May 8, 1956 R. P. FITZGERALD 2,744,315

METHOD AND APPARATUS FOR DIE-FORGING ARTICLES FROM BLANKS OF NORMALLY RIGID MATERIAL

Filed Nov. 15, 1951 3 Sheets-Sheet 1

Fig. 1.

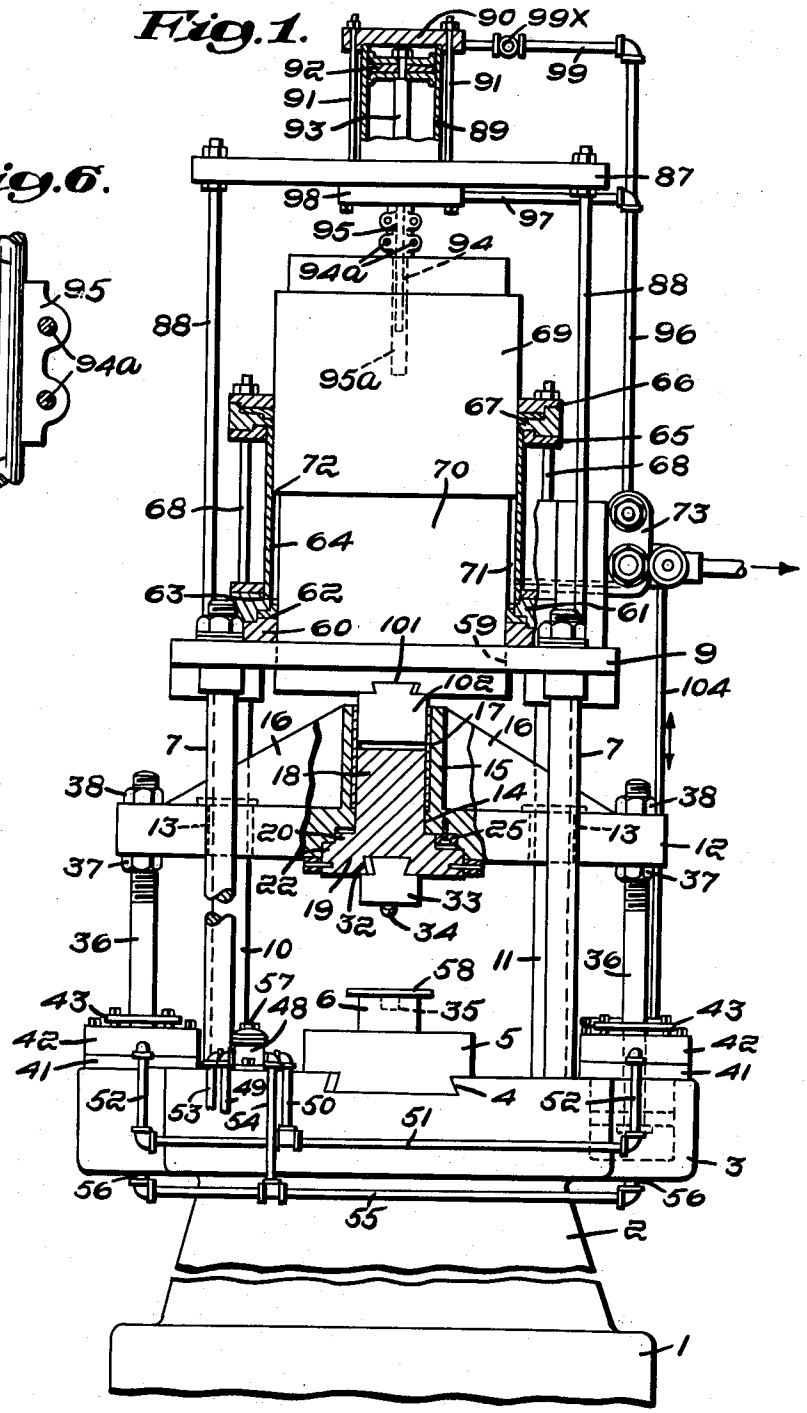


Fig. 6.

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Filed Nov. 15, 1951 3 Sheets-Sheet 2

Fig. 4.

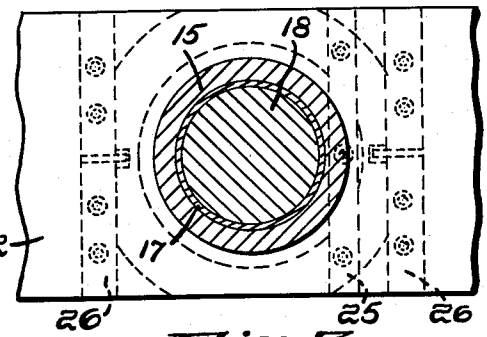


Fig. 2.

