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3,314,259

METAL FORMING

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No Drawing. Filed July 31, 1964, Ser. No. 386,736
10 Claims. (Cl. 72-46)

This invention relates to the forming of steels, and particularly to an improvement in the cold forming of steels by methods such as extrusion, stamping, drawing and the like.

A variety of steel products are manufactured by processes in which a workpiece of the metal, e.g. a rod, tube, sheet or block or the like, is changed in shaped and dimensions, for example by being forced through an extrusion or drawing die to shape it and reduce its thickness, or by being subjected to forming forces such as those imparted in a stamping machine, a press or the like. It is often desired to operate at essentially ambient temperatures without application of substantial external heat to the system. Such operations are commonly referred to as cold-forming operations, and by this term it is intended herein to convey this meaning.

The economics of the forming processes depend in large part on the extent to which the dimensions of the steel being treated can be reduced in one pass through the forming operation, and upon the amount of force needed to effect a given change. It is obvious that the cost of forming a steel product increases as the number of passes through the forming operation increases, and that the amount of force which must be applied to the workpiece to effect a given change influences the type of equipment which can be used. These economic factors are of prime importance in this competitive field. At the same time, the product must be left with a smooth surface, and attempts to improve process economics by increasing the extent of size or shape change per pass of the workpiece in each forming step often leads to products having marred surfaces, or to production of strains in the metal comprising the workpiece.

Furthermore, a reduction in the force, or pressure, required for extrusion is frequently essential to prevent destruction of the die. Thus, for example if a die would be destroyed at an extrusion pressure of 250,000 pounds per square inch, reducing extrusion pressure from 248,000 p.s.i. to 240,000 p.s.i. is an increase in the safety factor of five times, or 10,000 p.s.i. as versus 2000 p.s.i. This is most significant in practical terms.

A variety of means have been devised for improving the forming processes, both as regards the extent to which the processes change the shape or dimension of the workpiece and the amount of force required to effect these changes, and as regards the surface finish of the formed product. These means have included providing improved forming equipment, for example improved die surfaces and designs in extrusion or drawing techniques, and devising coating materials both for the die and the workpiece to be formed. These approaches have been fruitful; however, the search has continued for still better forming methods, particularly for better cold-forming methods.

It is a feature of this invention to provide a novel coating for steel workpieces such that workpieces carrying the new coating can be formed, particularly cold formed, effectively and without unduly affecting their surfaces.

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It has now been found that a steel workpiece carrying a coating of barium ferrate measuring 0.01 to 10 grams per square foot, and preferably 0.05 to 2.5 grams per square foot, can be formed effectively, without undue marring of the surface thereof, and with a reduction in the forming force required. It has been found, for example, that the extent of size reduction possible without undue marring of the surface in the case of cold extrusion of a stainless steel workpiece carrying the herein barium ferrate coating is greater than the extent possible with a steel workpiece carrying the best prior coating, namely a commercial oxalate coating.

The barium ferrate coating is a red-to-brown coating, and is provided on the steel workpiece to be formed in a thickness which provides 0.01 to 10, and preferably 0.05 to 2.5, grams of the ferrate per square foot of steel surface. Coatings measuring less than 0.01 gram per square foot are not sufficiently heavy to provide adequate improvement of cold-forming operations, whereas use of more than 10 grams of barium ferrate per square foot in a coating, while useful, is unnecessary and expensive. The barium ferrate coating is hard and is resistant to abrasion and the action of solvents and alkalies. The coating also is very smooth, and provides excellent lubrication between the forming die, for example an extruding, drawing or stamping die and the workpiece surface.

The coating suitably is provided by the method described in copending application Ser. No. 104,780, filed Apr. 24, 1961, now Patent No. 3,206,384 and assigned to the assignee of this application. This method involves immersing the ferrous metal as an anode in an alkaline electrolyte solution, containing barium ions, preferably introduced as the barium hydroxide, and passing an electric current through the ferrous metal anode at a potential of at least 1.4 volts in an amount of at least about 2 amperes per square foot of the ferrous metal. Any conductor which is resistant to the electrolyte can serve as the cathode.

