

Dec. 13, 1938.

W. WORTHINGTON

2,139,872

SHEET METAL AND PROCEDURE FOR PRODUCING THE SAME

Original Filed Aug. 7, 1933

4 Sheets-Sheet 1

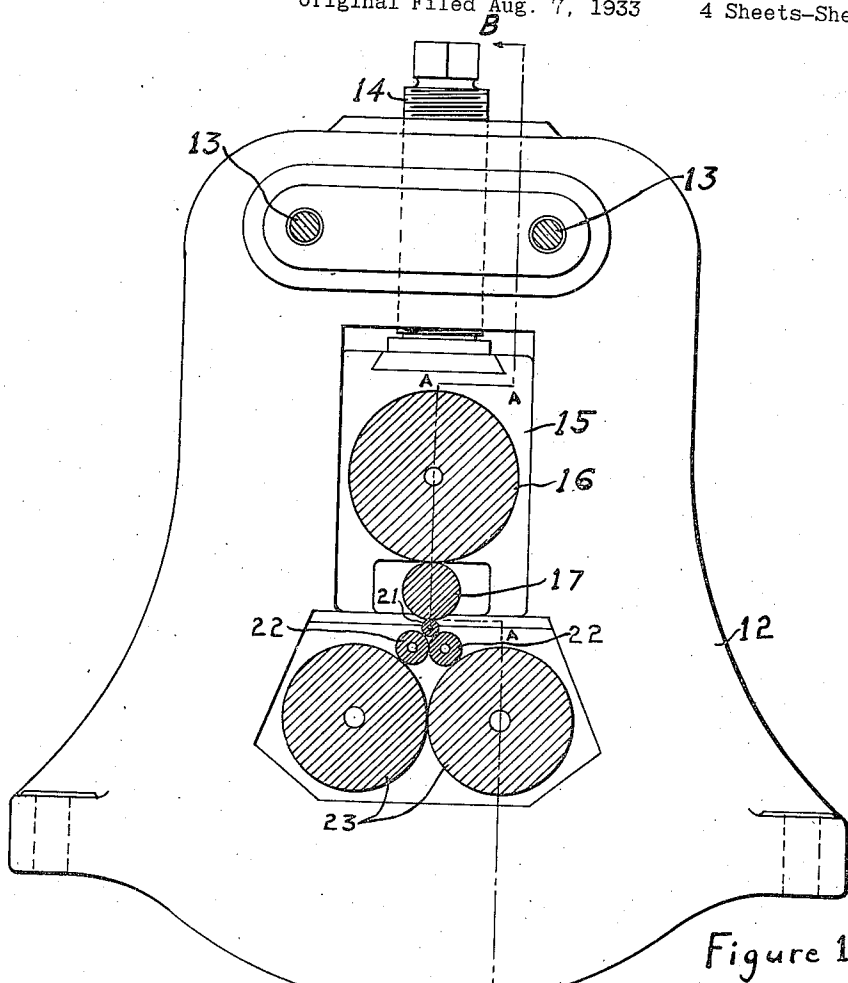


Figure 1

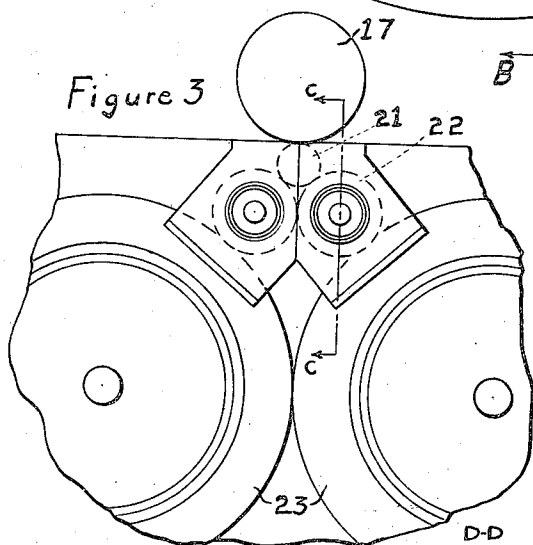
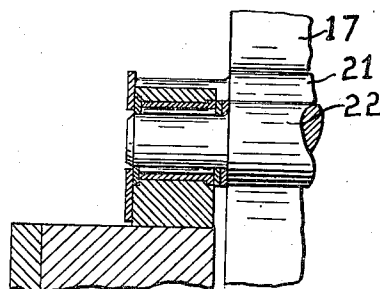


