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[54] CONTINUOUS ROLLED ROD DIRECT COOLING METHOD

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Related U.S. Application Data

[62] Division of Ser. No. 106,149, Jan. 13, 1971, Pat. No. 3,766,763.

[52] U.S. Cl. 72/45; 72/201
[51] Int. Cl. B21b 27/06; B21b 45/02
[58] Field of Search .... 72/41–45, 201, 72/202, 236; 148/153, 155, 156, 157; 266/4 S, 6 S; 29/527.7

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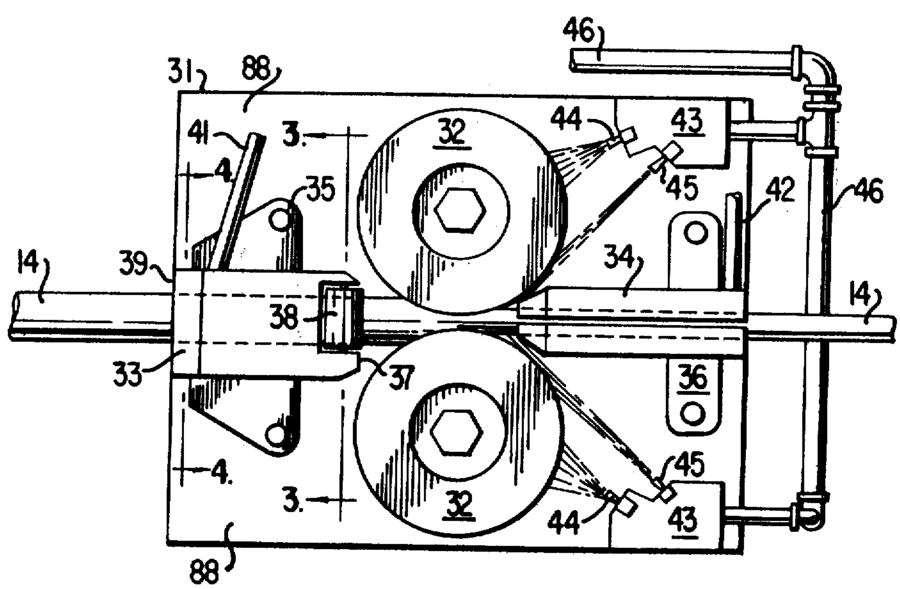
[57] ABSTRACT

This disclosure relates to a fluid cooling and lubricating system for metal rod being rolled down from a continuously cast bar and includes a multiple pressure arrangement wherein high pressure fluid is utilized to cool and descale the rod as well as the hot-forming rolls by spraying and wherein low pressure fluid is additionally utilized for cooling and lubrication by flooding roll stand entrance and exit rod-guide housings. Direct and controlled spray cooling of the hot-formed rod is obtained by wide-angled nozzles having solenoid-operated valves responsive to the exit temperature of the rod which is monitored by a photopyrometer whereby the volume of coolant is controlled to obtain a uniform finishing temperature of the rod.

