April 29, 1969 R. W. TOMBAUGH 3,440,853

METAL EXTRUSION METHOD

Filed Feb. 2, 1967

Fig. 1.

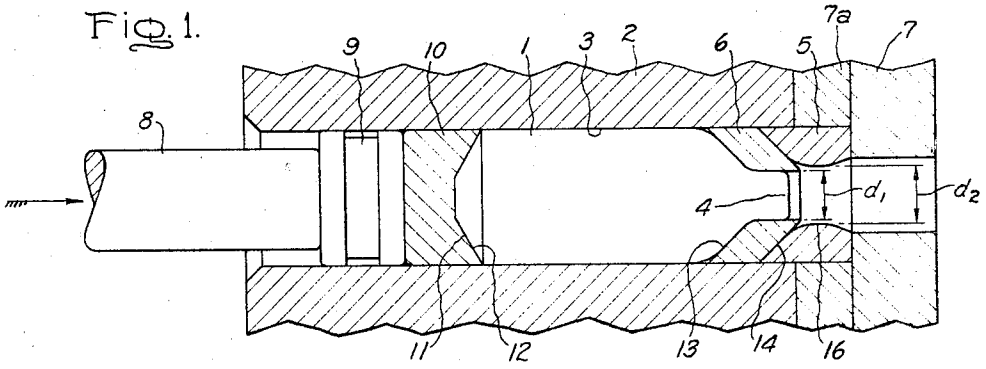


Fig. 2.

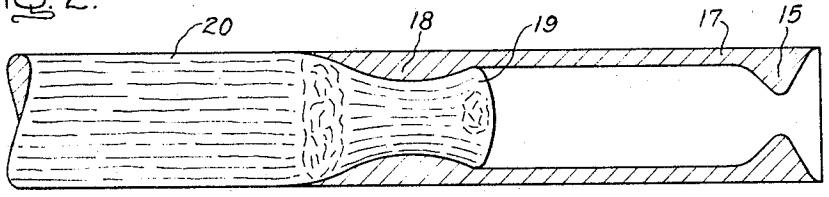
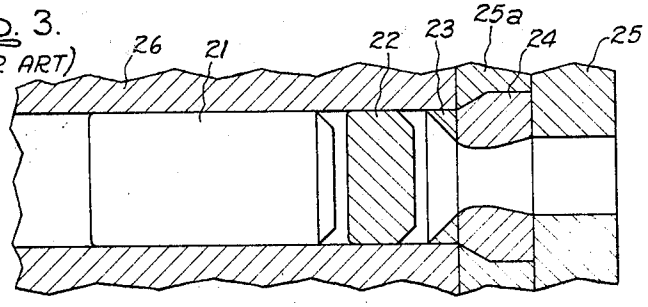


Fig. 3.
(PRIOR ART)



Inventor:
Roy W. Tombaugh
by Richard H. Burgess
His Attorney

United States Patent Office 3,440,853
Patented Apr. 29, 1969

3,440,853

METAL EXTRUSION METHOD

Roy W. Tombaugh, Lyndhurst, Ohio, assignor to General Electric Company, a corporation of New York

Filed Feb. 2, 1967, Ser. No. 613,557
Int. Cl. B21c 23/00, 23/22, 25/08
U.S. Cl. 72—253 7 Claims

ABSTRACT OF THE DISCLOSURE

A method for the extrusion of metals, particularly metals having great resistance to deformation at elevated temperatures, wherein the extrusion billet is provided with a projected central portion which fits within the extrusion die leaving some clearance and in which a metal ring is provided around the projected central portion such that it extrudes out over said projected central portion in the form of a tube at relatively high pressure. This facilitates extrusion of the billet at lower pressures than otherwise and minimizes bursts in the leading end of said extrusion. Also, the invention allows the use of undersized billets having greater than normal and less critical clearance within the container chamber of the extrusion press.

Background of the invention

The present invention relates to methods for the extrusion of metals and, more particularly, to methods for the extrusion of metals which have relatively great resistance to deformation at elevated temperatures and are difficult to extrude.