Figure 3



c-c Figure 4

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4 Sheets-Sheet 2

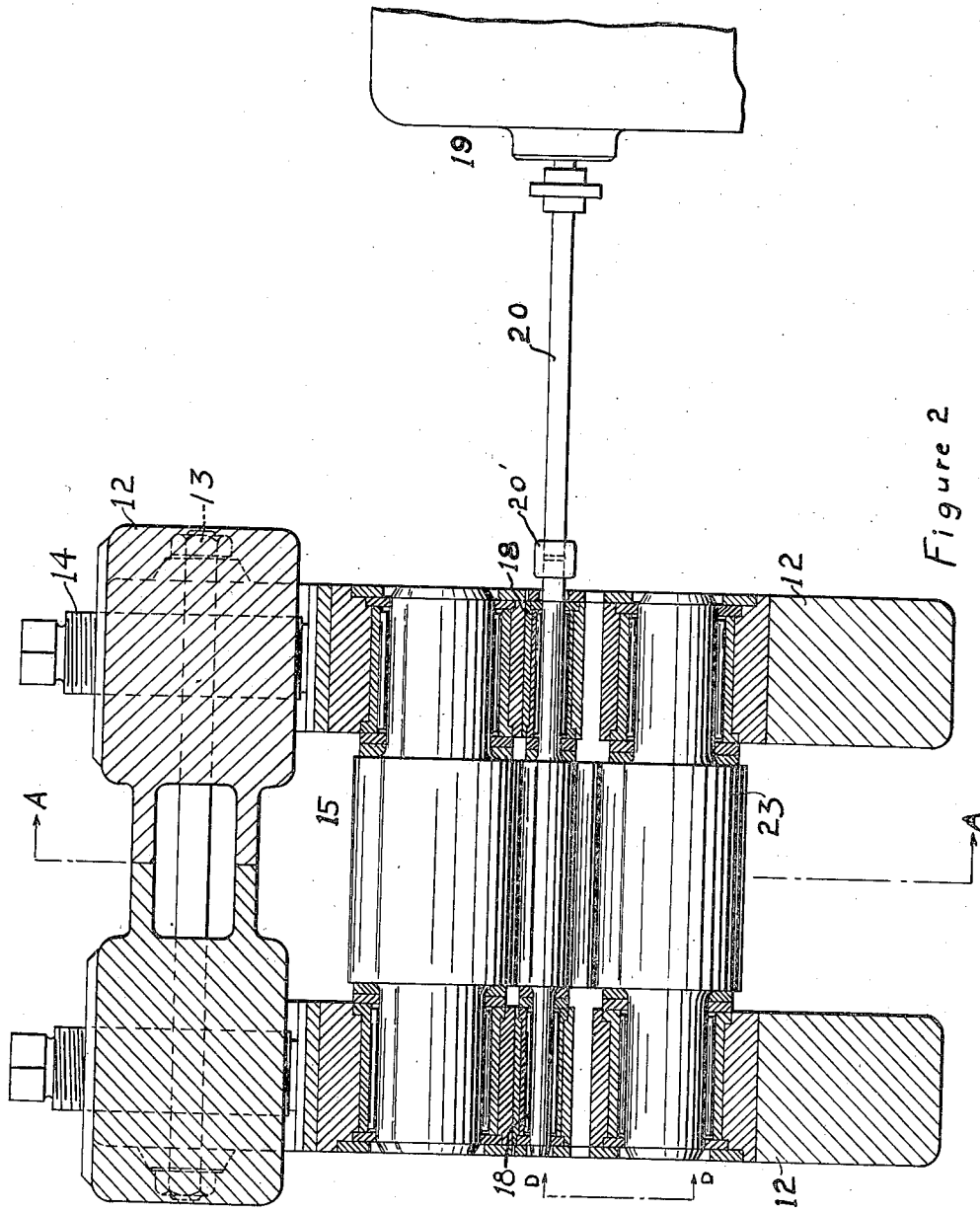


Figure 2

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Fig. 5.

