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Vydrin et al.

[11] **3,709,017**

[45] **Jan. 9, 1973**

[54] **METHOD OF ROLLING METAL SHEET ARTICLES BETWEEN THE DRIVEN ROLLS OF THE ROLL MILL**

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[52] **U.S. Cl.** **72/205,** 72/366, 72/199

[51] **Int. Cl.**.....**B21b 39/08,** B21b 1/00

[58] **Field of Search**.....72/205, 232, 199

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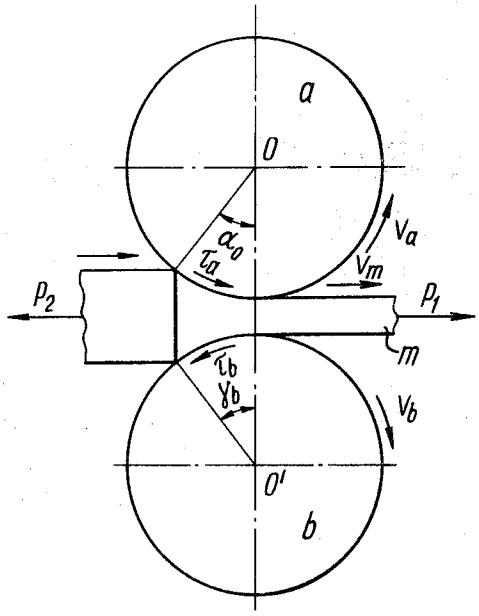
Primary Examiner—Milton S. Mehr

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[57] **ABSTRACT**

The present invention relates to a method of rolling metal sheet articles between driven rolls of rolling mills, the driven rolls being rotated in opposite directions at different peripheral speeds. A stretching strain is applied to the delivery section of the article, and the process is effected with the ratio between the peripheral speeds of the rolls being not less than the reduction of the article being rolled, and with the rate of travel of the delivery end of the article being equal to the peripheral speed of the driving roll that is rotated at a greater speed. The invention also discloses mills for effecting the present method, which are provided with means for insuring the required ratios between the peripheral speeds of the rolls.

