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2,731,145

METHOD OF HOT-WORKING STEEL BILLETS
BY FORGING OR EXTRUSION

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FIG.1.

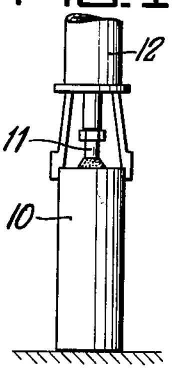


FIG.2.

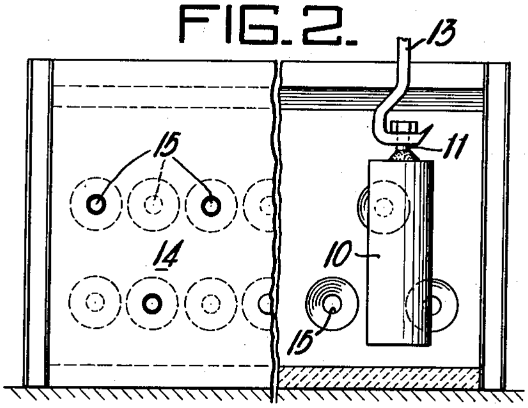


FIG.3.

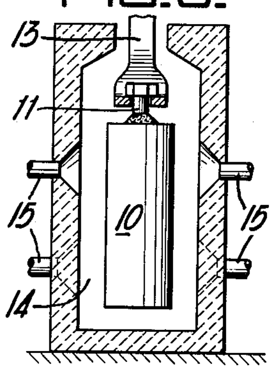


FIG.4.

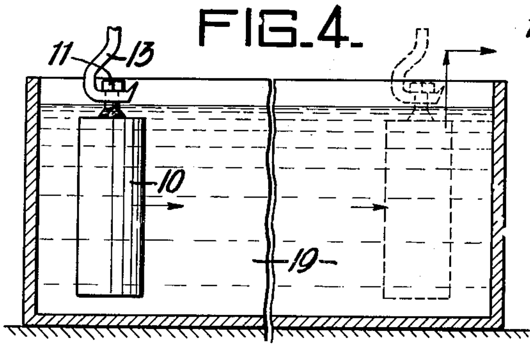


FIG.5.

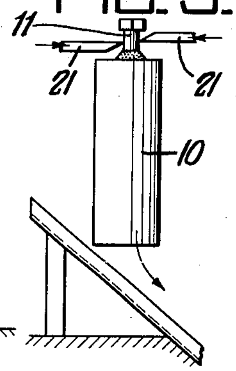
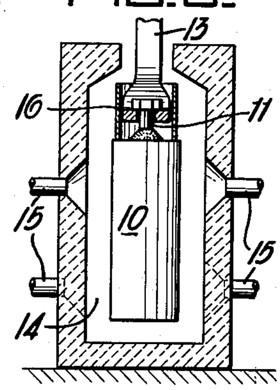


FIG.6.



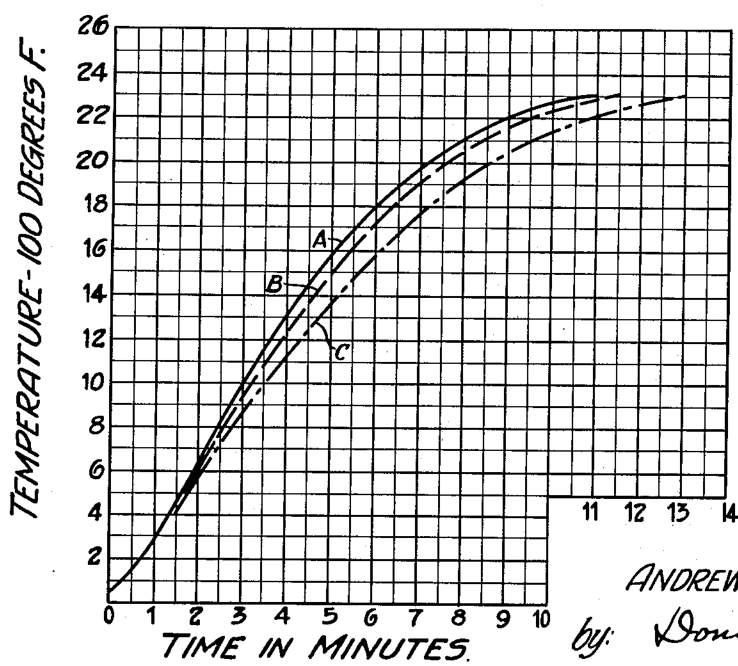


FIG.7.

