-stock and body of the lathe were cast in one solid piece, with holes cored out for the spindle and ways. The ways were merely accurately ground lengths of round steel shafting so placed that the ends projected through the cored holes in the bed. They were properly located by means of huge master jigs, and then type-metal was poured into the cored holes and around the ends of the shafting. This held them securely in place. The carriage and cross-slide guides were made and located in the same general way. The lathe spindle turned in a machined bushing which was set into the cored hole in the head and secured with type-metal. This method of construction saved an immense amount of machining, as there was no work put into its construction except such as could be turned or bored. The makers were enabled to turn out a large number of machines in an astonishingly short time, and they agreed to furnish any order for such machines at the rate of to % per day, beginning with the confirmation of the order. The American Car and Foundry Co. had 173 of these machines in one battery making shell, and other large installations were placed. A number of large gun-boring lathes were also made on the same plan, but the close of the World War put an end to this work, as the machines were not suited to other purposes. A wartime machine designed and built by Yeomans was a" concrete planer "with a 93-ft. table and 185-ft. bed, used for guncarriage work. All of the heavy parts, including the bed, table and housings, were made of reinforced concrete with inserted metal ways and facings. Five of these machines were made for Government war work. At the time the Armistice was signed the bed for a planer 500 ft. long had actually been almost completed.

Closely allied to the lathes are the machines of the vertical boring-mill type. Most of these are well known, but modern manufacturing methods have induced the design of certain advanced types, such as the duplex boring-mills made by two English houses, Webster & Bennett, Ltd., of Coventry, and G. Wilkinson & Sons, of Keighley (see Plate I., fig. 5).

Rapid production has also been responsible for what is known as the vertical" station-type "of machine. These machines are an outgrowth of the vertical boring-mill or" vertical turret lathe."A typical example is the *Mult-Au-Matic" (Plate I., fig. 6) made by the Bullard Machine Tool Co., Bridgeport, Conn. In this machine there are six "stations" or chucks, though other holding devices may be used. The chucks are mounted on a table which "indexes" or makes s of a revolution at set periods, bringing the work under different tools each time. Each chuck revolves or remains stationary on its own centre, making it possible to do drilling, boring, facing, turning and other work either simultaneously or successively. One station is used for the insertion and removal of the work, and after the chucks have once been filled all round, a piece of work is removed and another inserted at each indexing of the table. This machine is mechanically operated throughout; but a similar machine, in which all the feeding and indexing movements are hydraulically operated, is made by Giddings & Lewis, Fond du Lac, Wis.*

Drilling-machines of the station type are also made by several concerns. One made by the Cincinnati Automatic Machine Co., Cincinnati, Ohio, is shown in Plate II., fig. 7. Both of these types were foreshadowed by the five-spindle automatic screw machines made by the National Acme Co., Cleveland, O., whose machines have been on the market for over 25 years. The general principle is the same, the main difference, as in the case of the lathe and the boring-mill, being that one is horizontal and the other vertical, the latter being of much later date in each case.

Apart from the station-type drilling-machines, others now in common use include those of the "gang" and the "multiple spindle" types. The gang types consist mainly of several individual drilling-machines of a like size bolted side by side, or mounted on a single base. The multiple spindle type may have a considerable number of spindles mounted on a single head, the spindles being run by worms, gears or universal joints.

Gear-driven spindles lend themselves well to mounting in heads which may be used in the spindle of ordinary single-spindle drillingmachines. Holes of varied arrangement or "pattern" may be simultaneously and quickly drilled in this way. The worm-driven spindles are more conveniently used if mounted on a cross-rail, making it possible to drill a large number of holes in a straight line, although the spacing between the various holes may be varied. The universal joint-driven spindles (Plate II., fig. 8) furnish the most flexible means of arrangement of all, as they may be set to conform to almost any arrangement or pattern of holes. The National Automatic Machine Co., Richmond, Ind., and the Foote-Burt Co., Cleveland, 0., have made many machines drilling up to too or more holes at once. Some of their machines feed a large number of drills in from several angles at once. For instance, one model simultaneously drills from 5 to 20 holes in each of five sides of a cast-iron box.

Milling-machines form attractive subjects for tool designers, and new forms are constantly being evolved. The more modern forms include the continuous milling-machines, which are of two principal types, the rotary and the reciprocating.

