3,242,563
Patented Mar. 29, 1966

3,242,563

PLASTIC DEFORMATION OF ALLOYS

Philip George Turner, Wormelow, Hereford, England, assignor to The International Nickel Company, Inc., New York, N.Y., a corporation of Delaware

No Drawing. Filed Nov. 29, 1962, Ser. No. 241,033
Claims priority, application Great Britain, Dec. 6, 1961, 43,728/61
9 Claims. (Cl. 29—423)

This invention relates to plastic deformation of alloys containing nickel and/or chromium and, more particularly, to impact extrusion of nickel-chromium-cobalt base alloys.

It is well known that it is highly advantageous, and even necessary in many instances, to have a coating and/or lubricant on the surface of a metal workpiece when the workpiece is formed by metal working operations of the nature which create a high rate of metal flow, very substantial die pressures and resulting high friction between the workpiece and the forming tool. Such metal working operations (plastic deformation operations) include forging, drawing, extrusion, extrusion-forging, and impact extrusion. When these operations are performed on workpieces that are at temperatures below the recrystallization temperature of the metal of the workpiece at the time deformation is commenced, these operations are described as cold plastic deformation, cold impact extrusion, etc. Requirements for lubrication of workpiece surfaces are particularly severe in the case of impact extrusion of difficultly extrudable alloys such as heat resisting alloys and in such operations the lubrication of the workpiece is of even greater importance than in conventional extrusion techniques. The term "impact extrusion" is applied to extrusion operations wherein the extrusion is performed at a high rate of speed, such as the rate of speed obtained using a punch press. It is of course advantageous to produce articles by impact extrusion because very high production rates can be achieved by this process. In addition, it is possible by impact extrusion to produce some articles which cannot be produced in practice by other metal forming operations because metals behave with a greater degree of plasticity when subjected to the high rate of metal flow characteristics of this process than when formed by other metal working operations wherein the flow of metal is relatively slow. It is also to be understood that impact extrusion operations include impact extrusion-forging wherein an article is both forged and impact extruded in one operation. A lubricant between the die and the workpiece is an obvious aid to impact extrusion and it has been heretofore recognized in the art that the secret of success for impact extrusion operations as applied to difficultly extrudable metals is dependent upon the selection of a proper lubricant. Graphite, mica, chalk, fats, lubricating oils, mineral oils and soaps are known as metal working lubricants. Also, coatings, e.g., phosphate coatings, oxalate coatings, copper plating, etc., have been used on metal workpieces to facilitate the deformation thereof. Such coatings can serve the purpose of a lubricant, serve as a base for a lubricant or do both. However, alloys containing nickel and/or chromium pose special problems in die lubrication and, in spite of the many and diverse teachings of the prior art in the field of metal working, the known means for providing die lubrication in processes for plastic working of alloys containing 10% or more of nickel and/or chromium are not entirely satisfactory. For instance, it is well known that the plastic deformation of mild steel and other metals can be facilitated by the provision of a phosphate coating. Usually a lubricant is also applied to the coating. However, it is also known that phosphate coatings cannot be readily formed on

alloys containing nickel or chromium or both in a total amount of 10% or more, and that if they are formed they are found to crack, particularly in continuous drawing. Other coatings which facilitate plastic deformation can be formed on such alloys, but their effects on the surface of the alloy are not always satisfactory. A particularly acute problem is that of providing a satisfactory coating for facilitating impact extrusion of heat resistant alloys. Although many attempts were made to overcome the foregoing difficulties and other disadvantages, none, as far as I am aware, was entirely successful when carried into practice commercially on an industrial scale.

It has now been discovered that cold plastic deformation, especially cold impact extrusion, of alloys containing at least 10% nickel plus chromium is greatly facilitated by producing such products in accordance with a novel process which employs a new workpiece that is specially adapted to provide good lubrication between the workpiece and the forming tool, e.g., the die, during deformation of the workpiece.

It is an object of the present invention to provide an improved process for making alloy products by cold plastic deformation.

Another object of the invention is to provide a process for making cold impact extruded products of nickel-chromium-cobalt base alloys containing at least 10% nickel plus chromium.

The invention also contemplates providing as a new article of manufacture a novel workpiece for use in making alloy products by cold plastic deformation operations.

It is a further object of the invention to provide as a new article of manufacture a novel workpiece for use in making impact extruded products of nickel-chromium-cobalt base alloys containing at least 10% nickel plus chromium.

Other objects and advantages will become apparent from the following description.

Generally speaking, the present invention contemplates a process for making a cold plastically deformed product of an alloy containing at least about 10% of metal selected from the group consisting of nickel and chromium and characterized by a melting point of at least about 2250° F. comprising the steps of casting such an alloy in a sheath of ferrous metal, e.g., mild steel, to produce a billet, hot working the billet to form an alloy core having a metallurgically bonded thin layer of ferrous metal on at least part of the surface of said alloy core and then phosphate-coating the ferrous metal layer to form a workpiece. Thereafter, the workpiece, with or without a lubricant on the phosphate coating, is cold plastically deformed in a die and the ferrous metal and phosphate coatings are then removed to provide a plastically deformed nickel-chromium alloy product. Optionally, the billet can be divided into portions, either before or after phosphatizing, to provide a plurality of workpieces.

