Forging Shrapnel Shells*

Some Details of Modern Methods Now in Use

By Douglas T. Hamilton

WITHIN the last few months, many methods have been suggested for making shrapnel forgings, but a comparatively small number have been put into use. Practically speaking, no two governments have adopted the same method. The Russian government uses double-acting horizontal hydraulic forging presses in which two operations are performed at the same time on different forgings. For instance, while the punch in one end of the machine is piercing a heated billet, the ram on the return stroke performs the hot drawing operation on another shell located at the opposite end of the machine. In this way a shell is completed at each cycle of the machine—forward and return stroke. The French government, up to a short time ago, used steam hammers for this purpose, and produced shrapnel forgings in practically the same manner as a drop-forging is made, the punch being carried in the ram of the press and the die held on the bed. This is rather a slow process and requires more than one heating to complete the forging. The German government uses a horizontal hydraulic forging press for piercing the billet and a steam-driven machine for drawing the forging, which receives its motion from a rack and pinion. This method has the advantage over the hydraulic press of being more economical in the consumption of power.

The practice followed by different concerns in this country and Canada, at the present time, differs to a large extent. Some manufacturers are using a method that dates back as far as 1890. Others are using a more improved method developed about 1895, whereas about three concerns are using a still more improved method developed in the last three months.

The first method (known as the Caley process) of making shrapnel forgings in this country had its inception about 1890 and was used almost exclusively until 1895. This comprised a slug-forming and billet-piercing operation followed by a successive reduction and elongation of the forging through drawing dies. The order of these operations is shown diagrammatically in Fig. 1. The information given herewith pertains to the making of a forging for a 3-inch shrapnel shell. As shown at

D, a billet of steel $3\frac{3}{4}$ inches in diameter and $6\frac{1}{2}$ inches long was cut off from a bar with a cold saw, and formed into a cone shape under a vertical hydraulic press having a capacity of 100 tons. The billet was heated in a furnace to about 1,900 deg. Fahr., dropped into the impression in the die and forced into shape by a hydraulic plunger having a depression in the lower end which centered the blank. The result of this operation is shown at F.

The next step was to anneal the billet, after which it was pierced as shown at *C*, and at the same time slightly elongated. This operation was handled in a hydraulic press. On a 0.70 per cent carbon steel billet the pressure on the punch in the piercing operation was 20,000 pounds per square inch and the machine used was a vertical hydraulic forging press of the type referred to having a capacity of 100 tons. From the piercing operation the forging was taken direct without annealing to the horizontal hydraulic draw press, and as is shown at *H* was located on a punch and forced through a series of drawing dies which gradually reduced the shell to the correct diameter, $3\frac{3}{8}$ inches, and drew it out to the required length, about $8\frac{3}{4}$ inches.

A point worthy of attention is the preparation of the cone-shaped billet. The smallest end was made slightly smaller than the smallest reduction die in the series. The reason for this was that if any drawing were done on the end of the shell the front corner would be drawn over and deformed, increasing the amount of machining required. The drawing dies in this case were six in number, as shown at *H*, and were reduced on a sliding scale of the following proportional reductions. First, 0.100 inch; second, 0.080 inch; third, 0.060 inch; fourth, 0.040 inch; fifth, 0.030 inch; and sixth, 0.020 inch. This gave dies of the following sizes, in inches, starting with the largest in the series: 3.355, 3.275, 3.215, 3.175, 3.145, and 3.125.

The drawing punch was lubricated occasionally with graphite. After drawing, the forging is annealed to obtain the proper physical qualities. This method of making forgings for a 3-inch shrapnel shell is capable of producing 400 in ten hours.

About 1895 the following method, known as the Hollinger process of making shrapnel forgings, was devised. Instead of making the billet conical in shape before piercing, this preliminary operation was dispensed with, and to facilitate the work, as well as to reduce the friction of the flowing metal, the arrangement of the piercing punch and die was changed. This process is shown in Fig. 2, and was accomplished in a hydraulic press provided with two cylinders, one located at the bottom and the other at the top of the press.