2 Claims, 5 Drawing Figures



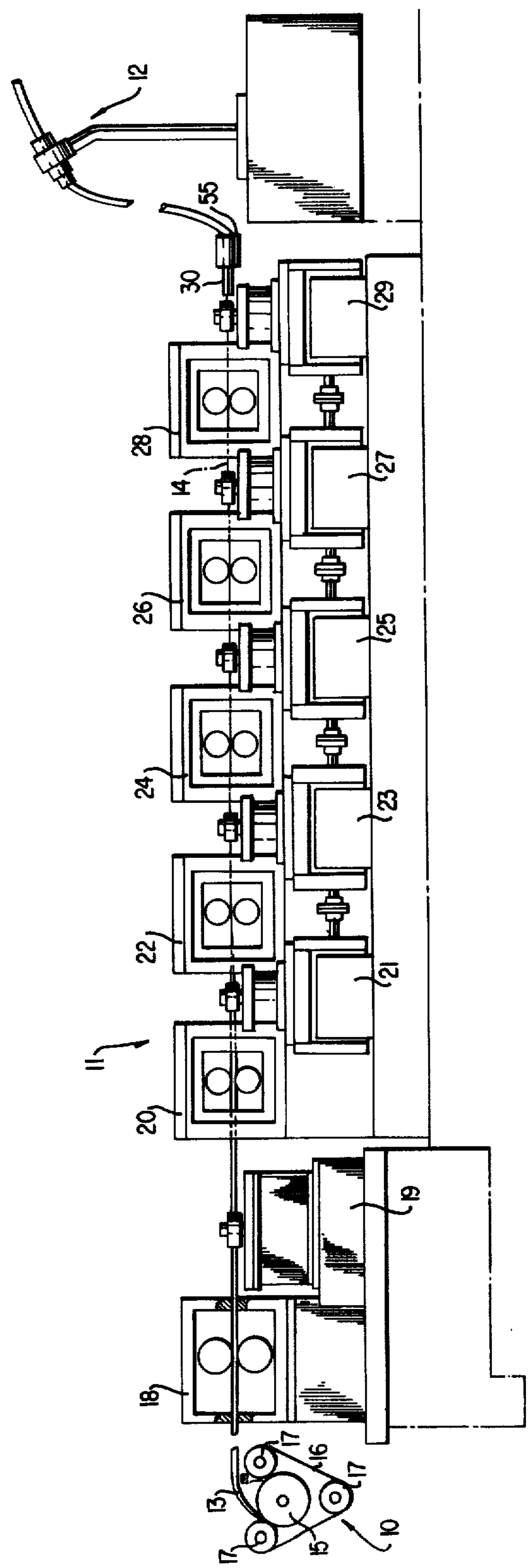


FIG. 1

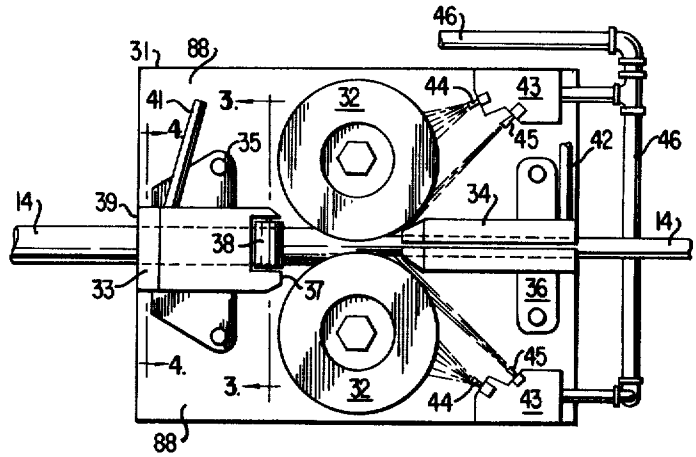


FIG. 2

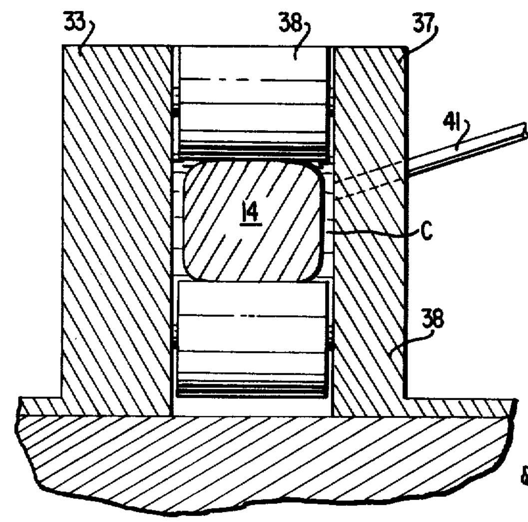
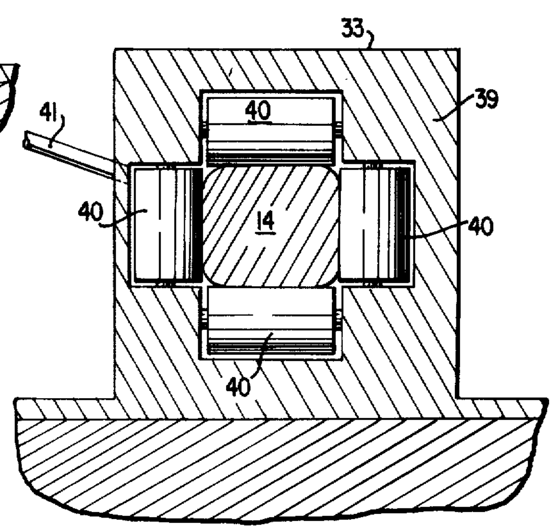