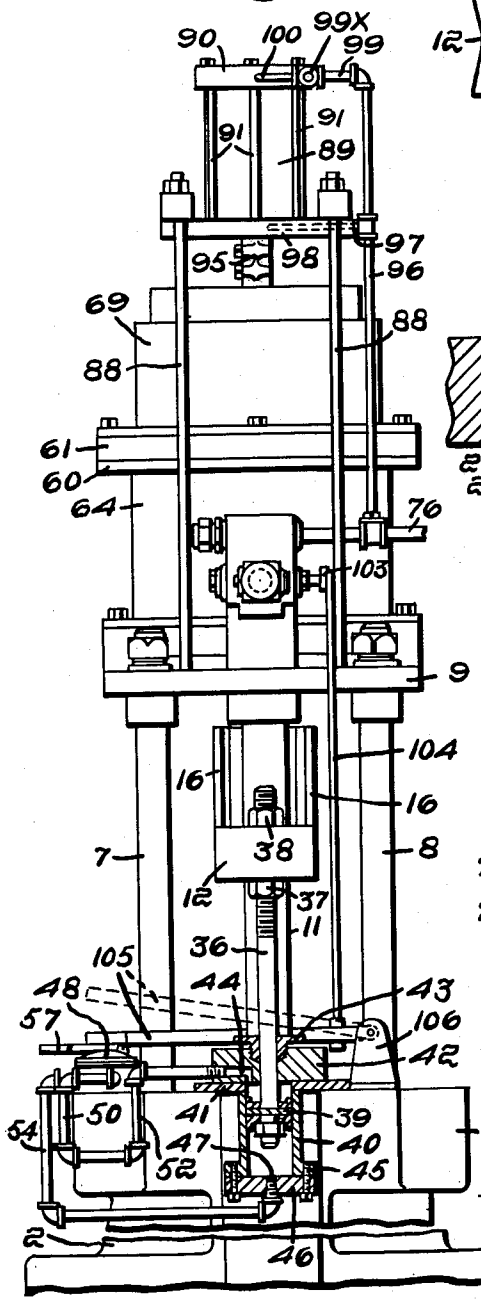


Fig. 3.

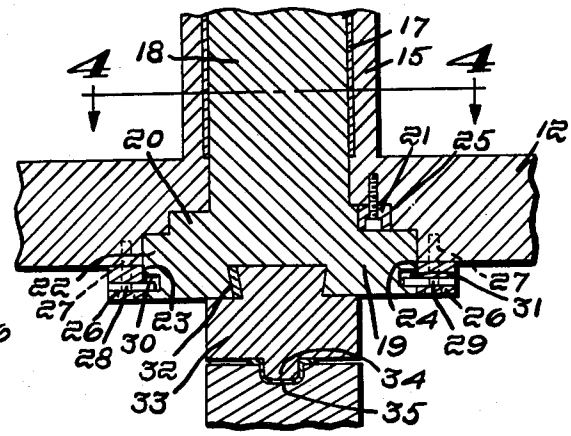
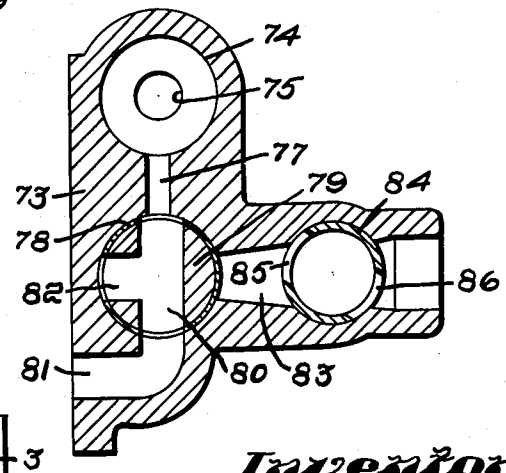


Fig. 5.



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Filed Nov. 15, 1951 3 Sheets-Sheet 3

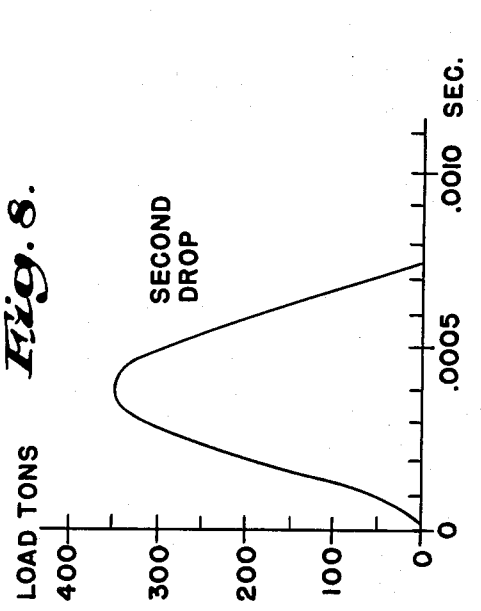


Fig. 8.

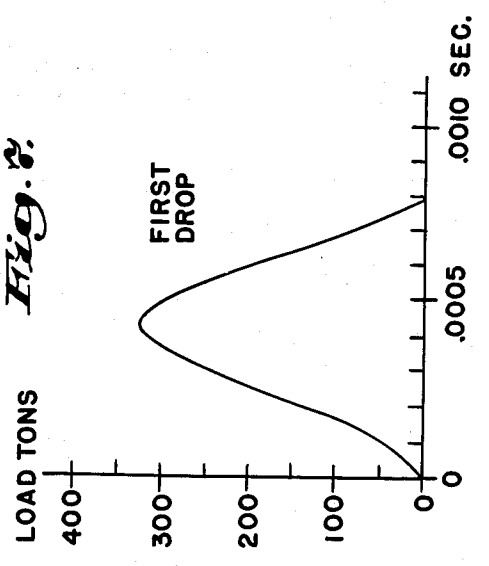


Fig. 9.

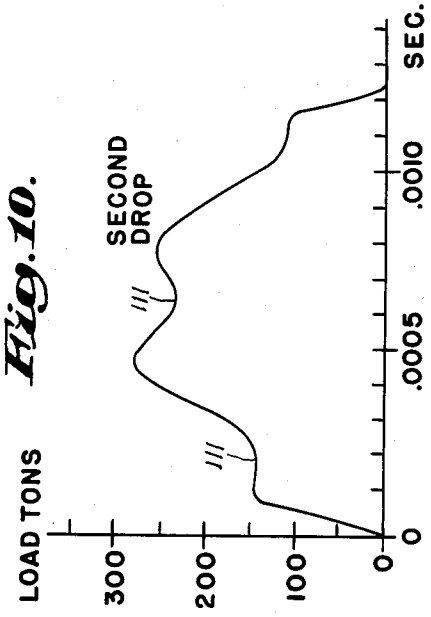
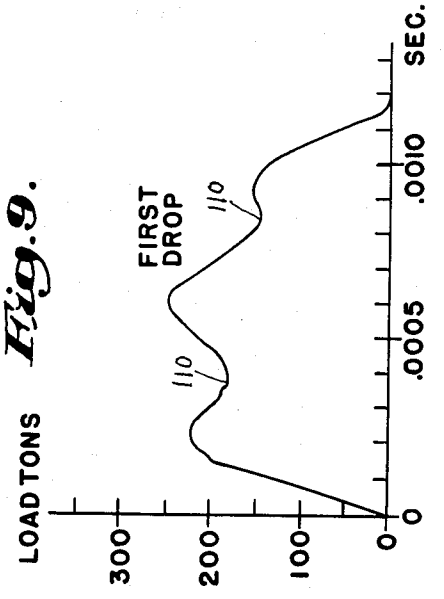


Fig. 10.



