July 6, 1965 F. D. CARTWRIGHT 3,192,756

CONTROL OF DIRECTIONAL PROPERTIES OF METALS AND THEIR ALLOYS

Filed April 5, 1963 3 Sheets-Sheet 1

Fig 1.

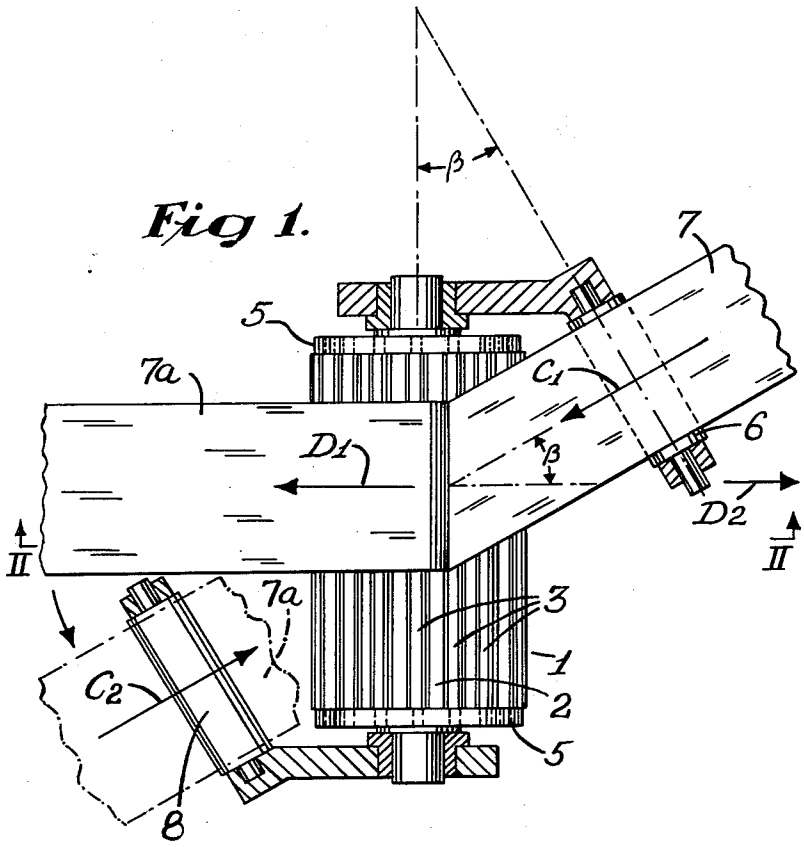
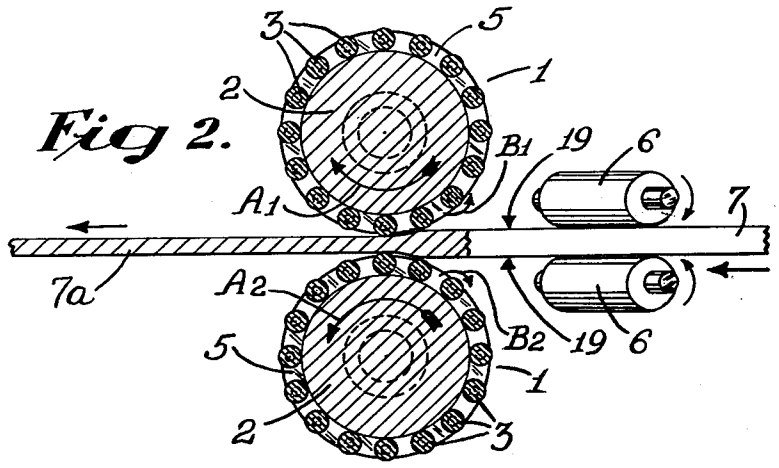


Fig 2.



