March 26, 1957 J. A. CHAPPUIS 2,786,267

METHOD FOR PRODUCING COLD FLOWING OF METALS

Filed Nov. 18, 1952 3 Sheets-Sheet 1

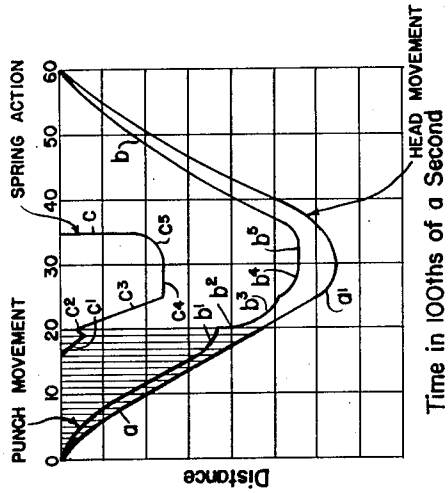


FIG. 6.

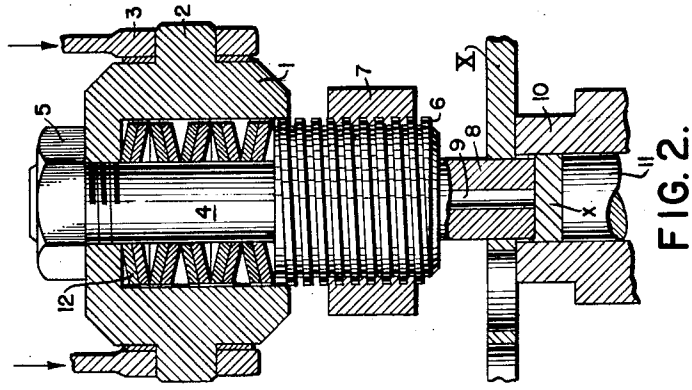


FIG. 2.

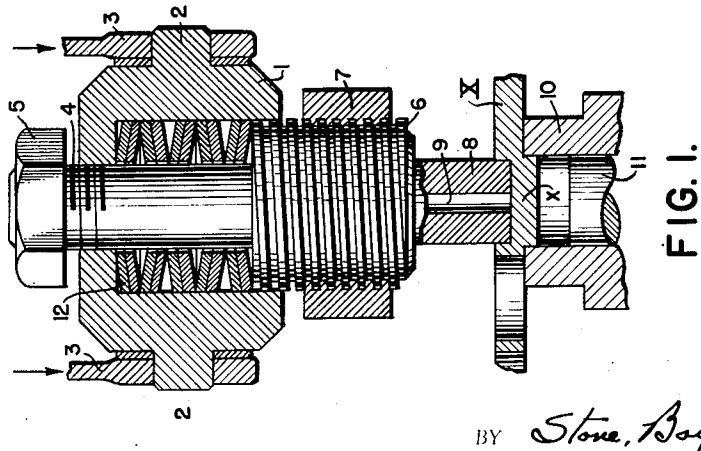


FIG. 1.

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METHOD FOR PRODUCING COLD FLOWING OF METALS

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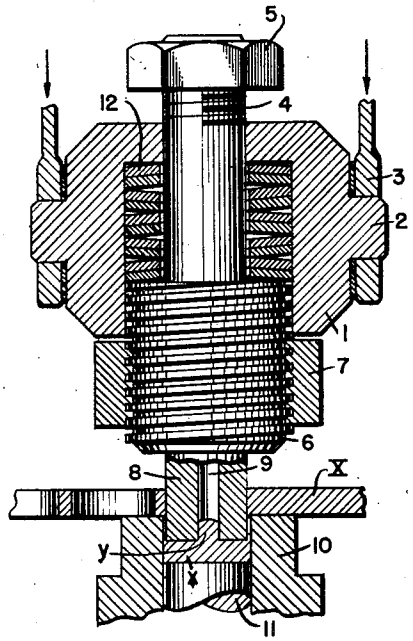


FIG. 3.

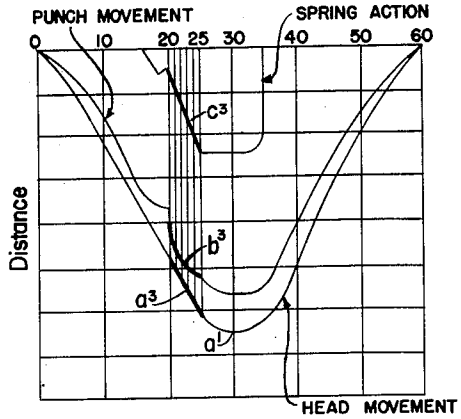


FIG. 7.

