CHAPTER VII.

BENDING PROCESSES.

BENDING.

FOLLOWING a natural order, we come next to forming or bending processes, where the metal has its surfaces pushed out of their original planes into some new shape, but where the thickness is supposed to be not materially altered, except where it is incidentally made thinner in certain spots by being stretched, etc. In Fig. 277 is shown a V-shaped pair of bend-

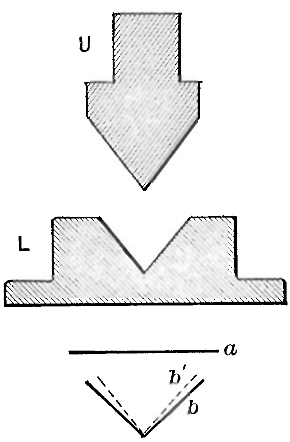

FIG. 277.

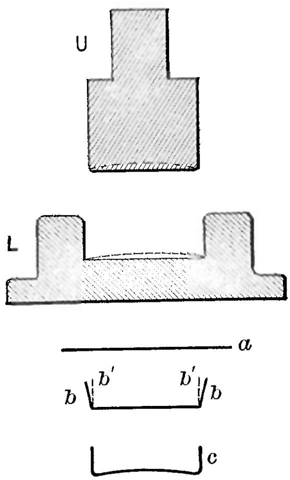

FIG. 278

ing dies and beneath them a straight plate of metal, *a*, together with the same as it appears after bending, at *b*. The dotted line *b'* shows where the dies tried to bend it, and the black line *b* its final position as assumed by its own elasticity. This, of course, varies with the material, a piece of lead or even copper remaining very nearly in the same shape as the die which forms it, while iron, mild steel, hard brass, etc., in the order named, require such a die to be of a more and more acute angle, as the metal approaches nearer the character of a spring.

In Fig. 278 is shown a pair of bending or forming dies which are removed one step further from the simplicity of the first named, giving two bends to the work instead of one. Here the same difficulty occurs in regard to the edges springing part-way toward their original shape after leaving the die, as shown again by the lines *b b*. It is not therefore possible with a die of this kind to produce edges which are exactly square with the main body of the plate. An approximation may, however, be sometimes made by bulging upward the horizontal surfaces of the dies, as shown by the dotted lines in Fig. 278, to an extent not greater than is suited to the elastic limit of the particular pieces of metal used. The die therefore attempts to make the work somewhat concave upon the bottom, as at *c*, which forms the corners at a sufficiently acute angle to approximately counterbalance the tendency to spring open; so that when the bottom has sprung back flat the edges will stand up perhaps nearly enough at right angles thereto. To place practical dependence upon this system, however, requires uniform blows by the press and uniform elasticity in the metal.

FORMING.

In Fig. 279 is shown a pair of round forming dies, where a flat circular blank, *a*, is laid in the recess *m*, which acts as a gauge merely for locating it centrally. It is then pushed by the upper die, or punch, *U*, through the parallel opening *n*, and falls beneath the dies—being stripped off the punch when the same is ascending by the sharp "stripping-edge" *o*. At *b* is shown the shape of the work when in a half-way stage of the operation, its final condition being as at *c*. With dies of this kind the edge of the work cannot be very deep in proportion to its diameter, on account of the wrinkles which evidently attempt to form when the circumference is reduced. It is true that these incipient wrinkles can be somewhat smoothed out by allowing the punch and die to fit tightly

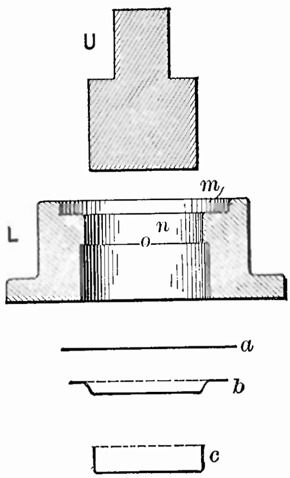

FIG. 279.