CONTROL OF DIRECTIONAL PROPERTIES OF METALS AND THEIR ALLOYS

Filed April 5, 1963 3 Sheets-Sheet 2

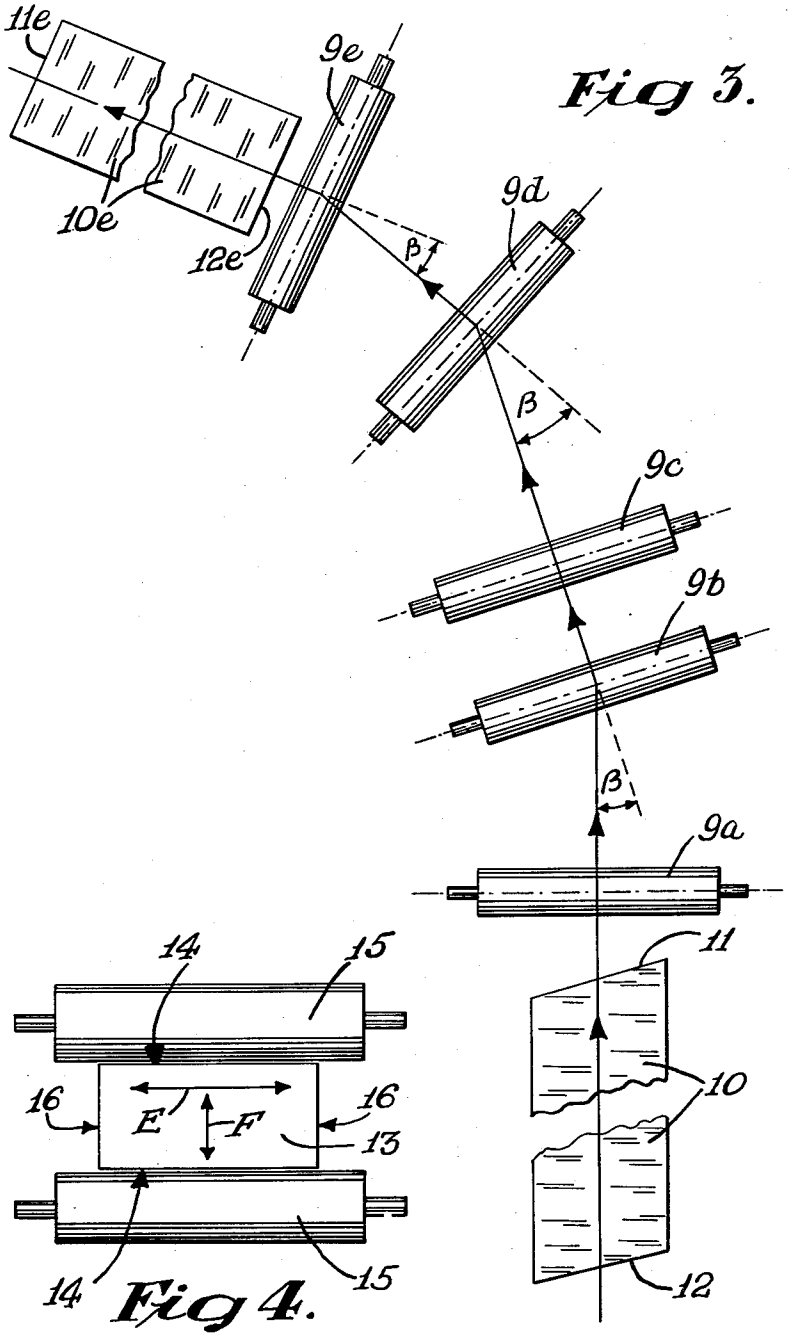


Fig 3.

Fig 4.

July 6, 1965 F. D. CARTWRIGHT 3,192,756
CONTROL OF DIRECTIONAL PROPERTIES OF METALS AND THEIR ALLOYS
Filed April 5, 1963 3 Sheets-Sheet 3