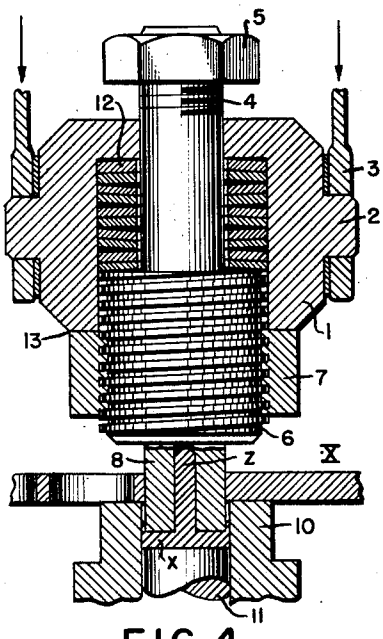


FIG. 4.

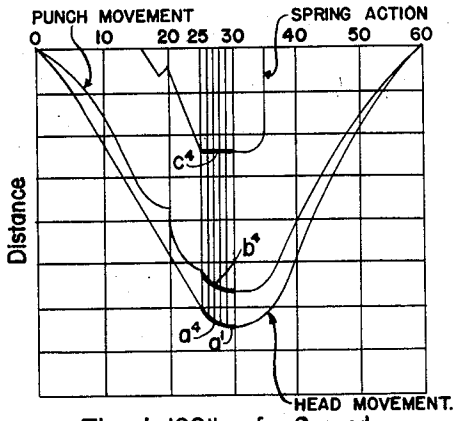


FIG. 8.

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METHOD FOR PRODUCING COLD FLOWING OF METALS

Filed Nov. 18, 1952 3 Sheets-Sheet 3

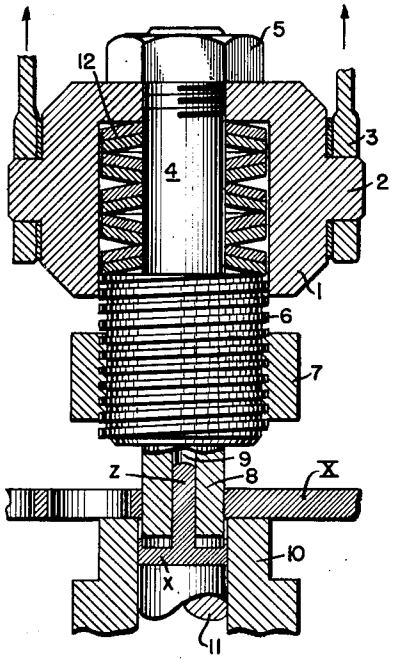


FIG. 5.

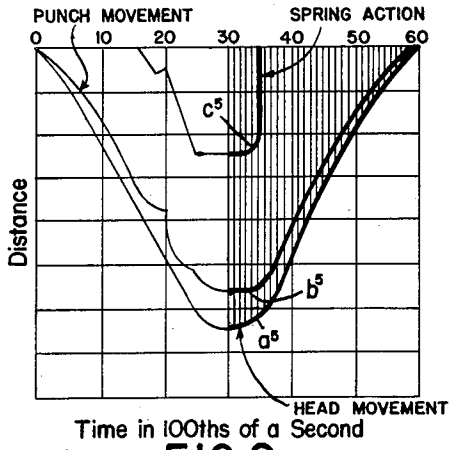


FIG. 9.

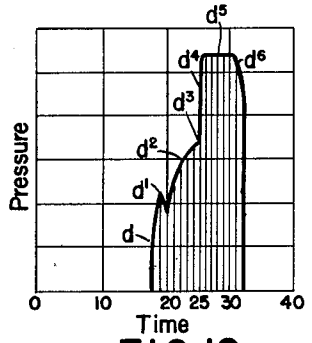


FIG. 10.

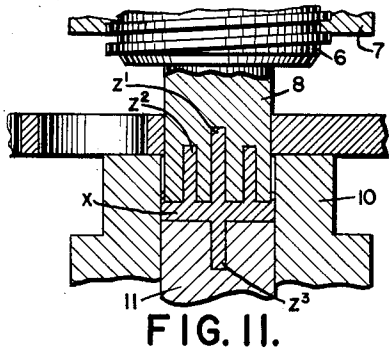


FIG. 11.

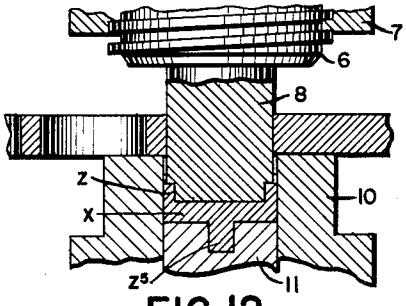


FIG. 12.

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2,786,267

METHOD FOR PRODUCING COLD FLOWING OF METALS

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Application November 18, 1952, Serial No. 321,199

5 Claims. (Cl. 29—552)

This invention relates to the forming of metal articles by shaping a blank between dies, and more particularly to the forming of such articles by movement or flowing of the metal in a cold state.

Still more specifically, the invention relates to the shaping of metal articles in a press in which the movement of one of the dyes is continuous and relatively rapid.