According to this invention, an alloy containing nickel or chromium or both in a total amount of 10% or more is cast into a mild-steel sheath to form a billet, and the sheathed billet is extruded so that the mild-steel covering constitutes only a thin coating on the alloy. The mild-steel surface is phosphate-coated and, advantageously, a lubricant such as lubricating oil is also applied to it to further lubricate the surface, and the billet, or a portion thereof, is then cold drawn, cold impact extruded, or otherwise cold plastically deformed. Thus, the advantage of the phosphate coating in facilitating plastic deformation, e.g., drawing, impact extruding and the like, is obtained. At the end of the process the coating together with any lubricant is removed by pickling.

The invention can be applied, inter alia, to all plastically deformable nickel-chromium creep-resisting or heat-resisting alloys and to stainless steels.

Alloys that are operable in the present invention include alloys such as those set forth in the following table (in weight percentages):

ALLOY COMPOSITIONS

Element	A	B	C	D	E	F	G	H
Ni	8	80	65	35	Bal.	36	42	Bal.
Cr	18	20	15	15	15	------	15	51
Fe	Bal.	------	20	50	up to 5	Bal.	Bal.	2
Co	------	------	------	------	20	------	------	------
Mo	------	------	------	------	5	------	6	------
Ti	------	------	------	------	1.2	------	2.5	0.7
Al	------	------	------	------	4.5	------	------	0.6

Bal.=Balance.

In the foregoing table, Alloys B, C, E and G are nickel-chromium heat resisting alloys, and Alloy E is also a nickel-chromium-cobalt base heat resisting alloy, i.e., a heat resisting alloy wherein nickel, chromium and cobalt are present in a total proportion of at least 50%.

The thickness of the sheath can be about 2% of the diameter of a cylindrical billet of which it forms a part. The sheath is a plastically deformable ferrous metal that is substantially devoid of nickel and chromium, e.g., mild steel or low-carbon steel. A ferrous metal substantially devoid of nickel and chromium does not contain nickel and chromium in amounts totaling more than about 0.05%.

The phosphate coating can be applied by known methods for producing phosphate coatings on steel.

Any lubricating oil used should be low in both sulfur and lead.

For the purpose of giving those skilled in the art a better understanding of the invention (and/or a better appreciation of the advantages of the invention), the following illustrative examples are given:

Example I

A hollow cylindrical sheath of ferrous metal substantially devoid of nickel and chromium is positioned in a billet mold. The ferrous metal of the sheath is SAE 1010 steel. A difficultly extrudable, heat-resistant nickel-chromium alloy of composition (in weight percentages):

Carbon	0.1 max.
Titanium	1.8–2.7.
Chromium	18–21.
Aluminum	0.5–1.8.
Silicon	1.0 max.
Manganese	1.0 max.
Iron	5.0 max.
Cobalt	2.0 max.
Nickel	Balance.

is cast into the sheath to produce a billet having a ferrous metal sheath. The sheathed billet is hot extruded through a round die to form an elongated, cylindrical composite billet comprising a nickel-chromium alloy core having a thin metallurigically bonded layer of ferrous metal on the outer curved surfaces of the extruded billet. The thickness of the thin ferrous metal layer is about 2% of the diameter of the elongated cylindrical billet. The elongated billet is then phosphate coated. The phosphate coated billet is cut into workpieces and the workpieces are lubricated and individually cold plastically deformed to the shape of turbine stator vanes. The ferrous metal, the phosphate coating and the lubricant are thereafter removed from the deformed workpieces by pickling to produce turbine stator vanes of the aforedescribed nickel-chromium alloy. The vanes are heat treated to develop optimum creep-resistant characteristics in the metal by methods known to the art.

Example II

A hollow cylindrical sheath of ferrous metal substantially devoid of nickel and chromium is positioned in a

billet mold. The thickness of the sheath is about 2% of the outer diameter of the sheath. The ferrous metal of the sheath is SAE 1030 steel. A difficultly extrudable, heat-resistant nickel-chromium-cobalt base alloy of composition (in weight percentages):

Carbon	0.1 max.
Titanium	1.8–3.0.
Chromium	18–21.
Aluminum	0.8–2.0.
Silicon	1.5 max.
Manganese	1.0 max.
Iron	5.0 max.
Cobalt	15–21 max.
Nickel	Balance.

is cast into the sheath to produce a billet having a ferrous metal sheath. The sheathed billet is hot extruded through an elliptically cross-sectioned die to form an elongated, elliptically cross-sectioned composite billet comprising a nickel-chromium-cobalt base alloy core having a thin metallurgically bonded layer of ferrous metal on the outer curved surfaces of the extruded billet. The extruded billet is divided into workpiece-size slugs and the slugs are phosphate-coated. Lubricating oil is applied to the phosphate-coated workpieces and the workpieces are individually cold plastically deformed to the shape of turbine rotor blades by an impact extrusion operation wherein the workpiece is at room temperature at the start of the operation. The ferrous metal, along with the phosphate coating and the lubricating oil, is thereafter removed from the deformed workpieces by pickling to produce turbine rotor blades of the aforedescribed nickel-chromium-cobalt base alloy. The vanes are heat treated to develop optimum creep-resistant characteristics in the metal by methods known to the art.