FIG. 3

FIG. 4



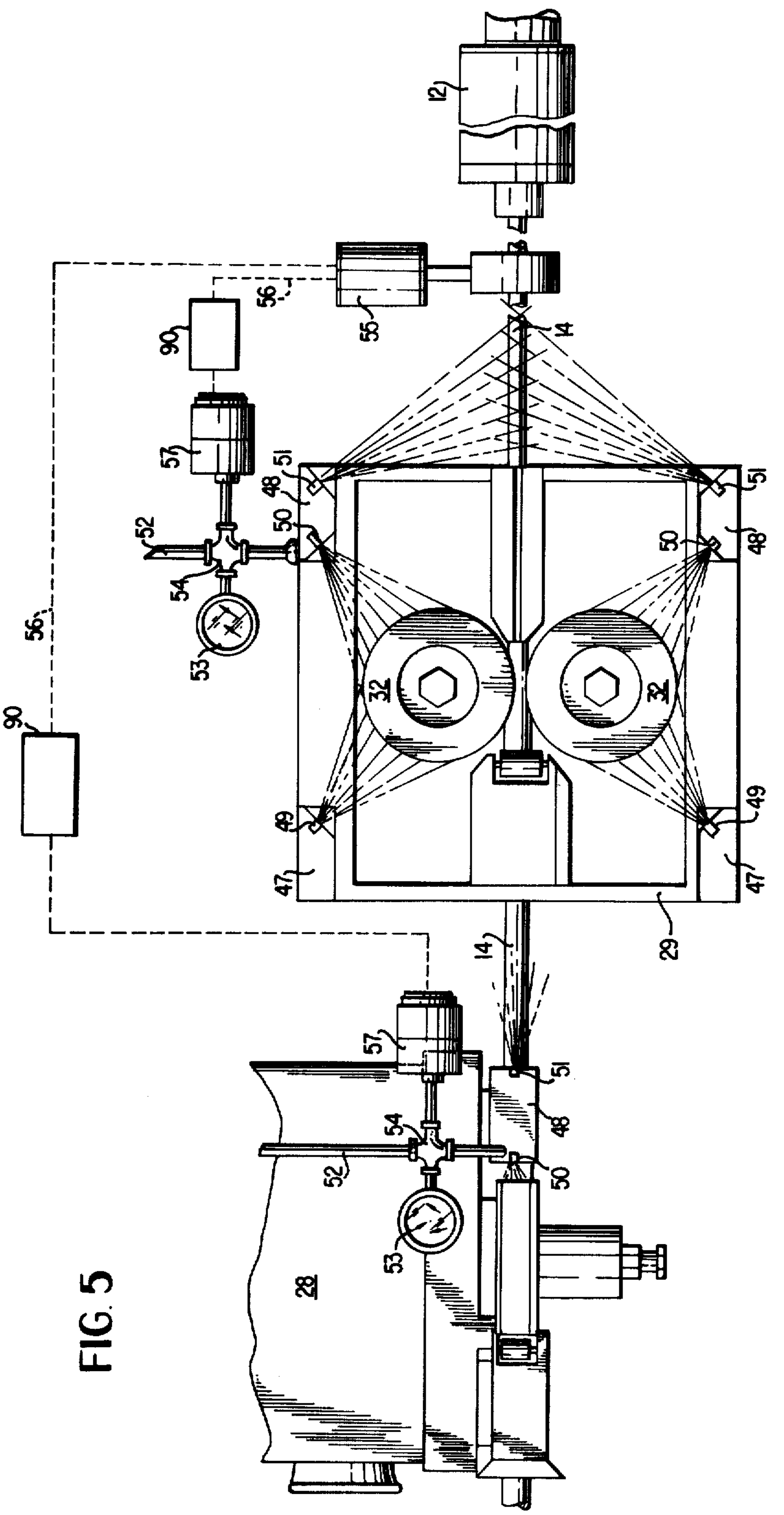


FIG. 5

CONTINUOUS ROLLED ROD DIRECT COOLING METHOD

This is a division of application Ser. No. 106,149 filed Jan. 13, 1971 now U.S. Pat. No. 3,766,763

This invention relates generally to the manufacture of fine wire or like products from metal rod, and particularly to a fluid cooling and lubricating system for metal rod being rolled down from a continuously cast bar.

In copending application Ser. No. 866,410, now U.S. Pat. No. 3,561,105 and assigned to the assignee of this invention, there is disclosed a method of producing a hot-formed aluminum-base product in which the as-cast grain structure of the cast metal is substantially completely destroyed and which is for this reason superior to prior art hot-formed aluminum-base products for drawing into fine wire or other uses.

The method disclosed in the above-identified patent is accomplished by using a continuous casting machine in which molten aluminum-base metal is solidified to obtain a cast metal and a rolling mill to which the cast metal is passed at hot-forming temperature from the casting machine and which has a plurality of roll stands which alternately change the transverse cross-sectional shape of the cast metal. The as-cast grain structure of the cast metal is substantially completely destroyed by deforming the cast metal a substantial number of times to cause an elongation of the cast metal along its axis of elongation by a factor of at least twenty and to cause a substantial movement of the cast metal along a plurality of axes substantially perpendicular to the axis of elongation.