The reciprocating machine is simply a modification of the regular type of milling-machine. It carries fixtures for holding the work at opposite ends of the table. While the cutters are acting on the work at one end of the table the fixtures at the other end are being emptied and reloaded. The feed of the table is reversed as soon as the work is milled, and the cutters immediately begin to cut on the work in the other fixture. The operator then steps to the other end of the table, removes the finished work and reloads the fixture, and so on.

The rotary continuous milling-machines may be of the horizontaltable-vertical-spindle, or the vertical-table-horizontal-spindle, type. On Plate II. are shown examples of the former, the more common (fig. 9), another form, with work-holding fixtures in place (fig. to), and of the vertical-table, or "drum type" (fig. I I). In all of these shown in the last three cuts the table moves continuously, the work being removed or inserted while in motion. A machine built on a slightly different plan is shown on Plate III., fig. 12. In this the table is tilted and the motion is not continuous. The table movement more closely resembles that of a station-type machine in that it indexes and remains stationary as the cutter is fed to the work by the sliding spindle head. Milling-machines of the planer type shown on Plate III., fig. 13, are made in a variety of forms, largely for automobile work. They may carry from one to a dozen cutters placed on spindles at various angles. In some cases the tables are made to reciprocate and one end of the table may be emptied and reloaded while the cutters are at work at the other end, after the manner of the lighter types previously referred to.

A highly developed type of milling-machine is shown on Plate III., fig. 14. This is an automatic profiling-machine designed for the sinking of forging dies and the like. In the illustration a model or master-die is shown below and a finished forging die above. Any number of dies may be made from the same pattern and they will be all alike. A "finger" is automatically fed over the surfaces of the model and as it moves a revolving cutter cuts corresponding depressions in the die block above. After the die is cut it must be smoothed by hand, as the milling cutter leaves a rather rough surface.

In grinding-machines there are several models made with rotary tables, like those of the continuous milling-machines. Magnetic chucks are largely used on this type, as well as on others of the reciprocating-table and the horizontal-table types.

One of the principal developments has been the use of grinding wheels, which are fed straight in to the work. These wheels are wide enough to finish the surface desired, and the face is formed to conform to the contour of the finished work. This shape of the grinding wheel is obtained by means of a master form and diamond truing tool. A form of machine, known as the "centreless grinder," makes use of a wide-faced wheel, the face of which is dressed bevel. Small steel pins or rods fed across the face of this wheel by means of a grooved guide are automatically ground to size without the necessity of having centre holes drilled in them, as is necessary with the usual type of cylindrical grinder.

Broaching-machines are largely a development of the automotive industry. The La Pointes in the United States and Alfred Herbert in England have built most of the machines of this kind.

A broach is a tool having a number of saw-like teeth so made that they will finish or machine a hole or surface when moved through or over it. As a rule, the teeth of a broach are made to increase a thousandth of an inch or more in size until the last few, or finishing teeth, are reached. These last teeth merely scrape so as to properly size the work. A very common use for broaches is in the production of keyways in gears or wheels. With a properly made broach a keyway may be finished at one pass with no danger of spoiled work. Broaches are either pushed through the work by means of a press or are pulled through by means of a special machine, such as shown on Plate III., fig. 15.

In the example shown the broach is used to finish the inside corner of a type-chase, but almost any form of hole may be broached. In many cases round broaches take the place of reamers for finishing round holes. A round hole may be squared at one pass, or it may be as easily made into a hexagon, splined or irregular shape. In the special machines the broach is pulled through the work by means of a screw in a majority of cases, though some machines are made with a rack-and-pinion movement instead of a lead screw.

Swaging-machines for the cold hammering down of bars or rods are made by the Langelier Manufacturing Co., Providence, R.I. One such is shown on Plate III., fig. 16. A small rod is shown held in a sliding holder. As this rod is pushed into the head of the machine it is hit on opposite sides by hammers operating at a high rate of speed. The rod will be reduced to a point, or to a smaller diameter, according to the shape of the ends of the hammer-heads. Round parts or reduced sections are easily produced almost instantly. A familiar example of swaging can be seen in the reduced sections of bicycle or wire automobile spokes. Sewing-machine needles and other similar work are also reduced in machines of this type.

(E. VI.)

Bibliography Information
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