2 Claims, 10 Drawing Figures



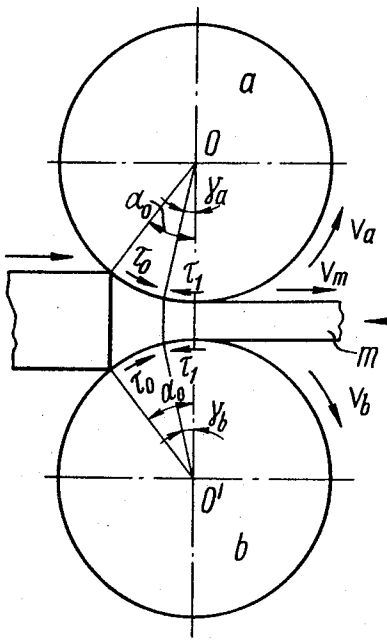


FIG. 1
PRIOR ART

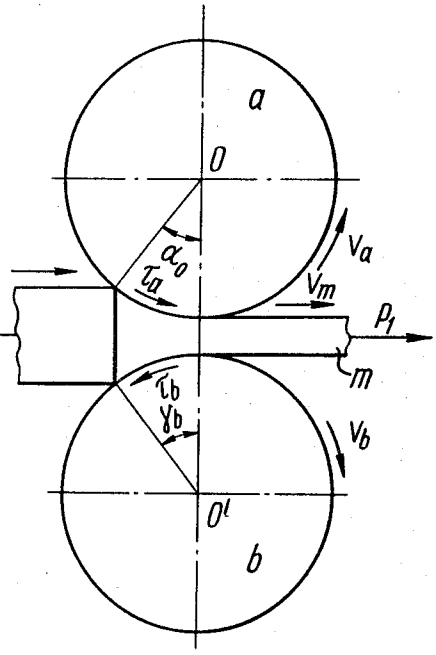


FIG. 2

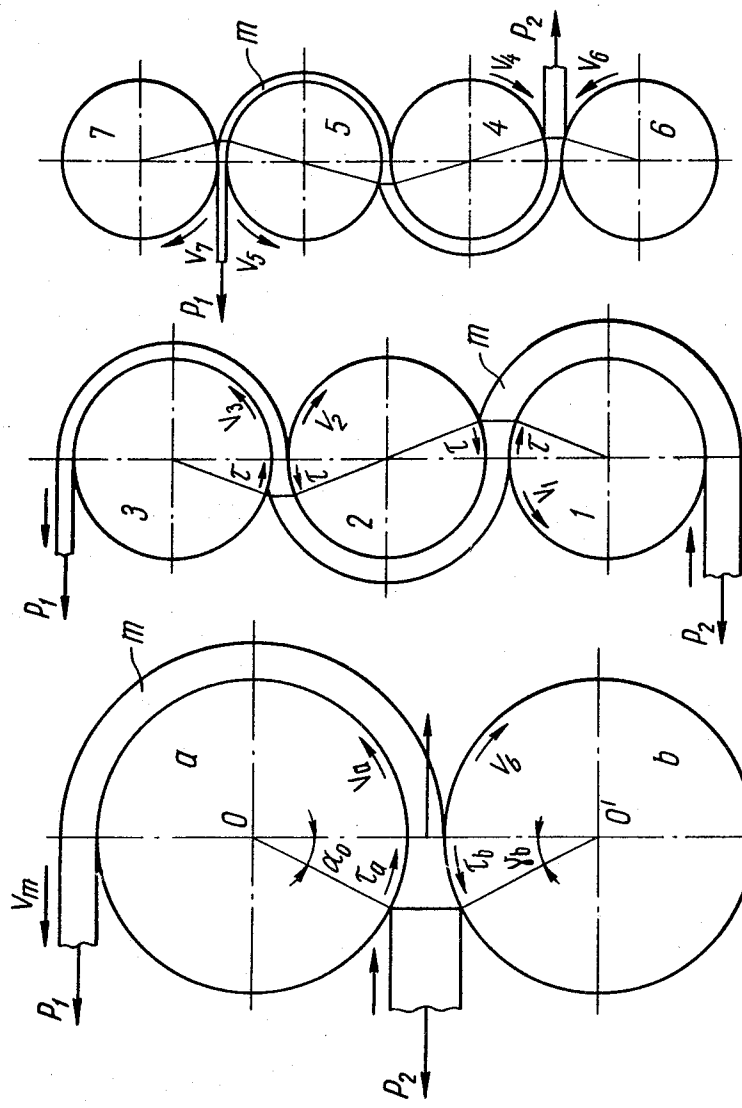


FIG. 5

FIG. 4

FIG. 3

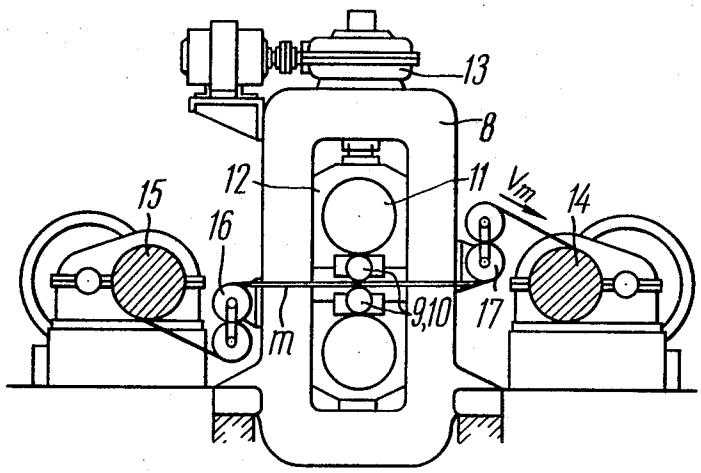


FIG. 6

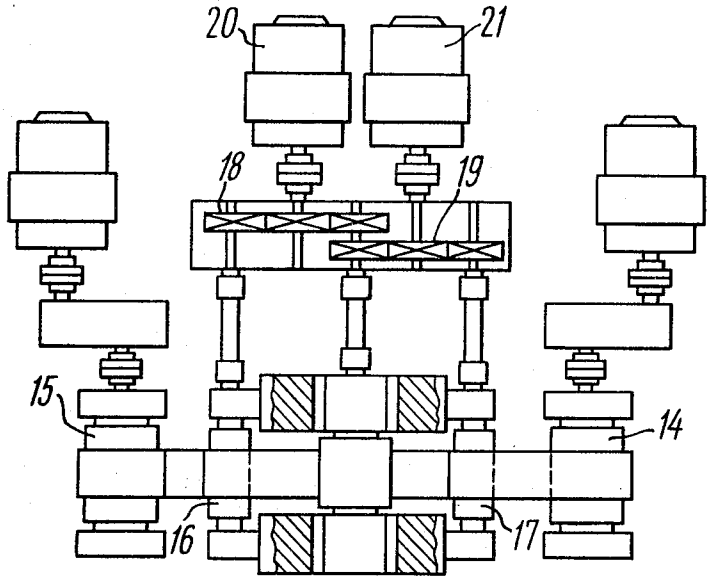


FIG. 7

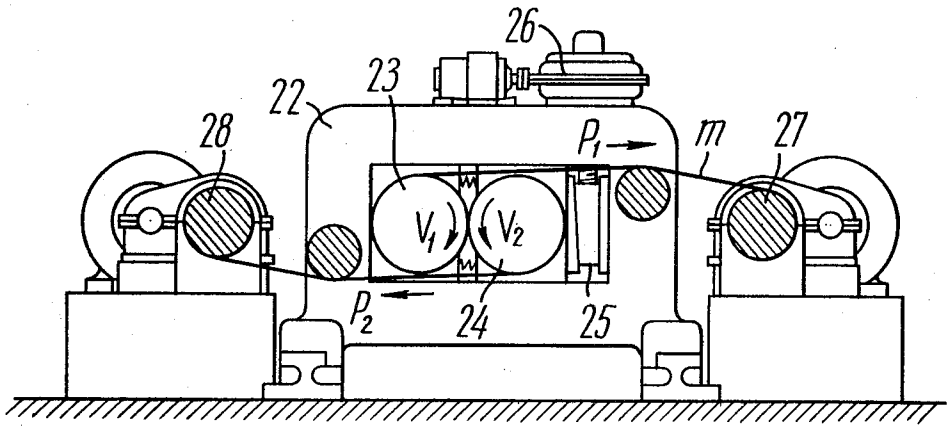

26
23
22
28
P_1
m
27
V_1
V_2
P_2
24
25

FIG. 8

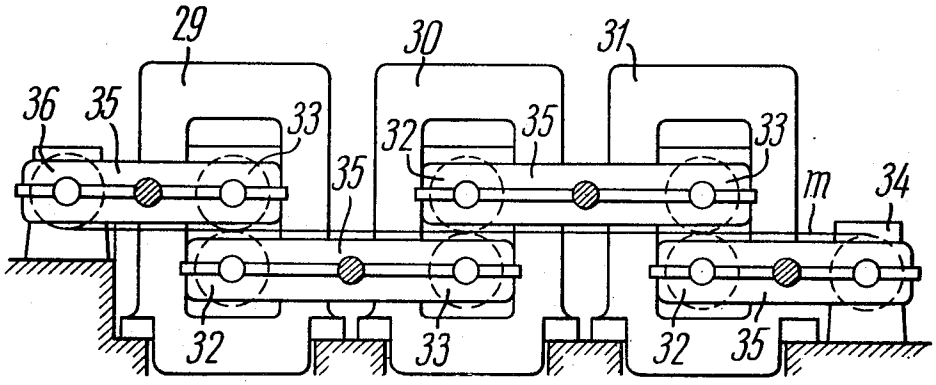

29
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31
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32
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m
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32
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32
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FIG. 9