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METHOD OF HOT-WORKING STEEL BILLETS BY FORGING OR EXTRUSION

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6 Claims. (Cl. 207—10)

This invention relates to the hot-working of masses of metal and, in particular, to the heating of billets or slugs of steel for hot-working by extrusion or forging.

The hot extrusion of steel heated to forging temperature (1950 to 2300° F.), through forming dies, has been accomplished but requires a special technique and is beset with numerous difficulties. For example, the heating of the billets or slugs has usually been effected in conventional furnaces at relatively low rates. This causes formation of a heavy scale which is abrasive in character and causes rapid wear of the dies, besides reducing the product yield per pound of billet weight. Such scale is not fully removed by conventional descaling practice and the portion left on the billets not only damages the dies but impairs the surface finish of the extruded product. In addition, the power required for the extrusion operation has been very high. Experience has shown, furthermore, that stainless-steel billets heated by conventional methods and equipment, i. e., involving long heating times such as several hours, occasionally will not "push" when placed in the press, although heated to the proper temperature.

It has been proposed to provide a lubricant film on the surface of heated steel billets or slugs for forging, by coating them and the forging dies, prior to heating the billets electrically, with a ceramic enamel slip which melts as the billet is heated, thus forming a viscous liquid coating, effective as a lubricant. Ordinary enamel slip, however, is composed largely of metal oxides, silicates, borates and fluorides which volatilize or deteriorate rapidly at forging temperatures. Such slip, therefore, cannot be used in a combustion-heated furnace having an oxidizing atmosphere. It has also been proposed to facilitate the extrusion of heated steel billets or slugs by wrapping them in a layer of glass fiber after they have been heated, whereby the glass is fused and acts as a spacing layer to prevent contact between the billet and die. With this procedure, the billets are unprotected during heating and the scale formed thereon must be converted to a non-abrasive form by immersing the billets for a short time in a fused salt bath. This is expensive although it gives good die life. It results, however, in a poor surface on the finished product which causes pits to show up on pickling to remove the adherent scale.

I have invented a novel method of heating and working steel billets or slugs for extrusion which overcomes the above difficulties and is characterized by further important advantages. The invention is also useful in heating billets for any hot-forging operation. In a preferred practice of my invention, I weld a stud of plain carbon steel to one end of a billet or slug of the steel to be forged, either carbon or stainless steel. The billet is suspended by the stud from a hanger on a moving conveyor. I then coat the slug with a protective layer of a liquid slip, basically glass frit and clay in water, the frit being composed largely of metal oxides, silicates and borates which do not volatilize or deteriorate at the forging temperature. The billet, being freely suspended by its stud, can readily be flooded or sprayed with the slip and the resulting coating preserved from contact with anything which would damage it prior to heating. The

billet is then conveyed through a continuous, radiant-panel furnace which heats it rapidly to extrusion or forging temperature. The use of radiant heating obviates flame impingement on the coated billets which is highly undesirable.

During heating, the coating fuses and protects the slug from oxidation to an appreciable extent. Some slight oxidation occurs, however, by either penetration of atmospheric oxygen through the coating, or in chemical combination with the oxides of the slip. When the slug has been heated to the desired temperature and has reached the exit end of the furnace, the stud is sheared and the slug is treated with a fluxing agent, such as borax, lime, or barium chloride. The fluxing agent may be dusted or blown onto the billet. Ordinarily it may more conveniently be incorporated in a blanket or pad of fiber glass, and the latter wrapped around the heated slug. The resulting fused coating on the billet is a combination of silica and other metallic oxides and the action of the flux is to reduce the viscosity thereof, converting any abrasive residue on the billet into liquid form. By such liquefaction of the coating, any residue remaining on the billet is rendered incapable of effecting a pit or pock mark in the surface of the product. This facilitates pushing the slug through the extrusion die and reduces die wear. The complex film remaining on the product after extrusion and cooling is easier to pickle off than the glass film resulting from prior practice and the surface of the product is markedly superior.