The present invention is directed to a novel fluid cooling and lubricating system adapted to be used with the rolling mill used to accomplish the method disclosed in the above-identified patent, as well as with other similar apparatus for rolling other metals such as cooper or steel rod. In the case of producing aluminum rod as by the method disclosed in the above-identified patent, the method and apparatus disclosed herein result in an aluminum rod that, when drawn into aluminum wire by use of standard, prior art drawing techniques, will have higher tensile strength and higher electrical conductivity than the same wire would have when drawn from rod produced by rolling equipment possessing prior art cooling and lubricating systems.

One problem with rolling mills having prior art cooling and lubrication systems the soluble oil system used for cooling and lubrication is set for production, its volume rate of flow is not adjusted though the casting rate, and therefore the velocity of the cast rod through the mill, changes quite frequently during operation. Consequently, the temperature of the rod at the exit from the rolling mill varies during production which results in rod having inconsistent metallurgical properties along its length. For rod being drawn into wire, the uncontrolled temperature variation has an adverse effect on its tensile strength, elongation and annealability characteristics which is generally solved by our invention.

In the case of copper, for example, (the mill exit temperature of which can vary between 900° and 1200° F,) as well as other metals such as steel, the rod may enter a cooling and/or pickling system upon its exit from the rolling mill. Here again, the variation in the exit temperature of the rolled rod caused by the prior art fixed coolant volume capacity adversely affects the quality of the pickling and the physical properties of the rod.

Moreover, to comply with the highest rod temperature presented to it, the pickling system must have a sufficiently high capacity to accomodate the highest speeds of rod expected to pass through the pickling system. Therefore, even under normal conditions, overdesigned pickling equipment must be purchased and placed in service in order to accomodate occasional high temperature rod. With rolling mills having prior art cooling and lubricating systems, for instance, the relatively high temperature of the rod exiting from the mill necessitates the use of high capacity pickling equipment that is generally inefficient and places an upper limit on the overall production rate of the rod.

The high exit temperature is occasioned by the necessity for rolling the rod at the maximum possible temperature in order to reduce the mechanical power requirements of the rolling mill. However, in multiple stand mills where the rod is first rolled through a series of roughing stands and then through a series of finishing stands, the power requirements obviously decrease as the rod progresses through the mill. Although the requirement for high temperatures concurrently decreases in each succeeding roll stand, the prior art cooling and lubricating systems have not increased the coolant capacity progressively in each succeeding stand so as to thereby capitalize on the lower temperature requirements of the mill and hence achieve a lower finishing temperature of the rod.

It is, therefore, the primary object of this invention to provide a fluid cooling and lubricating system for a rolling mill that produces metal rod having superior and more consistent metallurgical properties.

Another object of this invention is to provide a fluid cooling and lubricating system for a rolling mill wherein variations in the temperature of rod exiting from the mill are substantially eliminated.

Another object of this invention is to provide a fluid cooling and lubricating system for a rolling mill wherein the temperature of rod exiting from the mill is substantially reduced in comparison with exit temperatures resulting from prior art systems.

Still another object of this invention is to provide a fluid cooling and lubricating system for metal rod being rolled down from a continuously cast bar including a multiple pressure arrangement wherein high pressure fluid is utilized to cool and descale the rod as well as the hot-forming rolls by spraying, and wherein low pressure fluid is additionally utilized for cooling and lubrication and for rod oxidation control by flooding roll stand entrance and exit rod-guide housings. Such flooding also yields a better rod surface by reducing the friction between the rolls and the rod.

A further object of this invention is to achieve a consistent finishing temperature for hot-formed rod exiting from a rolling mill including a fluid cooling and lubricating system providing direct and controlled spray cooling of the hot-formed rod through wide-angled spray nozzles having flow control means responsive to the exit temperature of the rod for controlling the volume of coolant.

Yet another object of this invention is to provide a fluid cooling and lubricating system for a multiple stand rolling mill wherein the volume of coolant is progressively increased in each stand from the inlet to the outlet of the mill whereby rod is rolled in the primary roughing stands at desirable higher temperatues and finished at the lowest possible temperature consistent with power requirements.

With the above and other objects in view that will hereinafter appear, the nature of the invention will be more clearly understood by reference to the following detailed description, the appended claimed subject matter, and the several views illustrated in the accompanying drawings:

In the Drawings:

FIG. 1 is a semi-schematic elevation view of rod-manufacturing apparatus including a continuous casting machine, multiple stand rolling mill and pickling apparatus upon which the fluid cooling and lubricating system of this invention is adapted to be utilized.