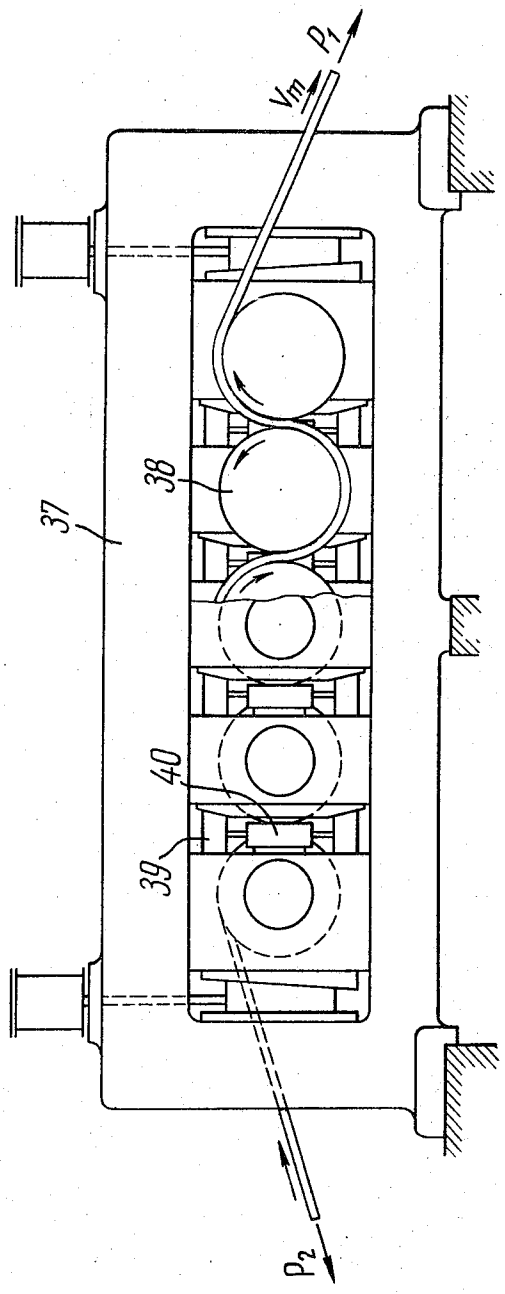


FIG. 10

METHOD OF ROLLING METAL SHEET ARTICLES BETWEEN THE DRIVEN ROLLS OF THE ROLL MILL

The present invention relates to a method of rolling metal sheet articles, particularly strips, bands, sheets, foil, preferably in the cold state, and to mills for effecting such method.

The term rolling as employed herein and below is to be understood as comprising also temper rolling and straightening of sheet articles.

Commonly known in the art are methods of rolling sheet articles, according to which the latter are reduced in rolls that are rotated in opposite directions with the same or different peripheral speeds with a stretching strain being applied to the front and back ends of the article or only to the front end thereof. In the process of rolling in accordance with such methods on the surfaces of each roll that contact the article being rolled there originate two zones of slippage — a zone of slippage on the entry side and a zone of slippage on the delivery side, the forces of friction within these zones being directed towards each other. The forces of friction are quite considerable and hinder the deformation of metal in the direction of rolling (drawing) the article, great efforts being thus required for deforming the metal.

This fact is especially manifested in cold rolling of sheet articles made of steels and alloys that are difficult to deform, the specific pressures exerted by the rolled metal onto the rolls reaching 200 kg/mm^2 and over.

Attempts were made to improve the known methods of rolling sheet articles. Thus, a method was proposed, according to which plastic deformation of metal was attained due to the action of normal, stretching and bending strains imposed on the article, In particular, such a method is described in "Journal of Metals," August 1967, in the article entitled "Status C.BdS.Rolling."