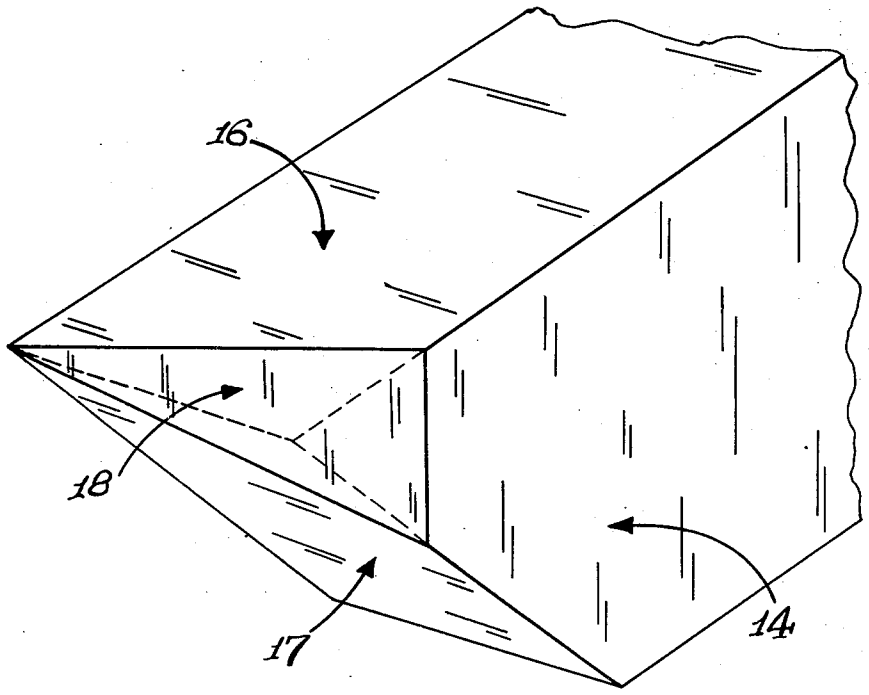


Fig 5.

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CONTROL OF DIRECTIONAL PROPERTIES OF METALS AND THEIR ALLOYS

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11 Claims. (Cl. 72—167)

This invention relates to the control of the directional properties of metals and metal alloys. For the purposes of this specification the term "metal" will hereinafter be used to signify not only a metal but also a metal alloy.

It is a well known phenomenon that when a metal casting is subjected to a working process, such as rolling, the metal develops "directionality," which means that the metal develops different properties in different directions. Mechanical as well as crystallographical directionality may be experienced.

In a conventional process of rolling hot wide sheet and strip metal, a heated metal ingot is generally reduced in a reversing or "to and fro" rolling mill from a large, more or less rectangular, cross-section to a smaller, more or less rectangular, cross-section generally called a slab. After reduction this slab may be cut hot and allowed to cool. Thereafter it is reheated and further rolled down to thin sheet or strip metal in a series of rolling mills which successively reduce the metal to various thicknesses depending upon end usage. According to present practice in the formation of a long sheet or strip of metal, the ingot is rolled in one direction only until the final thickness of the sheet or strip is reached.

One of the consequences of this unidirectional rolling is that the original, substantially equi-axed grains of metal of the ingot have a major pressure exerted between them in the longitudinal direction of the slab, and minor pressures in both the long transverse and the short transverse directions. Thus the "notch toughness" as measured on test pieces cut parallel to both the long transverse direction and the short transverse direction are inferior to the "notch toughness" as measured on test pieces cut parallel to the longitudinal direction. Other properties of the metal, such as elongation, reduction of area and resistance to bending, are similarly related.

Instances of fractures occurring along lines which are low in "notch toughness" in various manufactured products, such as shovel blades used in mining operations, are well known.

It is an accepted fact that the directional properties of unidirectionally worked metal elements leave much to be desired. It will be appreciated that where parts such as steering columns of vehicles possess some inherent weakness resulting from directionality, life and property is endangered.

It is known that directional properties can be improved by so-called "cross-rolling" in which a piece of metal is rolled in two directions which are at right angles to each other. As will be readily appreciated, such cross-rolling can in practice only be performed on metal elements of relatively small size. Hitherto no satisfactory suggestion has been made for the control of directional properties of metal elements of long length which cannot be cross-rolled. It is accordingly an object of the present invention to provide improved control of the directional properties of metal elements of long length.

According to the invention a method of controlling the directional properties of an elongated metal element includes the step of subjecting at least one pair of opposed surfaces of the element to a plurality of rolling passes between at least one pair of co-acting rolls. The element is fed longitudinally to the rolls in each pass in a direction displaced at an acute angle from a plane normal to the axes of the rolls. The element is caused to emerge from the rolls in each pass in a direction lying substantially in said normal plane. Preferably, the direction of feed is displaced to the same side of the normal plane in all the passes when viewed in the direction of feed.

By displacing the direction of feed from the normal plane and causing the element to emerge in a direction lying in the normal plane, pressure is exerted between the grains in the material in a direction off-set at an angle to the longitudinal axis of the element.