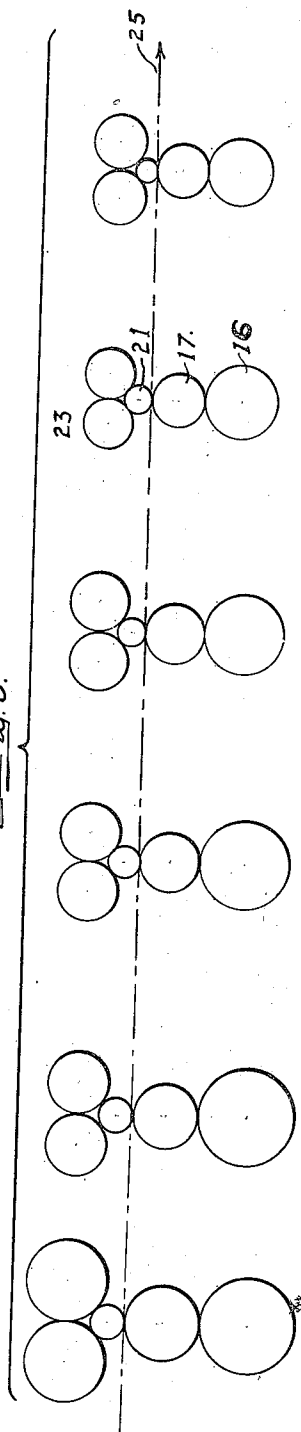


Fig. 6.

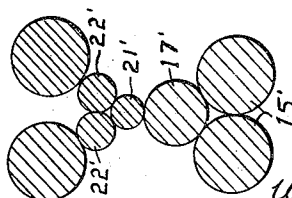


Fig. 7.

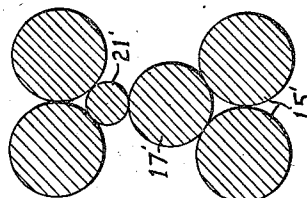


Fig. 8.

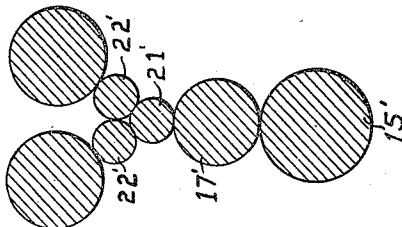
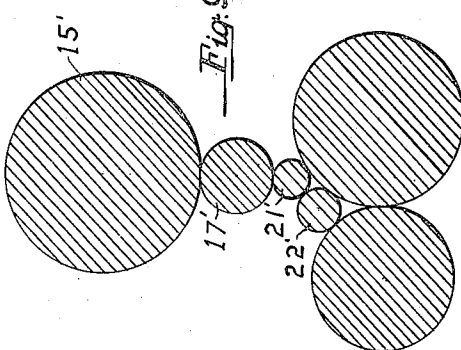


Fig. 9.