The known method of rolling was effected on mills of different designs: those with two driven rolls and with one floating roll disposed between the driven rolls; with three driven and two floating rolls, each of the two floating rolls being disposed between two adjacent driven rolls; with two driven work rolls, two idle support rolls and with one floating roll disposed between the work rolls. The diameter of the floating rolls was much smaller than that of the driven rolls. The ratio between the peripheral speeds of the driven rolls was equal to the drawing of the article which consecutively encompassed the driven and floating rolls. Due to the employment of floating rolls of a small diameter and to the plastic bending of the article around the rolls it was possible to reduce the pressure exerted onto the rolls and to increase the reduction of the article during one pass. This method could be employed for temper rolling and straightening of articles.

However, with the application of the known method the speed of rolling proved to be limited, since the number of revolutions of the floating roll is very great causing it to become rapidly heated. Moreover, it is difficult to make a small-diameter floating roll adequately rigid, this fact involving additional non-uniformity of the thickness of the article because of clearances originating when the floating roll is self-adjusted with respect to the driven rolls.

It is an object of the present invention to improve the method of rolling metal sheet articles between the driven rolls of the mill by selecting optimal ratios between the peripheral speeds of the driving and driven rolls in each adjacent pair, and also to provide improved rolling mills for effecting the proposed method.

Proposed in the present invention is a method of rolling metal sheet articles between the driven rolls of the mill, according to which the rolls of the adjacent pair are rotated in opposite directions with different peripheral speeds and stretching strains being applied to the delivery section of the article. According to the invention, the rolling is effected with a ratio between the peripheral speeds of the rolls, which is not less than the reduction of the article, and with the speed of motion of the delivery end of the article equal to the peripheral speed of the driving roll, that is, of the roll which rotates with a speed greater than that of the driven roll.

In this case the influence of the forces of friction in the zone of deformation on the process of deformation is excluded, since the forces of friction on the opposite contact surfaces of both rolls are equal and oppositely directed. The speed of metal of the article being rolled in the place of contact with the driving roll will be smaller than the peripheral speed of the driving roll, while the speed of metal of the article being rolled will exceed that of the driven roll. Thereby the pressure exerted by the metal onto the rolls is considerably diminished.

It is desirable, that the stretching strains be created simultaneously at the leading and trailing ends of the article, since reductions originating therein contribute to still greater reduction of the pressure of metal onto the rolls.

It is expedient, that the stretching strain at the delivery section of the article should be created by virtue of the article encompassing the driving roll that is rotated with a greater speed. In this case due to stretching on the arc of the encompassing the roll by the article there originate forces of friction of rest, which fact is conducive to the reduction of the stretching strain required and to stabilization of the process.

The most optimal version of the embodiment of the present method is accomplished in the case when the stretching strains on the entry and delivery sections of the article are created by the article successively encompassing the driven and driving rolls, and the ratio between the peripheral speeds thereof is maintained to be equal to the reduction of the article between said rolls. The pressure of metal will be reduced still further, and the process will be much more stable.

The friction between the driving roll and the rolled article in the deformation zone should be made to exceed that between the driven roll and the article. Then the required stretching strain at the delivery section will be smaller.

In case when the rolling is effected through a plurality of alternating driving and driven rolls, the article can encompass only the middle rolls, the extreme rolls remaining free. Then it becomes possible to employ the support rolls for diminishing the deflection of the extreme rolls.

The present method can be carried out on rolling mills of different designs.

For carrying out the method of rolling the article with tensioning the front end thereof, a mill is proposed that comprises rolls rotated with different peripheral speeds in opposite directions and at least one group of rolls for tensioning the front end of the article in the course of rolling. According to the invention, in the mill the driving roll is kinematically associated with the group of tension rolls so that said rolls rotate with the same peripheral speed as the driving roll.

For effecting the method of rolling with a simultaneous tensioning of the front and back ends of the article, said mill is provided with an additional group of rolls for tensioning the back end of the article during rolling, which group is kinematically associated with the driven roll so that their peripheral speeds be equal.

The carrying out of the method of rolling the article with tensioning its front and back ends by the article encompassing the driven and the driving rolls may be effected on a mill that comprises driven rolls rotated with different peripheral speeds in opposite directions and reels for tensioning the ends of the article during rolling. In accordance with the invention the reel that creates tension at the leading end of the article is arranged from the side of the driven roll, and the reel that creates tension of the trailing end of the article is arranged from the side of the driving roll.