The operation was as follows: The die *a* was held in a movable frame *b* and the piston *c* acted first. The first position after the billet was dropped into the die is shown at *B*. Here the die *a* and punch *d* remained stationary while the piston *c* descended, pushing the billet through the die and over the punch. When the piston reached the end of its stroke, as shown at *C*, the lower cylinder began to act and the frame carrying the die was raised. This frame, as shown at *D*, carried a stripper plate *e* which removed the pierced billet from the punch and located it so that it could be picked off with a pair of tongs. A subsequent operation of hot-drawing as shown at *E* was required, which is similar to that described in the first method. The method just described was used chiefly for 6- and 8-inch shrapnel and projectile forgings, and at the present time is still used for 3- and 6-inch shell forgings. It requires much less power and turns out a better and more concentric forging than the method previously described. The production on 8-inch shells is about 180 in ten hours, and 250 on the 3-inch shell.

The increased demand for shrapnel within the last few months has been instrumental in bringing about a radical improvement in the production of forged shells. Previously, the aim was to get the internal diameter as close as possible to the finished size and to do comparatively little machining on it; in fact, this is still, in a great number of cases, one of the requirements. While at first glance this would appear to be the logical way of handling the work, on further investigation it is found that the forging of the shell to the comparatively correct size is much more expensive than to leave sufficient metal to machine all over. In the first place, a hydraulic machine of 100 tons capacity costs considerably more in initial outlay than a turret lathe, and in

Fig. 4.—Examples of shrapnel forgings turned out on a power forging machine.

Fig. 1.—Diagram illustrating Caley process of making shrapnel forgings in hydraulic forging presses.

Fig. 5.—Diagram illustrating method of piercing and drawing shrapnel forgings in a power press.

Fig. 2.—Hollinger process of making shrapnel forgings.

the second place it is more expensive to operate. The cheapest method of making a shrapnel forging is to rough-forg it to approximately the correct shape and then finish to exact shape and diameter in turret lathes or semi-automatic chucking machines. This simplifies the forging process and also decreases the production costs.

One of the later methods of making shrapnel forgings is shown diagrammatically in Fig. 3. A billet of steel $6\frac{1}{2}$ inches long by $3\frac{1}{8}$ inches diameter is heated to a temperature of from 1,900 to 2,100 deg. Fahr., and then dropped into the impression in the die *a* held in a special cast-steel die-holder *b*. To do this, die *a* is drawn out from beneath the punch, punch guide *c* removed and the billet dropped in. Then the guide is replaced and the die-holder slid in until it contacts with the stop *d*. The press is now operated, and as shown at *B*, advances, piercing the billet and making the metal flow up around the walls of the punch.

The punch now retreats, carrying the centralizing guide *c* with it. The die-holder is now drawn out from under the punch onto a bracket projecting from the bed of the press. The high-carbon steel, hardened block *e* then drops out of the die, as is also the case with the finished forging. This block *e*, of course, is heated up to a considerable extent due to the hot metal resting on it so that several blocks of this kind are provided. In the illustration, as shown at *C*, centralizing guide *c* is shown attached to the punch. In actual operation this is not the case. When the punch rises, guide *c* is stripped from it by the stripper plate *f* so that the guide is gripped with a pair of tongs and laid down on the bed of the press until a fresh heated billet has been placed in the die impression ready for the next piercing. The punch is made from special hot punching steel and the die from chilled cast iron. The production of forgings by this method for a 3-inch shrapnel shell is about 600 in ten hours.

The amount of metal left for machining by this

method varies from $\frac{1}{8}$ to $\frac{3}{8}$ inch on the internal and external diameters. The forging after annealing is then machined inside and out on turret lathes, or semi-automatic chucking machines. The accepted method is to first machine the internal diameter and then hold the shell on an expanding arbor and machine it on the external diameter.