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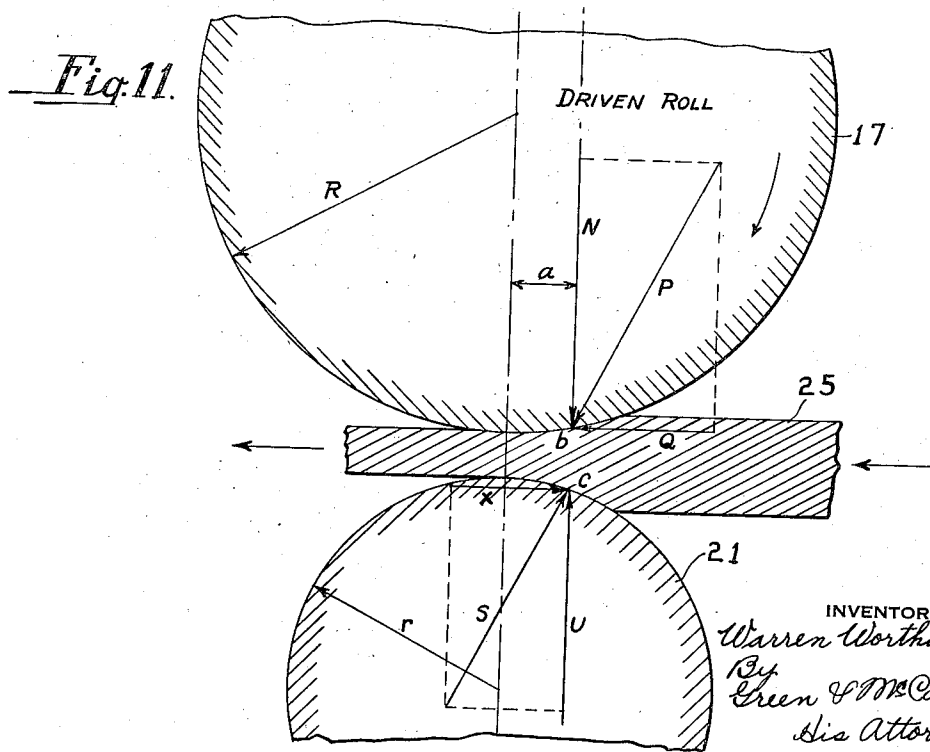
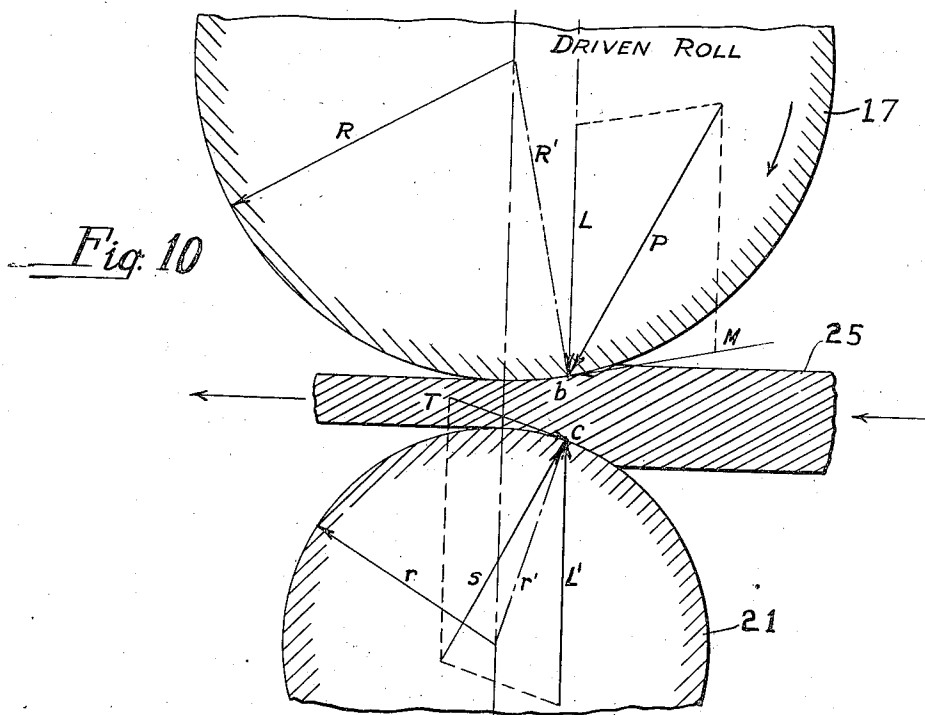
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4 Sheets-Sheet 4



UNITED STATES PATENT OFFICE

2,139,872

SHEET METAL AND PROCEDURE FOR PRODUCING THE SAME

Warren Worthington, Pittsburgh, Pa.

Application August 7, 1933, Serial No. 684,001
Renewed May 27, 1937

9 Claims. (Cl. 29—18)

This invention relates to procedure for producing sheet material, and also relates to the production of a new product having new and improved physical characteristics.

By the term "sheet material", I mean metal rolled to a thickness comparable to the thickness obtained in present sheet or strip rolling operations, and independent of the final length or width of the material.

An object of my invention is to improve the physical characteristics of sheet material.

A further object is to decrease the cost of production of sheet material.

A still further object is to decrease the cost of the rolling equipment employed in rolling sheet material.

A fundamental object of my invention is to produce a rolling procedure wherein both the rolling pressure and the power utilized for causing the material to traverse the roll pass are effectively employed.

For many years it has been generally recognized that the rolling of sheet material may be more effectively accomplished with small rolls and for this reason it has long been the practice to employ four-high and similar mills, such as cluster mills, because they provide structures in which working rolls of small diameters may be employed without excessive deflection under the forces encountered. I have, however, discovered that in order to most effectively employ the necessary forces, the projected line of contact between the rolls and the material being rolled must be reduced even further than is possible with existing apparatus. I have also discovered that the projected line of contact can be more effectively reduced by employing opposed working rolls of unequal diameter than with opposed rolls of equal diameter; that is to say, I have found that the opposed rolls which directly contact the material traversing the pass and apply the rolling pressure to that material, should be of different diameters in order that the most effective reduction of the projected line of contact may be obtained.