When rolling the article with tensioning of only the leading end thereof a mill can also be employed that has a plurality of consecutively arranged stands with driven rolls rotated with different peripheral speeds in opposite directions and a means for tensioning the front end of the article during rolling. In this mill, according to the invention, the driving roll of each preceding stand is kinematically associated with the driven roll of the subsequent stand.

The method of rolling the article with tensioning the front and back ends thereof by way of consecutive encompassing of the rolling rolls is effected by means of a mill that comprises driven rolls rotated at different peripheral speeds and in opposite directions, means for tensioning the article from both ends during rolling, and presser means for adjusting the distance between the axes of rotation of the rolls. According to the invention, the presser means are disposed at both sides of each roll.

The mills proposed herein are relatively simple in design. They can be produced by modification of conventional mills adapted for rolling sheet articles.

The invention will now be explained by the description of exemplary embodiments thereof with reference to the accompanying drawings.

In the drawings:

FIG. 1 shows a diagrammatic view of a conventional method of rolling sheet articles in driven rolls;

FIG. 2 is a diagrammatic view of a method of the present invention for rolling sheet articles in driven rolls;

FIG. 3 is a diagrammatic view of a proposed method wherein the front tension is created by the article encompassing the driving roll;

FIG. 4 is a diagrammatic view of a proposed method wherein the front and back tension of the article is created by the article encompassing the driven and the driving rolls of the entire row;

FIG. 5 is a diagrammatic view of a proposed method wherein the article encompasses only the middle driven and driving rolls of the row;

FIG. 6 shows a mill for effecting the method of rolling with the article tensioned from both ends by means of rolls kinematically associated with the mill rolls;

FIG. 7 shows a top cut-away view of the mill according to FIG. 6, which illustrates the kinematic connection of tension rolls with the driven rolls of the mill;

FIG. 8 shows a mill with two reels for tensioning from both ends the article that encompasses both rolls;

FIG. 9 shows a mill made as a plurality of consecutively arranged stands, wherein the driving roll of the preceding stand is kinematically associated with the driven roll of the subsequent stand; and

FIG. 10 shows a mill with a plurality of driven rolls that are encompassed by the article in the course of rolling and with presser means for adjusting the distance between the axes of the rolls.

For a better understanding of the essence of the present invention we shall first analyze the known method of symmetric rolling without tensioning of the article involved.

When implementing the conventional method, the peripheral speeds V_a and V_b of the rolls *a* and *b* (FIG. 1) are equal, critical angles γ_a and γ_b that determine the zones of slippage on the entry side of the metal of the article *m* and on the delivery side thereof relative to the rolls *a* and *b* being also equal. With an increase of the peripheral speed V_a of the roll *a* (which will be termed hereafter the driving one) the angle γ_a decreases, since the driving roll a starts delivering greater power into the deformation zone. At the same time the angle γ_b increases, and the power delivered by the driven roll *b* in to the deformation zone diminishes.

At a certain ratio between the speeds V_a and V_b the angle γ_a becomes zero. At this moment the zone of slippage on the entry side of metal *m* takes place over the entire contact surface of the driving roll a, with the exception of the place (plane 00^1) of the metal delivery, where its speed V_m is equal to the peripheral speed V_a of the driving roll a.

If the rotational speed of the roll a is increased still further, it will start slipping with respect to the metal.

A further mismatch between the peripheral speeds V_a and V_b of the rolls *a* and *b* is possible when an additional power is supplied into the deformation zone, which is necessary for running a stable process without slippage of the roll a relative to the metal.

This can be achieved, in particular, by applying a stretching strain P_1 to the front end (delivery section) of the article (FIG. 2). With $V_a/V_b = \lambda$ (where λ is the drawing of the article per pass) and $V_m = V_a$, we obtain $\gamma_b = \alpha_o$, where α_o is the angle of nip of the rolls a and b, that is, on the surface of contact of the driven roll with the article there will be "leading" of metal, while on the contact surface of the driving roll a the metal will "lag."