An object of the present invention is to devise a method by which articles may be shaped from metals such as steel by flowing in the cold state.

Another object is to devise a method by which such articles may be formed accurately at high speed, thus providing low cost production.

A further object is to develop a method of cold shaping articles from flat blanks by which projections of a length many times greater than the thickness of the blank may be formed on its flat face, and the volume of the metal displaced by flowing may amount to a substantial proportion of the total volume of the blank.

Still another object of the invention is to provide an improved method for forming articles from flat blanks by means of which the blank is cut out from a piece of stock and formed into the desired article at a single stroke of the press.

The achieving of the foregoing objects is rendered possible by reason of a far-reaching, fundamental discovery which I have made regarding the cold working of metals.

If a sudden impact is applied to a cold metal blank confined within a die cavity, as in an ordinary coining press, it is only possible to produce projections or raised parts of a height which is relatively small, compared to the thickness of the blank.

Attempts which have been made to extrude by impact and in the cold state even relatively soft metals show that the pressure, at the moment of contact of the movable die or punch with the blank, is enormous. Thus, for tin or lead, 85 to 110 kilograms per square millimeter (60 to 80 tons per square inch) is required. Commercially pure aluminum needs about 115 kilograms per square millimeter (80 tons per square inch), and various aluminum alloys require 85 to 170 tons per square inch. An alloy of other metals, having a hardness of about twenty (Brinell) has been found to require more than 400 tons per square inch.

It has been further found that the impact pressures developed, as above mentioned, amount to about twenty times the elastic limit of the respective metals. Since the elastic limit of the best tool and die steels is only about four times that of mild steel, it is clear that any attempt to extrude metal from a confined mild steel blank by impact in the cold state would result in crushing and breaking down the punch or die, by reason of the fact that the pressure developed at the moment of contact of the punch with the confined blank, especially when the punch moves at relatively high speed, would be many times greater than the elastic limit of the steel of which the tools are made.

As a result of my researches, it has become apparent that the most successful way to produce a flowing movement of a confined metal blank in the cold state is to so regulate the speed at which the punch moves, at the moment of contact with the blank, that the generation of unduly high stresses which the tools cannot withstand is avoided. That is to say, the speed of the punch at, and immediately after the moment of contact with the blank, must be relatively slow or, in other words, the application of the initial pressure must be controlled.

Such low speed movement of the punch, with controlled increasing pressure on the blank will not, however, alone and of itself, produce the desired flow.

I have discovered that the desired result can be obtained, by slowing down the punch so as to limit the pressure at the first contact with the metal, then maintaining or increasing this pressure during a definite time interval, and, at the end of such interval, suddenly substantially increasing the pressure for a brief period.

The preliminary or pre-conditioning pressure, above referred to, and which is applied for a very brief interval, appears to have the effect of rendering the blank relatively plastic, and of creating a quasi-hydrostatic or quasi-hydraulic pressure within the same. When, therefore, the pressure is immediately thereafter suddenly increased, the relatively plastic metal in the blank flows freely into the openings or recesses provided in the tools for forming the desired projections or raised parts of the article.

Although, in their broader aspects, not limited to any specific structure, the method of the invention can be carried out by, and the apparatus of the invention can be embodied in a conventional crank or eccentric press, and, by way of example, and for purposes of illustration, such a press will be described in the following specification.

In order that the invention may be readily understood, reference is had to the accompanying drawings, forming part of this specification, and in which:

Fig. 1 is a more or less diagrammatic vertical section through the head of a crank-type press modified in accordance with the invention and also showing the punch and die, parts being in elevation, this figure illustrating the position of the parts at the moment of cutting out the blank from the stock;

Figs. 2, 3, 4 and 5 are similar views showing the successive positions assumed by the parts during the completion of the stroke of the press;

Fig. 6 is a diagram showing the comparative movements of the head of the press and of the punch, the diagram also illustrating the action of the spring assembly as the head moves. The parts of the curves shown in heavy lines in this figure illustrate the steps shown in Figs. 1 and 2;

Figs. 7, 8 and 9 are similar diagrams, the heavy portions of the curves in these diagrams illustrating the steps shown respectively in Figs. 3, 4 and 5.

Fig. 10 is a diagram illustrating the changing pressures exerted on the blank, with respect to time, as the press makes its working stroke; and

Figs. 11 and 12 are fragmentary, vertical sections similar to Fig. 4, but on a larger scale, showing modified construction of the punch and anvil.

Referring to the drawings in detail, and more particularly first to Fig. 1 thereof, I have illustrated a press having a head 1 provided with trunnions 2 to which are attached connecting rods 3 extending to some suitable eccentric or crank shaft (not shown). The interior of this head is hollow so as to provide a cylindrical chamber and through the center of this chamber extends a vertical rod 4, sliding freely through the head and having its upper end threaded to receive a nut 5 which is adapted to engage the head.