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United States Patent Office

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METHOD AND APPARATUS FOR DIE-FORGING ARTICLES FROM BLANKS OF NORMALLY RIGID MATERIAL

Reginald P. Fitzgerald, Braintree, Mass., assignor to Pneumatic Drop Hammer Company, Braintree, Mass., a corporation of Massachusetts

Application November 15, 1951, Serial No. 256,575

15 Claims. (Cl. 29—553)

This invention relates to die-forging articles from suitable, normally rigid, materials, such as gold, silver, aluminum, metal alloys, and other materials having like characteristics, and the general object of the invention is to provide a method and apparatus which will produce die-forged articles more accurately and uniformly conforming to the contours of the dies than has heretofore been produced.

It is the object of the invention to provide a method and apparatus in which the dies, with the interposed blank of metal, are first clamped together to insure a firm grip of the metal and prevent any relative shifting of the dies and the blank particularly if successive blows are necessary, and second, then to cause a heavy mass falling freely a short distance to impinge upon the dies, preferably at the moment of the maximum clamping pressure, and force the metal of the blank into intimate contact with the surface configuration of the dies. The criterion of heavy mass and short distance required by the present invention is determined by the pressure wave curve produced. This pressure wave curve has well-defined characteristics by which it may readily be identified. First, it is of a generally wavy trapezoidal shape, second, it presents at the top at least two well-defined dips. Further, under the same conditions of material operated upon and in comparison with the ordinary drop hammer where a light mass falls a long distance, the maximum time ordinate which indicates duration of the blow is definitely longer and the maximum pressure ordinate is definitely shorter. The anvil ratio is also far smaller. This action of impact of a heavy mass falling a short distance, and consequently at low velocity with a long continued impetus, forces the metal into intimate contact with the surfaces of the dies and even in the case of complicated and intricate designs one or not more than two blows are usually sufficient.

The perfect die-forging of metal by complementary dies producing designs of the finest and most intricate character is secured by this invention and this by the combination of the two co-acting features of the operation. In the first place, the metal is first rigidly clamped between the complementary dies and is preferably subjected to a progressively increasing pressure exerting a force sufficient to overcome the resistance to deformation of the metal and force it to some extent into conformation to the surfaces of the dies. In the second place, at the moment of maximum pressure, and while the metal is thus still held with this deforming force applied, the heavy mass falling a short distance, and thus with low velocity and great momentum, is caused to impinge upon the dies and thus acts to continue the deformation of the metal and force it into the desired intimate contact with the surfaces of the dies.

The pressure first applied to the dies is preferably produced by hydraulic means but is a continuing increasing pressure and in many cases produces a plastic flow of the material clamped between the dies so that the impact of the heavy mass moving at low velocity acts to continue this plastic flow.

A preferred form of apparatus embodying the invention and suitable for carrying out the method of the invention is illustrated in the accompanying drawings, in which,

Fig. 1 is a front elevation of the machine, certain portions thereof being shown in vertical section;

Fig. 2 is an end elevation of the machine shown in Fig. 1;

Fig. 3 is a detail vertical sectional view of a portion of the upper die-supporting beam and hammer-actuated die and a portion of the anvil die;

Fig. 4 is a horizontal sectional view on line 4—4 Fig. 3;

Fig. 5 is a detail sectional view of the valve mechanism shown in Fig. 1 for actuating the hammer;

Fig. 6 is a detail illustrating the adjustable stop for the piston rod;

Figs. 7 and 8 illustrate pressure wave curves of the usual type; and,

Figs. 9 and 10 illustrate pressure wave curves such as produced by, and characterizing, the present invention.

The apparatus illustrated in the drawings comprises a heavy anvil base 1, preferably of rectangular form, having an upwardly converging section 2 upon the upper end of which a rectangular anvil member 3 is suitably mounted or formed integral therewith. The anvil 3 is provided midway of its length with a dovetail recess 4 in which a die-support 5 is adjustably mounted to permit forward and rearward adjustment thereof. An anvil die 6 is suitably secured centrally to the upper face of the die support 5. Front and rear pairs of vertical columns 7 and 8 are mounted upon and extend upwardly from the anvil in proximity to the corners thereof and are connected at their upper ends by a yoke 9. Another pair of accurately surfaced cylindrical columns 10 and 11, preferably of greater diameter than the columns 7 and 8, are mounted upon the anvil and extend upwardly therefrom midway of the distance between the columns 7 and 8 and are connected at their upper ends to the yoke 9.

An upper-die-supporting beam 12, which is slidably mounted upon the columns 10 and 11, is provided with bushings 13 fitting the columns to insure accurate vertical movement of the beam 12. The beam 12, has centrally of its length a vertical circular bore 14 which is surrounded by a cylindrical upwardly extending boss 15 integral with the beam and having vertical bracing webs 16 extending radially therefrom lengthwise of the beam. The cylindrical boss 15 is of slightly greater internal diameter than the bore 14 and a cylindrical sleeve or bushing 17 of the same diameter as the bore 14 extends vertically therefrom. An upper-die-supporting block, which is slidably mounted in the aperture 14 of the beam 12 and the upwardly extending boss 15, is provided with a cylindrical upper section 18 which slidably fits the aperture 14 and the sleeve 17 and is provided at its lower end with an enlarged preferably general cylindrical head 19 having an upper stepped portion 20 one side of which is slabbed off to provide a flat surface 21 extending perpendicularly to the longitudinal axis of the beam, and the lower larger cylindrical section 22 of the head is similarly slabbed off to provide flat surfaces 23 and 24 parallel to the flat surface 21 upon the upper section 20.