Extrusion is a process used for the reduction in cross section of metals. In addition to its traditional uses for forming complex shapes of relatively soft and easily worked materials such as aluminum, it is also useful for primary breakdown or initial working of refractory metals and other metals and alloys which are particularly difficult to work and which are subject to failure by general fracture or internal or surface cracking when subjected to tensile stresses. Most working processes produce tensile forces in various parts of the object being worked, such as around the edges in open die forging or swaging. On the other hand, extrusion is essentially a compressive working process with only the area at which the metal is extruded being not under compressive stress. Even metals which are quite brittle in the as-cast condition are much less likely to fail under compression than when subjected to tensile stresses. After reasonable amounts of deformation have been applied to the cast metals, the large cast grains with their relatively brittle grain boundaries have been broken up into worked structures which subsequently can be recrystallized to smaller grain sizes and are much less susceptible to fracture during further working by other processes. Thus, extrusion is often used for initial working of relatively brittle cast metals. However, many such metals have quite high melting temperatures and are very difficult to deform.

In the prior art, to facilitate extrusion of metals which are difficult to deform, various types of lubricants have been used to reduce friction between a billet being extruded and the extrusion container and die. Various lubricants include a salt coating remaining on the billet after the billet has been heated in a salt bath for extrusion, flake graphite dispersed in a grease carrier, and, particularly in the case of tungsten and molybdenum billets, refractory metal oxides such as oxides of the billet metal produced by exposure of the hot billet to air. Also, glass lubricants have been used in many ways. It is desirable to still further decrease pressures required for extrusion, since it is useful to be able to extrude larger billets than

those presently extruded commercially. The forces required for satisfactory extrusion of such larger billets can approach or exceed the capacity of existing equipment.

Although metals that melt at relatively low temperatures such as aluminum are often extruded commercially from flat-faced billets through flat-faced dies to complex configurations, the higher melting point metals such as steel, the superalloys and the refractory metals are normally extruded from billets which have convex forward ends configurated so as to meet with concave faces of the dies through which they are to be extruded. This enhances the desired metal flow patterns by converting the forward motion of the billet directly into metal flow from the periphery of the billet towards the center and out through the die. The concave entrance angle of such dies can either be built into the die or provided in the form of a separate piece of the extrusion press tooling, which may be replaced as often as desired. However, pressures required for extrusion through such tooling are still quite high, and lower required extrusion pressures are always desirable.

The stresses set up by metal flow of the extrusion billet to form the extrusion as it passes through the die can cause failure of the extrusion at its forward end and along its surfaces resulting in what is descriptively known in the trade as nose-bursting and alligatoring or palm-tree effect, with portions of the surface peeling back away from the leading end. Such failures directly cause great loss of metal from the extrusion and can be responsible for propagation of cracks down into and through the extrusion. To avoid such deleterious effects, the extruder is able to use several techniques including improved lubrication and a block of a softer metal than the billet placed in front of the billet which wraps itself back around the leading end of the extrusion and tends to minimize nose-bursts, alligatoring and palm-tree effects. For example, a steel nose block could be used with a tungsten extrusion to minimize these effects. Nose blocks often do lower the peak pressures required for starting the extrusion of the billet, but do not substantially lower the running pressures for extrusion of the bulk of the billet itself.

Also, it is a common practice to provide jackets of materials substantially softer than the billet and which enclose the billet, protect it from oxidation, lower the starting and running pressures for extrusion, and which can contribute to protection against fracturing of the billet material as it is extruded. Also, such jackets can be made of materials which are more responsive to lubricants than the billet material. Although jacketing is effective for several purposes, it is quite expensive, it takes space in the extrusion press container decreasing the maximum size of the billet which can be extruded, it must be stripped from the extruded bar, and it usually leaves a wrinkled surface on the extruded bar after stripping. Also, the jacket must be extruded at the same temperature of the billet, thus further limiting the choice of materials for the jacket.