Preferably, the sum of the angular displacements of the direction of feed in all the passes is substantially equal to 90°.

It will be appreciated that according to the invention the element is rolled in stages, preferably through 90°. By using suitable material temperatures and rolling pressures, variously controlled directional properties can be obtained. A major advantage flowing from the use of the method of the invention is that metal and metal alloy can be produced in which the degree of mutual pressure "welding" of the grains can be controlled in desired directions, as can the crystallographic directionality, which lead to the control of the strength of the metal with special reference to "notch toughness."

Any suitable means may be used to feed the element to the rolls in a direction displaced from the normal plane and to cause the element to emerge from the rolls in a direction lying in the normal plane.

Preferred embodiments of the invention will now be described purely by way of example with reference to the accompanying drawings in which:

FIGURE 1 is a plan view of rolling apparatus suitable for carrying out the method according to the invention and presenting one reversible rolling zone, and upper reducing roller being omitted for the sake of clarity;

FIGURE 2 is a section on line II—II in FIGURE 1, the upper reducing roller being shown in position;

FIGURE 3 is a schematic representation of alternative rolling apparatus for carrying out the method of the invention and presenting a plurality of spaced rolling zones;

FIGURE 4 is an end view of a metal element showing the effect of subjecting different pairs of opposed surfaces to rolling; and

FIGURE 5 is a perspective view of the end of a metal element which is suitably shaped to minimize end loss when two pairs of opposed surfaces are subjected to rolling.

Referring to FIGURES 1 and 2, a pair of parallel reducing rolls 1 each include a main roller 2 and a series of planetary rollers 3 arranged in substantially parallel, circumferentially spaced relationship about the periphery of the main roller 2. The periphery of each planetary roller 3 is in frictional engagement with the periphery of its main roller 2. Each set of planetary rollers 3 are rotatably mounted at opposite ends on a pair of spaced carrier rings 5 which, in turn, are rotatably mounted at opposite ends of the relevant main roller 2.

Main rollers 2 are arranged to be rotatably driven about their own axes in reversible manner by any suitable means (not shown). Each planetary roller 3 is rotatable about its own axis relative to its carrier rings 5 which, in turn, are also rotatable about their own axes. Each set of planetary rollers 3 is, therefor, also rotatable about a common axis, namely the common axis of the relevant set of carrier rings 5. The two sets of carrier rings 5 are mechanically coupled by any suitable means (not shown) so that a planetary roller 3 of the lower set passes simultaneously with a planetary roller 3 of the

upper set through the vertical plane containing the axes of main rollers 2.

When main rollers 2 are rotatably driven about their own axes in the forward direction indicated by arrows A_1 and A_2, frictional engagement between main rollers 2 and their planetary rollers 3, urges each set of planetary rollers 3 to rotate forwardly with their carrier rings 5 about its common axis in the same direction as its main roller 2, namely in the direction indicated by arrows A_1 or A_2 as the case may be, thereby to cause reduction in thickness of metal strip 7 fed between rolls 1. Also, each planetary roller 3 will be urged to rotate in reverse direction about its own axis as shown by arrows B_1 and B_2.

A pair of parallel feed rollers 6 are arranged to present strip of material 7 forwardly in the direction indicated by arrows C_1 in FIGURE 1 at right angles to their own axes into the rolling aperture between reducing rolls 1. The axes of feed rollers 6 lie in a plane disposed at an acute angle of $\beta=10°$ to the plane containing the axes of reducing rolls 1.

Reducing rolls 1 subject the pair of opposed faces 19 of strip 7 to a rolling action to reduce strip 7 to strip 7*a*, and simultaneously tend to force strip 7*a* to change direction and emerge at 90° to their axes as indicated by arrow D_1 in FIGURE 1.

As can be seen clearly from FIGURE 1, strip 7 is fed longitudinally to the rolling aperture between reducing rolls 1 in a direction displaced at an acute angle $\beta=10°$ from a plane which is normal to the axes of rolls 1. Furthermore, strip 7 emerges from the rolling aperture in the direction indicated by arrow D_1 which lies in the normal plane. It will be noted that the direction of feed (arrow C_1) is displaced to the right hand side of the normal plane when viewed in the direction of feed.