The lower end of the rod is rigidly connected with a

screw threaded block 6 on which works a nut 7 which may be vertically adjusted on the block by turning the same.

To the lower end of the block 6 is secured a punch 8, which cooperates with and closely fits a hollow die 10 having a cavity to receive the blank, and provided with an anvil 11 which supports the blank in the cavity. It will of course be understood that this die and anvil are suitably supported on the bed of the machine (not shown) and that means for ejecting the finished article from the die (not shown) are also employed.

The apparatus is illustrated as operating upon round disc shaped or cylindrical blanks such as indicated at *x*, these blanks being cut from a suitable sheet metal stock or strip X. This strip is supported on the top of the die 10 and the blanks are cut out therefrom by the punch 8 as it descends. Fig. 1 shows the punch in the act of cutting out such a blank, the blank being shown as partially severed from the stock.

It may be explained here that my improved method relates especially to the forming of metal articles from relatively small blanks of this nature having flat faces, and, as a result of my improved method, various kinds of projections or raised parts may be formed on the flat face of the blank. Such projections may be produced on either one or both faces of the blank and may take the form of either a single column or stud, or a plurality of such studs or columns, either of the same or different lengths. The invention is also equally well adapted for forming annular portions such as hollow hubs, rims or flanges projecting from the flat faces of the blank.

Such projecting parts are formed by providing suitable complementary openings or recesses in either the anvil or punch, or both.

For purposes of discussion, and for the sake of simplicity, it will be assumed that it is desired to form an article consisting of a circular disk or head with a relatively long stem or column projecting centrally from one face. For producing an article of this kind, the punch 8 is formed with a central opening or recess 9 extending axially thereof. As pressure is applied to the blank by the punch in accordance with the present invention, the metal of the blank is caused to flow up into this opening 9, thus producing the desired article.

Enclosed within the chamber of the head, and interposed between the screw threaded block 6 and the top wall of such chamber, is a suitable spring assembly which bears resiliently against the screw threaded block 6, it being understood that this block is of such a size as to be capable of entering the chamber in the head 1 and moving freely with respect thereto. Although other types of springs might be employed, I have illustrated a group of what are known as Belleville rings or washers 12. These surround the rod 4 and occupy the annular space between this rod and the walls of the cylindrical chamber in the head.

Each of these rings or washers is similar in shape to an ordinary saucer with the center portion cut out. Single rings may be assembled alternately face to face and back to back, so as to form an axially compressible stack, or they may be assembled in nested pairs, as illustrated in the drawing, or in any other desired nested groups, such groups being arranged alternately face to face and back to back. When the stack is compressed, the individual rings or washers tend to flatten out, as will be obvious. These rings or washers are of course made of stiff spring steel, so that they are extremely resilient and elastic, being distorted or flexed by heavy applied pressure, and immediately returning to their original shape when the pressure is removed. They are preferably so designed that relatively small increases in applied pressure will produce a substantially increased distortion.

The multiple groupings above mentioned are referred to as "series parallel" arrangements, and are identified by code numbers. Thus "5 x 2" would mean an assembly of five pairs or groups of two, as shown in the drawings. "6 x 4" would mean an assembly of six groups of four each, the rings of each group being nested, etc. It is obvious that by using more nested units in each group, the stiffness or resistance of the assembly is increased, and by using more groups the possible amount of deflection or compression of the stack is increased.

In the arrangement illustrated in the drawings, the spring assembly, when the press is idle, is under but little if any compression. In practice, however, it may often be desirable to put the spring assembly under substantial compression at the start, or, in other words, to "pre-load" the springs. This can be accomplished, to any extent desired, by screwing down the nut 5, thus drawing block 6 more or less up into the chamber of the head. Pre-loading the springs in this way results in rendering the assembly stiffer, and in reducing the amount of possible further compression.

As the head of the press makes its downward stroke, and the punch engages the stock X, the first effect is to compress the spring assembly 12, thus forcing the block 6 up into the cavity of the head to some extent as shown in Fig. 1. The springs are made of such strength that the elastic pressure which they exert on the punch is sufficient to cause it to cut the blank out of the stock. Immediately after the blank is cut out, as shown in Fig. 2, the pressure is relieved and the springs expand, thus forcing the block 6 downwardly out of the cavity in the head. The next instant, however, the punch enters the die cavity and engages the blank as shown in Fig. 2. Thereupon, as the head continues to descend, the springs 12 become more and more compressed, as the block moves further and further up into the cavity in the head, as shown in Fig. 3.

After the head has moved slightly further down than shown in Fig. 3, the bottom of the head engages the top of the nut 7 as shown at 13 in Fig. 4. No further compression of the springs is thereafter possible, but from this instant the punch is solid or rigid with the head and moves downwardly with it.