FIG. 2 is a plan view of a single roll stand of the multiple stand rolling mill shown in FIG. 1, and depicts the piping, nozzles and rod-guide housings used in the multiple pressure cooling and lubricating arrangement of this invention.

FIG. 3 is an enlarged generally schematic sectional view taken along line 3—3 of FIG. 2, and depicts the rod supported in a flooded guide housing.

FIG. 4 is an enlarged generally schematic sectional view taken along line 4—4 of FIG. 2, and depicts an idle roller rod support and seal arrangement for the rod inlet to the guide housing.

FIG. 5 is a generally schematic fragmentary plan view of two finishing roll stands of the multiple stand rolling mill shown in FIG. 1, and depicts the rod and rolls being sprayed by nozzles having solenoid-operated valves controlled by a photopyrometer which monitors the finishing temperature of the rod.

Referring now to the drawings in detail, there is illustrated No. FIG. 1 rod manufacturing apparatus including a continuous casting machine **10**, a multiple stand rolling mill **11** and pickling apparatus **12**. The continuous casting machine **10** serves as a casting means for solidifying molten metal to provide a cast metal such as a cast bar **13** that is conveyed in substantially that condition in which it solidified from the continuous casting machine **10** to the rolling mill **11**. The rolling mill **11** serves as a hot-forming means for hot-forming the cast bar **13** into a rod **14** of aluminum or another hot-formed aluminum-base product in accordance with the method disclosed in the above-identified and commonly assigned U.S. Pat. N. 3,561,105, or a rod of other hot-formed metals such as copper or steel. It should be understood that while the novel fluid cooling and lubricating system of this invention is particularly adapted to be used with the apparatus for accomplishing the method disclosed in the commonly assigned U.S. Pat. No. 3,561,105, it is not so limited and in fact, is useful with hot-forming rolling equipment generally.

The continuous casting machine **10** is of conventional casting wheel type similar to that shown in U.S. Pat. No. 3,318,367 and has a casting wheel **15** with a casting groove (not shown) partially closed by an endless band **16** which is supported against the casting wheel **15** by a plurality of idler wheels **17**. The casting wheel **15** and endless band **16** cooperate to provide a mold (not shown) into one end of which molten metal is poured to solidify and form, and out of the other end of which emits the cast bar **13** in substantially that condition in which it solidified.

The rolling mill **11** includes a plurality of roll stands **18 through 29** which are arranged in alternate horizontal and vertical dispositions to hot-form the cast metal by a series of successive deformations. The continuous casting machine **10** and the rolling mill **11** are positioned relative to each other so that the cast bar **13** enters the rolling mill **11** substantially immediately after solidification so as to be in substantially that condition in which it solidified and at a hot-forming temperature within the acceptable range of temperatures for hot-forming the cast bar **13**. No heating of the cast bar **13** is required between the casting machine **10** and the rolling mill **11**, but in the event that it is desired to closely control the hot-forming temperature of the cast bar **13**, means for adjusting the temperature of the cast bar (not shown) may be placed between the casting machine **10** and the rolling mill **11**.

It will be understood that with the apparatus of FIG. 1, the cast bar **13** may be any one of a plurality of lengths determined only by the amount of molten metal available and will extend in the form of a cast bar between the continuous casting machine **10** and the rolling mill **11**. It should be thus apparent that the steps of solidifying molten metal to obtain cast metal and of hot-forming the cast metal, as well as the step of pickling (ie. copper or steel) the hot-formed cast metal in the pickling apparatus **12**, are generally being performed simultaneously once the apparatus of FIG. 1 is in operation.

In the production of rod, the cast metal bar **13** enters the rolling mill **11** through preliminary or roughing stands **18** and **19** and proceeds down its path through a series of finishing stands **20** through **29**, out exit point **30** and, if desired, as sometimes is in the case of copper or steel, into the pickling apparatus **12** downstream from the rolling mill **11**. As will become hereinafter apparent, the power requirements for hot-forming, and hence the desired temperature levels, are at a maximum in the roughing stands **18** and **19** and thereafter progressively decrease through the finishing stands **20–29**.

