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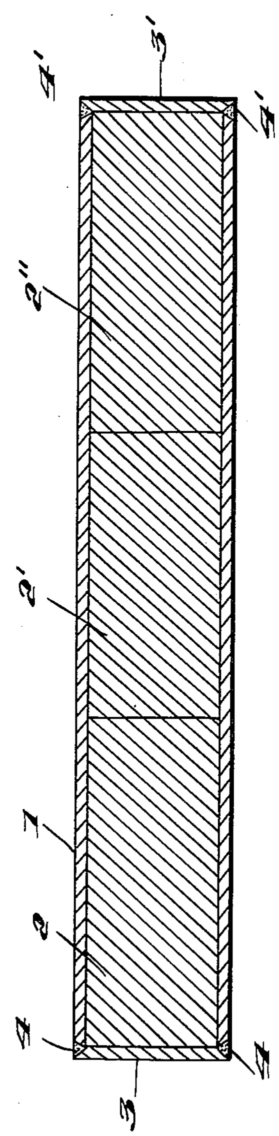

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CONVERSION OF HEAT-SENSITIVE ALLOYS WITH AID OF A THERMAL BARRIER

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This invention relates to the art of converting ingots of heat-sensitive alloys—in particular, heat-sensitive non-ferrous and ferrous alloys—into plates, sheets, rods, bars or other standard shapes. By "heat-sensitive" is here meant alloys having a relatively narrow temperature range of "hot-working." Illustrative but non-limiting examples of heat-sensitive alloys the conversion of which is very substantially improved by the carrying out of the present invention are nickel-base alloys of the so-called "unworkable" class, "Udimet 700," "Udimet 500," a variety of titanium alloys and certain cobalt-containing steels and certain tool steels of which "BR4" is an outstanding example.

In the conventional procedure, the conversion of ingots of such heat-sensitive alloys is relatively slow and laborious. This is because these alloys tend to become embrittled, due to cooling, during the working steps, and their conversion conventionally requires very frequent "conditioning" steps between stages of reduction. Again, in following the conventional conversion procedure, conditioning operations to remove surface roll tears—especially, tears at billet corners—necessarily are numerous, resulting in loss of valuable material (alloy) as well as contributing to high labor cost. For example, in converting to one inch bar stock an ingot three and three-eighths inches in diameter of a non-ferrous nickel-base alloy, having the following approximate composition:

ALLOY COMPOSITION #1

	Percent
Cr	14.0–17.0
Co	13.0–20.0
Mo	4.5–5.5
Al	4.0–4.5
Ti	3.25–3.75

Balance, substantialy all Ni

the conventional (i.e., hitherto "standard") procedure was as follows:

(1) Cast 22# Ingot 3⅜" diameter x taper.
(2) Roll to 2¾" square—⅛" reduction per heat—5 heats.
(3) Condition all over.
(4) Roll to 2⅛" square—⅛" reduction per heat—5 heats.
(5) Condition all over.
(6) Roll to 1⅝" square—⅛" reduction per heat—4 heats.
(7) Condition all over—Crop hot top.
(8) Roll to 1⅜" square—⅛" reduction per heat—2 heats.
(9) Condition all over.
(10) Roll to 1⅛" square—⅛" reduction per heat—2 heats.
(11) Condition all over.
(12) Roll to final bar—centerless grind.

Summary

(*a*) 19 heats—18 cogs, 1 final roll
(*b*) 5 laydowns for conditioning
(*c*) Standard yield 48% of poured weight of ingot.

I have discovered that if loss of heat from the heated heat-sensitive alloy ingot—and especially the setting up of a relatively steep thermal gradient as between the interior of the ingot and its surface layer—can be significantly de-

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layed if not prevented the workability of the alloy metal is (or, may be) greatly improved. I made this discovery with reference to "cladding" the ingot with a thick-walled envelope, more particularly, with a thick-walled envelope of low-carbon steel. I found that ingots so protected can be converted (cogged, rolled, ground) with a minimum of laydowns for conditioning and with heavier reductions per heat and, at the same time, with a very materially larger yield of product based on the poured weight of the ingot. As will, of course, be understood by anyone skilled in this art, the composition of the envelope used in this way must be inert at all working temperatures.

I have found that the advantageous thermal barrier effect of the envelope can be realized, with a great saving in over-all costs, by carrying out the improved procedure about to be described. My improved procedure consists essentially in (*a*) enveloping the ingot within a relatively very thick-walled sleeve of suitable metal, e.g., steel (i.e., a "can" having a wall thickness of the order of 0.75 inch); (*b*) subjecting the "canned" ingot to an extrusion or deep-drawing operation which reduces the diameter of the sleeve and brings the latter into the most intimate over-all contact with the surfaces of the ingot; (*c*) hot-rolling the "canned" ingot nearly to desired dimensions of the enveloped billet of heat-sensitive alloy; (*d*) stripping off the "can"; and (*e*) rolling to final dimensions and centerlessly grinding. In some fact situations, a conditioning step may be desirable between steps (*d*) and (*e*), but I have found that—in general—no conditioning step is necessary at this stage. I have found in actual practice that the number of re-heats may be lessened by as much as 80 percent, and that the over-all "yield" of finished stock may be increased from the "conventional yield" of say 48% to as much as 60–65%.