From the foregoing, it will be seen that as the punch engages the blank, as shown in Fig. 2, and the head continues to move downwardly, the punch does not move downwardly at the speed of the head, but its movement is slowed or delayed by reason of the yielding or deflection of the spring assembly 12. In other words, at the moment of contact between the punch and the blank, the speed of the punch becomes less than that of the head, and from this point onward until the parts reach the position shown in Fig. 4, the punch exerts a gradually increasing elastic pressure on the blank as the spring assembly 12 is more and more compressed.

Finally, when the position of Fig. 4 is reached, and the punch becomes rigid with the head, a suddenly increased pressure or solid thrust is applied to the punch and blank.

It appears that the first effect of applying the yielding or elastic pressure to the blank, beginning with the position of the parts as shown in Fig. 2, and thereafter gradually increasing, is to cause the blank to completely and absolutely fill the cavity of the die in which it is confined. It further appears that this application of pressure on the confined blank creates a quasi-hydrostatic or quasi-hydraulic pressure within the blank itself, which hydrostatic pressure, maintained during a definite, controlled time interval, renders the metal of the blank relatively plastic. At the end of the period of application of elastic pressure, or, in other words, when the elastic pressure has reached its maximum, the blank has been rendered plastic to such an extent that it will usually begin to flow into the opening or recess 9 of the punch, as indicated at *y* in Fig. 3, but if the operation should be stopped at this stage, no satisfactory movement of metal would be produced.

When, however, at the next instant, the nut 7 engages the head 1, thus rigidly coupling the punch to the head, a sudden increase of pressure is developed and delivered to the already plastic blank and this increased pressure results in causing the metal of the blank to freely flow up into and fill the opening in the punch as shown at *z* in Fig. 4.

It will thus be seen that I achieve this remarkable flowing of the metal in a cold state by first generating in the blank a kind of hydrostatic pressure, thus rendering it relatively plastic and then, at the proper instant, suddenly subjecting the plastic blank to a positive force which causes the metal to move freely into the opening in the punch.

To look at it another way, during the time that the spring assembly is becoming more and more compressed, as the head moves downward, the punch is slowed up and lags behind the movement of the head. When, however, the head engages the nut 7, and the punch thus becomes rigidly coupled to the head, the punch is given an accelerated further movement, at the speed of the head. While, during the previous time interval, the punch had been exerting a yielding pressure on the blank, at the instant of contact of the head with the nut 7, the punch applies a positive, unyielding thrust to the blank.

In the embodiment shown, the pressure applied to the blank through the spring assembly is a yielding, gradually increasing pressure. The fact that this pressure is "gradually increasing" is inherent in the particular type of press illustrated, but is by no means essential to the invention. So far as the improved method is concerned, the applied pressure might be uniform during the definite time interval above mentioned.

There are, in fact, two time intervals involved in my improved method, namely the interval during which the preliminary or pre-conditioning pressure is applied, and the interval during which the actual flow takes place. The first, although on the order of a few hundredths of a second, is relatively longer than the succeeding interval. The first is adjustable, the second is not, but determined by the existing physical factors.

With a given speed of the press, the duration of the first interval may be adjusted or controlled by selecting any desired number of rings to make up the spring assembly, and by pre-loading the assembly to any desired extent by means of the nut 5. The duration of the second interval, however, is determined by the speed of the press, the thickness of the blank, and the amount of displacement of the metal. It will be understood that the setting of the spring assembly as above mentioned, controls both the magnitude of the initial pressure, and also the length of the time interval through which it is applied.

It should be explained that the clearance necessary between the punch and anvil of the die when the punch reaches its extreme position at the end of its stroke, varies in accordance with the original thickness of the blank and the amount of metal to be displaced, or, in other words, with the final thickness of the blank after the article has been formed. This clearance may be controlled as desired, either by making the punch 8 longitudinally adjustable with respect to the block 6, or by adjusting the height of the anvil by means of suitable shims. It has not been deemed necessary to illustrate this in the drawings, since it is believed to be obvious.

Referring now to Figs. 6–9, I have attempted to show diagrammatically a curve *a* indicating the movement of the press head and a curve *b* indicating the corresponding movement of the punch. In these figures, I have also attempted to incorporate a third curve *c* showing the action of the spring assembly. It will be understood that these are time-distance curves and, for purposes of illustration, the speed of the press is assemed to be such that it makes a complete stroke in 6%100 of a second.

The curve *a*, showing the movement of the head, is a simple sine wave, since the head moves with a regular harmonic motion as the crank rotates. The punch, however, does not describe a simple harmonic motion, due to the fact that the inter-position of the spring assembly 12 causes it to lag behind the head at some points.

The portion b^1 of the curve *b*, as illustrated in Fig. 6, shows how the punch is slowed down by engagement with the stock as shown in Fig. 1, and it is then freed and moves suddenly at increased speed as it cuts through the stock and the springs expand as shown in Fig. 2, and as indicated by the portion b^2 of the curve.