The invention is applicable to the production of products made of alloys which contain at least 10% of metal selected from the group consisting of nickel and chromium and which can be metallurgically bonded to iron by practical hot working operations, including hot extrusion. Such alloys are characterized by a melting point of at least about 2250° F. and include nickel alloys, chromium alloys, cobalt alloys, iron alloys, nickel-chromium alloys such as nickel-chromium-cobalt alloys, nickel-chromium-iron alloys and nickel-chromium-cobalt-iron alloys, nickel-cobalt alloys such as nickel-cobalt-iron alloys, nickel-iron alloys, chromium-cobalt alloys and chromium-iron alloys such as chromium-cobalt-iron alloys that contain nickel or chromium or both in a total amount of 10% or more. In addition, small optional amounts of aluminum, titanium, molybdenum, tungsten, columbium, tantalum, silicon, manganese, zirconium, and boron can be present in these alloys.

The invention is also applicable to cold plastic deformation of heat resisting alloys. It is to be understood that the term "heat resisting alloys" is used to include austenitic nickel-chromium alloys, including nickel-chromium-iron and nickel-chromium-cobalt and cobalt-chromium alloys, including cobalt-chromium-iron alloys, which contain a total of at least about 25% nickel plus chromium, cobalt plus chromium or nickel plus chromium plus cobalt (i.e., a total of at least about 25% of chromium plus nickel and/or cobalt), in addition to small amounts of aluminum, titanium, molybdenum, tungsten, niobium, tantalum, silicon, manganese, zirconium and boron which may optionally be present in the alloys. These alloys are adapted to be subjected in use to temperatures up to about 700° C. or above.

The invention is particularly applicable to the production of alloy products by cold impact extrusion and by cold forging of slugs, including the performance of such operations on workpieces that are at room temperature. Enormous quantities of work are put into the alloy in a short period of time by cold impact extrusion especially when the workpiece is at room temperature at the start of the operation, and in such an operation the lubrication of the workpiece in accordance with the invention provides a special benefit. For instance, although it is known to provide oxalate coatings on stainless steel to lubricate or facilitate cold deformation thereof, the steel and phosphate lubricating coating of the invention is superior to an oxalate coating in lubricating or otherwise facilitating cold plastic deformation, including cold impact extrusion of alloys high in nickel or chromium. The process of the invention and the novel workpiece of the invention are useful in producing a variety of metal products including turbine rotor blades, turbine stator vanes, bolts, and general precision forgings.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

I claim:

1. A process for producing a plastically deformed metal product comprising the steps of casting a core alloy containing at least about 10% of metal selected from the group consisting of nickel and chromium into a sheath of ferrous metal substantially devoid of nickel and chromium to form a sheathed billet, hot extruding the sheathed billet to reduce the thickness thereof and to produce a composite billet having a thin layer of said ferrous metal metallurgically bonded thereto, providing a phosphate coating on the ferrous metal surface, cold plastically deforming at least a portion of the phosphate coated billet and thereafter removing the ferrous metal from the core alloy.

2. A process as set forth in claim **1** wherein the core alloy is an alloy selected from the group consisting of nickel-chromium heat-resisting alloys and stainless steels.

3. A process as set forth in claim **1** wherein the core alloy is a nickel-chromium-cobalt base heat resistant alloy.

4. A process as set forth in claim **1** wherein at least a portion of the phosphate coated billet is cold plastically deformed by cold impact extrusion.

5. A process as set forth in claim **3** wherein at least a portion of the phosphate coated billet is cold plastically deformed by cold impact extrusion.

6. A process as set forth in claim **1** wherein a lubricant is applied to the phosphate coated billet before cold plastically deforming the billet.

7. A cold plastic deformation process comprising phosphate coating the surface of a composite workpiece having a core of an alloy containing at least about 10% of metal selected from the group consisting of nickel and chromium and having a metallurgically bonded thin layer of ferrous metal substantially devoid of nickel and chromium covering at least a major part of said core, cold plastically deforming said phosphated composite workpiece and thereafter removing the ferrous metal from the plastically deformed core to produce a plastically deformed alloy product.

8. A process as set forth in claim **7** wherein the core alloy is an alloy selected from the group consisting of nickel-chromium heat-resisting alloys and stainless steels.

9. A process as set forth in claim **7** wherein the composite workpiece is cold plastically deformed by cold impact extrusion.

References Cited by the Examiner

UNITED STATES PATENTS

2,990,610	7/1961	Luckerath et al.	29—528
3,122,828	3/1964	Haver	29—528

WHITMORE A. WILTZ, *Primary Examiner.*

P. M. COHEN, *Examiner.*