In all rolling operations where small rolls are employed, the rolling torque limits the size of the driving reducing rolls. That is to say, each such reducing roll must be of sufficient size to provide the necessary torsional strength to transmit the propelling force to the material traversing the pass. This necessarily has an influencing effect on the projected line of contact. I have, however, discovered that the projected line of contact may be reduced by not only employing rolls

of unequal diameter, but by employing one driven roll and a smaller undriven roll, which contacts with the material being rolled and is in fact driven by that material. I have also discovered that there is a definite relationship between the projected line of contact and the permissible diameter of this smaller roll. This discovery has led to the further discovery that in continuous mill operations both reducing rolls and particularly the smaller and undriven reducing rolls of the various stands may be, and preferably should be, progressively decreased in diameter toward the delivery end of the mill. This follows from the fact that although the percentage of reduction in each of the successive stands of a continuous mill may be maintained the same, the vertical displacement of the material necessarily decreases from stand to stand, and this in turn results in a progressive decrease in the projected line of contact from stand to stand.

It has been recognized that in any rolling procedure where but one roll is driven, the resulting re-arrangement of the molecules in the material rolled differs, to some extent, from the molecular re-arrangement obtained by employing two driven reducing rolls, but I have discovered that an improved molecular structure and a consequent improvement in the physical properties of sheet material can be obtained by employing an undriven reducing roll which is of materially less diameter than has heretofore been considered practical in any rolling operation. A further object of my invention is, therefore, to produce strip material having a molecular formation different from sheet material heretofore produced and having physical characteristics which correspond to its molecular characteristics.

These and other objects are attained by means of the procedure herein defined, which is carried forward by means of apparatus having the characteristics of the apparatus herein illustrated.

In the drawings accompanying and forming a part hereof, Figure 1 is a sectional view of a mill embodying my invention and of a mill capable of carrying forward the procedure herein defined as a part of the present invention; the section of Fig. 1 is taken along the line A—A of Fig. 2;

Fig. 2 is a sectional view along the line B—B of Fig. 1;

Fig. 3 is a fragmental side elevation of the mill shown in Figs. 1 and 2;

Fig. 4 is a fragmental sectional view along the line C—C of Fig. 3;

Fig. 5 diagrammatically discloses a roll assem-

bly which may be employed for successive stands of a continuous mill;

Figs. 6 to 9, inclusive, show permissible variations of roll assemblies which may be employed in carrying out my improved process;

Fig. 10 is a diagram illustrating the relationship of the forces encountered and their effect on the material rolled; and

Fig. 11 is a diagrammatic view corresponding to the view of Fig. 10, except that it is predicated on the horizontal and vertical components of the forces illustrated in Fig. 10.

It will be understood that various modifications of the apparatus for carrying out my invention may be employed, and that the several views of the drawings are merely illustrative of such apparatus. The mill illustrated in the drawings, however, includes the usual base plate (not shown), the usual side frames 12, which are provided with the usual windows for the bearing boxes or housings. As illustrated, the side frames 12 are separately formed and are secured together adjacent their upper ends by means of bolts 13. Each side frame is provided with the usual screw-down 14, which acts in the usual manner on the bearing housing 15 of a backing roll 16. As illustrated, the backing roll 16 engages a working or reducing roll 17 of relatively small diameter, which, like the backing roll, is provided with roll necks and is journaled in separate bearings 18, which are movable with relation to the frame 12. As shown, the boxes for the bearings 18 fit within recesses in the boxes of the backing roll bearings. The roll 17 is a driven roll and is shown in Fig. 1 as operatively connected to a driving means, such as a motor 19, by means of a spindle 20 and coupling 20'. This roll is what is ordinarily termed a working roll in that it engages the material to be reduced, i. e., the sheet material traversing the pass. As shown in Fig. 1, the opposed working roll 21 is of materially less diameter than the roll 17 and it is held in place within the crotch formed by two idler rolls 22, which in turn are located within the crotch formed by two co-operating backing rolls 23. The backing rolls 23 are provided with the usual form of bearing boxes, which are held rigidly in place with relation to the frame 12-12'. The idler rolls 22 are also provided with roll necks, which are mounted in suitable bearing boxes as shown in Figs. 3 and 4. These bearing boxes may be fitted in recesses formed in the bearing boxes of the backing rolls 23 and, as shown, each of the recesses for receiving these boxes extends radially with relation to one of the backing rolls 23 so that the rolls 22 may move radially, with relation to the rolls 23, for the purpose of taking up wear.