In this Fig. 6, the portion c^1 of the curve *c* shows the gradual compression of the spring assembly as the punch encounters the stock in Fig. 1, the portion c^2 of the curve indicating the sudden relaxing of the spring pressure as the punch goes through the stock as in Fig. 2.

In Fig. 7, the portion b^3 of the curve *b* shows how the punch is delayed or slowed down as it imposes a gradually increasing pressure on the blank as the springs are compressed up to the position shown in Fig. 3. It will be particularly noted that the portion b^3 of the curve is by no means parallel with the corresponding portion a^3 of the curve *a*, since the downward movement of the punch during this interval is much less than the downward movement of the head. Similarly in Fig. 7 the portion c^3 of the curve *c* shows how the spring assembly is progressively compressed as the head moves down.

Fig. 8 illustrates the step of the operation shown in Fig. 4 in which the block 6 and head 1 are rigidly coupled together and in which the punch moves at the same speed as the head. In this figure the portion b^4 of the curve *b* is substantially parallel with the corresponding portion a^4 of the curve *a*, showing that the punch and head move together during this brief period. In the same figure, the portion c^4 of the curve *c* is a straight horizontal line, showing that there is no further compression of the spring assembly during this period. The punch remains rigidly coupled to the head until after the lower dead center of the crank is reached as indicated at a^1, which point is shown as substantially on the vertical line "30," which marks the middle of the stroke.

Referring finally to Fig. 9, this illustrates what happens as the crank passes dead center and the head begins to rise. The portion b^5 of the curve *b* at this point again does not follow the corresponding portion a^5 of curve *a*, because, at this instant, the spring assembly is relaxing and holds the punch down for a short time after the head begins to rise. Also, in this figure, the portion c^5 of the curve *c* shows how the spring assembly expands as the head moves up. After a brief instant, the springs have fully expanded, as shown in Fig. 5, and remain in this condition during the completion of the stroke.

Referring now to Fig. 10, I have endeavored by means of a time-pressure diagram to illustrate in a general way the variations of pressure to which the blank is subjected during the stroke of the press. The point d^1 of this curve *d* represents the maximum pressure at the instant when the punch cuts through the stock as shown in Fig. 1, and the curve then drops away showing that the pressure is relieved at the instant that the parts occupy the position shown in Fig. 2. From this point, a gradually increasing pressure is applied to the blank as indicated by the portion d^2, and this continues until the point d^3 is reached at which the head becomes rigid with the punch as shown in Fig. 4. At this moment, there is a sudden increase of pressure applied to the blank as indicated by the portion d^4 of the curve. The exact shape of this part of the curve is problematical. At the moment at which the punch becomes rigidly coupled to the head, the pressure rises abruptly, but, as the punch continues its downward movement, and the metal flows, as described, it seems probable that this flowing may relieve, or at least limit the pressure. The diagram shows the pressure curve rising vertically

to a maximum, and then flattening out, as indicated at d^5, while flowing takes place. This pressure is maintained substantially until dead center is reached. The portion d^6 of the curve indicates how the pressure on the blank is prolonged for a brief period by the expansion of the spring assembly immediately after the dead center is passed. After this brief period the pressure of course immediately falls away to zero.

When working with flat blanks of the character described, tests show that the metal layer in contact with the recessed tool does not contribute to the formation of the raised parts or projections. The deeper or intermediate layers, on the contrary, supply the metal to provide the projections. This metal flows at first in a direction parallel to the faces of the blank and afterwards bends to a direction at right angles and flows into the opening or recess in the tool.

During the deformation of the blank, a certain amount of heat is generated, this heat assisting somewhat in keeping the metal malleable and tending to prevent the hardening effect which is sometimes noticed in the cold working of metals.

With soft metals, extrusion may be obtained with little difficulty due to the fact that the stresses necessary to deform these metals very quickly and cause the blank to completely fill the cavity of the die do not exceed the resistance of tool steel. When working steel, however, a longer time is necessary to obtain this result, and for this reason my improved method includes the step of slowing down the speed of the punch at the moment it comes into contact with the blank so as not to generate unduly high stresses in the tools. The desirable speed is a function of the elastic limit of the particular metal, and the higher the elastic limit, the lower the speed of the punch should be.

Not only must the speed be lower, the higher is the elastic limit of the metal, but the speed must remain low for a longer time the more the shape of the blank differs from the shape of the cavity in the die, that is to say, a longer time is needed to obtain the quasi-hydrostatic or quasi-hydraulic pressure in the metal, above referred to. Once this condition of hydrostatic pressure is produced, however, the deformation or flowing must then be performed rapidly.

