ABSTRACT: Liquid metal forging process comprising pouring liquid metal into a mold, applying high pressure by a punch to said liquid metal through a sealing member of thin plate interposed between the pressure-applying surface of said punch and the liquid metal, wherein during pressing the rim of said sealing member because of high pressure and high temperature deforms and closely fits the mold to seal the clearance between the punch and mold against entrance of said liquid metal, thereby preventing the formation of flash.
LIQUID METAL FORGING PROCESS

The present invention relates to an improvement in liquid metal forging in which molten or half-molten metal in a metal mold is pressed by a punch, or a plunger and solidified under high pressure to produce products in various desired shapes. The apparatus used in the present invention utilizes a sealing member, interposed between said punch and said liquid metal which prevents leakage of the liquid metal into the clearance space between the mold and the punch, and thus, applies pressure from the punch to the liquid metal more effectively and prolongs the life of the mold and punch.

Throughout the specification and the claims the term "liquid metal" is defined to include molten, half-molten, and partially molten metal to be forged.

In conventional metal forging, liquid metal is poured into a metal mold, and a punch of a size having a predetermined clearance with the wall surface of the pressure portion of the mold is inserted therein. High hydraulic pressure is then applied to the liquid metal by the punch until solidification of the liquid metal is completed. The resultant product evidences fine grain, compact internal structure. In order to retain the punch pressure (generally from 500 to 2,000 kg/cm²) effectively until the solidification of the liquid metal is completed, the clearance between the punch and the wall surface of the pressure portion of the metal mold is made as small as possible (from 0.01 to 0.05 mm.), and the liquid metal, which is solidified into the punch clearance when pressure is applied, is quickly cooled and is made to work as a packing, hereinafter termed "self-metal packing." However, there is a strong tendency for the packing to freeze the punch and mold together and when the punch clearance is too small, the wall surface of the mold and the punch come in contact with each other causing galling, and damage increases until the mold is broken by the tremendous friction between the self-metal packing, or flash, and the mold. Another disadvantage is that the pressure-effect of the punch is reduced, and it becomes impossible to exert sufficient pressure to the central portion of the liquid metal because the surrounding portion of the liquid metal is quickly solidified, producing a resistance to pressure which the ram cannot overcome.

When the liquid metal to be forged is one of the metals belonging to the group of aluminum, or copper, the wear and damage to the mold is relatively small, but when the liquid metal is one of the metals of the iron group, the hardness of the self-metal packing is remarkably high as it becomes iron oxide, or the like, and, therefore, the mold and the punch are greatly damaged when pressure is applied, and often to an extent that they are unusable only once and cannot be further employed. It has been suggested that a mold reinforcement be used in the form of an antiabrasive alloy such as a molybdenum alloy placed at the portion of the mold most subject to abrasion, but this has been found to be almost useless. Especially, in forging liquid metals of the iron group, the above mentioned disadvantages and drawbacks have led to poor results and no progress in the art of liquid metal forging.

In the present invention, the pressure is applied by the ram, or plunger, as in the conventional method, but a sealing member in the form of a metal plate is interposed between the liquid metal and the pressure applying surface of the punch, and pressure is applied by the punch to the liquid metal through sealing member. At that time, the sealing member is plastically deformed by the resultant high temperature and high pressure, and the rim of the sealing member is thereby deformed to closely fit to the wall surface of the pressure portion of the mold, and acts as a seal to prevent entrance of the liquid metal to the clearance space between the mold and the punch. As a result, no flash is formed, abrasion and flash damage are prevented, and the pressure of the punch is more effectively applied to the liquid metal. The rim of the sealing member has its hardness lowered by the high temperature, and moves smoothly in contact with the wall surface of the metal mold during the entire time the punch is being lowered.

From the above brief description it will be apparent that a primary object of the present invention is to provide an improvement in liquid metal forging which will overcome the defects and disadvantages of the previously outlined conventional method of liquid metal forging.

Another important object of the present invention is to provide an improvement in liquid metal forging which permits the forging of metals of the iron group without breakdown, or rupture, of the mold or the punch, except after repeated use, in contrast with conventional liquid metal forging wherein the mold and associated parts can be used only once.

The invention will best be understood from the following description of specific embodiments when read in connection with the accompanying drawings, wherein like reference characters indicate like parts throughout the FIGS., in which:

FIG. 1 is a cross-sectional view of an apparatus used in an embodiment of the present invention;
FIGS. 2 and 3 are fragmentary sections similar to FIG. 1 showing apparatuses used in other embodiments; and
FIGS. 4 to 6 are sectional views of the FIG. 3 apparatus with the punch in successively lowered positions during the forging operation.

Referring now more particularly to the drawings, FIG. 1 illustrates the apparatus used in an embodiment of the invention differing from conventional liquid metal forging apparatus in the addition of a thin metal plate 12 to the punch 3. Plate 12 is temporarily adhered by means of an adhesive, such as a resin, on the pressure applying end surface 4 of the punch 3. The remainder of the apparatus which is conventional includes a metal mold 1 having a cylindrical molding space inside thereof, the upper portion of the cylinder being the pressure portion 2 and the bottom portion thereof being the casting shaping portion or cavity 6. The molding space may have other and even irregularly shaped cross sections. The mold 1 is fixed on the base 8 by means of bolts 9.

In the conventional process, liquid metal 11 is poured into said mold and pressed with the punch, or plunger 3, capable of moving longitudinally within the pressure portion 2 by fluid, hydraulic, or any other pressure means, (not shown) until the metal is solidified into a dense, fine grain, round bar. Nearly uniform clearance space 5 exists between the punch 3 and the wall surface of the pressure portion 2 and the liquid metal passes into this space to form flash, as explained above. The knockout pin 10 is movable through an aperture in the base 8 to lift the forged casting out of the mold 1 upon completion of the process of forging.