One of the latest developments in the art of producing forgings for shrapnel shells is the adaptation of the power forging machine to this work. As has been previously mentioned, there are several methods of producing shrapnel shells, and as it has been conclusively proved that the forged shell is superior to the shell made from bar stock, it is only natural that several methods for making the forgings would be developed. In the forging machine method, a bar slightly larger than the finished diameter of the forging is cut off, making a billet about $5\frac{1}{2}$ inches long. This billet, for a 3-inch shell, weighs about $9\frac{1}{4}$ to $9\frac{1}{2}$ pounds.

The billet is heated to a white heat in a furnace, the temperature being about 2,000 deg. Fahr., depending on the carbon content and other constituents in the steel, and is then placed in the lower impression of the forging die. The machine used for this size of forging is a standard upsetting and forging machine provided with a special crankshaft. Upon being operated, the lower plunger, which is larger than the diameter of the powder pocket in the shell, advances and pierces the billet. The pierced billet is then raised to the next impression, and the machine again operated. The second punch is longer than the first and smaller in diameter. The billet is forced up on this punch, which reduces it in diameter and increases its length. After the second impression the partially formed shell is then placed in the third or final die impression, where it is given two blows, being given one half turn after the first blow to form it more perfectly. The operations just enumerated are performed with only one heating of the billet, and the production of a 3-inch shell ranges from 400

to 450 perfectly formed rough forgings in ten hours.

The dies for this work are, of course, constructed upon a somewhat different principle from the ordinary forging die, because in this case it is necessary to make the metal flow upon the punches. The dies, therefore, are so constructed that they recede as the punch advances, which tends to make the metal flow up on the punch. The practicability of this method is well illustrated by the samples shown in Fig. 4. Here *A* is the rough forging just as it comes from the machine, with the exception that the mouth has been trimmed. *C* is a section of a shell made from low-carbon steel about 0.30 per cent carbon; *B* is a shell made from 0.50 per cent carbon, $3\frac{1}{2}$ per cent nickel steel. This has been rough-turned, as the illustration shows. The homogeneity of the forgings is clearly indicated. *A* is a forging made from low-carbon steel, finish-turned.

One of the most interesting points about this method is its cost as compared with shells made from bar stock. To produce a 3-inch shell from bar stock requires about 22 pounds of material, and on metal costing 10 cents per pound, a bar shell—exclusive of machining—costs \$2.20; to produce the same shell on a power forging machine requires about $9\frac{1}{4}$ to $9\frac{1}{2}$ pounds, and figuring on 10 cents per pound the cost for material is only \$1—a saving of \$1.20 on each shell. Furthermore, the production of shells from bar stock on automatic machines is about twelve to fifteen per day. The number of forgings that can be turned out in the same time is 400 to 450, and the number that can be machined in this time varies from forty to fifty for two operations. It is therefore evident that the production of shells by forging is far superior to the bar method, and the forged shell is more satisfactory from every standpoint.

Another interesting development in the forging line is shown diagrammatically in Fig. 5. This method comprises three operations, and is handled in a No. 80½ Bliss press capable of exerting a pressure of 1,200 tons. A billet $3\frac{1}{4}$ inches in diameter by $3\frac{1}{2}$ inches long is

Fig. 3.—Improved method of making shrapnel forgings in one heat and operation.

Fig. 6.—Diagram illustrating flow of hot metal while being pierced.

heated in a furnace to 1,976 deg. Fahr. and then quickly placed in the die shown at A. The press is operated, and the punch in descending pierces the billet, being guided by the guide *a*, as shown at B, which also acts as a stripper. The forging retains its heat to a certain extent after this operation, the temperature being about 1,380 to 1,425 deg. Fahr. This is sufficient to perform the second minor operation which, as shown at C and D, consists in forcing the heated billet into the die-block to reduce the diameter of the lower end and facilitate the succeeding operation. This reducing operation is

performed with the same type of punch as is used in the succeeding operation, and the die-block is simply laid on the top of a bolster while the reducing is being done.