As above mentioned, my improved method comprises limiting the pressure on the blank at the first contact of the punch with the metal, and then maintaining or increasing this pressure. In the embodiment illustrated, the pressure is increased due to the fact that the elastic assembly is more and more compressed. It is during this period, the duration of which is of the order of some hundredths of a second, that the blank is caused to completely conform with the shape of the cavity in which it is confined. Immediately afterwards, when a state of quasi-hydrostatic pressure has been reached within the blank, a positive flowing pressure is applied to obtain the desired displacement of the metal. At this point, it is no longer necessary to limit the speed at which the punch moves. On the contrary, the flow of metal will be more substantial if the speed is relatively high.

In practice, and with a press of the type described, the extent of slowing down of the punch and the duration of the period in which the increasing elastic pressure is applied, is regulated by varying the characteristics of the spring assembly. The fewer Belleville rings or washers employed, the less will be the slowing down of the punch and the shorter will be the time interval during which elastic pressure is applied. If it is desired to increase the time interval, a greater number of rings or washers is employed. The time interval may also be shortened by pre-loading the spring assembly by screwing up the nut 5, as above explained.

Tests were carried out with a crank type press running at a speed of 100 strokes per minute, and with a 60 mm. stroke, on blanks of mild steel having a diameter of 11.5 mm. and a thickness of 3 mm. and with a punch closely fitting the die cavity and having an opening or recess the diameter of which was about 22% of the diameter of the blank. With these dimensions, it will be seen that the blank was confined within the die cavity over about 98% of its total surface. While the exact percentage will of course vary with the number and size of the openings in the tool, the essential thing is that the blank be confined over a major portion of its surface. When no springs at all were used, the metal of the blank entered the opening of the punch to the extent of only 0.3 mm. When a 2 x 4 spring assembly having a short time interval and a very small elastic deformation such as 2.2 mm. was used, nearly the same result was obtained at the end of the application of yielding pressure, not followed by any rigid coupling of the punch to the head. When the press was so arranged that at the end of the application of the yielding pressure, the punch became rigidly coupled to the head, as shown in Fig. 4, a plug or column was forced into the opening of the punch to a height of 1.5 mm.

When a 4 x 4 spring assembly capable of an elastic deformation twice as large as that above referred to, namely, about 4.4 mm. was employed, a plug of about 3.2 mm. was obtained.

Using a 6 x 4 spring assembly having a still greater elastic deformation, namely, a deformation of about 6.6 mm., three times that referred to in the first example, it was possible to obtain a plug or column 4.1 mm. in height.

Experiments have shown, however, that increasing the elastic deformation of the spring assembly beyond this point, that is to say, still further lengthening the time interval during which the preliminary pressure is applied, does not improve the results, but, in fact, is a disadvantage. Thus, when the elastic deformation of the spring assembly was increased to four times that of the first example, namely, to 8.8 mm., a plug or column of only 3.1 mm. in height was obtained. Further increasing the elastic deformation by another 25%, yielded a plug of only 2.6 mm. in height. There appears to be therefore an optimum amount of elastic deformation or, in other words, an optimum time interval during which the elastic pressure is applied, this optimum producing a maximum flow. Such an optimum depends, among other things, upon the nature and hardness of the metal and can be calculated or predetermined for any particular kind of metal, and the amount of displacement to be produced.

Although, as indicated by the diagrams of Figs. 6–10, the time, during which the elastic pressure was applied to the blanks, is shown as about $\frac{5}{100}$ of a second, such time may vary from 5 to $\frac{15}{100}$ of a second, while the period during which the punch moves rigid with the head and subjects the blank to a positive flowing pressure is usually considerably less, namely, on the order of 1 to $\frac{5}{100}$ of a second. In practice, the time intervals will vary, depending upon particular conditions such as the size and hardness of the blank, the amount of displacement to be produced, etc.

The exact point of transition between the application of elastic pressure and the rigid coupling of the punch to the head can be selected as desired by adjusting the position of the nut 7 on the block 6, and in this way the relative lengths of the respective time periods for the two phases of the operation may be altered at will.

As to the actual amount of pressure necessary, it has been found that mild steel blanks of a hardness of 100 to 115 Brinnell and having a surface of 100 to 110 square millimeters required a maximum elastic pressure of about 17 tons, that is to say, a pressure of about 200 kilograms per square millimeter.

The size and stiffness of the spring rings necessary to provide the desired amount of pressure, can be determined by tests, or may be ascertained from the manufacturer's ratings.

The percentage of metal displaced by my improved

method is relatively large. For mild steel blanks, and working with a punch closely fitting the die cavity and having an opening of a diameter of 22% of the diameter of the blank, the metal displaced or caused to flow into the opening was about 28% of the total initial volume of the blank. When the die or punch had a number of holes or openings instead of one, and where the thickness of the blank did not exceed 25% of its diameter, still greater displacements have been obtained.

While, for the sake of simplicity, the foregoing description has been based upon an imperforate anvil and a punch having a single opening, thus producing an article consisting of a flat head and single, long shank or stem, the invention is not, of course, limited to such configurations but is applicable to articles of a wide variety of shapes.