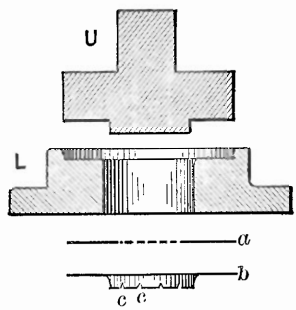

FIG. 280.

enough to confine the metal to its original thickness—providing this thickness came uniform, which it usually does not in practice. In doing this, however, the metal of the edge is lengthened in certain spots in a vertical direction, which causes a jagged edge. If the depth is too much increased, the wrinkles so fold upon one another as to tear the metal entirely away at certain places. The remedy for this will be considered later on under the head of the drawing process. With metal like ordinary tin-plate, in diameters of not less than 2 inches, a width of edge from $\frac{1}{8}$ to $\frac{1}{4}$ inch can usually be obtained in plain forming dies without objectionable wrinkles.

With cylindrical work like that in question, and also with elliptical work (which resembles it by having a convex contour with an edge extending all around), the outward springing of this edge does not occur to an objectionable degree, as it does with rectangular work having two separate and unconnected edges, like that shown in Fig. 278. This is because the edge *c* forms itself into a hoop, as it were, to confine itself from moving outwardly, which it cannot do when released from the die without actually stretching in a circumferential direction; and this evidently can occur but in a very slight degree.

In Fig. 280 is shown a pair of forming dies for turning an edge upon an internal, instead of an external, circular contour. These take a perforated blank, *a*, and open out the hole, turning it downward into a cylindrical-shaped edge, as at *b*. If an attempt is made to get this edge too wide, certain cracks will appear, as at *c c*, etc., in the picture. As the edge in opening outwardly increases its circumference, it will not stand more than a certain amount of tensile strain, the stress here being of exactly an opposite character to the compressive one which forms the wrinkles in work like that in Fig. 279.

EMBOSSING.

In Fig. 281 is shown one type of a pair of embossing dies, so called. The word "embossing" is used in this treatise, and very generally in the sheet-metal trades, to denote a small degree of forming or bending at various points upon the surface of a piece of sheet-metal, the location of which usually tends to show in top view a figure or design of some kind, decorative or otherwise, as, for instance, pictures, symbols, lettered inscriptions, etc. In such work the metal is pushed downward or upward more or less at various points into ridges and grooves, but not to a sufficient extent to tear it apart. The tendency is evidently to so tear it, as its outer edges are maintaining a rigid resistance against inward flow (except in

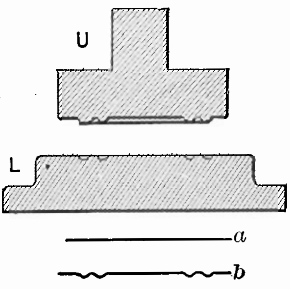

FIG. 281.

certain forms of the drawing process), and the metal has therefore to elongate where forced to take a shape whose cross-section shows a longer profile-line. This is shown by the section of the piece of embossed work, *b*, which is longer in profile than is the blank from which it was made, *a*. In the case given I have represented a pair of circular dies with two annular grooves sunk in *L*, corresponding ridges projecting from *U*. This is a design sometimes used upon the heads of tin cans, etc., its object being partly to make them stiffer, and perhaps partly for ornament. Such embossing, however, is merely typical of an infinite number of designs which may be thus stamped upon ductile metal. The word embossing, as applied to this process, should not be confounded with the same term as sometimes used to designate the process known more properly as coining, to be described further on.

In Fig. 282 is shown a broken-away vertical section of one groove and ridge of a pair of embossing-dies, where the flat surfaces have approached each other within a distance measured by the thickness of the metal, represented by *m*. Theoretically the space between upper and lower die might properly

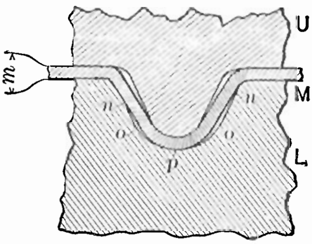

FIG. 282.