During the hot-forming of the rod **14** there is employed a water-soluble oil solution for cooling and lubricating purposes. This oil solution is of suitable concentration according to the type rolling mill and the type metal being rolled into rod. In accordance with one aspect of this invention, there is illustrated in FIG. 2 a novel multiple pressure arrangement for delivering a cooling and lubricating oil solution to one stand of multiple stand rolling mill **11** of FIG. 1. The stand includes a frame **31** upon which are suitably mounted hot-forming rolls **32** driven by conventional means (not shown) which will be apparent to those skilled in the art. The rod **14** is adapted to be passed between the rolls **32** which deform the cast metal in the case of roll stand **18**, and thereafter change the cross-sectional shape of the rod **14**. The rod **14** is guided to and from the rolls **32** by entrance and exit rod-guide housings **33** and **34**, respectively. The rod-guide housings **33** and **34** are suitably secured to the frame **31** by means of brackets **35** and **36**, respectively.

As seen most clearly in FIG. 3, the guide housing **33** includes an outlet end **37** in which are suitably journalled upper and lower idler roller guides **38** which support the rod **14** through the housing **33**. The housing **33** also includes an inlet end **39** in which are also suitably journalled idler roller guides **40** which provide a similar function as the roller guides **38**. As can be seen in FIG. 4, the roller guides **40** may be so arranged as to provide a partial seal around the rod **14** at the inlet end **39** of the guide housing **33**. Similar roller guides and seals (not shown) may be provided with the exit rod-guide housing **34**. It should be understood, however, that the specific structure shown in FIGS. **3** and **4** is for illustrative purposes only and is not intented to limit the general concept of the invention. In fact, any method of rod guiding, supporting, and sealing may be utilized within the scope of the appended claims.

Low pressure fluid coolant C, such as soluble oil, is directed through piping **41** from a source (not shown) into the rod-guide housing 33 at a point near the rod inlet end **39**. The rod-guide housing **33** fills or floods in the same manner as a sink with a drain too small to remove the fluid as fast as it enters. The fluid coolant C therefore surrounds the rod **14** as shown in FIG. **3** to cool both housing **33** and the rod **14**. Exiting fluid may be directed out of the rod outlet end **37** of the housing **33** towards the rolls **32** to reduce the friction between the rod and the rolls and also to lubricate and cool the rolls. The partial seal arrangement effected by the idler guide rollers **40** at the inlet end **39** of the housing **33** assures that the major portion of the overflowing coolant C will be directed out of the outlet end **37** towards the forming rolls **32**. Both the guide housing **33** and the forming rolls **32** are protected by the cooling and lubricating action of the fluid coolant C. The reduced friction between the rod and the rolls, meaning less friction than in prior art rolling mills, yields a rod having better rod surface quality than prior art rod.

Low pressure fluid coolant is also directed through piping **42** to the rod-guide exit housing **34** and delivered near the point where the rod **14** exits therefrom. It should be apparent, therefore, that the coolant C will be directed through the housing **34** in counterflow relationship to the movement of the rod **14** therethrough. The coolant C floods the exit housing **34** and then spills out to flood the rolls **32** in a manner similar to the flooding of the entrance housing **33**.

The rod stand illustrated in FIG. **2** also includes spray blocks **43** suitably secured to the frame **31**. Each of the spray blocks **43** has two adjustable spray nozzles **44** and **45**. Fluid coolant from a source (not shown) is conducted through piping **46** to the spray blocks **43** where it is emitted by the spray nozzles **44** and **45**. Low pressure sprays (albeit of higher pressure than found in pipes **41**, **42** and in guides **33**, **34**) emitted by the spray nozzles **44** are directed against the rolls **32** for the purpose of cooling and lubricating the rolls **32** as well as for removing surface scale, picked up by the rolls from the rod **14** during working, which scale tends to be deposited upon and to build up upon the surface of the rolls **32**. This deposit is detrimental to the surface quality of the subsequent rod produced as well as being detrimental to the useful service of the rolls **32**.

High pressure sprays emitted from the nozzles **45** are directed against the junction of the rolls **32** and the rod **14** for the purpose of removing surface scale from the rod **14** as well as in assisting in the cooling of the rod **14**. The nozzles **44** and **45** may be made adjustable as to angle of spray and flow rate in accordance with known, prior art nozzle technology, so as to provide flexibility in both spray pattern and volume for both the roll **44** and rod **45** sprays.

Additionally, further spray blocks similar to blocks **43** may be mounted on frame **31** in the vicinity of points **88**. These additional spray blocks would possess spray nozzles similar to rod spray nozzle **45** and roll spray nozzle **44** for spraying fluid on rod **14** and rolls **32** respectively. Thus, these additional spray blocks would augment the beneficial rod surface and friction effects provided by the exiting fluid directed out of rod outlet end **37**, and it should be noted that in addition to reduced friction and better rod surface quality, the combined effect of all of these fluid flows is to provide a measure of rod oxidation control within the rolling mill by preventing exposure of the rod surface to the atmosphere within the mill. This is especially so within the flooded interiors of guides **33**, **34** where virtually no contact between the atmosphere and the rod is possible.