The lower portion of the beam 12 is provided with stepped recesses complementary to those of the enlarged head of the upper-diesupporting member. A gib 25, which is mounted in a recess in the beam 12, engages the flat slabbed-off surface 21 and is secured thereto by machine screws, and serves to prevent rotative movement of the die-supporting block.

A pair of flat bars 26, which engage the flat surfaces 23 and 24 of the lower enlarged cylindrical portion of the upper-die-supporting block, are secured to the under face of the die by suitable machine screws 27. The bars 26

are provided with inwardly extending pins 28 and 29 which respectively engage vertical recesses 30 and 31 extending inwardly from the slabbed faces of the lower enlarged portion of the die-supporting block and permit the die-supporting block to have a limited vertical movement relatively to that of the beam 12. The lower cylindrical portion of the upper-die-supporting block is provided with a dovetail recess 32 which is parallel to the slabbed-off sides 23 and 24, and the upper die 33 is provided with an upwardly extending dovetail portion fitting the dovetail recess 32 in the die-supporting block. The upper die 33 is provided with a central downward extending punch 34 in axial alinement with a complementary matrix 35 in the lower die 6.

Suitable hydraulic means are provided for reciprocating the upper-die-supporting beam 12. As illustrated herein vertical piston rods 36 extend symmetrically through end portions of the beam 12 and are adjustably secured thereto by lower and upper nuts 37 and 38. The piston rods 36 are provided at their lower ends with pistons 39 which are mounted in vertical cylinders 40 preferably in vertical bores in the anvil or base. The upper end of each cylinder 40 is provided with an integral laterally extending flange 41 which rests upon and is secured to the upper surface of the anvil 3 and an upper cylinder head 42 which is bolted to the cylinder flange 41 is provided with a gland 43 through which the piston rod 36 extends. Liquid under pressure is supplied to and released from the upper chamber of the cylinder 40 through a bore 44 in the upper cylinder head to force the piston 39 and the beam 12 downwardly. The lower end of the cylinder 40 is provided with an outwardly extending flange 45 to which the lower cylinder head 46 is fixedly secured and is provided with a central threaded bore 47 through which liquid is introduced to lift the piston 39 and beam 12.

The entrance of liquid under pressure to the respective upper and lower chambers of the cylinder is controlled through a vertical rotatable controlling valve in a casing 48 to which liquid under pressure is supplied through a pump or other suitable source to the valve. When the valve is positioned to supply liquid under pressure to the upper chamber of the cylinder it passes through a downwardly extending pipe 50 to a horizontal pipe 51 the ends of which are provided with vertical pipes 52 leading through the heads 42 of the respective cylinders to the upper chambers of the cylinder 40. When it is desired to release the pressure from the upper chambers of the cylinders the valve is rotated about its vertical axis so that the liquid from the upper chambers of the cylinder may pass through it to an outlet pipe 53 to a suitable reservoir connected to the pump. Conversely, when liquid is to be supplied to the lower chambers of the cylinder the liquid passes from the inlet pipe 49 which leads to the pump through suitable ports in the valve to a downwardly extending pipe 54 to a horizontal pipe 55 which communicates with branches 56 leading through the lower heads of the respective cylinders.

Suitable rotation of the controlling valve will permit exhaust from the lower chambers of the cylinder through the outlet pipe 53 to the reservoir, as above described. The amount of hydraulic pressure thus applied to the cylinder may be regulated by the operation of the controlling valve which is provided with a horizontal handle 57 adapted to be rotatable in a horizontal plane.

In the operation of the mechanism above described a suitable blank 58 is placed upon the lower die 6 and hydraulic pressure is supplied to the upper chambers of the cylinders 40 to force the upper die downwardly into engagement with the blank. This pressure must be sufficient to lock the dies and the interposed blank firmly together so that there can be no relative shifting of the blank with respect to the dies even when more than one blow is applied. Preferably, however, the pressure is progressively increased even after the dies and the blank

are firmly locked together and acts to overcome the resistance to deformation of the metal engaged by the dies and thus bring it into general or approximate conformation to the contours of the die surfaces. The pressure thus exerted may in many cases be sufficient to produce a plastic flow of the metal thus assisting in bringing it into approximate conformation to the die surfaces.

But to whatever extent the pressure thus applied to the dies is increased the invention provides for the impact of a heavy mass falling a short distance, and therefore moving at low velocity, to take place before this pressure is released, and preferably when this pressure is at the maximum and thus with a continuing impetus to continue the flow of metal into the contours of the dies.

In the construction illustrated the impact takes place upon the upper die which is so mounted upon the beam 12 as to have a limited vertical sliding movement with respect thereto, through a drop hammer falling by gravity a short distance, and consequently at low velocity, striking the upper cylindrical end 18 of the upper die-supporting block, causing the continuing deformation of the metal of the blank bringing it into intimate contact with the surfaces of the dies.