The final forming or drawing of the forging is accomplished as shown at E and F, the same type of press, being used for this purpose.

In the manufacture of shrapnel shell forgings, the first operation is that of piercing, and to accomplish this satisfactorily, it is necessary to understand the action of a piercing punch on a semi-plastic billet of steel. There are certain fundamental laws governing the flow of metals under pressure and a study of these is of exceptional interest. An attempt has been made in Fig. 6 to illustrate diagrammatically some of the principles involved, and in the following discussion it should be understood that the billet is made from 50-point carbon, 70-point manganese steel, $6\frac{1}{2}$ by $3\frac{1}{8}$ inches in diameter.

At A a round-end tapered punch is shown in contact with the heated billet, and the lines show the possible flow of the metal, i. e., the material commences to "pack" at the end of the punch. In this case the walls of the die are straight. At B the billet is being pierced, and the resultant effect on the flow of the metal is indicated. Here it will be seen that the pressure increases as the punch descends, because of the wedging action on the metal and the friction between the surfaces of the sides of the punch and die. The pressure on the end of a punch of this shape is about 20,000 pounds per square inch.

By leaving the sides of the die of the same shape as at B, but making the end of the punch square instead of round and not tapered, different action is caused. When the flat punch, as shown at C, first contacts with the metal, the pressure required is greater than at A, but as soon as the metal commences to flow as at D, the pressure decreases. For instance, suppose the pressure required at B to pierce the billet was 100 tons; on

the same material at D the required pressure would be only 70 tons—a decrease of 30 per cent. The metal, however, does not follow the sides of the punch as closely at D as at B, and this accounts in part for the reduction of power required. The action of hot flowing metal on the face of a square punch is just the reverse of what would naturally be expected. Instead of the punch wearing away at the edge, the center first shows signs of wear as indicated at *e*. Seams are opened up in a radial direction caused by the hot metal attacking the softest parts in the face of the punch.

Again, a different condition exists to that shown at B and D, when both the die and the punch are tapered as shown at E. Here the friction of the extruded metal on the walls of the die and sides of the punch is excessive, and it is practically impossible to produce a satisfactorily pierced billet in this manner. From a theoretical standpoint, the conditions shown at F are ideal. Here the sides of the punch are straight, the end flat, and the walls of the die taper or increase in diameter toward the bottom. In this case the friction of the flowing metal is greatly reduced because of the lessening of the wedging action. Other considerations, however, make this method impracticable.

A still greater reduction in the pressure necessary to pierce a billet is shown at G. Here a square billet instead of a round one is being pierced. In the plan view it will be noticed that the friction on the walls of the die is greatly reduced, and the pressure continues low until the extruded billet contacts all around with the surface of the die. The completed product, however, is inferior to that made from a round billet. From the previous remarks it will be seen that a punch and die that would best meet the requirements is one having a rounded end as at B, straight sides as at D, and straight walls in the die. The most satisfactory punch and die for piercing shrapnel forgings when all the variable conditions are considered would be as shown at H.

Plating by Impact

AN account has been published of a metal spray process of plating, the invention of a Swedish engineer, and from a patent recently issued it appears that a similar process has been in course of development by Mr. C. Francis Jenkins of Washington, D. C., better known as the inventor of the now standard type of motion-picture projecting machine.