One beneficial effect of out thus described invention has been found in the production of the ordinary, industry-wide, standard aluminum EC rod. It has been found that when aluminum EC rod produced in accordance with out invention is subsequently drawn into wire by use of standard, prior art drawing techniques, the wire will have both higher tensile strength and higher electrical conductivity than the same wire would have when drawn from rod produced by rolling equipment possessing prior art cooling and lubricating systems. For instance, the normal increase in tensile strength which occurs when prior art EC rod is drawn into wire is between 7,000 and 12,000 lbs./in.^{2} But using our invention, the wire generally experiences an increase in tensile strength of between 8,500 and 18,000 lbs./in.^{2}, yet it still remains flexible enough not to be classified as brittle. Also, wire drawn from rod which has been produced in accordance with our invention has a higher average tensile strength than does prior art wire. Our wire also exhibits a greater range of tensile strengths in computing one and two standard deviations from the average tensile strength than does prior art wire. As for the conductivity, the average conductivity in prior art wire drawn from EC rod containing 0.24% Fe is 61.0% IACS (International Annealed Copper Standard), but using our invention, the average conductivity of the wire has been found to be 61.9% IACS. This is significant when you compare it to pure aluminum which is only ±64.0% IACS.

It should be thus apparent that the multiple pressure cooling and lubricating system illustrated in FIGS. **2–4** provides low pressure fluid for cooling the rod **14** and lubricating the rolls **32** by the flooding of and subsequent spill-over from the guide housings **33**, **34** while simultaneously providing multiple, relatively high pressure fluid sprays for spraying the rolls **32** and rod **14** to achieve descaling and additional cooling, all of said sprays helping to reduce rod oxidation. While the above-described multiple pressure system is specifically disclosed herein as being applied to only one of the roll stands of the multiple stand mill **11** illustrated in FIG. **1**, it should be readily apparent that the system in actual practice may be applied to any number or all of the stands in accordance with the particular cooling and lubricating requirements dictated by the metal being formed and the specific design of the rolling equipment.

Referring now to FIG. **5**, there is illustrated apparatus for direct and controlled cooling of the rod **14** which facilitates the production of rod with the lowest possible finishing temperature, while at the same time substantially eliminating variation in the finishing temperature so as to obtain rod with consistent metallurgical properties along its length. Although FIG. 5 illustrates the direct and controlled cooling apparatus applied only to the last two finishing roll stands **28** and **29**, it is to be understood that the system could apply to all the roll stands or only to all the finishing roll stands **20–29** inclusive. The primary roughing stands, in the latter case, could be provided with the multiple pressure cooling and lubricating system shown in FIG. **2**, for instance.

As discussed above, the rod **14** is rolled in the mill **11** at the maximum possible temperatures in order to reduce the mechanical power requirements of the mill. On the other hand, in the case of copper or steel rod which is treated in the pickling apparatus **12** subsequent to hot-forming in the mill **11**, it is especially desirable to finish the rolling operation at the lowest possible temperature so that not only is rod oxidation reduced but the pickling apparatus **12** may be designed for a lower capacity than would be needed to accomodate higher temperature rod while simultaneously being more efficient and capable of operating at essentially higher production rates. In accordance with this invention, these divergent temperature criteria are accomodated by rolling the rod **14** in the primary roughing stands **18** and **19** at the maximum possible temperatures and thereafter, as the power requirements progressively decrease, rolling the rod **14** at progressively lower temperatures through the finishing stands **20–29** so that the rod **14** exits from the mill **11** at the lowest desired temperature which from a metallurgical point of view for copper, for example, may be between 700° and 800° F. This is accomplished by progressively increasing the volume of cooling fluid applied directly to the rod **14** at each roll stand as the rod **14** moves through the mill **11**. The volume of cooling fluid is at a minimum at stand **18** and increases progressively to a maximum at stand **29**.

The direct and controlled cooling of the rod **14** may be achieved by providing each of the finishing roll stands **20–29** with primary and secondary nozzle blocks **48** and **47**, respectively. The secondary nozzle blocks **47** include wide-angled spray nozzles **49** which direct a wide-angled spray of coolant fluid against the hot-forming rolls **32**. The primary nozzle blocks **48** also include wide-angled spray nozzles **50** which direct a wide-angled spray of coolant fluid against the hot-forming rolls **32**. In addition, however, the primary nozzle blocks **48** also include wide-angled spray nozzles **51** which direct a high pressure wide-angled spray of coolant fluid directly on the rod **14**. The pressure of the fluid coolant conducted to the nozzle blocks **48** through piping **52** may be monitored by pressure sensing means such as pressure gauges **53**. Flow control means such as valves **54** in the piping **52** may be adjusted to control the volume of coolant delivered to each of the nozzle blocks **48**. Nozzles **49, 50, 51** are adjustable as to the width of the spray angles.