Since planetary rollers 3 rotate about their own axes in the reverse direction indicated by arrows B_1 and B_2 during reduction, planetary rollers 3 only roll on and reduce strip 7 as it is presented to them by feed rollers 6, and do not drag it along their surface in a direction parallel to the axes of rolls 1 towards their right hand extremities when viewed in the direction in which strip 7 passes through rolls 1. In this way ease, speed and accuracy of rolling in long lengths are attained with no or minor guide formations being required. Also, strip 7 is caused to emerge from the rolling aperture in a direction lying in a plane normal to the axes of rolls 1.

After strip 7 has passed through reducing rolls 1 and has been reduced to strip 7*a*, main rollers 2 are reversed and strip 7*a* is displaced bodily in any suitable manner, such as is well known in metal rolling practice, to the position shown in dotted outline in FIGURE 1 in which it is fed by a set of feed rollers 8 in reverse direction shown by arrow C_2 between reducing rolls 1 for a second displaced pass. As in the case of feed rollers 6, the axes of feed rollers 8 lie in a plane disposed at an acute angle of $\beta=10°$ to the plane containing the axes of reducing rolls 1 so that the direction of feed to rolls 1 in the second pass as indicated by arrow C_2, is also displaced at an acute angle $\beta=10°$ from the plane normal to the axes of rolls 1. The displacement is also to the right hand side of the normal plane when viewed in the direction of feed (arrow C_2). As before, the direction of emergence from rolls 1 in the second pass as indicated by arrow D_2, lies in the normal plane.

The metal strip is passed to and fro nine times through the single rolling zone presented by rolls 1 to subject the same pair of surfaces 19 to nine displaced rolling passes, the sum of the angular displacements of the direction of feed in all the passes being equal to 90°. All the displacements should be to the same side of the normal plane in all passes when viewed in the direction of feed, so that the strip can be rolled in stages through 90°. By suitably selecting the temperatures of the strip subjected to rolling, and the rolling pressures, the directional properties of the strip can be controlled suitably.

If required, the strip of metal can be subjected before commencement of the displaced passes to at least one preliminary rolling pass between rolls 1, the strip being fed longitudinally to, and also being caused to emerge from rolls 1 in a direction lying in the plane normal to the axes of rolls 1. Alternatively or additionally, the strip of metal may be subjected at one or more stages between pairs of displaced passes to at least one intermediate rolling pass between rolls 1, the direction of feed to, and also the direction of emergence from rolls 1 lying in the normal plane. Furthermore, the strip of metal may be subjected after completion of the displaced passes to at least one final rolling pass between rolls 1, the direction of feed to, and also the direction of emergence from rolls 1 lying in the normal plane.

Instead of passing an element to and fro through a single rolling zone to achieve a plurality of rolling passes, the arrangement of FIGURE 3 may be used. As shown, a series of spaced rolling zones 9*a*, 9*b*, 9*c*, 9*d* and 9*e* are provided. Strip 10 is fed to rolling zone 9*a* in a direction lying in a plane normal to the axes of the reducing rolls of zone 9*a*. The direction of emergence of strip 10 from zone 9*a* is in line with the direction of feed to the zone and there is no displacement of the direction of feed from the normal plane.

The direction of feed to rolling zone 9*b* is displaced at an acute angle β from a plane normal to the rolls of rolling zone 9*b*. It will be noticed that the direction of feed is displaced to the left hand side of the normal plane when viewed in the direction of feed. The direction of emergence from the rolls of rolling zone 9*b* lies in the normal plane.

The direction of feed to, and also the direction of emergence from rolling zone 9*c* again lie in a plane normal to the axes of the rolls of the rolling zone. This in-line rolling zone does not add any angular change in the directional properties possessed by strip 10 after emergence from zone 9*b*, but consolidates and may even improve the metal properties in the direction of rolling imparted by zone 9*b*.

Rolling zones 9*d* and 9*e* again provide displaced passes, the direction of feed being displaced to the left hand side of the normal plane as is the case with rolling zone 9*b*. The direction of emergence from the rolls of each of rolling zones 9*d* and 9*e*, lie in the relevant normal plane.

If required, strip 10 may be subjected to a final in-line pass in which the direction of feed to, and also the direction of emergence from the relevant rolling zone (not shown) lie in a plane normal to the axes of the rolls of that rolling zone.