Some of the extrusion characteristics of metals can be characterized according to the following formula:

$$F = A_o K \ln \frac{A_o}{A_1}$$

wherein:

F=total force required for extrusion (pounds).

K=resistance to deformation at the extrusion temperature (p.s.i.), this will normally be greater for the initiation of extrusion or breakthrough than for continuation running of the extrusion.

A_o=cross-sectional area of the container, which is the same as that of the upset billet within the container just before extrusion (square inches).

A_1=cross-sectional area of the die (square inches).

These parameters can be expressed in other units. The ratio A_0/A_1 is referred to as the extrusion ratio.

Summary of the invention

Briefly stated, it is an object of this invention to provide a process for the extrusion of metals which will substantially lessen the forces required for such extrusion, thereby increasing the effective capacity of extrusion apparatus by allowing extrusion of larger billets or extrusion at higher extrusion ratios or lower temperatures.

A further object is to reduce fracturing of the leading end and of surfaces of the extrusion due to stresses created during extrusion and to improve material yield.

It is also an object of the invention to allow the use of extrusion billets which have greater than normal clearance from the walls of the extrusion press chamber without unduly risking fracturing of the billet when it is upset to fill the container before commencement of extrusion. Since the fit of the billet in the container will not be as critical, the extrusion process will be more flexible.

Briefly stated, the present invention in one embodiment provides a process for the extrusion of metals wherein the billet is provided with a projecting central portion on its front end which faces the extrusion die and a metal ring is provided in the extrusion container configurated to match the entry face of the die and the front end of the billet but with a hole at its center so that the projected central portion of the billet extends part of the distance through the hole. On extrusion, the projected central portion preferably does not reach quite all the way through the hole in the metal ring so that the ring starts to extrude toward the center and out through the die at relatively low pressures in front of the projected central portion of the billet until the projected central portion reaches the die and then acts as a mandrel over which the metal ring extrudes further in the form of a tube. As the billet continues to move forward, extruding the metal ring as a tube, the extrusion force becomes so high and the friction between the tube being extruded and the projected central portion becomes so great that the billet itself tends to be pulled into the die and begins to extrude at a substantially lower pressure than would be required without the use of the metal ring. Initial temperatures of the billet and the metal ring are adjusted so that the pressure for extrusion of the tube from the metal ring is comparable to and not greatly different from the pressure required to extrude the billet itself.

Contributing to the lowering of billet extrusion pressure is the fact that the metal ring will normally push down into the part of the projected central portion of the billet adjacent the bulk of the billet, thereby forcing the projected central portion forward and tending to pull the balance of the billet into the die. Thus, the present invention seems to be somewhat equivalent in effect to a combination of extrusion and drawing of the billet. While the extrusion ram pushes, the metal ring grasps the projected central portion and pulls it through the die.

For obtaining the advantages of the invention it is desirable that the die have a concave entry, and it is preferable that the front end of the billet exclusive of the projected central portion substantially match the curvature or the angle of the entry of the die. Also, it is desirable that the rear end of the billet, opposite the end adjacent the die, be substantially convex to minimize the generation of pipe or cracks down the center of the extrusion from the tail end.

The invention is particularly effective for the extrusion of metals having relatively high melting points and which are relatively difficult to extrude, such as steel, the superalloys and refractory metals, and including but not limited to iron, cobalt, nickel, chromium, tungsten, molybdenum, tantalum, columbium and alloys based on one or more of such metals. The metal ring should be composed of a metal and at a temperature for extrusion such that it is considerably more easily deformed than the billet material at its temperature of extrusion. It should be understood that the actual temperature of metal being extruded can vary during extrusion. Heat losses to the tooling and heat generated internally by deformation can cause decreases or increases in temperature. The invention is particularly useful in the extrusion of tungsten and tungsten alloy billets with metal rings of steel, preferably low carbon steel.