It should be apparent, therefore, that the wide-angled sprays emitted from the nozzles **49, 50** and **51**, as well as the direct cooling of the rod **14** by the spray from the nozzles **51**, coupled with direct control of the coolant pressure at each roll stand, results in more effective cooling which lends itself to a greater degree of control and thus permits the selective temperature vairation through the mill **11** as discussed above.

In order to achieve a uniform finishing temperature for the rod **14**, the apparatus illustrated in FIG. **5** includes a temperature sensing means such as photopyrometer **55** which permits a constant monitoring of the temperature of the rod **14** as it exits from the mill **11**. Temperature sensing means **55** is electrically connected, as shown schematically by the dotted lines **56** in FIG. **5**, to a valve actuating means such as electromagnetic solenoid actuators **57** which, when commanded to do so by controllers **90**, operate the flow control means **54** and thus control the flow of coolant into the nozzle blocks **48**. As the photopyrometer **55** monitors the temperature of the hotformed rod **14** and this is relayed through the controllers **90** to the electromagnetic solenoid actuators **57**, the flow of coolant is adjusted during the rolling operation and according to the need and as required by the temperature of the rod **14** to maintain the rod temperature at a constant level. Coolant piping to each of the roll stands **18** through **29** is threttled by separate valves with separate electromagnetic solenoid actuators **57**, each actuator **57** being connected through separate controllers **90** with the photopyrometer **55**. The temperature of the rod **14** at the exit from the mill **11** thus controls the coolant flow in each individual stand through this arrangement. The coolant flow, therefore, is no longer fixed, as in the prior art, but is now variable and thus both more efficient and more effective. In the case of copper rod, for instance, this controlled, more effective cooling produces copper rod having a lower, more consistent annealing temperature--a highly desirable result. One theory explaining this phenomenon is that the impurities which are in solution within the copper are given a uniform, relatively long cooling period during which they precipitate into the copper grain boundaries where they are much less detrimental to annealing than prior art impurities which are trapped in solution by a relatively quick quenching process such as being immediately plunged from a temperature as high as 1,100° F into a cooling and/or pickling system. Rod produced in accordance with our invention also has higher tensile strength and lower elongation characteristics than prior art rod.

In view of the foregoing, it should be readily apparent that there is provided in accordance with this invention a novel fluid cooling and lubricating system for a rolling mill that permits the rolling down of rod from cast metal at maximum possible temperature while achieving the lowest possible finishing temperature, and simultaneously controlling the cooling to obtain a uniform finishing temperature thereby inproving the effects of a pickling operation, if required, as well as resulting in wire drawn from the rod having higher tensile strength and lower elongation characteristics.

Although only preferred embodiments of the invention have been specifically illustrated and described herein, it is to be understood that minor variations may be made without departing from the spirit of the invention.

We claim:

1. A method of producing aluminum rod while employing rod oxidation control techniques which rod, when drawn into wire using prior art drawing techniques, will possess higher tensile strength and higher electrical conductivity than aluminum rod not produced in accordance with the method, said method comprising the steps of:

passing aluminum rod through a continuous rolling mill having a plurality of roll stands each of which includes an entrance guide means and an exit guide means,

sealingly enclosing said aluminum rod in said entrance guide means and

sealingly engaging said aluminum rod therein to form said sealing enclosure and to support said rod as it enters a roll stand,

flooding said sealingly enclosed entrance guide means with a cooling and lubricating liquid,

rolling said rod down into smaller rod while simultaneously providing a cooling and lubricating liquid to the area in which rolling is occurring, wherein at least a portion of the liquid provided to the area in which rolling is occurring is obtained by overflowing the liquid from the entrance guide means while supplying the liquid to the entrance guide means at a rate greater than the rate of overflowing,

spraying a high pressure stream of cooling and lubricating liquid directly onto said rod immediately after rolling,

enclosing said aluminum rod in said exit guide means, and

flooding said exit guide means with cooling and lubricating liquid.

2. A method as defined in claim **1**, wherein the aluminum rod is produced from a bar cast from molten aluminum, and further including the step of drawing the aluminum rod into wire, said drawing resulting in a wire having higher tensile strength and higher electrical conductivity than prior art wire.

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