The number of passes, the angles of displacement at displaced passes, the order of in-line and displaced passes, the metal temperature and the reducing pressure of each pass are selected according to requirements. The angle of displacement need not be the same in each displaced pass.

Although it is expected that optimum control or balancing of directional properties will be obtained if a metal element is subjected to a preliminary in-line pass followed by a plurality of displaced passes in all of which the direction of feed is displaced to the same side of the normal plane, so as to achieve a cumulative rolling in stages through 90°, it is believed that rolling through a lesser or greater angle, with or without a preliminary in-line pass, will also improve the directional properties of the element, even if the direction of feed is not displaced to the same side of the normal plane in all the displaced passes.

It will be appreciated that since an element is subjected to rolling at an angle to its length in a displaced pass, the leading and trailing ends of the element will be so distorted after a series of displaced passes that

such ends will have to be removed, if the ends of the elements were at right angles to the longitudinal axis of the element before rolling commenced. By arranging for the leading end **11** and trailing end **12** of strip **10** to lie at suitable angles dependent on reducing pressures, material temperatures, the number of passes and the angles of displacement at displaced passes, to the longitudinal axis of strip **10**, the leading and trailing edges **11***e*, **12***e* of strip **10***e* emerging from the last pass will lie substantially at right angles to the longitudinal axis of strip **10***e*. This reduces end waste.

In the embodiments of FIGURES 1 to 3, only one pair of opposed surfaces of each strip is subjected to rolling. FIGURE 4 shows the effect of displaced rolling according to the invention applied to different pairs of surfaces of an element **13** of rectangular cross-section.

When the pair of opposed horizontal surfaces **14** of element **13** is subjected in accordance with the invention to a plurality of rolling passes in each of which surfaces **14** pass between reducing rolls, such as **15**, the directional properties of the element in a longitudinal direction at right angles to the plane of the paper are improved and controlled. Also the directional properties in the long transverse direction indicated by arrows E are improved and controlled. By subjecting surfaces **14** to rolling little, if any, improvement is achieved in the short transverse direction indicated by arrows F.

If the metal properties in the short transverse direction of arrows F are to be improved and controlled it is necessary to subject the pair of opposed vertical surfaces **16** to a plurality of rolling passes in accordance with the invention.

The pair of opposed horizontal surfaces **14** may first be subjected to a plurality of displaced rolling passes to improve and control the metal properties in the long transverse direction of arrows E. Thereafter, element **13** may be rotated through 90° about its longitudinal axis to bring the other pair of opposed surfaces **16** into horizontal position, and this pair of surfaces **16** subjected to a plurality of displaced rolling passes. One or both pairs of opposed surfaces **14**, **16** may also be subjected to one or more in-line passes as required.

Instead of first completing the rolling applied to surfaces **14** before commencing the rolling applied to surfaces **16**, element **13** may be rotated to and fro through 90° about its longitudinal axis so as alternately to subject the one and the other pair of surfaces to rolling. Instead of an alternate rolling relationship, the rolling of surfaces **14** and **16** can be performed in any required relationship or order.

Instead of rotating element **13** through 90° about its longitudinal axis, horizontally and vertically disposed rolls may be used to subject surfaces **14** and **16** to rolling without having to rotate element **13**.

Where the shape of an element permits, such as with a round or hexagonal bar, the element may be rotated about its longitudinal axis through an angle or angles greater or smaller than 90° to roll different pairs of opposed surfaces or surface portions.

In order to minimise end losses where both pairs of surfaces **14** and **16** are subjected to rolling, it is contemplated that the ends of element **13** should be shaped as shown in FIGURE 5. End surface **17** is disposed at an angle to the longitudinal axis of element **13** for the case where surfaces **14** are subjected to rolling. Also, end surface **18** is disposed at an angle to the longitudinal axis of element **13** for the case where surfaces **16** are subjected to rolling.

It will be appreciated that many variations in detail are possible without departing from the scope of the appended claims. For example, an element may be subjected to rolling according to the invention in a heated condition with or without subsequent heat-treatment, or in a cold state with or without subsequent heat-treatment.