A complete understanding of the invention may be obtained from the following detailed description and explanation which refer to the accompanying drawings illustrating the present preferred practice. In the drawings,

Figure 1 is a diagrammatic elevation illustrating the welding of a stud to one end of a billet;

Figure 2 is an elevation partly broken away showing the heating furnace with a billet traveling therethrough;

Figure 3 is a partial cross-section through the furnace;

Figure 4 is a longitudinal vertical section through a tank containing a fused salt bath;

Figure 5 is a diagram illustrating the shearing off of the stud;

Figure 6 is a section like Figure 3 showing in elevation the upper end of the billet, the hook for suspending it and a shield for protecting the supporting stud; and

Figure 7 is a set of curves showing the effect of colored coatings on the billet-heating rate.

Referring now in detail to the drawings, a billet or slug **10** of the desired composition and having the size and shape appropriate for the intended operation of forging or extrusion, has a stud **11** of low-carbon steel flash-welded to one end thereof normal to the surface thereof as shown in Figure 1. The billet may be any shape and length but is usually elongated in form, and of any weight which can be supported by a single stud or an arrangement of several studs if necessary. The stud is preferably headed and its shank has such diameter as to provide a section which retains sufficient strength to carry the billet suspended thereby for a short time, at least, without excessive elongation, when the billet has been heated to the maximum temperature required for extrusion.

The stud welding may conveniently be effected by a conventional device **12** designed for such purpose and available commercially. This device operates first to strike an electric arc between the stud and billet and then, after fusing a pool of metal in the surface of the latter, to thrust the stud forcibly thereinto and hold it there until the molten metal solidifies. Such a weld, when cold, has a strength greater than that of the stud proper. Even at elevated temperatures, say 2300° F., the weld strength is at least equal to or greater than that of the stud. A plurality of studs may be used, depending on the weight to be supported since the latter determines the total sectional area of studs needed for a given billet. The sectional area of the stud or studs necessary to support a given billet for a definite time at the desired maximum temperature can easily be determined.

When the stud has been welded to the billet, the latter is hung on a supporting hook **13** suspended from a conveyor trolley (not shown). The hook is slotted or bifurcated to receive the shank of the stud and engage the underside of its head. The trolley from which the hook depends travels above a furnace **14** of the radiant panel type having a longitudinal slot in the top thereof through which the shank of the hook passes.

Before the billet enters the furnace, it is coated with a slip of glass frit and clay in water by spraying or dipping whereby it is completely covered with a substantially uniform layer which will dry on the billet surface by evaporation or from the heat upon entering the furnace. The coating should form a homogeneous, unbroken seal around the billet, either in the form of a bisque or a soft layer. The function of this layer, when fused, is to seal the billet surface against contact with free oxygen or any available oxygen in the furnace atmosphere and to dissolve such scale as forms beneath the fused layer. This layer need not be and preferably is not tightly adherent to the billet when cold, as in the case of an ordinary porcelain enamel coating. Coatings of the general type of specialized high-temperature ceramic formulations will be found suitable for the purpose. The following table gives the composition of the coating slip:

TABLE I

Slip formula

Material	Range (Parts by weight)	Typical Example (Parts by weight)
Ceramic frit	70–100	70
Cr_2O_3	0–30	30
Pyrophyllite	0–30	--------
Ball clay	0–8	7
China clay	0–10	--------
Sodium nitrite	0–1	--------
Sodium pyrophosphate	0–0.2	--------
Water	40–70	65

The ceramic frit composition is given by the following table:

TABLE II

Ceramic frit

Compound	Range (Percent)	Typical Example (Percent)
Al_2O_3	.5–40	2.0
BaO	10–50	30.5
B_2O_3	3–15	7.5
C	0–30	--------
CaO	4–10	4.0
Co_3O_5	0–40	0.5
CuO	0–20	--------
K_2O	0–5	0.8
MgO	0–20	1.7
Na_2O	0–4	1.0
NiO	0–40	0.5
P_2O_5	0–5	0.5
SiO_2	30–70	30.0
TiO	0–40	7.5
ZnO	0–10	3.5
ZrO_2	2–20	10

The frit is smelted and the slip is ground in accordance with known practice in the enameling art.

Since the slip coating rubs off easily prior to drying and since its protective continuity when fused will be thereby impaired, the billet should be supported free from contact with anything after coating. This requirement is fully met by the method of suspending the billet from the welded-on stud for passage through the furnace.

As the coated billet travels through the furnace, a reaction occurs progressively through the thickness of the coating layer between it and the billet surface leaving the outermost portion of the coating substantially unchanged. Preferably the coating is of such a nature that it will absorb any oxide formed on the billet during heating.