The thin metal plate 12 is made of a material whose melting point is almost the same as, or higher than, that of the liquid metal 11 to be forged, and is shaped as a disk whose diameter is nearly the same as, or slightly larger than, that of the pressure portion 2. The rim 121 of plate 12 is preferably inturned, or bent, in one direction. The thin metal plate 12 is placed against and affixed to the end surface 4 of the punch in such a manner that the inwardly bent rim 121 faces toward the surface of the liquid metal 11 to be forged.

The disk 12 can be easily attached coaxially to the pressure applying end surface 4 of the punch by fitting a central projection 31 of the punch into a central hole 122 in the disk 12, as shown, for example, in FIG. 2. Alternatively, the disk 12 can be attached to the end surface 4 of the punch by inserting therebetween a thin plate 13 of compressed glass fiber, or ceramic fiber, of virtually the same disklike form as the metal disk, as shown in FIG. 3. The disk 12, with or without disk 13, must be temporarily attached coaxially to the end surface of the punch 4 by any suitable adherent means including the means mentioned above, and or glue, adhesive, pins, bolts, or the like.

In use of the described inventive embodiments, when the punch 3 is pushed into the pressure portion 2 of the mold to press the liquid metal, the gas at the surface of the liquid metal 11 escapes through the clearance space 5 past the bent rim 121 of the metal plate 12. When the punch 3 is further lowered and the plate 12 touches the upper surface of the
liquid metal 11, the temperature of the plate 12 is quickly raised to the heat of the liquid metal and the plate 12 is plastically deformed. During lowering of the punch 3, the bent rim 121 of the plate is pushed upwardly and spread outwardly by pressure of the molten metal 11 so that its outer edge fits closely against the cylindrical wall surface of the pressure portion 2 of the mold. This prevents the liquid metal 11 from leaking into the clearance space 5, as the entrance of said clearance space is thus shut by the plate 12, and flash is not produced. Consequently, damage to the metal mold usually caused by flash in conventional forging is avoided and at the same time the pressure of the punch 3 is effectively applied to the liquid metal because the edge of rim 121 of the plate 12, contacting against the cylindrical wall surface of the metal pressure portion of the mold is softened and moves smoothly therealong with a minimum of friction.

FIGS. 4 to 6 show successive positions of the punch in the mold and the resultant deformation of the thin plate 12 as the punch is lowered. Considering the forging of a metal in the iron family, preferably, plate 12 is of stainless steel of 0.3 mm., thickness and is attached to the end surface of the punch 3 by a thin glass fiber plate 13 inserted therebetween. The liquid metal 12 to be forged is molten cast iron and the diameter of the cylindrical pressure portion 2 of the mold is 45 mm.

When the liquid metal 11 is compressed under pressure of 2,500 kg/cm², the stainless steel plate 12 contacts the liquid metal, and then the outer edge of rim 121 is pushed up and out by the pressure of the liquid metal (as shown by arrows in FIG. 4) to closely fit the cylindrical pressure portion 2. Upon further downward movement of the punch, the plate 12 is further deformed under greater pressure as is shown in FIG. 5, and finally takes the shape shown in FIG. 6.

The stainless steel plate 12 is softened by the high temperature, and its movement against the metal mold 1 is smoothly carried out, because the glass fiber disk 13 is melted and works as a lubricant to reduce the friction between stainless plate 12 and the metal mold 1. After the pressing operation is completed, the stainless steel plate 12 is adhered to the upper surface of the product, but it can be easily removed by simple mechanical processing, such as grinding, after the product is removed from the mold.

It will be readily apparent from the above description that the present invention improves the conventional liquid metal forging process by use of a sealing member in the form of a thin metal plate attached to the pressure applying surface of the pressure punch for contacting the surface of the liquid metal. The added plate prevents the formation of flash in the clearance space between the punch and the mold, and as a result the friction between the flash and the metal mold is entirely eliminated. Thus, the life of the metal mold is greatly prolonged. At the same time the pressure of the punch is retained without undue loss in overcoming flash-friction and is effectively applied to the liquid metal. The operation is very easily carried out as described, and can be effectively applied to all kinds of metals.

Although certain specific embodiments of the invention have been shown and described, it is obvious that many modifications thereof are possible. The invention, therefore, is not intended to be restricted to the exact showing of the drawings and description thereof, but is considered to include reasonable and obvious equivalents.

We claim:

1. A liquid metal forging process of the type including the steps of pouring liquid metal into the cavity of a mold, applying high pressure to said liquid metal by a punch which is inserted into said cavity with clearance space, and compressing liquid metal until it solidifies, the improvement comprising the step of inserting between the surface of said liquid metal and a pressure applying surface of said punch a first sealing member made of a metal plate having a surface area to fit the cross-sectional area of the mold and interposing between the first sealing member and the pressure applying surface of said punch a second sealing member made of a thin plate of a glasy substance having a melting temperature below that of the first-named sealing member and below the temperature of the metal to be forged, whereby said high pressure is applied through both said sealing members to said liquid metal, while simultaneously sealing the clearance space between said punch and the walls of said mold against entrance of liquid metal by deformation of the first sealing member to closely fit the mold, and the movement of said first sealing member along the wall of the mold is lubricated by melting of said second sealing member.

2. The liquid metal forging process of claim 1, wherein is further included the step of adhering said first-named sealing member to the pressure applying surface of said punch with the second sealing member interposed therebetween prior to inserting the punch into the cavity of said mold.