The diagram presented in FIG. 2 illustrates the effect of forces of friction in the deformation zone with the method of rolling of the present invention on the deformation process: tangent strains τ_a and τ_b are equal and oppositely directed, whereby the "backing-up" action of the forces of friction onto the deformed volume of metal is excluded, and the pressure exerted on the rolls is considerably diminished as compared to the conventional method of rolling.

For minimizing the pressure of metal onto the rolls *a* and *b*, stretching strains P_1 and P_2 are created simultaneously on the front and back ends of the article, respectively.

To reduce the necessary tension of the front end of the article m and to stabilize the process of rolling, the article is made to encompass the driving roll a (FIG. 3) so as to utilize for tensioning the force of friction of rest on the arc of encompassing. Under the terminology friction of rest we understand here that the article and the roll move without slippage.

Since the force of friction of rest on the arc of encompassing may vary within wide limits with the tension of the end of the article remaining the same, the process will run more steadily.

The most favorable will be the case, when the stretching strains are created at both ends of the article by making it encompass each roll **1**, **2**, and **3** as shown in FIG. **4**, so that the process can be effected on two and more rolls. The article m is reduced between each preceding and subsequent rolls **1**, **2** and **3** in the direction of rolling, and the ratio between the peripheral speeds V_1, V_2 and V_3 of each adjacent pair of rolls is equal to the drawing λ of the article *m* therebetween, that is, $V_2/V_1=\lambda_1$; $V_3/V_2=\lambda_2$; $V_3/V_1=\lambda_1 \cdot \lambda_2$, where λ_1 and λ_2 are the values of drawing the article between the rolls **1** and **2** and **2** and **3**, respectively. All what has been stated above with respect to the proposed method applied to the given case as well.

It is always expedient, that the pressure between the article and the driving roll created within the deformation zone should be greater, than the pressure between the article and the driven roll. This can be achieved by varying the force of friction through appropriately selecting the surface finish of the rolls, or by feeding grease into the deformation zone. Then it will be possible to diminish the stretching strain P_1 effective on the front end of the article.

Sometimes, when rolling the article through a great number of rolls (more than two), it is preferable to make the article encompass only the middle rolls **4** and **5** (FIG. **5**), leaving the extreme rolls **6** and **7** free. This is done when the extreme rolls are to be protected against deflection under the pressure of metal, or such deflection is to be reduced, additional support rolls being installed in such a case for the extreme rolls (the support rolls being not shown).

The above-described embodiments of the method can be carried out on mills of different designs.

In particular, the embodiments where rolling is effected with tensioning the leading and trailing ends of the article without encompassing the rolls may be effected on a mill shown in FIGS. **6** and **7**.

The mill has a housing **8** in which at least two driven work rolls **9** and **10** are mounted, as well as support rolls **11** which through their chocks **12** interact with a presser means **13** that provides a required clearance between the rolls **9** and **10**.

At each side of the housing **8** there are disposed reels **14** and **15** which are used, respectively, for winding and unwinding the article m which is passed between the rolls **9** and **10**.

For tensioning the both ends of the article two groups of rolls **16** and **17** are attached to both sides of the housing **8**.

The group **16** is kinematically associated with the driven roll **9** by means of gear trains **18** (FIG. **7**), and the group **17** is kinematically associated through gear trains **19** with the driving roll **10**, each of the rolls **9** and **10** being rotated from one of individual drives **20** and **21** at different peripheral speeds and in opposite directions. The gear trains **18** and **19** are so selected, that the peripheral speed of the tension rolls kinematically associated therewith, and the ratio between the speeds of the rolls **9** and **10** is made equal to the drawing of the article.

Slippage of the article *m* relative to the groups **16** and **17** of the rolls is prevented by virtue of additional tensioning of the ends of the article by the reels **14** and **15**.

The method of rolling with the article being tensioned from both ends and encompassing the rolls can be effected on a mill as represented in FIG. **8**.