The barium ions are preferably introduced as barium hydroxide, and preferably are present at a concentration of about 1/2 N to the saturated condition. The solution also frequently contains an alkali, e.g. sodium hydroxide, to raise its pH.

Steels generally are benefitted in their forming properties by the barium ferrate coating, however, such stainless steels as AISI 316, AISI 304-L and AISI 305 and others are particularly benefitted.

The steel workpiece to be extruded or otherwise formed may be in the form of a rod having a circular or other cross-section, or in the form of a sheet, a tube or the like. Its physical form is dependent upon the forming operation to be applied; for example, drawing and extrusion are normally carried out on billets, rods, tubes or wires, whereas stamping is generally performed on a sheet of the metal. The barium ferrate coating of this invention provides for very effective separation of the steel workpiece from the surface of the forming apparatus, and thus improves the overall operation.

The following examples demonstrate the effectiveness of the barium ferrate coating of this invention in representative extrusion and drawing techniques employing several typical varieties of steel having the compositions shown in Table 1 which follows.

TABLE 1.—WEIGHT PERCENT COMPOSITION

Steel	C	Cr	Ni	Mn	Cu	P	S	Mo	Al	Si	Balance
A Stainless 304-L-----	0.03	18.6	9.43	1.69	0.21	0.022	0.016	-----	-----	0.34	Fe
B Plain Carbon Steel C-1018-----	0.23	0.02	0.03	0.73	-----	0.009	0.03	0.01	0.004	0.19	Fe
C Stainless 316-----	<0.1	17	12	-----	-----	-----	-----	2.5	-----	-----	Fe
D Music Spring Wire ¹ -----	0.7 to 0.9	-----	-----	0.2 to 0.4	-----	<.025	<0.25	-----	-----	0.12 to 0.25	Fe

¹ The music spring wire was annealed by heating the wire coil in a retort containing forming gas at 1,500° F. for one-half hour; the retort then was removed from the furnace and cooled in air, the flow of forming gas being continued during the cooling. The forming gas was approximately 90% nitrogen and 10% hydrogen.

The Forward Extrusions shown in the following examples were carried out by forcing a billet of steel through an extrusion die to form a solid bar of smaller cross-section. The forward end of the billet was tapered to conform to the entry angle of the extrusion die, and the nose had the appearance of a truncated right-circular cone, the conical surface extending about ¼ inch as measured parallel to the axis of the cylinder, the rear base diameter being 1.480 inches and the forward base diameter being 1½ inches. The billets were 2½ inches long. The extrusion die had an inner diameter of 1.167 inches and a 90 degree entry angle. The extruded bar size was 1.167 inches in diameter and the billet was extruded until the extruded portion was 2 inches in length. This ex-

A 700 ton vertical hydraulic press was used in the extrusions, and extrusion pressures were measured by a Bacharach Hydraulic Pressure Recorder; and actual pressures on the extrusion punches were calculated from the hydraulic pressure recorded by the Bacharach device.

Surface finish quality of the extruded samples was measured with a Brush Surfindicator, which measures surface roughness with a stylus-type pick-up which contains an electromagnetic element. Motion of a stylus over a rough surface generates a current which is proportional to surface variations. The values are recorded as R.M.S. (root mean square) with higher numbers representing rougher surfaces. Results of some typical tests are shown in Table 2, which follows:

TABLE 2.—BACKWARD EXTRUSION

Example No.	Steel	Coating	Extrusion Pressure, ³ p.s.i.	Surface Finish (microinches R.M.S.)
1-----	A (Type 304-L Stainless)-----	Barium Ferrate ¹ (1 g./ft. ²)	359,000	15 to 40—Smooth and shiny.
2 (comparative)-----	do-----	Commercial Oxalate Coating (recommended by manufacturer of coatings).	384,000	50 to 60—Slightly less smooth and shiny than Ex. 1 sample.
3-----	B (C-1018 Carbon Steel)-----	Barium Ferrate ² (2.2 g./ft. ²)	256,000	15 to 40—Smooth and shiny.
4 (comparative)-----	do-----	Commercial Zinc Phosphate Coating (recommended by manufacturer of coatings).	258,000	Do.