In Figs. 6 to 9, I have shown various roll assemblies in section, but it will be understood that in each such assembly, the roll 21' is an undriven working roll and that the roll 17' is a driven working roll, that the rolls 16' correspond in function to the backing rolls 16 of Fig. 1 even where two such rolls are shown; and that the idler rolls 22' correspond in function to the idler rolls 22 even where but one is illustrated.

It will be apparent that some means must be employed for preventing lateral displacement of the undriven working roll 21', and in each illustrated roll assembly, I have so arranged the co-operating rolls that the undriven working roll is held in place by co-operating backing rolls which in some cases act on the roll 21 through the agency of idler rolls. Other means for preventing lateral displacement of the undriven working

roll, may, of course, be employed without departing from either the spirit or scope of my invention.

In the operation of a stand such as illustrated in Fig. 1, the vertical deforming force is applied to the material by adjusting the screw-downs so that the space between the working rolls 17 and 21 corresponds to the desired thickness of the material after it has traversed the pass, consequently, the vertical force exerted by these rolls will depend upon the resistance of the material to the distorting force so applied.

In Figure 10, I have diagrammatically illustrated the positions of the opposed working rolls and their relation to the piece traversing the pass and I have also illustrated by force diagrams the forces encountered. In Fig. 10, R is any radius of the driven roll 17; R' is a radius extending to the so-called neutral point within the pass; L represents the magnitude and direction of the distorting force applied through the roll 17; M represents the magnitude and the direction of the tangential force acting at the periphery of the roll on the material 25 as it passes the neutral point; and P represents the magnitude and the direction of the resultant of these two forces. The force diagram associated with the roll 21 in Figure 10 may be termed a diagram of the reactive forces, since it discloses the forces which are in effect transmitted to the roll 21 through the material acted upon. As there illustrated, r is any radius of the undriven roll and r' a radius extending to the so-called neutral point; L' represents the magnitude and the direction of the vertical distorting force occasioned by roll 21 and it is apparent that this force is equal and opposite to the force represented by L. T represents the direction and magnitude of the tangential force transmitted by the periphery of the roll 21 to the material 25 at the neutral point within the pass, and S represents the direction and magnitude of the resultant of the two forces T and L'. In the drawings, I have so considered the forces acting on the material 25 that the neutral points on the upper and lower surfaces of the material are opposite each other. This, however, may or may not be an absolutely accurate representation of the conditions, but it gives a fair approximation of the action of the opposed forces on the material rolled and the force diagrams substantially disclose the relative directions and magnitudes of the forces acting on both the material being rolled and on the undriven working roll.

Figure 11 shows the magnitude and direction of the vertical and horizontal components of the resultants P and S of Figure 10. In both Figures 10 and 11, the resultant force P is equal in magnitude and acts in the same direction. This is also true of the resultant S. The vertical and horizontal components N and Q of the resultant P, necessarily differ in magnitude from the forces L and M, but they disclose both the direction and magnitude of the deforming and the propelling forces transmitted to the material 25 by the roll 17. The components u and x of the resultant S necessarily differ in magnitude from the forces L' and T as illustrated in Fig. 10, but they represent the direction and magnitude of the vertical force and the retarding force transmitted to the material rolled by the roll 21.

From the foregoing it is apparent that the material 25 is subjected to opposed forces during its movement through the pass and that these forces, acting as a couple, not only have a deforming effect on the material itself, but they also have a