In a housing **22** of the mill there are disposed driven work rolls **23** and **24** that are rotated at different peripheral speeds and in opposite directions, but in such a manner, that the ratio between their speeds remains equal to the drawing of the article *m*, the roll **23** being the driving one and rotating at a greater speed than the driven roll **24**. The clearance between the rolls is adjusted with the help of a presser means **25** of a wedge type, the presser means being actuated by a drive **26**.

The article is fed between the rolls **23** and **24** and encompasses them, while the tensioning of the article is effected by reels **27** and **28**.

The reel **27** that creates tension of the front end of the article is mounted from the side of the driven roll **24**, and the reel **28** adapted to create tension of the back end of the article is disposed from the side of the driving roll **23**. Such an arrangement of the reels **27** and **28** makes the provision for the rolls **23** and **24** to be encompassed by the article along a maximum possible arc.

There is a possibility of performing continuous rolling of sheet articles without encompassing the rolls of the mill as shown in FIG. **9**. This mill comprises a plurality of consecutively arranged stands **29**, **30** and **31** having driven rolls **32** and **33** that are rotated at different peripheral speeds and in opposite directions, but in such a manner as to make the ratio between their speeds equal to the drawing of the article *m*, the latter of which is passed between the rolls **32** and **33** of each stand and tensioned from at least the front end thereof by a reel **34**, the roll **32** being the driving one and the roll **33** the driven one, respectively.

In each preceding stand the driving roll **32** is kinematically associated with the driven roll **33** of the subsequent stand through a common reduction gear **35**, with both rolls being rotated by the same drive (not shown).

The kinematic connection between the rolls is effected so, whereby the peripheral speed of the driving roll in the preceding stand is equal to the peripheral speed of the driven roll in the subsequent stand, and the ratio between the peripheral speeds of the rolls in each stand is equal to the drawing of the article in the respective stand, while the peripheral speed of the driving roll **32** in each stand accordingly increases in the direction of rolling by the value λ of drawing in the

given stand. In the mill provision may be made for a reel **36** for tensioning the back end of the article. Mills of this type have been proven to be more efficient.

The method of continuous rolling with the rolls being encompassed by the article tensioned from both ends can be effected on a mill of the type shown in FIG. **10**, that comprises a plurality of driven rolls **38** mounted in a housing **37**, that are rotated in opposite directions with different peripheral speeds, but in such a manner, that the peripheral speed of the driving roll in each adjacent pair of rolls increases in the direction of rolling by the value of drawing the article *m* therebetween. In the said mill wedge-type presser means **39** are provided that operate from drives **40** and are disposed from both sides of each roll **38**. The presser means are adapted to adjust the distance between the axes of the rolls **38** so as to vary the effort with which the article *m* is reduced and to exclude uneven thickness of the article which consecutively encompasses all the rolls **38** in the course of being rolled. However, the article should not necessarily encompass the extreme rolls.

Industrial tests of the present invention have shown it to be quite promising and confirmed the advantages offered thereby and pointed out hereinabove.

In particular, when carrying out the method of cold rolling of sheets with a thickness of 2 to 0.2 mm in rolls with a radius of 500 mm, the pressure of metal onto the rolls is diminished by as much as 3 to 10 times and higher, which makes it possible to essentially increase the degree of reducing of the article per pass and to improve the efficiency of rolling.

What is claimed is:

1. A method of rolling metal sheet articles by reducing between two driven rolls, comprising; rotating the rolls in opposite directions so that the peripheral speed of one driven roll is greater than the peripheral speed of the other driven roll at a predetermined speed differential, said speed differential being in the same proportion as the thickness of the article before reduction is greater than the thickness thereof after reduction between said pair of rolls; adjusting the speed of the article leaving the reduction zone to equal the peripheral speed of the driven roll rotating at said greater speed, and applying a stretching strain to the end of the article leaving the rolls, while moving the article along a straight path during the rolling and reduction process.

2. A method of rolling as claimed in claim **1**, including applying a stretching load to the end of the article entering the rolls simultaneously with applying a stretching load to the end of the article leaving the rolls.

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