The terms "heavy mass" and "short distance" as used herein and as applied to this invention mean that the relation between the mass and the distance is such that the pressure wave curve produced has certain well-defined and distinctive characteristics. This is illustrated by Figs. 9 and 10 of the drawings representing typical curves, wherein the time co-ordinates extend horizontally and the pressure co-ordinates vertically. These pressure wave curves have well-defined characteristics, first, they are of generally wavy trapezoidal shape; second, at the top of the curve there are at least two well-defined dips indicated at 110 in Fig. 9 and 111 in Fig. 10. Typical pressure wave curves of the ordinary drop hammer employing a relatively light mass falling at high velocity as through a relatively long distance, are shown in Figs. 7 and 8. It is apparent that these curves of Figs. 7 and 8 have a characteristically generally elongated parabolic shape. There are no well-defined dips at the top of the curves, but rather a generally substantially continuous convex curve and the maximum time co-ordinate is less than the maximum pressure co-ordinate.

The pressure wave curves of Figs. 7, 8, 9 and 10 are typical of those produced by hammers operating upon the same conditions of material and differing only in that the hammer of Figs. 7 and 8 was of the ordinary type and operated with a light mass falling a long distance, while the hammer of Figs. 9 and 10 embodied the present invention and operated with a heavy mass falling a short distance and with both developing substantially the same amount of energy at the moment of impact.

Not only is the shape of these two sets of curves characteristically different, but further it will be seen that the maximum time ordinate indicated in seconds, which represents the duration of the blow or pressure of the hammer on the dies is far longer, on the order of 50% longer, and that the maximum pressure ordinate indicated in tons is far shorter, also on the order of 50%, in Figs. 9 and 10 of the present invention than in Figs. 7 and 8 of the old and ordinary type of hammer.

Again the anvil ratio in an apparatus of the present invention is characteristically far smaller than that of the comparable ordinary hammer employing a relatively light mass falling a relatively long distance. For example, with a typical apparatus of the ordinary type the hammer mass may be of 900 pounds and the anvil of 18,000 pounds thus with an anvil ratio of 20/1. A comparable apparatus of this invention would have an anvil of the same weight but a hammer mass of about 2700 pounds and consequently an anvil ratio of 20/3 or three times smaller.

The pressure wave curves of Figs. 7 and 8 are typical

of those produced by a hammer of 900 pounds and the curves of Figs. 9 and 10 of those produced by a hammer of 2700 pounds or on the order of three times the mass of the former with the distance of the drop of the 900 pound hammer on the order of three times the distance of the drop of the 2700 pound hammer.

A typical drop hammer embodying the principles of this invention, as illustrated in the drawings and employed for the die-forging of solid silver tableware, is a hammer of 2700 pounds weight falling freely a maximum distance of 10", producing pressure wave patterns such as illustrated in Figs. 9 and 10 and forming accurately and uniformly highly intricate patterns in the blanks. The exact weight of the hammer and distance it is allowed to fall may, of course, vary provided this relation of heavy mass and short distance as herein defined is secured and suitable means may be provided for raising the hammer and releasing it from its raised position to allow it to fall.

In the construction illustrated in the accompanying drawings the yoke **9** is provided with a cylindrical aperture **59** and a plate **60** having an aperture coincident with the aperture **59** is mounted upon the upper face of the yoke. A clamping plate **61** having an aperture therethrough coinciding with the aperture **59** is secured to the plate **60** with its under face recessed to receive a gasket **62** of equal diameter. The upper plate **61** is provided with a rabbet **63** of larger diameter than the aperture **59** in the yoke **9** and that of the plate **60** and the lower end of a vertical cylinder **64** is mounted in the rabbet **63**. The upper end of the cylinder **64** has welded to it a horizontal ring **65** which with an upper ring **66** and an interposed gasket **67** is secured to the plate **60** by a plurality of suitable tie rods **68**. The hammer comprises an upper section **69** which slidably fits within the cylinder **64** and the lower section **70** of smaller diameter which slidably fits within the gasket **62**, the aperture in the plate **60**, and the aperture **59** in the yoke **9**. The hammer is raised by means of air under pressure introduced through suitable controlling valve mechanism into the annular chamber **71** between the rabbet **62** and the shoulder **72** forming the junction of the upper and lower sections **69** and **70** of the hammer.

Suitable controllable means are provided for supplying air under pressure to the annular chamber **71** to lift the hammer and to permit exhaust of said pressure to permit the hammer to drop. As illustrated herein a controlling valve mechanism which is illustrated in Figs. 1 and 2 and in vertical section in Fig. 5 comprises a valve block **73** which is mounted upon the yoke **9** and extends upwardly therefrom and has in its upper portion a manually operable rotary valve **74** provided with an axial bore **75** to which air under pressure is admitted through a pipe **76**. The valve **74** has a radial port **77** adapted to register with a continuing port **78** which leads to a manually controlled rotatable three-way valve **79** in said block. The valve **79** is provided with a diametrical port **80** adapted to communicate with a conduit **81** which leads to the annular chamber **71** between the lower end portion **70** of the cylinder and the cylinder **64** to supply lifting pressure for raising the hammer. The rotary valve **79** is provided with a lateral port **82** extending at right angles to the port **80** and adapted upon manual rotation of the valve **79** to cut off the supply of air under pressure through the port **76** to the chamber **71** and to establish communication with an exhaust passage **83** in the block **73**.

A suitable manually operable rotatable valve **84** having diametrically opposite ports **85** and **86** is provided in the exhaust passage **83** for controlling the discharge of air from the chamber **71**. This control is desirable to extend the range of usefulness of the apparatus for various purposes but the primary purpose of the invention is secured when the hammer is allowed to fall freely.