Any suitable rolling apparatus may be used for carrying out the invention. For example, a two or three high rolling mill, or a merchant bar type or rolling mill may be used for to and fro rolling.

Although planetary type rolls are particularly suitable for carrying out the method of the invention, any other suitable apparatus may be used. For example, the reducing rolls in a displaced pass and means for feeding an elongated element to the reducing rolls may be interrelated and/or synchronized so that the element is fully presented to the rolls by the feeding means and so that the rolls only perform a reducing action on the element without drawing the element towards them. When fed to the reducing rolls in a direction displaced from a plane normal to the roll axes, the element will be caused to change direction and emerge in a direction lying substantially in the normal plane. Also, there will be little tendency, if any, for the rolls to drag the element longitudinally along their axes.

The invention is applicable to any form of metal element, such as, for example, slabs, blooms, billets, plate, sheet, strip, skelp, squares, flats, rounds and ovals. The original form or shape of an element may change during the course of rolling in accordance with the invention.

In the appended claims the term "opposed surfaces" is intended to include opposed surface portions of an elongated metal element.

I claim:

1. A method of controlling the directional properties of an elongated metal element comprising subjecting at least one pair of opposed surfaces of the element to a plurality of displaced rolling passes between at least one pair of co-acting rolls, each displaced rolling pass comprising the steps of feeding the element longitudinally to the rolls in a direction displaced at an acute angle from a plane normal to the axes of the rolls, and causing the element to emerge from the rolls in a direction lying substantially in said normal plane, the direction of feed being displaced to the same side of the normal plane in at least two of the displaced passes when viewed in the direction of feed.

2. A method according to claim 1, including the step of subjecting the pair of opposed surfaces of the element before commencement of the displaced rolling passes to at least one preliminary rolling pass between at least one pair of co-acting rolls, the element being fed longitudinally to the rolls in the preliminary pass in a direction lying substantially in a plane normal to the axes of the preliminary pass rolls, and the element further being caused to emerge from the rolls in the preliminary pass in a direction also lying substantially in the normal plane.

3. A method according to claim 1, including the step of subjecting the pair of opposed surfaces of the element at at least one stage between displaced passes to at least one intermediate rolling pass between at least one pair of co-acting rolls, the element being fed longitudinally to the rolls in the intermediate pass in a direction lying substantially in a plane normal to the axes of the intermediate pass rolls, and the element further being caused to emerge from the intermediate pass rolls in a direction also lying in the normal plane.

4. A method according to claim 1, including the step of subjecting the pair of opposed surfaces of the element after completion of the displaced passes to at least one final rolling pass between at least one pair of co-acting rolls, the element being fed longitudinally to the rolls in the final pass in a direction lying substantially in a plane normal to the axes of the final pass rolls, and the element further being caused to emerge from the final pass rolls in a direction lying substantially in the normal plane.

5. A method according to claim 1, in which the element is rolled by passing it to and fro through the same rolling zone.

6. A method according to claim 1, in which the element is rolled by passing it successively through a series of spaced rolling zones.

7. A method according to claim 1, in which at least a second pair of opposed surfaces of the element is subjected to rolling as defined in claim 1.

8. A method according to claim 7, in which the element is turned about its longitudinal axis for rolling to be performed on the one and the other pair of surfaces as required.

9. A method according to claim 1, in which the sum of the angular displacements of the direction of feed in all the displaced passes in which the direction of feed is displaced to the same side of the normal plane when viewed in the direction of feed is substantially equal to 90°.

10. A method according to claim 9, in which the element is subjected to nine displaced rolling passes in which the direction of feed is displaced to the same side of the normal plane at an angle of substantially 10° in each rolling pass when viewed in the direction of feed.

11. A method of controlling the directional properties of an elongated metal element comprising the steps of successively rolling the elongated metal element through at least one pair of co-acting rolls, guidably advancing the metal element for each rolling step such that the element approaches the rolls at an acute angle with respect to a plane perpendicular to the rolls, and withdrawing the metal element from the rolls in a direction perpendicular to the rolls such that the metal element undergoes a change in direction in each rolling step, the change in direction in each rolling step being substantially equal and effected in the same angular direction, whereby pressure is exerted between the grains of the metal element in a direction offset at an angle with respect to the axis of the element and thereby the directional properties of the element is controlled.

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