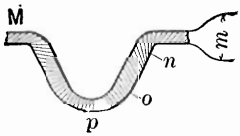

FIG. 283.

be this thickness, *m*, at the points *n*, *o*, and *p*, as the metal would then exactly fill between at all points. Practically, however, it is better to give an embossing-die clearance at such points as *n* and *o*, letting the metal follow the "tight points" to suit itself, as in the picture. This is desirable, because some of the metal may be a little too thick, or dirt may accumulate in the dies, in either of which cases there would be a jam between the points *n* and *o*, which would prevent the dies coming down home, or which, at any rate, would require a great deal more pressure to do the work. Another reason for this clearance is the practical difficulty of the die-maker being perfectly sure that there is space enough everywhere, unless he follows the method here given, of being sure there is enough by having too much. It is customary to give a little clearance at *p* also, but this is not of so much importance, as contact at that point would simply prevent the flat surfaces from coming together quite so tight.

A simple method devised by the writer, and long practiced by those working under his instructions, for ascertaining the clearance of forming and embossing dies is to lay pieces of small lead wire, whose diameter may be about two times *m*, across the dies at the various points requiring a test. Between these points small pieces of the sheet-metal to be used, whose thickness is *m*, are laid upon the lower die to act as blocking, so that the proper stopping-point of the upper die may be insured. The press ram is then brought hard down, with the result of the lead being smashed out to the varying thicknesses represented by the spacing of the dies, and as shown in Fig. 283. It is evident that all such points as *n* and *o* ought to be thicker than *m*, and this is generally easily determined by the eye. Such points as *p* must, of course, never be less than *m*, and may be a little more.

CUTTING-FORMING-EMBOSSING.

Almost all the various processes of forming and embossing may be combined with cutting, and with each other, wherever the work is of suitable shape. The tools for conducting such operations are usually called "combination dies," although the term is not very definite, being sometimes used, as before described, for the combining of two or more sets of cutting-edges. In Fig. 284 is shown, in vertical axial section, a pair of combination-dies such as are very extensively used for producing fruit-can "tops," as shown in section at *a*, and "bottoms," as shown with embossed groove at *a′* or plain at *a″*. In practice these dies are assembled in separate pieces to some extent, to insure cheapness, durability, and facility of repairs, but they are here depicted in conventional form. It will be seen that the outer cutting die has the female at the bottom as well as the inner one, a result which was not obtained in Fig. 265, Chapter VI, where the work remained flat. In this case the latter part of the upper die's descent cuts the central hole while the forming of the edge at *b* and the embossing of the groove at *c* is taking place. It will be noticed that the turning upward of the inner wall of this groove causes a tendency to crack, as in *b*, Fig. 280, although in practice it is not made deep enough to produce this effect. Such action does not take place in *a′*, because the stretching action is resisted by the continuous surface in the center, which is retained in the case of this can-bottom by removing the central cutting-punch *d* from the upper die. Should a plain flat bottom be desired, as at *a″*, the embossing-punch *e* is also removed.

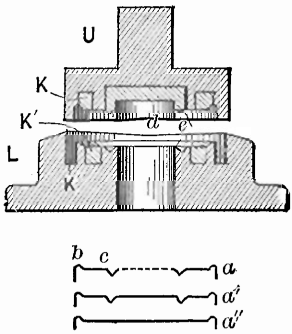

FIG. 284.

Sometimes combination cutting-forming, etc., is done in a double-action press with dies similar to the drawing-dies to be described in Chapter IX, Figs. 331 and 343. These dies have the advantage of strong and simple construction, and, in operation, of dropping the work through beneath the lower die.

Knockouts.