So also the invention comprises means for regulating the height to which the hammer can be raised and for cushioning the upward movement of the hammer, but for the primary object of the invention the height to which the hammer is raised, and consequently the distance it drops, must be correlated to the weight of the hammer in accordance with the principles herein set forth. In the preferred construction illustrated herein an upper deck or platform **87** is supported upon four vertical rods **88** which are mounted at their lower ends upon the yoke **9**, and a cushioning cylinder **89**, which is mounted upon and extends upwardly from the central portion of this deck, is provided with an upper head **90** which is clamped upon the upper end of the cylinder **89** by parallel vertical rods **91**, the lower ends of which are fixedly secured to the deck **87**. A piston **92**, which is reciprocably mounted in the cylinder **89**, is provided with a vertical piston rod **93** which extends downwardly through a suitable bushed aperture in the deck **87**, the lower end **94** of the piston rod projecting some distance below the cylinder head **98**. A stop collar **95** is adjustably clamped to the lower end portion **94** of said piston rod and the enlarged section **69** of the hammer is provided with a well or axial recess **95***a* which is alined with the piston rod and into which the lower terminal of said piston rod enters when the hammer is in its raised position.

During the upward movement of the hammer it engages the stop collar **95** and during the final upward movement of said hammer the piston rod **93** and piston **92** will be moved upwardly in the cushioning cylinder **89**. The hammer is limited in its upward movement by the engagement of the collar **95** with the cylinder head **98**, as shown in Fig. 1.

Means are provided for introducing air under balanced pressure into the lower and upper chambers of the cushioning cylinder **89**. As illustrated herein a pipe **96** leads from the pipe **76** through which air under pressure is introduced into the lifting chamber **71** for the hammer and is provided with a branch pipe **97** which communicates with a conduit in the lower head **98** of the cylinder **89** with the lower chamber thereof. An extension of the pipe **96** is provided with a branch **99** which leads through the conduit **100** to the upper chamber of the cylinder **89** and is provided with a restricting valve **99***x*. The area of the shouldered portion **72** of the hammer-lifting chamber **71** is sufficiently greater than the area of the piston **92** in the cylinder **89** to enable the hammer to be raised against the pressures in the cylinder **89** and thereby to compress the air in the upper chamber of the cylinder **89** and upon upward movement of the piston to force the air from the chamber through the branch pipe **99** against the pressure therein and thereby to cushion the upward movement of the hammer. The height to which the hammer is lifted and the distance through which it may be dropped can be regulated by adjusting the collar **95** on the projecting end **94** of the piston rod **93**.

The collar is shown as divided axially into two halves which are clamped together and thus clamped to the piston rod by means of suitable clamping bolts **94***a*.

The lower face of the lower section **70** of the hammer is provided with a dovetail slot **101** which receives a complementary dovetail of a cylindrical extension **102** of the hammer which slidably fits within the sleeve **17** of the boss **15** which extends upwardly from the beam **12**.

The valve **79** is provided with a laterally extending arm **103** which is connected to the upper end of a vertical rod **104** the lower end of which is connected to a lever **105** which is pivotally mounted upon a boss or bracket **106** mounted upon and extending upwardly from the anvil **3** at the side of the machine diametrically opposite to the hydraulic controlling valve mechanism **48**. The lever **105** is of sufficient length to enable it to be grasped by one hand of the operator while his other hand is adapted to grasp the operating arm **57** of the valve controlling the hydraulically operated mechanism. The

elements 105 and 106 are shown in Fig. 2 but omitted for clearness from Fig. 1.

In the operation of the mechanism illustrated in the drawings the lever 105 is first depressed to rotate the valve 79 of the hammer-actuating mechanism to the position shown in Fig. 5, thereby to admit air under pressure to the lifting chamber 71 for the hammer and thereby to raise the hammer. The arms 57 of the valve for controlling the flow of liquid is next operated by the hand of the operator to admit liquid under pressure to the lower chamber of the hydraulic cylinder 40, thereby to raise its piston and piston rods and the beam 12 which supports the upper die and to separate the dies such distance as is permitted by the adjustment of the sectional piston rod 94 and piston 92 of the cushioning cylinder 89. The blank 53 is thereupon placed upon the lower die 6, the arm 57 of the hydraulic controlling valve is then rotated first to permit escape of liquid from the lower chamber of the hydraulic cylinder 40 through the pipe 55 and its branches and the outlet pipe 53 to the reservoir. The arm 57 of the controlling valve is then rotated to establish communication between the pipe 49 leading from the pump to the pipe 50, thence to the pipe 52 and its branches leading to the upper chambers of the cylinders 40 to force the beam 12 downwardly and to cause the punch 34 first to clamp the blank firmly between the dies and then to overcome the resistance to deformation of the material engaged between the dies and in some cases causing a plastic flow of the material. Before the pressure applied to the dies is released, and preferably when the pressure is at the maximum, the lever 105 is operated by the other hand of the operator to rotate the valve 79 in a direction to cut off the supply of air under pressure to the lifting chamber which surrounds the lower portion 70 of the hammer and to establish communication through the ports of the valve 79 with the exhaust passage 43, thereby to permit the hammer to drop and to cause the extension 102 of the hammer to impinge upon the cylindrical section 18 of the upper die-supporting block.

The invention acts to insure complete penetration of the material into irregularities in the contours of the die surfaces and into the interstices of intricate designs in the wall or walls of the respective dies, thus producing a finished article the surfaces of which are hardened and planished by the force of the blow of the hammer.

The invention enables finished articles to be produced at a more rapid rate than has heretofore been possible.

The preferred construction of machine illustrated is adapted to permit placing of successive blanks upon the lower die by automatically operated feeding mechanism which will further increase the rate at which the finished articles may be produced.

The method and apparatus of the invention may be employed by the use of suitable dies to forge coins having ornamental surfaces or by the use of dies having a complementary punch and matrix to produce hollow articles by drawing the material of the blank by the hydraulic pressure applied to approximate contact with the surfaces of the dies and then applying the force of impact by a heavy mass moving a short distance and thus with low velocity and continuing impetus.

This application is a continuation-in-part of application Ser. No. 129,222 filed November 25, 1949, now abandoned.