In passing through the furnace, the billet is quickly heated by radiant burners **15** mounted in the spaced side walls or by radiant panels, as it travels from one end to the other. While only one billet is shown in the furnace, it will usually be preferable to pass a continuous succession of billets therethrough in close order. Instead of a headed stud and a bifurcated hook, I may use headless studs and engage them with gripping jaws carried by a traveling trolley.

The firing rate of the burners, the speed of travel of the billets, and the length of the furnace are correlated so that the billets are rapidly heated to a forging temperature in the range of 1950°–2300° F. by the time they reach the exit end of the furnace. The total heating time should be not more than about seven minutes per inch of diameter of the billet and is preferably less, i. e., from four to six minutes per inch of diameter as compared to from fifteen to twenty minutes per inch of diameter by known practice. This rapid heating permits the studs to safely carry the weight of the billets since plain-carbon steel studs will stand 2500 p. s. i. at 2000° F. and 1500 p. s. i. at 2300° F., for about thirty minutes.

The heating of the billets according to the invention is shown graphically in Figure 7. As there shown, the heating curve is steep and smooth. The heating rate attainable far exceeds the maximum rate heretofore thought feasible for stainless steel. The most significant fact shown by the curves is that the billets reach final temperature before the strength of the studs is materially reduced as a result of the heating. An important result of the rapid heating is that, even without a protective coating, only a thin layer of scale is formed on the billets. The rapid heating also allows a wider range in the choice of the coating since it is the time at high temperatures which controls coating deterioration and rapid oxidation of steel.

Figure 7 also illustrates the effect of the color of the coating, showing how the use of any colored (i. e., non-white) coating will increase the heating rate attainable by my process. A light-colored or white coating materially reduces the heating rate by reflection. The use of a black coating offers the greatest benefits in this respect. Faster heating means a shorter time at high temperature which allows a greater load to be carried by a stud of a given cross-sectional area, before its strength decreases below the weight of the billet. The color of the coating is determined by the relative amounts or contents of carbon and the oxides of cobalt, copper, chromium and nickel used in the frit.

In Figure 7, curves A, B and C represent, respectively, the progressive heating of billets coated with black, green and white slip. If unsymmetrical sections are to be heated, it may be desirable to coat the thinner portions with a light-colored slip or to leave them bare and to coat the thicker portions with a dark-colored slip. This will tend to equalize the rates at which the temperatures of the thin and thick portions rise.

In order to reduce the loss of strength by the stud supporting the billet as they are both heated during travel through the furnace, I may employ a cylindrical shield **16** of thermal insulation surrounding the stud and resting on the top of the billet, as shown in Figure 6. Such a shield utilizes the so-called "stack effect." That is to say, the ascent of hot gases through the central region of the shield will induce a downflow of cool air along the inner surface of the wall thereof, which keeps the stud at a temperature somewhat lower than that of the billet. In addition, the shield serves as a radiation barrier and the weld as a conduction barrier. The combined effect aided by the cooling effect of the hook, keeps the stud several hundred degrees below the temperature of the billet.

The billets may be rotated as they pass through the furnace, if desired, as by rotating the hooks on which they are suspended, for greater uniformity of heating although this will not ordinarily be necessary.

As stated above, on reaching the exit end of the furnace, the billets have been heated to a forging temperature of from 1950° to 2300° F. The slip coating has by then fused to a sticky or gummy state but when the surface of the coating is chilled by the air, it becomes highly abrasive, and must be treated to alter its character. I do this by fluxing the coating with a material such as lime, barium chloride, borax, a combination thereof or simply powdered glass. The flux may be applied directly to the billet by dusting or blowing it thereon. Conveniently, the suspending stud **11** is severed by shears **21** and the billet falls onto a sloping chute, rolling downwardly and passing over a previously deposited elongated pad of glass or silicate-type fibers impregnated with the fluxing agent. The pad adheres to the gummy layer of fused slip on the billet and wraps itself around the latter. The flux and glass fibers are immediately fused by the heat of the billet, accomplishing two objects. First, the fused glass and flux absorb or dissolve the oxide mixed with the fused slip on the billet surface and reduce its viscosity. Second, the fluxing converts the fused slip to a non-abrasive character. As a result, I obtain a heated billet for forging or extrusion which, when fluxed, is covered with a siliceous non-abrasive film. In a typical practice of the invention, fiber made from glass which softened at about 1050° F., served the purpose satisfactorily.