The invention will now be described in further detail and with reference to the accompanying drawing, in which

The single figure diagrammatically represents an operable mode of carrying out the principles of the present invention.

In the drawing, 1 represents a six inch (I.D.) steel pipe having a wall thickness of approximately 0.75 inch, into which there have been slipped three ingots, 2, 2′ and 2″ of the aforesaid nickel-base alloy, each ingot having a diameter of 5.75 inches and each representing approximately 96 lbs. of alloy. The ingots had been hot top cropped prior to insertion into the pipe, the length of which latter had been chosen so that the pipe would snugly accommodate the three ingots. The ends of the pipe were sealed shut by means of circular steel discs 3, 3′ welded at 4, 4, 4′, 4′, to the ends of the pipe 1.

In carrying out the procedure, the cylindrical ingots 2, 2′, 2″ are cast in specially prepared molds, are hot top cropped, and then are slid into the thick-walled steel pipe 1, as many ingots being placed in each pipe as needed for producing an extrusion billet of any desired length. The ends of pipe 1 are sealed shut by welding on discs 3, 3′ of 0.5 inch steel plate.

The resulting article is then extruded or drawn through a round die having such a diameter—preferably, about 3.5 inches—that the diameters of steel pipe 1 and ingots 2, 2′, and 2″ are so reduced that the pipe is pressed into the most intimate over-all contact with the contained ingots, thereby producing a master billet 3.5 inches in diameter. Then the extrusion usually is cut to appropriate lengths of clad billet pieces.

These clad billet pieces are rolled through a cogging mill to 1.25 inches square, in one (1) heat. Thereafter, the steel pipe ("can") is removed from the bar-shaped pieces, by high-temperature scaling in a heat-treatment furnace, or by mechanical stripping or by pickling or grinding or by a combination of two or more of these measures, and the bar-shaped pieces may—but frequently need not—be finally conditioned all over and, if necessary, rolled to final dimensions. Finally the pieces may, if desired, be centerlessly ground and be conditioned all over and finish-rolled.

My improved procedure may be compared with the hereinabove "standard" procedure as follows:

Improved Procedure

(1) Cast 5¾" diameter x 96# ingot.
(2) Crop hot top.
(3) "Can" in 5¾" I.D. x 7¼" O.D. pipe (3 ingots per can).
(4) Extrude or draw to 3½" diameter.
(5) Roll to 1¼" square—1 heat.
(6) Strip "can."
(7) Heat and roll to final bar.

Summary

(*a*) 3 heats—1 extrusion, 1 cog, 1 final roll.
(*b*) Yield 60%–65%.

As will be appreciated, the improved procedure of the present invention reduced the heats from 19 to 3, diminished the laydowns for conditioning from 5 to none, and increased the yield of product from the conventional yield of 48% to 60–65%.

The presence of the thick protective cladding provided a unique thermal barrier effect, minimizing the temperature differential between the surface and interior of the ingots (or, billet pieces). It appears that, for realization of the effectiveness of this invention, it is necessary that the thermal barrier wall have a thickness of at least ⅙ of an inch after the last rolling operation. Preferably the thick-walled thermal barrier has a wall thickness of at least ¾ of an inch at the start, and a wall thickness of at least ¼ of an inch after the extrusion or drawing operation, and a wall thickness of 1/16 of an inch after repeated rollings. This is in contrast to conventional "canning" in which the wall thickness may be as much as 0.06 inch at the start, and be reduced to 0.01 inch after extrusion, and ending up with a wall thickness of about 0.001 inch at the conclusion of the rolling operations. Due to the efficiency of this thermal barrier, reductions from 3.5 inches diameter to as much as 1.25 inch have, to date, been routinely effected, without re-heating and without surface tearing, and greater reductions appear probable. This is in contrast to a maximum of 0.125 inch reduction, per heat, in the case of un-clad ingots of the same alloy composition. In addition, ingots of the heat-sensitive alloys have been converted to round (or, square) bar stock without any intermediate or in-process conditioning.

By the "routine" protecting of this improved procedure, I have converted 5.75 inch ingots to 1.125 inch billets with a "weight yield" value of 80.0% based on the poured weight of the ingots.

In the above illustrative example the "envelope" consisted of low-carbon steel. It is to be appreciated that the most important feature with respect to the envelope is that the same must be materially more malleable than is the enshrouded alloy composition being rolled. Aside from this criterion, and from the obvious criterion that the enshrouding material must be "inert" with respect to the composition of the clad billet, there appears to be no limit to the composition of the enshrouding metal.