Having thus described the invention, what is claimed as new, and desired to be secured by Letters Patent, is:

1. The method of die-forging articles from blanks of normally rigid material which comprises placing a blank between complementary dies, moving the dies into tight clamping engagement with the blank to prevent shifting of the blank with respect to the dies when the dies are struck a heavy blow, and while the dies still clamp the blank causing a heavy mass falling a short distance to impinge upon the dies with the said mass so related to the said distance that the pressure wave curve produced is of a wavy trapezoidal shape as distinguished from a generally parabolic shape.

2. The method of die-forging articles from blanks of normally rigid material which comprises clamping a blank of said material between complementary dies by means of a progressively increasing pressure applied to said dies, said pressure being sufficient to lock the dies and the interposed blank firmly together so as to prevent shifting of the blank with respect to the dies even when more than one blow is applied to the dies, and while said pressure is still being applied causing a heavy mass falling a short distance to impinge upon the dies with the said mass so related to the said distance that the pressure wave curve produced is characterized at the top by at least two well defined dips as distinguished from a single substantially continuous convex curve.

3. The method of die-forging articles from blanks of normally rigid material which comprises clamping a blank of said material between complementary dies, applying to said dies a progressively increasing force sufficient to overcome the resistance to de-formation of the interposed material and to force it into approximate conformation to the surfaces of the dies, and then, while said force is still applied, causing a heavy mass falling a short distance to impinge upon the dies with the said mass so related to the said distance that the pressure wave curve produced is of a wavy trapezoidal shape as distinguished from a generally parabolic shape, thus to continue the de-formation of the material and force it into intimate contact with the surfaces of the dies.

4. The method of die-forging articles from blanks of normally rigid material which comprises clamping a blank of said material between complementary dies, applying to said dies a progressively increasing force sufficient to overcome the resistance to de-formation of the interposed material and to force it into approximate conformation to the surfaces of the dies, and then, while said force is still applied, causing a heavy mass falling a short distance to impinge upon the dies with the said mass so related to the said distance that the pressure wave curve produced is characterized at the top by at least two well defined dips as distinguished from a single substantially continuous convex curve, thus to continue the de-formation of the material and force it into intimate contact with the surfaces of the dies.

5. A machine for rapidly die forging from flat blanks of normally rigid metal comprising a stationary heavy anvil, a die mounted thereon having a matrix, suitably spaced vertical columns mounted on said anvil, a yoke rigidly connecting the upper ends of said columns to insure true parallelism thereof, a die-supporting beam slidably mounted on said columns, a die block slidably mounted in said beam in axial alinement with said anvil die, means securing said die block to said beam to permit limited vertical movement thereof relatively to said beam, an upper die mounted in said block having a punch complementary to said matrix, manually controlled hydraulically operable means for raising said beam and its die to permit a blank to be positioned upon the anvil die and operable to move said beam downwardly to cause the punch of the upper die to clamp the blank upon the anvil and thereupon to apply to said beam a progressively increasing force sufficient to cause the blank-engaging elements of the dies to overcome the resistance to distortion of the area of metal engaged between the punch and matrix and to plasticize the same and cause a flow of the plastic metal into approximate conformity with the walls of the matrix and punch of the respective dies, a hammer reciprocably mounted in said yoke to move vertically, and means for actuating said hammer to cause it to strike a blow upon said die-block of such force as to cause the plasticized material to contact with all the complementary surfaces of the matrix and punch.

6. A machine for rapidly die forging from flat blanks

of normally rigid metal comprising a stationary heavy anvil, a die mounted thereon having a matrix, suitably spaced vertical columns mounted on said anvil, a yoke rigidly connecting the upper ends of said columns to insure true parallelism thereof, a die-supporting beam slidably mounted on said columns, a die block slidably mounted in said beam in axial alinement with said anvil die, means securing said die block to said beam to permit limited vertical movement thereof relatively to said beam, an upper die mounted in said block having a punch complementary to said matrix, manually controlled hydraulically operable means for raising said beam and its die to permit a blank to be positioned upon the anvil die and operable to move said beam downwardly to cause the punch of the upper die to clamp the blank upon the anvil and thereupon to apply to said beam a progressively increasing force sufficient to cause the blank-engaging elements of the dies to overcome the resistance to distortion of the area of metal engaged between the punch and matrix and to plasticize the same and cause a flow of the plastic metal into approximate conformity with the walls of the matrix and punch of the respective dies, a heavy drop hammer reciprocably mounted in said yoke and manually controlled means for actuating said hammer to cause it to strike a blow upon said die block with such force as to cause the plastic material to contact with all complementary surfaces of the matrix and punch and having continuing impact which will insure complete penetration of the plastic material into interstices of the intricate design in the wall or walls of the matrix.

7. A machine for die forging articles from blanks of normally rigid material comprising a vertical stationary base having an anvil upon the upper end thereof, a lower die mounted centrally thereon having a matrix, suitably spaced parallel vertical columns mounted on said base centrally of the width of the anvil and equidistant from said die, a yoke rigidly connecting the upper ends of said columns having a vertical cylindrical aperture therethrough in vertical axial alinement with said lower die, vertical spacing posts connecting said yoke to the anvil, an upper-die-supporting beam slidably mounted on said columns, a vertical die-supporting block having an upper portion slidably mounted in said beam and having an enlarged lower head provided with an upper die having a punch complementary to the matrix of the lower die in axial alinement therewith, means for permitting a limited vertical movement of said die block relatively to said beam, means for preventing rotation of said die block about a vertical axis, manually controlled hydraulically operable means selectively operable to raise said beam to permit the blank to be placed upon the lower die and to move the beam downwardly to cause the upper die to clamp the blank upon the lower die and thereupon to apply to the area of the blank engaged between the dies sufficient force to overcome the resistance to deformation of the material of the blank engaged by the dies and to plasticize the same and cause the plasticized material approximately to conform to the contours of the respective dies, and means for applying to the upper die-supporting block an impinging force sufficient to cause further flow of the plastic material to conform to the complementary surfaces of the matrix and punch of the respective dies.

