not more than *three* times the thickness of the specimen.

Rivets are to be of the best quality of iron, and so ductile that a bar of the diameter of the largest rivet used will bend close through one hundred and eighty degrees without sign of fracture.

*Test of structure.*—On the completion of the entire structure, any bridge, after being in constant use for one day, may be tested by a load equal to that for which it was designed, remaining upon it for at least one hour, without showing any permanent set.

## ON SOME MODERN SYSTEMS OF CUTTING METALS.*

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In this paper it is proposed to treat of some of the processes of Cutting Metals which the writer has adopted since he read a paper on Tool-holders before the Institution (Proceedings, 1866, p. 288). The success of the round tool-holders then described has led to the further adoption of mechanical means of making and maintaining the tools used in various machines for cutting and finishing metals in their cold state. Such machines are commonly known by the term "machine tools;" and comprise lathes, planing, shaping, and slotting machines, milling machines, drilling and boring machines, screwing and chasing machines, etc.

### Tool-Holders and Cutters.

The former paper mainly described what have since become known as right and left-hand round tool-holders. They are used in different machine tools principally for "roughing out," or, in other words, for rapidly reducing castings, forgings, etc., from their rough state to nearly their finished forms and dimensions. The tool-holders are called round from their cutters being made of round steel cut from the bar. Notwithstanding that they are very widely applicable, take heavy cuts, and do the bulk of all machine-work in lathes, and in planing, shaping, and slotting machines, it was soon found that they could not compass the whole of the work required in the shops; and it was therefore necessary still to allow the use of some of the common forged tools in conjunction with the round tool-holders. This however was objectionable, as no positive rule could then be laid down to define what number of forged tools should be allowed to each workman; and it became apparent that the tool-holder system, in order to reach the highest degree of efficiency, must be made complete and independent in itself. This led to the designing of another tool-holder of the most general kind the writer could devise, in the hope thereby to complete the system.

With this object in view, all the remaining forged tools then in use were collected together, and the swivel tool-holder was schemed. Figs. 1 to 3, page 264; with cutters so adjustable that they could not only be swivelled round and then fixed to any desired angle, but could also be made to project at pleasure to any required distance in order to reach and cut into all sorts of difficult and awkward corners; in fact to machine any work which the round tool-holder could not finish. Two of the principal objects aimed at were to devise a system of cutters which should not require any forging or smithing, and should yet be capable of being adapted by the simplest possible means, and by grinding the ends only, to all forms which the round cutters would not meet. The special section of steel decided upon was a sort of deep V section the lower part of which is slightly rounded, as shown in Fig. 4. The angles of the sides give the same amount of clearance (1 to 8) as that given in the round tool-holders, and this same angle of clearance is given to the ground parts. The section of the swivel cutter is made very deep, in order to obtain ample strength in the direction of the pressure it has to support when cutting, as shown by the arrows, Figs. 1 and 4. The angle of the cutter, as in Fig 21, page 268 is 68°, and is common to every swivel tool-holder. In the cutter for the round tool-holder two angles had been fixed upon as standards, one to cut all kinds of wrought metals, the others all cast metals. To avoid complication however, in the swivel toolholders one cutting angle was fixed upon for all metals, and applied to all cutters. The angle selected, or 68°, is one differing slightly from that of the round cutters, but is that which worked out the best in practice. The cutters of the round tool-holders are found very advantageous in producing and finishing standard-size round corners in journals of shafts, etc., and in other cases, where the engineer of the present day is anxious to preserve all the strength possible in the parts; but there are still cases where square, angular, or undercut surfaces must be produced, as illustrated in Figs. 5-11, page 264. These are front views showing the tool-holders at work planing or shaping. They are supposed to be travelling forward, or the work to be moving in the opposite direction; and the arrows in each view indicate the direction in which the tool-holder is being fed at each stroke of the machine, to take the next cut.

Fig. 5, page 264, shows the mode of planing the under horizontal surface of a lathe bed. The cutter shown in use is ground to an angle of 86°, or 4° less than a right angle, and thus has a clearance of 2° at each side when cutting either horizontally or vertically. This cutter is very general in its applicability, and is devised so as to finish with one setting both the vertical surface A, and the horizontal surface H, without the necessity for disturbing the cutter in any way. The ordinary system is to use at least two tools for roughing out, and two for finishing, on two surfaces at right angles with each other.

Fig. 6, page 264, shows the method of planing in a very limited space the under horizontal surface S; the corresponding surface B is planed afterwards, without disturbing the tool-holder in the tool-box, by simply slacking the nut, swivelling the bolt N halfway round, replacing the cutter with one of the opposite hand, and again securing it by the nut.

Fig. 7, page 264, shows a swivel tool-holder clearing without difficulty a boss which projects and would be very much in the way of any ordinary tool. The cutter in this case planes not only the horizontal surface C, but the inclined surface V also, with one setting and without being being disturbed in the tool-box.

Fig. 8, page 264, shows the method of cutting a vertical slot in a horizontal surface of metal. The cutter in this case is called a parting tool. Fig. 9, page 265, is a side elevation of this same cutter, showing the cutting angle, which is 68°.

Fig. 10 and 11, page 264, are tool-holders with cutters of rather special forms. The former is shown planing out or under-cutting a T-shaped slot; and the latter is planing out a small rectangular clearance corner.

Figs. 12 and 13, page 265, show a swivel tool-holder with a round shank, such as is used on the slide-rest of a screw-cutting lathe, for cutting square threads. It is carried on a wrought-iron or steel block, provided with a groove, semicircular in section, in which the round shank of the tool-holder lies, and is clamped down in the usual way. The cutters for cutting out the spaces between the square threads are of very simple form, and by aid of this tool-holder any tool made to the correct width of the space will cut either right-hand or left-hand screws, no matter whether they are single threads, double threads, or any other. To cover the same ground with forged tools, no less than six expensive cutters would be required, each one forged from square steel, and carefully filed up and hardened. With the tool-holder only one cutter is required, and it costs probably not more than 10 per cent. of one of the six forged tools, while it maintains its size much better, and consequently lasts much longer. It also takes off about twice the weight of cuttings per hour as compared with an ordinary forged tool. This system is useful where many screws of odd forms and pitches are required; but where there are sufficient numbers to be cut, special chasing lathes are far preferable to ordinary screw-cutting lathes, as they will do about six times as much casing of V threads, or cutting of square threads, as can be accomplished in the ordinary lathe in the same time. Instead of carrying one chaser, the chasing lathes carry, in a chasing apparatus, three or four chasers; and these have their threads, whether square, V, rounded, or any other form, cut in their places by aid of a master tap. They are then tapered at the mouths, backed off, and hardened ready for work. The number of shavings cut simultaneously from a screw by this process varies from twelve to twenty-four, according to the size, strength, and pitch of the thread. Screws up to 6 in. diameter, can be very rapidly cut by this system, on which very much more might be said if time permitted. A few screws cut by this process are exhibited.

When the two systems—the round and the swivel tool-holder—are worked in conjunction with each other, their universality of application is so thorough that almost every difficulty is met; and it was only in the case of paring and shaping articles

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