very particular effect on the molecular structure of the material. The components Q and x , operating in opposed and offset relation, not only tend to advance the molecules or crystals on the driven roll side of the material 25 ahead of the molecules or crystals on the undriven roll side, but the relationship of these two forces is such that they also tend to impart a rotative movement to each of the various crystals, with the result that the 10 crystals are not only displaced longitudinally of the piece and with reference to each other, but each crystal is turned about a point within itself during the deforming operation. I have discovered that this longitudinal translation of the 15 molecules with relation to each other should bear some relation to the percentage of reduction, or better, to the amount of vertical distortion to which the piece is subjected and that the relationship of the opposed forces acting on the material should be such that the longitudinal displacement of the molecules on the driven roll side of the material with relation to those on the undriven roll side should be at least 4% of the vertical distortion accomplished in each pass. As a 20 matter of fact, the opposed forces should be so proportioned that this longitudinal translation of molecules should somewhat exceed 4% of the vertical distortion. Under such conditions, the 25 piece 25, after having traversed the desired number of passes, will not only be reduced to the requisite thickness, but the molecules of the piece will also have been subjected to such rearrangement with relation to each other that each molecule is turned about an internal axis. One of the 30 advantages of this new molecular structure is that the material being rolled does not increase in hardness in proportion to the rolling strains to which it is subjected and consequently, in cold rolling operations, the material may be subjected 40 to greater reductions per pass and a greater number of passes without the necessity of intermediate annealing.

These beneficial results are the direct result of employing working or reducing rolls of small 45 diameter, one of which is an undriven roll of a diameter substantially less than that of the driven roll. I have discovered that there is a relationship between the diameters of the driven and undriven working rolls and the draft of the pass 50 which must be adhered to in order to obtain the best results. In designing the rolls, I take into consideration the percentage of reduction to be accomplished in the pass, and I necessarily consider the torsional strength of the driven working roll under the conditions of draft encountered. 55 This fixes the minimum diameter of the driven work roll. The diameter of the undriven work roll must then be such that the projected line of contact will at least equal the draft divided by the 60 coefficient of friction between the material rolled and the surface of the driven roll, or in round numbers equal to about ten times the draft, and this relationship of the two reducing rolls should be maintained at least within close limits. From 65 the foregoing it is apparent that I employ small reducing rolls of unequal diameter, and that I drive the roll of larger diameter, while maintaining the undriven roll as small as possible and while maintaining the proper relationship between 70 the rolls and the projected line of contact. It is also apparent that my improved sheet rolling procedure consists in subjecting the material being rolled to opposed deforming forces so applied that the forces act on the material as a couple, 75 and not only decrease the thickness, but produce

a new molecular structure by in effect longitudinally displacing one portion of the material with relation to another portion and to such an extent that each molecule or crystal is rotated about an axis within itself. 5

My procedure not only contemplates successive applications of such forces to the material rolled in a succession of stands, such as in a continuous mill, or in a tandem arrangement of stands, but I also contemplate a modification of the procedure 10 above outlined wherein the material after traversing one or more such passes is subjected to a cross rolling operation under conditions above defined, so that the molecular structure is further modified by longitudinally advancing the molecules or crystals on one side of the material with 15 relation to those on the other side, and in causing each such molecule to roll or turn about an internal axis substantially at right angles to the axis of its former rotation. It will also be apparent that the direction of rolling may be varied after each pass or after any desired number of passes so that after one or more cross rolling passes the material may again be rolled in the 20 original direction of rolling or even in a reverse direction and may then again be subjected to one or more cross rolling passes. I, of course, contemplate the necessary cutting of the material in order that it may be rolled in a direction at right angles to its former direction of rolling. 30

In my improved process, the material rolled is not only reduced in gauge by each pass, but it is also subjected to a longitudinal deformation. This longitudinal deformation not only involves the extrusion normally resulting from subjecting 35 metal to the action of a reducing roll pass, but also consists of a relative offsetting of the molecules or crystals under such conditions that each crystal is rotated through an appreciable arc about an internal axis. As previously pointed out, 40 this molecular displacement and rearrangement produces a new molecular pattern.

In accomplishing this I contemplate a relation between the diameter of the driven work roll and the undriven work roll on the order of more than 45 two to one, that the diameter of the undriven work roll may be $1\frac{1}{2}$ " or less, in the case of extremely thin material, and that the diameter of the co-operating driven roll may be 16" or more. It will be understood that this general relationship in size of driven and undriven work rolls is reproduced in all of the mill stands except, as heretofore stated, I contemplate a successive reduction in the diameter of the undriven work roll from stand to stand and toward the delivery end 55 of the mill. In this connection I am referring to a continuous or a tandem mill.