In addition to lowering the pressures and forces required for extrusion, the steel ring of the invention, as it extrudes around the projected central portion of the billet, provides restraint which minimizes the likelihood of cracking in the forward end of the extrusion. Also, if the billet does not completely fill the extrusion container, the metal ring is capable of extruding backward around the billet, in effect to jacket the billet in situ during extrusion and minimize the likelihood of cracking on upsetting of the billet.

The invention is particularly useful for the extrusion of metals which have a K value in accordance with the above-described formula exceeding about 100,000 pounds per square inch (p.s.i) at the temperature of extrusion without the use of the invention.

Brief description of the drawing

FIG. 1 is a schematic illustration of a typical extrusion arrangement for use in performing the method of the invention showing, partly in section, the tooling, the billet, the metal ring and expandable materials.

FIG. 2 is a sectional schematic drawing of the leading end of an extrusion which has been made in accordance with the invention showing the remnants of the steel ring attached to the deformed projected central portion of the billet.

FIG. 3 is a schematic drawing partly in section showing various arrangements of the prior art.

Description of the preferred embodiments

FIG. 1 illustrates a typical extrusion system making use of the invention. Although this is shown in horizontal arrangement, the invention is not necessarily restricted to that position and might be used in a vertical arrangement. The billet **1** is positioned within the container **2**, generally with a lubricant such as colloidal or flake graphite suspended in oil or grease at its surface **3** and on the face **14** of the die **5**. Projected central portion **4** of the billet **1** is at the end of the billet facing the die **5**. Between the billet **1** and the die **5** is a metal ring **6**. The die **5** is supported in backup tooling **7** and **7***a* which serves to keep it in place. Typically, the billet **1**, its projected central portion **4**, the metal ring **6**, the die **5**, the container **2** and the support tooling **7** and **7***a* will all have circular or cylindrical cross sections, although they can assume whatever configuration is desired for the production of shapes and forms from the billet, as is known in the art.

The present invention requires that the size or diameter d_2 of the opening in the die be somewhat larger than the size or diameter d_1 of the projected central portion **4** of of the billet **1**. This leaves an annular space between the projected central portion **4** and the die **5** through which the metal ring **6** can extrude in the form of a tube. Completing the basic elements of the apparatus, ram **8** is coupled to a force capable of moving it forward in the direction indicated by the arrow to effect the extrusion. Dummy block **9** is situated at the front end of the stem to act as a replaceable seal and for transmitting pressure to the materials being extruded and to prevent material confined in the container from extruding back around the stem. If, as shown in the drawing, the tail end of the billet is convex, it is preferable to use a tail block **10** of steel to aid in holding together the tail of the extrusion. This schould be followed by an ejection block, preferably of graphite, which serves the function of pushing the last

portions of the billet through the die so that no butt is left to be discarded from the die or container. The ejection block is not shown in the drawing, but would be a simple cylindrical block of graphite between dummy block **9** and tail block **10**. This improves material efficiency, avoids the necessity of sawing off the butt, and allows much faster repetitive extrusion.

In order to prevent or minimize the formation of voids at the center of the tail end of the extrusion, often referred to as pipe, it is desirable to provide a convex configuration of the tail end of the billet such as shown at **12**. Matching this, the ejection block should be formed in a concave shape such as shown at **11**. Curved surfaces such as semispherical or angular surfaces such as those shown in the drawing can be used to provide these convex and concave configurations. Total included angles of 90° to 120° have been found satisfactory. Likewise, it is desirable with the invention to provide the die with a concave entry as shown at **14**, and it is preferable for the forward end of the billet **1** exclusive of the projected central portion **4** to substantially match the configuration of the die, as shown in **13**. Die entry and mating billet shapes known in the art are satisfactory.