In the above disclosure, it has been emphasized that the conversion of the ingot or billet while enshrouded in relatively very thick-walled envelope prevents the generation of cracks—especially, the generation of tears at billet corners—during the working of the billet to final form. Another, and very surprising result of the carrying out of the process of the present invention is the lessening of the load necessary for converting the ingot or billet to final form. Thus I have found that rolling with the "thermal protector" of the present invention reduces the mill (power) load by as much as 40% enabling conver-

sions to be carried out on equipment which normally would be inadequate. I believe that the diminution in power requirement stems from the circumstance that the cogging rolls readily "bite" into the relatively very malleable envelope material—thereby clearly promoting the rolling operation—as opposed to the unclad surface of the ingot or billet being converted.

It is to be appreciated, then, that the practice of the present invention serves very substantially to lower the over-all cost of converting heat-sensitive alloy ingots and billets.

The extrusion step may be carried out using conventional apparatus and following conventional extrusion procedure. The cogging mill used for rolling the clad billet pieces may be equipped with either diamond, square or gothic passes.

It is to be appreciated that the improved process of the present invention is not restricted to converting ingots of any specific size or form, or of the specific alloy composition chosen for illustrative purposes in the above specific example. Rather, the procedure is equally applicable to heat-sensitive alloys generally, including—as further illustrations of the scope of operability of the process—the following particular compositions:

ALLOY #2

	Percent
C	0.38
Mn	1.50
Si	.70
Cr	20.0
Ni	20.0
Mo	4.0
W	4.0
Cb	4.0
Fe	3.0

Balance substantially all cobalt.

ALLOY #3

	Percent
Al	7.0
Mo	4.0

Balance substantially all Ti.

ALLOY #4

	Percent
Al	6.0
V	4.0

Balance substantially all Ti.

ALLOY #5

	Percent
C	2.40
Si	.40
Mn	.40
Cr	13.0
V	4.0
Mo	1.2
Ni	max__ .5

Balance substantially all Fe.

Finally, it is to be explained that the hereinabove described "thermal barrier effect" is not realized by conventional cladding of the sort adapted to prevent unwanted oxidation of the metal undergoing conversion, in which conventional procedures an ingot is clad with a shell of relatively thin sheet metal, e.g., a steel sheet of, say, 16–20 gauge. While such thin cladding is quite operable for sealing the ingot from the atmosphere, it is quite incapable of effecting any appreciable lessening of chilling (of the ingot) to below the critical temperature (ductile to brittle). Thus, in a comparison of the improved conversion procedure of the present invention with the conversion of an ingot conventionally clad in a 16–20 gauge "can," I found that the necessary heats were reduced from, say 19 (for un-clad ingot) only to 18 or 17 (for the thin-walled cladding), whereas an ingot of identical alloy composition but "canned" in a protected "skin" of thick-walled (0.75 inch wall thickness) pipe made it possible to convert the ingot to the same final product in a total of only 3 heats.

I claim:

1. In the process of converting an ingot of heat-sensitive alloy composition involving rolling the ingot while at a temperature above the critical temperature of the alloy, the improvement which consists in enveloping the ingot in a metal shell having such wall thickness as materially to retard the setting up of a sharp temperature differential between surface and interior of the ingot, hot-extruding or drawing the so-enveloped ingot through an extrusion or drawing die having such a size of opening as to compress said shell onto said ingot and materially to reduce the cross-sectional area of the enveloped ingot; thereafter hot-rolling the extruded or drawn article to approximately final cross-sectional size without in-process conditioning; and removing the shell from the resulting reduced billet.

2. In the process of converting an ingot of heat-sensitive alloy composition involving rolling the ingot while at a temperature above the critical temperature of the alloy, the improvement which consists in enveloping the ingot in a metal shell having such wall thickness as materially to retard the setting up of a sharp temperature differential between surface and interior of the ingot, extruding or drawing the so-enveloped ingot through an extrusion or drawing die having such a size of opening as to compress said shell onto said ingot and materially to reduce the cross-sectional area of the enveloped ingot; thereafter rolling the extruded or drawn article to approximately final cross-sectional size without in-process conditioning; removing the shell from the resulting reduced billet and finish-rolling the un-clad article.

3. In the process of converting an ingot of heat-sensitive alloy composition involving rolling the ingot while at a temperature above the critical temperature of the alloy, the improvement which consists in enveloping the ingot in a metal shell having such wall thickness as materially to retard the setting up of a sharp temperature differential between surface and interior of the ingot, extruding or drawing the so-enveloped ingot through an extrusion or drawing die having such a size of opening as to compress said shell onto said ingot and materially to reduce the cross-sectional area of the enveloped ingot; thereafter rolling the extruded or drawn article to approximately final cross-sectional size without in-process conditioning; and removing the shell from the resulting reduced billet conditioning all over and finish-rolling the un-clad article.

4. The improved process defined in claim 1, in which the shell is composed of a metal having substantially greater malleability than that of the alloy composition of the ingot.

5. The improved process defined in claim 1, in which the wall thickness of the shell is at least 0.0625 inch at the conclusion of the rolling operations.

6. The improved process defined in claim 1, in which the wall thickness of the shell, as applied to the ingot, is of the order of 0.75 inch, and in which the wall thickness of the shell is reduced to about 0.25 inch by the extrusion or drawing operation.

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