8. A machine for die forging articles from blanks as defined in claim 9, in which a drop hammer is slidably mounted in the aperture in said yoke in axial alinement with the upper die-supporting block, in which manually controlled pneumatically operable means are provided for raising the hammer and permitting it to drop, in which the hammer is of sufficient weight and capable of being so regulated by said pneumatic controlling mechanism as to strike a blow of low velocity and insure penetration of the plasticized material into interstices in intricate designs in the walls of said matrix and punch, and, in which the hammer has a cylindrical lower section slidably fitting the aperture in said yoke and an upper cylindrical

section of larger diameter forming a shoulder therebetween, a vertical cylinder mounted on said yoke fitting the upper section of said hammer and providing an annular space below said beam, and manually controlled means selectively operable for introducing air under pressure into said space to raise the hammer and for releasing the air therefrom to permit the hammer to drop.

9. A machine for die forging articles from a blank of normally rigid material which comprises a vertical stationary base having an anvil upon the upper end thereof, a lower die mounted on the anvil, a pair of suitably spaced vertical cylindrical columns mounted on said base centrally of the width of the anvil and equidistant from said dies, a yoke rigidly connecting the upper ends of said column having a cylindrical aperture therethrough in axial alinement with said lower die, vertical spacing posts connecting the yoke to the anvil, an upper die-supporting beam slidably mounted on said columns, a vertical upper die-supporting block slidably mounted in said beam in axial alinement with said lower die, means for limiting the sliding movement of said block, hydraulic mechanism for actuating said beam comprising vertical cylinders mounted on said base having vertical piston rods respectively adjustably connected to the end portions of said beam, manually controlled means for alternately supplying liquid under pressure to and releasing it from the lower and upper chambers of said cylinders, a cylinder mounted on said yoke surrounding the aperture therethrough and of greater diameter than said aperture, a hammer having a cylindrical lower section slidably fitting the aperture in said yoke and a cylindrical upper section slidably fitting said cylinder, means for supplying air under pressure to the space between the lower section of said hammer and the upper section thereof to lift the hammer comprising valve block mounted on said yoke having a conduit communicating with the space between the lower section of the hammer and the surrounding cylinder and a conduit for exhausting the air therefrom, a manually operable rotatable three-way valve in said conduit having ports therein for selectively establishing communication with said space to supply air under pressure thereto or to exhaust the air therefrom, an inlet conduit in said block leading to said valve, an air line for supplying air under pressure to said inlet conduit, a plurality of vertical posts mounted on said yoke, a deck mounted on said posts having an aperture therethrough in axial alinement with said hammer, a cylinder mounted on said deck having a piston and a vertical piston rod extending therefrom through said deck connected to said hammer, and a pipe leading from said air line having branches leading respectively to the lower and upper chambers of said cylinder.

10. A machine for rapidly die-forging flat blanks of normally rigid material comprising a stationary heavy anvil, a die mounted thereon, suitably spaced vertical columns mounted on said anvil, a yoke rigidly connecting the upper ends of said columns to insure true parallelism thereof, a die-supporting beam slidably mounted on said columns, a complementary die mounted on said beam, manually controlled hydraulically operated means for raising said beam and its die to permit a blank to be positioned upon the anvil die and operable to move said beam downward to clamp the blank between the dies and thereupon to apply to said beam a progressively increasing force sufficient to overcome the resistance to distortion of the area of metal engaged between the dies and force it into approximate conformity with the surfaces of the dies, a heavy hammer mounted for vertical movement, and means for releasing the hammer from an elevated position to allow it to fall freely against the dies and force the distorted metal into intimate contact with all the surfaces of the complementary dies.

11. The method of die-forging an article from a blank of normally rigid material clamped under blank deforming pressure between complementary dies which com-

prises producing an impinging impact upon the dies the pressure wave curve of which has a characteristic wavy trapezoidal shape as distinguished from a generally parabolic shape.

12. The method of die-forging an article from a blank of normally rigid material clamped between complementary dies which comprises applying to said dies a progressively increasing pressure sufficient to overcome the resistance to deformation of the blank and to force it into approximate conformation to the surfaces of the dies and thereupon producing an impinging impact upon the dies the pressure wave curve of which has a characteristic wavy trapezoidal shape as distinguished from a generally parabolic shape.

13. The method of die-forging articles from blanks of normally rigid material which comprises placing a blank of said material between complementary dies, bringing said dies together under pressure at least sufficient to firmly lock the dies and the interposed blank together so that there can be no relative shifting of the dies and the blank, progressively increasing said pressure in opposition to the resistance to deformation of said blank, and producing an impinging impact upon the dies the pressure wave curve of which has a characteristic wavy trapezoidal shape as distinguished from a generally parabolic shape while said increased pressure is still being applied.

14. The method of die-forging articles from blanks of normally rigid material which comprises clamping a blank of said material between complementary dies, subjecting said dies to pressure at least sufficient to firmly lock the dies and the interposed blank together so that there can be no relative shifting of the dies and the blank, progressively increasing said pressure in opposition to the resistance to deformation of said blank, and causing a heavy mass falling a predetermined distance to impinge upon the dies, the force applied by said heavy mass being added to that of said previously applied increasing pressure to cause complete deformation of the material by forcing it into intimate contact with the surfaces of the dies.

15. The method of die-forming articles from blanks of normally rigid material which comprises placing a blank of said material between complementary dies, subjecting said dies to pressure at least sufficient to firmly lock the dies and the interposed blank together, progressively increasing said pressure to the extent necessary to cause substantial deformation of the blank by said dies, and causing a heavy mass falling a predetermined distance to impinge upon the dies while said increased pressure is still being applied to continue deformation of the material and force it into intimate contact with the surfaces of the dies, whereby the material is shaped into the configuration which the dies are designed to provide.

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