Thus, for example, in Fig. 11, I have illustrated the making of an article consisting of a disk having a plurality of projections or stems z^1, z^2, on one face, and one or more projections z^3, on the other face. In this case, an aperture or recess is formed in the anvil 11 to produce the lower projection.

In Fig. 12, I have illustrated the making of an article having on one face a peripheral flange z^4, and on the other face, a central projection z^5. In this case I provide the punch 8 with an annular groove to form the flange, instead of with an opening.

Where a number of projections are thus formed on one or both faces of the blank, it is possible to displace even a larger percentage of the metal than in the case of a single projection, but the projections, of course, will not be as long.

While, by way of example, I have illustrated the blank as a circular disk, it will of course be understood that the invention is equally applicable to the formation of articles from square or other polygonal blanks.

What I claim is:

1. The method of forming a metal article from a disc-shaped metal blank of substantial thickness in a cold, rigid state comprising confining the blank in a die cavity between an anvil and a punch, one of said parts having an opening extending at substantial right angles to the plane of the disc, subjecting said confined blank, by means of the punch, to a preliminary elastic pressure, gradually increasing this pressure during a definite time interval of a few hundredths of a second until the metal of the blank becomes relatively plastic and begins to flow into said opening, and thereupon suddenly exerting on said confined, relatively plastic blank, by means of said punch, an unyielding thrust, to cause the metal to flow further into said opening to form on the blank a projection of substantial length.

2. The method of forming an article from a disc-shaped steel blank of substantial thickness in a cold state comprising confining the cold blank in a die cavity between an anvil and a punch, one of said parts having an opening, causing said punch to apply an elastic pressure to said confined blank, gradually increasing such pressure during a time interval of a few hundredths of a second until it reaches a value on the order of two hundred kilograms per square millimeter and the steel begins to flow into said opening, and immediately thereafter causing said punch to exert a suddenly increased, unyielding pressure on said confined blank, whereby the steel is caused to flow further into said opening to form on the blank a projection of substantial length.

3. The method of forming an article from a disc-shaped steel blank of substantial thickness in a cold state comprising confining the cold blank over approximately ninety-eight percent of its total surface in a die cavity, subjecting the confined blank to a preliminary elastic pressure for a few hundredths of a second until the metal of the blank reaches a state of such relative plasticity that it is caused to conform to and completely fill the cavity of the die, and thereupon suddenly increasing such pressure by applying an unyielding thrust, whereby the relatively plastic metal of the blank is caused to flow out over the approximately two percent of its surface which is not confined.

4. The method of forming an article from a disc-shaped cold metal blank in a press having a punch and a die, such method comprising causing the punch to perform three consecutive steps at a single stroke, namely, first, by its initial movement, to cut the blank from sheet metal stock and force it into the die, second, by a further movement in the same direction, to exert a gradually increasing elastic pressure on the confined blank until it conforms to and completely fills the die cavity, and third, by a final movement in the same direction to exert on the blank a sudden, unyielding thrust to produce the desired deformation, all three steps being performed within a total time interval of a fraction of a second.

5. The method of forming an article from a solid steel blank in a cold, rigid state, said blank having a flat face, comprising confining over a major portion of its surface the cold blank in a die cavity between an anvil and a punch closely fitting said die cavity, one of said parts having an opening extending at substantial right angles to said flat face of the blank, subjecting the flat face of the confined blank to a controlled preliminary pressure on the order of two hundred kilograms per square millimeter by means of the punch, maintaining such pressure for a few hundreths of a second until the steel of the blank reaches a state of such relative plasticity that it is caused to conform to and completely fill the cavity of the die and to enter said opening to a minor extent, and thereupon suddenly increasing the pressure applied by said tool on the flat face of said confined, relatively plastic blank to such a degree as to cause a major flow of the steel into said opening.

References Cited in the file of this patent

UNITED STATES PATENTS

850,212	Conlen	Apr. 16, 1907
1,063,632	White	June 3, 1913
1,380,250	Reymond	May 31, 1921
1,484,490	Goldschmidt	Feb. 19, 1924
1,921,654	Burbank	Aug. 8, 1933
1,955,243	Liebergeld et al.	Apr. 17, 1934
2,125,068	Dempsey	July 26, 1938
2,135,803	Dumert	Nov. 8, 1938
2,162,132	Spire	June 13, 1939
2,225,345	Lemoreaux	Dec. 17, 1940
2,241,735	Redsecker	May 13, 1941
2,261,304	Sparks	Nov. 4, 1941
2,382,045	Flowers	Aug. 14, 1945
2,432,717	Berger	Dec. 16, 1947
2,473,371	Heath et al.	June 14, 1949

FOREIGN PATENTS

698,303	France	Nov. 17, 1930

OTHER REFERENCES

Iron Age, pp. 69–75, Oct. 19, 1950.

Wall Street Journal, page 5, Sept. 20, 1951.