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(54) Improvements in and relating to control systems for rolling mills.

(57) A dynamic control system for a mill for producing metal stock within desired dimensional tolerances in at least two roll passes, comprises means for measuring the rolling load applied to the stock by the ultimate stand of the mill and means for controlling the effective modulus of the ultimate stand to produce in the ultimate stand a loaded roll gap marginally less than the nominal for lower than nominal roll loads and marginally greater than nominal for higher than nominal rolling loads

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IMPROVEMENTS IN AND RELATING TO CONTROL SYSTEMS FOR ROLLING MILLS

This invention relates to control systems for controlling the roll gap of mills for rolling relatively thick metal stock such as billets, bars, rods or the like. More especially, but not exclusively, the invention concerns such control systems for improving the dimensional tolerances achievable for these products in conventional rolling mills. The invention has especial application to the rolling of steel bars.

In many cases the required dimensional tolerances of steel bars cannot be achieved by conventional rolling techniques without excessive yield losses. Additionally in continuous mills with frequent programme changes it is conventional to roll test billets, this having an adverse effect on the overall economic efficiency of the rolling process.

Excessive yield losses experienced when rolling to tight tolerances on conventional bar mills together with the practice of rolling test billets after every size change has led to the need to develop new methods of reducing dimensional errors which arise during rolling. In the case of rolling round bars, the desired tolerances are expressed both by variation of nominal diameter and by ovality, that is to say by reference to any difference existing between maximum and minimum diameters of a round section. Maximum and minimum diameters normally occur along the vertical and horizontal axes of the bar if the round pass groove is not worn.

Factors which affect the dimensions of a bar can be grouped into two areas, these being in-bar variations caused by, for example, thermal rundowns and skid chills (these normally occurring along the length of a bar and conventionally referred to as "cold spots"), and variations in the properties of individual bars caused by, for example, changes in furnace drop-out temperature or steel quality (these variations being conventionally referred to as "bar-to-bar variations").

In normal production, it is usual to observe that once a mill has been correctly set for a particular bar size and quality, the occurance of variations in gauge is mainly due to in-bar variations, the major influencing parameter being temperature.

Two methods of dimensional control are conventionally employed, these being mill set up control and dynamic control. Each of these fulfills a particular requirement and for the optimum product both schemes are necessary.

Mill set up control is used to set the roll gap and roll speed of the several stands of a mill such that a bar exiting a given stand, assuming no in-bar variation, will be at the required size. Various levels of sophistication can be included in a mill set up control ranging from the use of look-up tables and computers through to more complex schemes in which the optimum set up is estimated from, for example, a knowledge of historical data and measurements made upstream and downstream of the stand about to be set.

Dynamic control provides the only means by which in-bar variations can be dealt with effectively. Dynamic schemes require adjustments to roll gap in response to sensed in-bar variations and the response times required by the adjustment mechanisms employed suggest that, at least for relatively high speed mills, hydraulic actuators are necessary as opposed to electric screw downs.

Examples of conventional control systems for rolling mills are disclosed in US-PS-3468145 and US-PS-3650135.

In operation of a rolling mill a bar is passed through a succession of rolls stands, these stands operating to deform the bar to achieve sequential reductions in height and width. During these passes, bar material spreads tranversely of the pass line to produce, together with an elongation, an increase in width and a reduction in height.

Hitherto, both mill set up and dynamic control systems have operated to produce bar having the required dimension in one direction (normally the "height" of the bar) and a dimension above or below that required in a direction normal to the first direction (normally the "width" of the bar). The present invention sets out to provide a control system for rolling mills by which a significant improvement in overall dimensional tolerance of the rolled product can be achieved.

It is generally accepted that the "height" dimension is taken in the direction in which the load is applied by the mill to the stock being rolled. Thus, in practice, a "height" may lie in either a horizontal or vertical plane, or indeed in a plane inclined to the vertical.

According to the present invention in one aspect, there is provided a dynamic control system for a mill for producing metal stock within desired dimensional tolerances in at least two roll passes, the control system comprising means for measuring the rolling load applied to the stock by the ultimate stand of the mill and means for controlling the effective modulus of the ultimate stand to produce in the ultimate stand a loaded roll gap marginally less than the nominal for lower than nominal roll loads and marginally greater than nominal for higher than nominal rolling loads.

Means may also be provided for measuring and controlling the rolling load applied to the stock by the penultimate stand to eliminate or minimise variations in the width (or height) of the stock as it leaves the penultimate stand; thus the effective modulus of the penultimate stand is increased to a value significantly in excess of that normally to be employed in the penultimate stand of the conventional rolling mill.

According to the present invention in another aspect, there is provided a dynamic control system for a mill for producing metal stock within desired dimensional tolerances in at least two passes, the control system comprising means for measuring the rolling load of the penultimate stand of the mill and for controlling the effective modulus of the stand to impose a load on the stock greater than that required to produce a nominal bar or a bar with no height deviation thereby to compensate dynamically the roll gap of the penultimate stand such that the height and width dimensions of the stock emerging from the ultimate stand are within the required dimensional tolerances.

Means may be provided to control the effective modulus of the ultimate stand to eliminate or minimise variations in the height (or width) of the stock emerging from the ultimate stand.

The invention will now be described, by way of example, with reference to the following examples of control systems in accordance with the invention.

