of the teeth back at the required radius. Relieved cutters can of course be strung together on a single arbor to form gang mills, by which very complicated profiles may be tooled, beyond the capacity of a single solid mill.

*Scrapes.—*The tools which operate by scraping (fig. 21) include many of the broad finishing tools of the turner in wood and metal (cf. fig. 2), and the scrape of the wood worker and the fitter. The practice of scraping surfaces true, applied to surface plates, machine slides and similar objects, was due to Sir Joseph Whitworth. It superseded the older and less accurate practice of grinding to a mutual fit. Now, with machines of precision, the practice of grinding has to a large extent displaced the more costly scraping. Scraping is, however, the only method available when the most perfect contact is desired. Its advantage lies in the fact that the efforts of the work­man can be localized over the smallest areas, and nearly infinitesimal amounts removed, a mere fine dust in the last stages.

*Files.*—These must in stricthess be classed with scrapes, for, although the points are keen, there is never any front rake. Collec­tively there is a shearing action because the rows of teeth are cut diagonally. The sectional forms (fig. 22) and the longitudinal forms (fig. 23) of the files are numerous, to adapt them to all classes of work. In addition, the method of cutting, and the degrees of coarseness of the teeth, vary, being single, or float cut, or double cut (fig. 24). The rasps are another group. Degrees of coarse­ness are designated as rough, middle cut, bastard cut, second cut, smooth, double dead smooth; the first named is the coarsest, the last the finest. The terms are relative, since the larger a file is the coarser are its teeth, though of the same name as the teeth in a shorter file, which are finer.

*Screwing Tools.—*The forms of these will be found discussed under Screw. They can scarcely be ranked among cutting tools, yet the best kinds remove metal with ease. This is due in great measure to the good clearance allowed, and to the narrowness of the cutting portions. Front rake is generally absent, though in some of the best screwing dies there is a slight amount.

*Shears and Punches.—*These may be of cutting or non-cutting types. Shears (fig. 25) have no front rake, but only a slight clearance. They generally give a slight shearing cut, because the blades do not lie parallel, but the cutting begins at one end and continues in detail to the other. But strictly the shears, like the punches, act by a severe detrusive effort; for the punch, with its bolster (fig. 26), forms, a pair of cylindrical shears. Hence a shorn or punched edge is always rough, ragged, and covered with minute, shallow cracks. Both processes are therefore dangerous to iron and steel. The metal being unequally stressed, fracture starts in the annulus of metal. Hence the advantage of the practice of reamering out this annulus, which is completely removed by enlargement by about an ⅛ in. diameter, so that homogeneous metal is left throughout the entire unpunched section. The same results follow reamering both in iron and steel. Annealing, according to many experiments, has the same effect as reamering, due to the rearrangement of the molecules of metal. The perfect practice with punched plates is to punch, reamer, and finally to anneal. The effect of shearing is practically identical with that of punching, and planing and annealing shorn edges has the same influence as reamering and annealing punched holes.

*Hammers.—*These form an immense group, termed percussive, from the manner of their use (fig. 27). Every trade has its own peculiar shapes, the total of which number many scores, each with its own appropriate name, and ranging in size from the minute forms of the jeweler to the sledges of the smith and boiler maker and the planishing hammers of the coppersmith. Wooden hammers are termed mallets, their purpose being to avoid bruising tools or the surfaces of work. Most trades use mallets of some form or another. Hammer handles are rigid in all cases except certain percussive tools of the smithy, which are handled with withy rods, or iron rods flexibly attached to the tools, so that when struck by the sledge they shall not jar the hands. The fullering tools, and flatters, and setts, though not hammers strictly, are actuated by

percussion. The dies of the die forgers are actuated percussively, being dosed by powerful hammers. The action of caulking tools is percussive, and so is that of moulders’ rammers.

*Moulding Tools.*—This is a group of tools which, actuated either by simple pressure or percussively, mould, shape and model forms in the sand of the moulder, in the metal of the smith, and in press work. All the tools of the moulder (fig. 28) with the exception of the rammers and vent wires act by moulding the sand into shapes

by pressure. Their contours correspond with the plane and curved surfaces of moulds, and with the requirements of shallow and deep work. They are made in iron and brass. The fullers, swages and flatters of the smith, and the dies used with hammer and presses, all mould by percussion or by pressure, the work taking the counter- part of the dies, or of some portion of them. The practice of die orging consists almost wholly of moulding processes.

*Tool Steels.—*These now include three kinds. The common steel, the controlling element in which is carbon, requires to be hardened and tempered, and must not be overheated, about 500° F. being the highest temperature permissible— the *critical* temperature. Actually this is seldom allowed to be reached. The dis- advantage of this steel is that its capabilities are limited, because the heat generated by heavy cutting soon spoils the tools. The second is the Mushet steel, invented by R. F. Mushet in 1868, a carbon steel, in which the controlling element is tungsten, of which it contains from about 5 to 8%. It is termed *self-hardening,* because it is cooled in air instead of being quenched in water. Its value consists in its endurance at high temperatures, even at a low red heat. Until the advent of the high-speed steels, Mushet steel was reserved for all heavy cutting, and for tooling hard tough steels. It is made in six different tempers suitable for various kinds of duty. Tools of Mushet steel must not be forged below a red heat. It is hardened by reheating the end to a white heat, and blowing cold in an air blast. The third kind of steel is termed *high-speed,* because much higher cutting speeds are practicable with these than with other steels. Tools made of them are hardened in a blast of cold air. The controlling elements are numerous and vary in the practice of different manufacturers, to render the