This process can perhaps be best understood if one remembers that when an electric lamp bulb gives way a discoloration of the inside of the bulb occurs; and also that when a fuse plug "blows" the mica cover is discolored. This color is black when the fuse is of lead, but it is a reddish color when a piece of copper wire is used. This would seem to indicate some kind of a de-

tinuously fed. A pair of small rollers actuated by a motor pulls the wire off the supply spool and projects it across the barrel until the end touches the opposite surface. The inner lining of the barrel and the propelling rollers are in series in an electric circuit, though insulated from each other, so that a short circuit is formed between the rollers and the lining, and the wire is instantly melted, and the heat of the wire causes it to be thrown out of the barrel against any object held in position for that purpose. When a plurality of wires are used, or a flat ribbon, in order to cover a larger area in a given time, it is found desirable to add a propelling force, and this is done by introducing into the barrel behind the wire a small charge of explosive gas, i. e., oxy-hydrogen gas, gasoline vapor, ether, or common city gas properly mixed with air will answer. The melting of the wire explodes the charge which projects the miniature metallic particles, that are momentarily suspended in the gas, against the object to be coated. As the wire is steadily fed across the barrel, and the melting is instantaneous, there are time intervals during which new charges of gas are introduced following successive ignitions, and a succession of miniature explosions following each other with rapid frequency, something like the exhaust of an automobile motor.

It has been found that objects of a great variety can be coated in this manner and that any electrically conductive material can be used for the purpose. Coatings of lead, tin, zinc, aluminium, iron, copper, silver, and gold are readily formed in this manner. The different melting points of the different metals is taken care of by means of an adjustable rheostat in the melting circuit. A coil is better than a grid, for reasons not necessary here to explain.

Wood, metals, fabrics, plaster, wax, glass, in fact almost any substance, can be successfully coated. Metallic platings of one's thumb can be taken in this manner, for it seems that the metallic particles, being so very, very small, give up what heat they carry so quickly that no unpleasant sensation results. With wax or glue casts one can produce a shell of extreme thinness by melting out the glue in hot water. In like manner ribbons of extreme thinness can be made as a continuous process.

One of the meritorious features of this method is its great economy, for all of the heat developed in the melting of wire is usefully employed; none of it is wasted. Articles which would be destroyed in an acid electroplating bath can be coated, and coating by this process is many times more rapid than electroplating.

The accompanying line drawing illustrates the general construction of the gun, B being the stock, A the barrel, lined with mica, as shown by the heavy black line D, with a conductive lining E electrically connected through one of the wires I to the source of current. Another of the wires I is electrically attached to the gun barrel and the wire-propelling rollers H. The third

of the wires I goes to the latch S, which is an electric switch controlling the motor (not shown) which actuated the rollers H through a flexible shaft. G is the wire to be volatilized, and J is a tube which leads explosive gas into the barrel of the gun. A small ball in the enlargement of the tube J near the upper end serves as a check valve, preventing "backfire" down the tube.

The operation of the gun is perhaps almost obvious from the drawing, the wire G being fed forward by the rotation of the rollers H, soon comes into contact with the inner lining E of the gun barrel and thereupon is instantaneously melted. The melting of the wire explodes the gas which has meantime entered the gun

Diagram illustrating general construction of the gun.

barrel through the tube J and the minute globules into which the metal forms immediately it is melted are projected with violence against whatever is set in front of it, and stick thereto. Subsequent charges of these minute pellets, so small as to be invisible to the unaided eye, strike on the same spot, forming a permanent weld with the preceding charges until a homogeneous coat of any thickness desired results.

Tin, says a writer in the *Bulletin* of the Imperial Institute, has always been to a large extent a British product.

Early experimental apparatus using electric fan motor to operate the feed rolls.

posit resulting from the blowing of the fuse, that it is not completely volatilized. Under a magnification of 300 diameters, or more, minute particles of a copper wire are discovered, adhering to the cover of the fuse plug, and when a common visiting card is used for a cover instead of the mica, a decided deposit is attained. Repeated charges of such a fuse result in a complete coating on the card. When this surface is burnished with some smooth, hard object, a shiny, polished metal surface results.

A fuse used in this manner is in effect a gun which throws out a shower of miniature shot so small as to be invisible to the naked eye, and this would operate successfully for covering almost any surface but for the annoyance of the frequent replacements with short pieces of copper wire.

This led naturally to the development of a special "gun" into the barrel of which a copper wire is con-