FORWARD EXTRUSION

5-----	A (Type 304-L Stainless)-----	Barium Ferrate ¹ (1 g./ft. ²)-----	145,000	50 to 65—Slightly less smooth and shiny than Ex. 1 sample.
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¹ The barium ferrate coating was provided by HCl acid cleansing the billet for one minute, immersing the cleaned billets in an aqueous 1 N Ba(OH)₂ electrolyte bath and imposing a voltage of 4.5 volts at 150 amps/ft.² for 30 minutes at 95° C., the billets serving as anodes.

² The barium ferrate coating was provided by HCl acid cleansing the billet for one minute, immersing the cleaned billet in an aqueous 1 N

Ba(OH)₂ electrolyte bath containing 5 N NaOH and imposing a voltage of 4 volts at 300 amps/ft.² for 2 hours at 95° C. the billets serving as anodes.

³ Extrusion of uncoated billets at these pressures would heavily score and therefore render worthless, the extrusion dies, and/or would produce an extruded product having a heavily scored surface.

trusion provided a cross-sectional size reduction of 40%. The punch speed was 6 inches per minute.

The Backward Extrusions shown in the following examples were carried out by piercing a solid billet with a punch to form a hollow cup. The deformed portion of the base of the billet formed the inside surface of the cup. The billets treated were 1.480 inches in diameter 1¼ inches long. The leading end of the extrusion punch had a diameter of 1.046 inches and was a spherical segment subtended by an included angle of 140 degrees. The finished cup had a diameter of 1.500 inches, a 0.227 inch wall, was 1¼ inches deep and had a ½ inch thick base. This provided a billet reduction of 50% in the cross-sectional area of the metal in the pierced section. The punch speed was 6 inches per minute.

In both the Backward and Forward Extrusions common aqueous sodium stearate soap lubricants were applied to the billets before extrusion. In the case of the commercial oxalate coating (used as a comparative example) the lubricant applied over the coating before extrusion contained in addition to the sodium stearate soap, some borax soap. This was recommended by the manufacturer of the oxalate coating in order to provide a lubricant not reactive with the oxalate coating. The lubricants were applied by conventional means, namely by dipping the billet in the lubricant solution held at 170° to 180° F., followed by drying the lubricated billet in an oven at 120° F. for 15 to 20 minutes.

These examples 1 to 5 demonstrate the effectiveness of the herein barium ferrate coatings in facilitating the extrusion of a typical carbon steel (C-1018) and a typical stainless steel (Type 304-L). As noted in the footnote to Table 2, extrusion of uncoated billets of these steels under the test conditions employed above would cause destruction of the dies employed in the extrusions, whereas with the barium ferrate coating of the invention, the samples were extruded at useful pressures to provide products having surfaces which exhibited smooth and shiny surfaces.

When compared with the best commercial coatings, namely the zinc phosphate coating and the oxalate coating, the barium ferrate proved to be at least as effective as other coatings in facilitating effective extrusion. In the case of Example 1 and comparative Example 2, the results of the extrusion were even superior in the case of the barium ferrate coating, providing a very substantial reduction in extrusion pressure required for the extrusion, and providing somewhat better surface character in the extruded product.

The following Wire Drawing tests, reported in Table 3, which follows, were carried out by drawing the indicated wires through tungsten carbide dies having 12 degree entrance angles. The wires tested had initial diameters of 0.050 inch.