EXAMPLE I

This control system for controlling the dimensions of material rolled in bar (and billet) mills included the use of a dynamic control of the roll gaps of two successive stands of the mill, the dynamic control being responsive to measured and inferred changes in bar size and hardness (effective yield strength). By this system, it is possible to achieve significant improvements in the dimensional tolerance of hot rolled bars.

By measuring the rolling load of the ultimate rolling stand it is possible using a gaugemeter (for example, that described in US-PS-3650135) to modify the effective modulus of this stand. It has been found that by varying this effective modulus with regard to the material being rolled such that the effective modulus is less than that naturally occurring, improvements in the dimensions of the material being rolled will be experienced when that stand is subjected to variations in bar hardness or cross-sectional area. The effect of the dynamic control is such that the final height tolerance of the stock is worse than that to be found using an uncontrolled mill but the final width tolerance deviation of the stock is improved. The net effect of the control system is to approximately halve the overall tolerance of the stock but greatly to reduce ovality of the stock.

Additionally, gap control on the penultimate stand of the mill can be employed to eliminate any variation in the width of the stock passing to the ultimate stand. This is achieved by using a measurement of the rolling load and an appropriate Gaugemeter equation (as, for example, specified in US-PS-3650135) greatly to increase the effective modulus of the penultimate stand. The resulting improvements include an improvement in tolerance particularly with respect to the final width of the product.

Typically, screwdown (or capsule) movements to compensate for a typical disturbance on a nominal 24mm finished diameter product of a given quality are, for the penultimate stand, approximately 75 m and for the ultimate stand, approximately 210 m.

EXAMPLE II

By measuring the rolling load on the penultimate stand it is possible, knowing the modulus characteristics of the ultimate stand and the physical properties of the material being rolled, dynamically to compensate the roll gap at the penultimate stand such that the final height and width of the stock after the ultimate stand are significantly improved. This compensation is such that for a material disturbance which increased the rolling load at the penultimate stand the roll gap will be closed to such an extent that the bar dimension in the plane of the rolls is reduced below nominal. The amount of indentation is calculated to be such that after the rolling in the final stand, the material will spread out to the nominal desired width with any height variation being dictated by the natural modulus at the last stand.

The net effect of this system is greatly to improve the height, width and ovality tolerance of the finished bar.

Additionally, control on the last stand may be employed to eliminate any variations in final height. This is achieved by using a measurement of the rolling load of the last stand and an appropriate Gaugemeter equation greatly to increase the effective modulus of the stand. The resulting improvements include additional tolerance improvements due to the positive control and therefore knowledge of final height.

Typically, screwdown (or capsule) movements to compensate for a typical disturbance on a nominal 24mm finished diameter product of a given quality are, for the penultimate stand, approximately 830 m and for the ultimate stand, approximately 40 m.

The control systems discussed above may be assisted by measurement of the actual bar size (by using a bar gauge as, for example, disclosed in United Kingdom Patent 2021260) to provide a dimensional feedback signal in addition to the existing control system. This feedback is used to correct for any initial mill set-up errors, errors in the controller tuning parameters that are material or temperature related and any long term drift within the system such as would be expected due, for example, to roll wear and thermal expansion.

A measurement of the actual bar size (using, for example, a gauge such as that disclosed in United Kingdom Patent 2021260) may be employed as a dimensional feed forward signal. This feed forward signal can be used to modify the roll gap(s) of the controlled stand(s) to compensate for any variations in feedstock dimensions. The improvements resulting from such use include tolerance improvements due to the anticipatory nature of this type of control. Additionally, this method of control is expected further to improve the tolerance at the head end of the bar with reduced yield losses.

Additionally, or alternatively, measurements of the actual bar size may be used as dimensional feed back and dimensional feed forward. Indeed, both feed back and feed forward systems may operate alongside the control systems described in Examples I and II above.

It is to be understood that the foregoing Examples are merely examplary of control systems in accordance with the invention and that modifications can readily be made to the Examples described without departing from the true scope of the invention.

Claims

1. A dynamic control system for a mill for producing metal stock within desired dimensional tolerances in at least two roll passes, the control system comprising means for measuring the rolling load applied to the stock by the ultimate stand of the mill and means for controlling the effective modulus of the ultimate stand to produce in the ultimate stand a loaded roll gap marginally less than the nominal for lower than nominal roll loads and marginally greater than nominal for higher than nominal rolling loads.

2. A control system for a mill as claimed in claim 1 characterised in that means is provided for measuring and controlling the rolling load applied to the stock by the penultimate stand of the mill to eliminate or minimise variations in the width (or height) of the stock as it leaves the penultimate stand.

3. A dynamic control system for a mill for producing metal stock within desired dimensional tolerances in at least two passes, the control system comprising means for measuring the rolling load of the penultimate stand of the mill and for controlling the effective modulus of the stand to impose a load on the stock greater than that required to produce a nominal bar or a bar with no height deviation thereby to compensate dynamically the roll gap of the penultimate stand such that the height and width dimensions of the stock emerging from the ultimate stand are within the required dimensional tolerances.

4. A control system for a mill as claimed in claim 3 characterised in that means is provided to control the effective modulus of the ultimate stand of the mill to eliminate or minimise variations in the height (or width) of the stock emerging from the ultimate stand.