In carrying out the procedure herein outlined, I am able to decrease the cost of production of sheet material, primarily because the projected 60 line of contact and consequently, the projected contact area is materially reduced. This reduces the roll separation forces, the skin friction encountered and the pressure per bearing, all of which reduces the power required to accomplish 65 the rolling operation and thus results in a reduction in the cost of rolling. The smaller and lighter rolls employed are not only in themselves cheaper, but the bearings, bearing housing and 70 all parts of the stand structure are proportionately reduced in size and in this way the cost of rolling equipment is reduced. One important feature of my invention in connection with cost of equipment and cost of upkeep is that by em- 75

ploying but one driven working roll, I eliminate the necessity for employing pinions.

It will be apparent that my improved procedure is not limited to cold rolling operations, but may also be employed in hot rolling operations and that various modifications of the procedure herein outlined may be made without departing from the spirit and scope of my invention as defined by the appended claims.

10 What I claim as new and desire to secure by Letters Patent is:—

1. The method of making sheet material, which consists in roll reducing metal to strip or sheet form in a number of roll passes and in at least one pass causing the molecules in one surface of the material to move further in the direction of rolling than those in the opposite surface and each such molecule to turn through a substantial arc about an internal axis, and then in cross rolling the material so as to obtain a transverse relative displacement of the molecules and a partial rotation of each such molecule about an internal axis substantially at right angles to the axis of prior rotation.

25 2. The method of making sheet metal, which consists in roll reducing metal to strip or sheet form in a number of roll passes and in at least one such pass in causing the molecules in one surface of the material to move further in the direction of rolling than those in the opposite surface, in cutting the strip material thus formed into lengths, in cross rolling such lengths and in at least one such cross rolling pass causing the molecules in one surface of the material to move further in the direction of rolling than those in the opposite surface; such differential movement in each case being equal to at least 4% of the amount the material is reduced in thickness in each pass.

3. The method of making metal sheet material, which consists in roll reducing metal to strip or sheet form in a number of roll passes and in each such pass causing the molecules in one surface of the material to move further in the direction of rolling than those in the opposite surface; such differential movement occurring in the same direction in each pass; in cutting the material into lengths and in cross rolling such material and in causing the molecules in one surface of the material to move further in the direction of rolling than those in the opposite surface.

4. The method of making metal sheets, which consists in roll reducing metal to strip or sheet form in a number of roll passes and in each pass in causing the molecules in one portion of the material to move further in the direction of rolling than those in an opposed portion; such differential movement reoccurring in successive passes and the maximum relative movement between opposed molecules during each pass being equal to at least 4% of the amount the material is reduced in thickness in each such pass; in cutting the material and then in cross rolling the

same in a number of passes and in each pass in causing the molecules in one portion to move further in the direction of rolling than those in an opposed portion.

5. A method of producing sheet-like material, which consists in subjecting ferrous material to a cold reducing operation while subjecting such material to a force couple acting within the material, and then in cold reducing such material, while subjecting it to a force couple acting within the material and across the direction of application of the former force couple.

6. The method of rolling sheet material which includes, deforming a metal piece of material by applying pressure thereto and simultaneously, causing the crystals adjacent one side of the material to advance ahead of the crystals adjacent the other side of the material and in such a manner exerting a rotative influence upon each of such crystals about an axis, and thence, exerting a rotative influence upon each of such crystals on an axis substantially at right angles to the axis of the first-mentioned rotative influence.

7. As a new article of manufacture, sheet-like material having properties characteristic of those obtained when metal is reduced to sheet-like form in a number of roll passes in at least one of which the molecules in one surface are caused to move further in the direction of rolling than those in the opposite surface; each such molecule being caused to turn through a substantial arc about an internal axis and the material being then cross rolled so as to obtain a transverse relative displacement of the molecules and a partial rotation thereof about internal axes substantially at right angles to those of the prior rotation.

8. As a new article of manufacture, sheet-like material having properties characteristic of those obtained when metal is roll reduced to sheet form in a number of roll passes in each of which the molecules in one surface are caused to move further in the direction of rolling than those in the opposite surface and the material is then cross rolled to cause the molecules in one surface to move further in the direction of rolling than those in the opposite surface.

9. As a new article of manufacture, sheet-like material having properties characteristic of those obtained when metal is roll reduced to sheet form in a number of roll passes in each of which the molecules in one portion of the material are caused to move further in the direction of rolling than those in an opposed portion; such differential movement recurring in successive passes and the maximum relative movement between molecules in each pass being equal to at least 4% of the reduction in such pass; the material being then cross rolled in a number of passes in each of which the molecules in one portion are caused to move further in the direction of rolling than those in an opposed portion.

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