A knockout-ring is shown in Fig. 284 in the upper die at *K*, and in the lower die at *K'*. They are unnaturally given in closed position (as they would be were the dies shut together) merely to show better the general contour of the sectional view. Sometimes what is called an "edge knockout" is used instead of the construction shown at *K'*, consisting of a thin ring rising in the groove *K''* and pushing against the edge of the work rather than underneath its flat surface. This ring at *K''*, if driven up by strong springs, acts in some degree as a spring-drawing attachment (to be described later on), and serves to smooth out the slight wrinkles which usually otherwise appear in the edge of the work. The knockouts described are generally driven by springs, but sometimes by pins extending through the dies and attached to or pushed by certain positive-action knockout devices. In some cases such special knockout "attachments" to a press are not positively driven, but are actuated by a strong spiral spring, or a spring made of rubber disks, etc.

Speed and Pressure.

The speed at which forming- and embossing-work is done is of little consequence, as in practice the ram speeds of the presses in common use are none of them fast enough to tear the metal by moving it more rapidly than its molecular inertia will permit.

The pressure required for the processes above described varies too greatly to be formulated in a general way, being dependent upon the character of the work and the condition of the dies. For given pieces of metal, however, it frequently happens to be a good deal more than for the cutting operations performed upon the same. When the dies are so set as to actually squeeze the metal thinner, it is forced to flow sidewise, and a "coining" action is set up. In such case the required pressure is very great, often exceeding the crushing strength of the metal. This, in its turn, is usually something greater per square inch of section than is the tensile strength.

Assembling.

Analogous to forming processes proper are various operations where the assembling of two or more pieces is done, oftentimes upon the same general principle as the riveting down of an eyelet, or a rivet, which has been passed through two pieces of paper or metal. In general, some piece of metal which has previously been brought to shape by dies or otherwise is driven tightly, or perhaps dropped loosely, into or onto some other piece or pieces, whereupon they are all fastened together by some auxiliary forming process which bends or forms certain edges or surfaces in a manner best adapted to locking the various parts permanently together.

In this way two cup-shaped pieces are connected to form a certain style of door-knob; ornamental stamped-out parts are assembled into the stem of a gas-fixture; and the base-piece is fastened onto a cuspidor or coal-scuttle. Such work will be further set forth in the next chapter, under the head of curling, etc.

Involuntary Processes.

In addition to the humanly invented processes we have been considering there are sometimes developed others which, to a careless observer, might seem to emanate from the brain and hand of his Satanic Majesty. Among what may thus be called involuntary processes is the very annoying one known as warping, which occurs especially in the products of embossing and forming dies, as well as to some extent in drawn-work also. The most favorable conditions for its occurrence are thin metals, large diameters, and edges so shallow as not to form stiff trusses in themselves. The die-maker is often blamed for work thus coming from the press twisted and sprung, so that it is impossible to make it lie flat upon a plane surface. Generally, however, a result of this kind is entirely owing to its design; and Dame Nature, rather than the die-maker, must be blamed for one of the most provoking and perplexing problems which the die-user is called upon to solve.

Mechanically, the cause of this warping is due to the middle of the stamped sheet of metal being too small for the outside thereof, so to speak. This occurs when the central parts have been embossed or otherwise drawn together and put under a tensile strain, while the average circumference of an outer zone, near the edges, has not been correspondingly reduced, and therefore does not assume the shortest distance around its course, which would naturally lie in a plane. A remedy is sometimes found by altering the design so that this outer zone may have various ribs and corrugations running approximately in a radial direction toward the center, such corrugations tending to take up the surplus metal in a circumferential direction. These additional features can often be added by a judicious designer in a way to serve a decorative purpose. A similar warped effect can obviously be produced by letting the middle of the metal alone and stretching or otherwise increasing too much the area near the edges. This is often done by forming-dies when turning a narrow vertical edge around a large thin blank. Such action is due to imperfect "upsetting" where the circumference is reduced, and perhaps also to a too tight squeezing of the edge between the dies, which has a stretching effect.