In accordance with the invention, the metal ring **6** preferably but not necessarily extends beyond the projected central portion **4** of the billet **1** when the billet and ring have been moved forward to the die and before extrusion begins. This allows the metal ring to begin to extrude at a fairly low pressure by moving towards the center and out through the die beyond the forwardmost reach of the projected central portion **4**. Extrusion pressures are proportional to the natural logarithm of the extrusion ratio, thus a relatively low extrusion ratio for the metal ring **6** as it initially begins to move into the die requires relatively low extrusion pressures. The initial inwardly extruded portion of the metal ring **6** is shown at **15** in FIG. 2. After the projecting central portion **4** has moved forward to the narrowest part of the die **16**, known as the land, the projected central portion **4** acts as a mandrel while a substantial part of the rest of the material in the metal ring **6** extrudes over this mandrel and out through the die in the form of a tube. Since the cross-sectional area of the metal in the tube is quite small compared to the initial cross section of the metal ring, its extrusion ratio is quite high and higher extrusion pressures than initially are required. The pressures are supplied through the stem **8** and are whatever pressures are required to move the stem forward at the predetermined speed, up to the capacity of the equipment.

If billet **1** is of a smaller diameter than container **2**, part of the metal ring can back extrude around the billet as the billet upsets or increases in diameter so that the container is filled when the pressure becomes high enough.

As the metal ring **6** extrudes out as tube **17**, it is also pushed radially down into the sides of the projecting central portion **4** as shown at **18** in FIG. 2. This could be described as a swaging effect and causes the material of the metal ring to grasp and deform the projecting central portion **19** and pull it forward. The pulling force is apparently just enough to substantially lower the required force for extrusion, and not enough to cause harmful fracturing of the billet material. FIG. 2 shows the leading end of the resulting extrusion, with the front portion of the rest of the extrusion at **20**. Due in part to the greater ease of initiating deformation of the metal ring **6** and then continuing to extrude it into tube **17**, the forces required for extrusion of the billet **1** to form extrusion **20** are substantially decreased from the forces required without use of the invention.

The advantages of the invention are not achieved by use of prior art techniques such as those illustrated in FIG. 3 including nose blocks **22** which deform around the billet **21** but do not substantially decrease running pressure of extrusion. Neither are they achieved by the use of replaceable inserts such as shown in **23** which do not deform about any projected central portion of the billet as is the case in the present invention. FIG. 3 also shows a die **24**, support tooling **25** and **25***a* and container **26**.

As examples of the invention, billets of an alloy containing about 2% thoria, balance essentially all tungsten, were extruded at an extrusion ratio of about 2.6:1 using low carbon steel nose rings of AISI-SAE No. 1018 steel. In different tests, the billets were heated to temperatures of 2600° F. (1427° C.) and 2750° F. (1510° C.), and the steel nose rings were heated to temperatures of about 1832° F. (1000° C.) for the 2600° F. extrusion and 1877° F. (1025° C.) for the 2750° F. extrusion. Table I below gives the pressures required for starting and running the extrusion of the billet and the peak pressure required for the extrusion of the steel nose rings in total tons of pressure required. Also given is the effective K value for each of these conditions. The effective extrusion ratios for the steel rings were about 18:1.

Billets and testing conditions were essentially identical. The billets were approximately 8 inches in overall length and 3.490 inches in diameter, and the inside diameter of the extrusion container was about 3.5625 inches. The projected central portions of the billets were about 2.050 inches in diameter and 0.50 inch long, while the dies had inside diameters of about 2.210 inches leaving a certain clearance between the die and the projected central portion. Said projected central portion is an integral part of said billet. The steel nose rings had inside diameters of about 2.220 inches, overall lengths of 2.145 inches and lengths at the inner diameter of 1.50 inches. The dies, front ends of the billets, and steel rings all had included entry angles as shown in FIG. 1 of about 90° with rounded fillets and corners. The tail ends of the billets were shaped to an included angle of about 120°, meeting in a ½ inch radius curve, and followed by a matching steel block, in turn followed by a graphite ejection block. The dies were hot-worked die-steel coated with zirconia, and extrusion speeds of about 4 inches per second used. Pressures were monitored in the hydraulic system which provided force to the stem.