While I do not wish to be bound by any theory to explain the foregoing, the following explanation appears to have a reasonable basis in the observed phenomena. The initial slip coating contains finely ground glass frit (metal oxides and silicates) in water suspension with clay as a suspending agent. As the billet is heated, the coating dries and then forms a hard layer or bisque which later fuses and forms a continuous surface film around the metal. It thus clings to the surface and does not flake off. The billet surface oxidizes slightly under the film because of penetration of atmospheric oxygen and contact with the oxides in the coating. Substantially no scale forms before fusion of the coating, however, because of the protection afforded by the latter.

By the end of the heating period, the glassy film, initially gummy and viscous, becomes solid because of the excess oxides of iron which have become absorbed by the coating. The flux and glass fibers, when fused with the solid mixture, tend to lower the melting point of the coating residue because of the higher concentrations of these components. Any type of glass tends to make the coating film more fluid. The pad of glass fibers, on fusion, takes up some of the dissolved scale, reducing the concentration thereof in the film resulting from the initial coating and heating to temperature. The glass, having a lower melting point than the resulting iron silicate, also tends to re-fuse the latter so that it does not constitute an abrasive layer objectionable in forging or extrusion because of excessive friction and resulting die and tool wear. In the final film, it is probable that silica and other metal oxides or silicates exist along with some iron oxide although the greater portion of the latter appears to be dissolved or combined with the other oxides forming a silicate of undetermined composition.

After forging or extrusion of a billet, the product may be cooled in air or water-quenched. This quick cooling causes some of the glassy film left thereon to flake off removing the scale dissolved therein. Any portion of the film remaining adherent to the product may be removed by a light pickle which leaves a superior finish on the surface. The ease of pickling appears to result from the presence of a uniformly distributed film of fused oxides on the product after extrusion.

If desired, the heated billets, before extrusion, may be immersed in an elongated tank **19** containing a bath of fused salt such as barium chloride, heated to a temperature approximating the desired final temperature of the billets, and caused to travel therethrough, thus continuing the immersion for a short time. The salt bath serves several purposes. In the first place, it exerts a descaling action. The salt bath also equalizes the temperature in various portions of the billet. Finally it forms a film on the surface of the billet which acts as a lubricant during the extrusion. A coated billet may be heated to its final temperature in the salt bath with the result that the double protection afforded by both coating and salt-bath immersion reduces the power required for forging or extrusion below the amount required with either alone.

It is to be noted that the invention is characterized by numerous advantages some of which have already been mentioned. Outstanding among these is the reduction in the power required by the extrusion press for working billets heated according to the invention. In fact, the extrusion ratio of a given press may thereby be increased by as much as 10 or 15%. In addition, the yield of product per billet is increased by reducing the amount of scale. Rapid heating is facilitated by the method of supporting the billets on a suspending stud which fully exposes the billet surfaces and by the use of a radiant-panel furnace. The billet is supported at all times free of contact with a furnace hearth or refractories which would abrade the billet surfaces. By using a suitable conveyor, the billets are conveyed through the furnace without disengagement from the supporting hooks **13**, thus expediting the overall heating cycle and eliminating conveying baskets or carriers which are very expensive and have but a limited life.

Although I have disclosed herein the preferred practice of my invention, I intend to cover as well any change or modification therein which may be made without departing from the spirit and scope of the invention.

I claim:

1. In a method of working metal billets by forging or extrusion, the steps including coating the exterior surface of a billet with a slip of clay and glass frit, heating the billet thereby first drying the coating to a bisque and then, as the billet approaches forging temperature, fusing the coating, applying to the coating after the billet reaches said temperature, a flux effective to reduce the viscosity and abrasiveness of the coating, and working the billet by engagement of a shaping tool with said surface, with the fluxed coating remaining thereon.

2. The method defined by claim 1 characterized by coating the billet with a dark-colored slip.

3. The method defined by claim 1 characterized by said fluxing being effected by incorporating a fluxing agent into a pad of glass fiber and applying the pad about the heated billet.

4. The method defined by claim 1 characterized by immersing the billet, on emergence from the furnace, in a fused salt bath.

5. The method defined by claim 1 characterized by suspending the billet, during travel through the furnace, by a stud welded thereto.

6. The method defined by claim 1 characterized by coating one portion of the billet with a dark-colored slip and another portion with a slip of lighter color.

References Cited in the file of this patent

UNITED STATES PATENTS

1,919,136	Smith	July 18, 1933
2,458,715	Marencik et al.	Jan. 11, 1949
2,464,163	Weesner	Mar. 8, 1949