The converse of the conditions above mentioned occurs when the middle part of the sheet is too big for the outside, as is the case in any dished or saucer-shaped work. This is often seen in the bottoms of buckets, etc., which have been somewhat bulged, and which can be "flopped" back and forth, always staying in a position at either side of the plane of the outer zone of the metal. In such case the said outer zone is pushed outwardly by the central parts, and is therefore in a taut condition, which tends to make it stay flat rather than otherwise. If that surpassingly skillful artisan known as the "saw-maker" were to tackle a sheet of this kind, he would soon flatten it by hammering it near the edges. If, on the contrary, he hammered it in the middle, it would be on account of converse conditions.

SOFT PUNCHES.

Forming work, especially in drop presses, is sometimes performed by using a punch made of soft and easily fusible metal like lead, or, preferably, a mixture of lead and tin, in proportion of about two of the former to one of the latter. The object in making such a punch in this way, is: 1st, cheapness, because it can be cast directly into the die, which is usually of harder metal, and of more expensive construction; 2d, a soft punch of this sort under the influence of a quick and powerful blow will maintain its shape by reason of its particles flowing by their own momentum, in whatever direction they can go to perfectly fill the die, or rather the interior of the work, which is supposed to be a slightly smaller copy of the same. If, therefore, the punch moves down quickly enough (as is usually the case in a drop-press), it will flow out and fill the interstices of a somewhat intricate die, as, for instance, in the case of ornamental brass-work in designs of imitation carving, etc.

In drop press work these punches are sometimes used for thin metals, as in making dish-pans, wash-bowls, sauce-pans, etc.; though formerly they were employed, before the advent of the drawing-press, very much more than now. In such dies a good many successive operations are necessary, that the work may be coaxed down, so to speak, a little at a time. It is then easy to cast a punch part-way down in the die for the first operation, and after running through a batch of work tear it off and remelt it, to pour another one a little deeper, and so on. Thus a batch of pans can be run through over and over again, the die never being removed from its position. The punches are cast blocked off at part depth by laying a diaphragm in the die part-way down, or by using one of the unfinished pans itself for the purpose. The press ram has, of course, a proper "anchorage," so to speak, to which the soft cast metal will cling.

Fluid Punches.

A rather curious modification of forming a deep article to shape by a punch entering a die is to make the former of water or other liquid. In other words, the idea is to force the work outward and down into the form of the die by means of hydraulic pressure inside of the same, proper arrangements of course being made for packing around the edges of the dies so that the fluid cannot escape. This system is chiefly used for comparatively soft metals, such as silver, britannia-metal, and other materials used for table-plate and analogous constructions. It is generally applied to a cup-like article which has already been brought nearly to shape in a drawing-press or otherwise. It is especially useful where the dies are "undercut"—that is, larger part-way down than they are at the top; such are used for producing forms like the tea-pots, sugar-bowls, etc., often seen upon our breakfast-tables. In such cases the die must of course be split into such a number of parts as to enable it to open and the work to be removed from it. It is evident, however, that such a water-punch can enter it and be withdrawn without the difficulties incident to a solid punch. In some cases metal can thus be forced out into ornamental figures sunk in the surface of the die in a way not easy otherwise to attain.

I have never heard of air or other gases being used in this same way for metallic work, but such a pneumatic punch, entering a separable iron die, is the tool used every day by glass-blowers throughout the world. Another instance of similar work, minus the lower die, is seen in the industry of blowing soap-bubbles.

Presses Suitable.

For the various forming and embossing processes described in this chapter almost any type of press may or may not be suitable, according to circumstances. The type least likely to meet all conditions is, perhaps, a drop-press, which usually has the peculiarity of a faster moving and more loosely fitting ram than have other presses. These machines, however, are especially adapted to some kinds of embossing-work, and are sometimes used for forming, particularly in producing shallow pans, plates, trays, etc., in tin-plate and sheet-iron. In recent years they have been, for these latter functions, superseded to a considerable extent by drawing-presses. For heavy embossing, a short-stroke toggle press, similar to those used for coining, is sometimes a very effective tool.