TABLE I.—REQUIRED EXTRUSION FORCES

	2,600° F. billet		2,750° F. billet	
Condition	Tons	K (p.s.i.)	Tons	K (p.s.i.)
With nose ring:				
Starting	550	116,900	460	97,000
Running	507	106,500	438	92,300
Nose ring peak	434	30,250	437	30,300
Without nose ring:				
Starting	764	162,700	657	138,500
Running	668	142,000	610	129,000

Table I shows that the peak pressure for the tubular extrusion of the steel nose ring is at least substantial relative to the running pressure required to extrude the billet.

Table II below shows what small percentages of the pressures required without the invention are actually needed when the invention is used. Pressures without the steel nose rings are taken to be 100%.

TABLE II.—PERCENTAGE OF PRESSURE REQUIRED

Condition	2,600° F. billet	2,750° F. billet
Starting	77	65
Running	80	68

The foregoing is a description of illustrative embodiments of the invention, and it is applicant's intention in the appended claims to cover all forms which fall within the scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a process for extruding metals wherein a metal billet is extruded from an extrusion container through a die to form an extrusion having smaller cross-sectional area than said billet by means of a force pushing said bil-

let through said die, a method comprising the following steps:

providing said billet on its forward end which is adjacent to said die with a projected central portion having a cross-sectional area and shape that will fit through the opening in said die, leaving a certain clearance between said projected central portion and said die;

providing a metal ring around said projected central portion, said ring conforming substantially to said extrusion container, the entrance of said die, and the forward end of said billet, said ring having a volume sufficient so that on extrusion said ring begins to extrude over said projected central portion, creating substantial back pressure, before said billet begins to extrude and is deformed by said die;

providing said billet and said metal ring to said extrusion apparatus in a position for extrusion with each of said billet and said metal ring at suitable temperatures such that on extrusion the peak pressure required to extrude said metal ring through said certain clearance between said die and said projected central portion of said billet is at least substantial relative to the running pressure required to extrude said billet through said die;

forcing said metal ring and said billet through said die so that first said metal ring extrudes in a tubular form over said projected central portion which acts as a mandrel within the die, followed by extrusion by said billet itself, whereby the pressure required to extrude said billet is substantially lower than it would have been without the use of said metal ring.

2. The method of claim 1 wherein, when said billet and said ring have been moved into position for extrusion adjacent to said die, said ring extends beyond said projected central portion so that on extrusion said ring initially begins to extrude radially toward the center of said die and in front of said projected central portion before said projected central portion moves within said

die to act as a mandrel for subsequent extrusion of said ring in the form of a tube.

3. The method of claim 1 wherein, after beginning to extrude in the form of a tube, said ring radially deforms inwardly the end of said projected central portion adjacent said billet, grasping said billet and tending to pull it into said die.

4. The method of claim 1 wherein the forward end of said billet exclusive of said projected central portion is substantially convex and approximates the shape of the entrance to said die which is substantially concave to facilitate metal flow of said billet into said extrusion.

5. The method of claim 1 wherein the rear end of said billet which is opposite the end adjacent to said die is substantially convex.

6. The method of claim 1 wherein said billet is composed of a metal having a high resistance to deformation at its extrusion temperature and selected from the group consisting of iron, cobalt, nickel, chromium, tungsten, molybdenum, tantalum, columbium and alloys based on one or more of such metals, and said metal ring is composed of a metal having a substantially lower resistance to deformation at the temperature at which it is used than does said billet at its extrusion temperature.

7. The method of claim 4 in which said billet is composed of a metal selected from the group consisting of tungsten and tungsten-base alloys, and said metal ring is composed of steel.

References Cited

UNITED STATES PATENTS

2,946,437	7/1960	Edgecombe	72—253 X
3,072,251	1/1963	Sauve	72—253 X
3,182,474	5/1965	Buffet	72—253 X
3,205,692	9/1965	Kemppinen et al.	72—260 X

MILTON S. MEHR, *Primary Examiner.*

U.S. Cl. X.R.

18—12; 72—258, 260