TABLE 3

Example No.	Drawing No. at about 132/min.	Steel Wire	Coating ^a	Die Diameter	Wire Diam. Following Draw	Percent Area Reduction Effected by Draw	Total Area Reduction	Average Drawing Load
6 (comparative)	1	C (Type 316 Stainless)	None	0.042	0.0413	31.7	31.7	120.0
	2			0.038	0.0367	^d 21.0	46.1	118.0
	3			0.036	0.0360	^d 6.4	49.6	101.0
	1			0.042	0.0421	29.1	29.1	103.5
	2			0.038	0.0373	24.4	46.4	118.0
7	3	C (Type 316 Stainless)	Barium Ferrate, ^b 0.19 g./ft. ²	0.036				
	4			0.034	0.0320	25.4	59.5	85.5
	5			0.030	0.0293	15.1	65.6	90.0
	6			0.028	0.0275	11.9	69.7	46.0
	7			0.0265	0.0258	15.3	74.4	48.0
8 (comparative)	1	D (Music Wire)	None	0.048	0.0475	10.8	10.8	82.5
	2			0.045	0.0446	10.7	20.4	93.5
	3			0.042	0.0415	13.4	31.1	90.0
	4			0.040	0.0397	8.4	36.9	63.0
	1			0.048	0.0476	9.3	9.3	69.5
9	2	D (Music Wire)	Barium Ferrate, ^c 0.07 g./ft. ²	0.045	0.0448	12.6	20.8	85.5
	3			0.042	0.0421	11.8	30.1	80.0
	4			0.040	0.0398	9.3	36.6	53.5
	2							
	3							

^a Both coated and uncoated wires were lubricated with a lubricant compounded of 29 gallons of kerosene, 29½ gallons of 100 second oil and 5½ gallons of lard oil.

^b Ferritized for 30 minutes at 9.4 amps/sq. ft. at 5 volts, in a 1 N Ba(OH)₂-5 N NaOH, aqueous solution at 95° C.

^c Ferritized for 1½ minutes at 19.8 amps/ft.² at 5 volts in a 1 N Ba(OH)₂-5 N NaOH aqueous solution at 95° C.

^d Wire broke upon being drawn.

Examples 6 through 9 demonstrate the effectiveness of the herein barium ferrate coating in facilitating drawing of a musical wire and a typical stainless steel wire. Examples 6 and 7 show that uncoated 316 stainless steel wire could be drawn only through the first of the multiple size reduction dies used in these tests without breaking, whereas the coated 316 wire was drawn through a total of 6 dies and underwent a 75% size reduction overall before the test was stopped.

Examples 8 and 9 demonstrate that the barium ferrate coated music wire was reduced about 37% in thickness in four passes with much lower drawing loads required per pass than was uncoated music wire. This is of obvious importance in wire drawing, since the amount of force required per draw substantially affects the type of wire which can be drawn, and the type of equipment necessary for the drawing.

Pursuant to the requirements of the patent statutes, the principle of this invention has been explained and exemplified in a manner so that it can be readily practiced by those skilled in the art, such exemplification including what is considered to represent the best embodiment of the invention. However, it should be clearly understood that, within the scope of the appended claims the invention may be practiced by those skilled in the art, and having the benefit of this disclosure, otherwise than as specifically described and exemplified herein.

What is claimed is:

1. Method of cold forming a steel workpiece, comprising providing on said workpiece a coating of barium ferrate measuring 0.01 gram to 10 grams per square foot, and cold forming said workpiece carrying said barium ferrate coating.

2. Method of claim 1 in which the barium ferrate coating measures 0.05 gram to 2.5 grams per square foot.

3. Method of claim 1 in which the workpiece which is cold formed is a stainless steel workpiece.

4. Method of extruding a steel workpiece comprising providing on said workpiece a coating of barium ferrate measuring 0.01 gram to 10 grams per square foot, and extruding said workpiece carrying said barium ferrate coating through a die.

5. Method of claim 4 in which the barium ferrate coating measures 0.05 gram to 2.5 grams per square foot.

6. Method of claim 4 in which the steel workpiece which is extruded is a stainless steel workpiece.

7. Method of drawing a steel wire, comprising providing on said wire a coating of barium ferrate measuring 0.01 gram to 10 grams per square foot and drawing said wire carrying said barium ferrate coating through a die.

8. Method of claim 7 in which said barium ferrate coating measures 0.05 gram to 2.5 grams per square foot.

9. Method of claim 7 in which said wire is a stainless steel wire.

10. Method of claim 7 in which said wire is music spring wire.

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