Oct. 26, 1943. P. H. HUME 2,332,796

REDUCTION OF ELONGATED BODIES

Filed Jan. 25, 1941 3 Sheets-Sheet 1

FIG. 1.

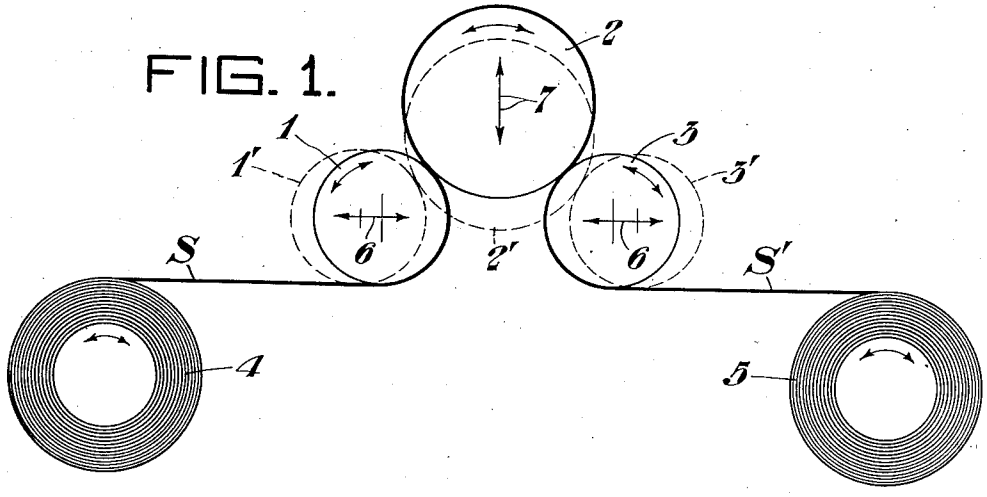


FIG. 2.

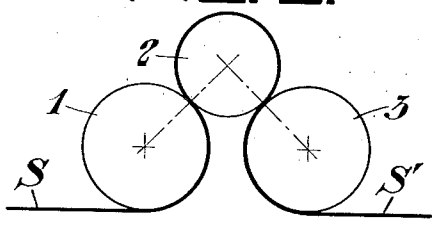


FIG. 3.

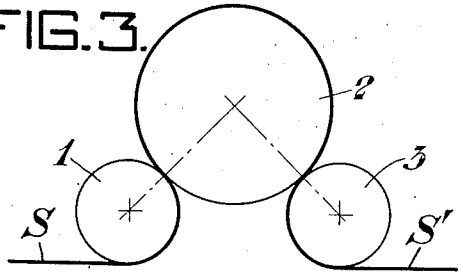
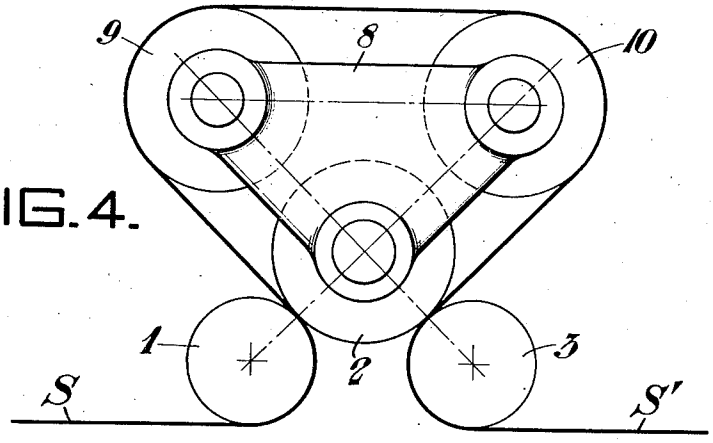


FIG. 4.



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REDUCTION OF ELONGATED BODIES

Filed Jan. 25, 1941 3 Sheets-Sheet 2

FIG. 5.

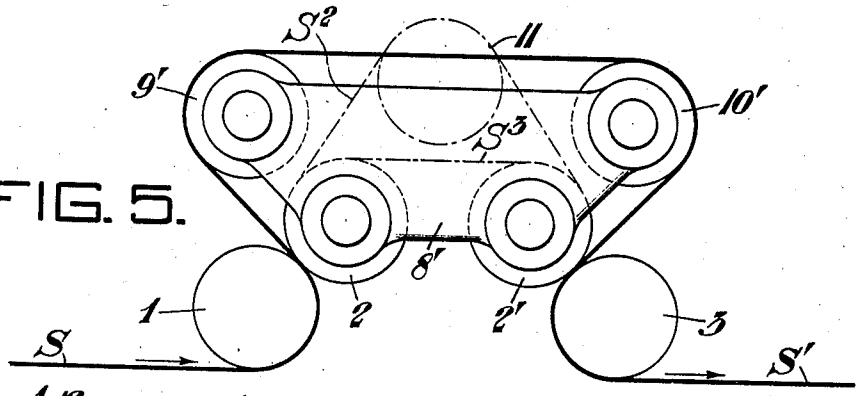


FIG. 6.

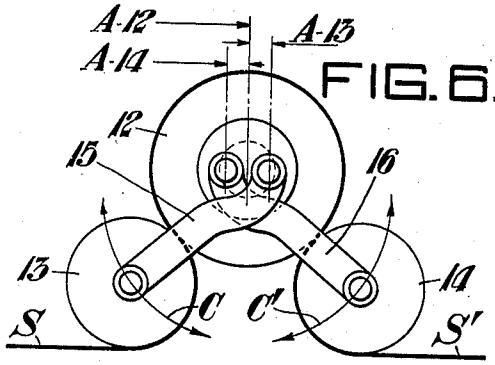


FIG. 7.

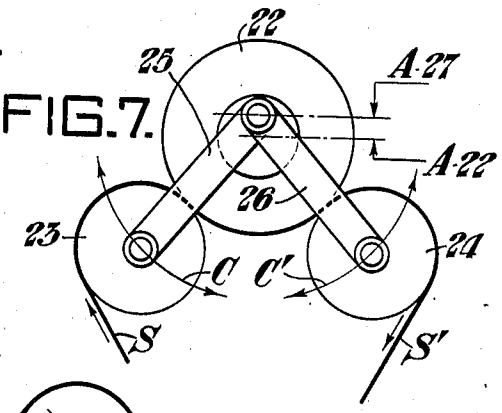
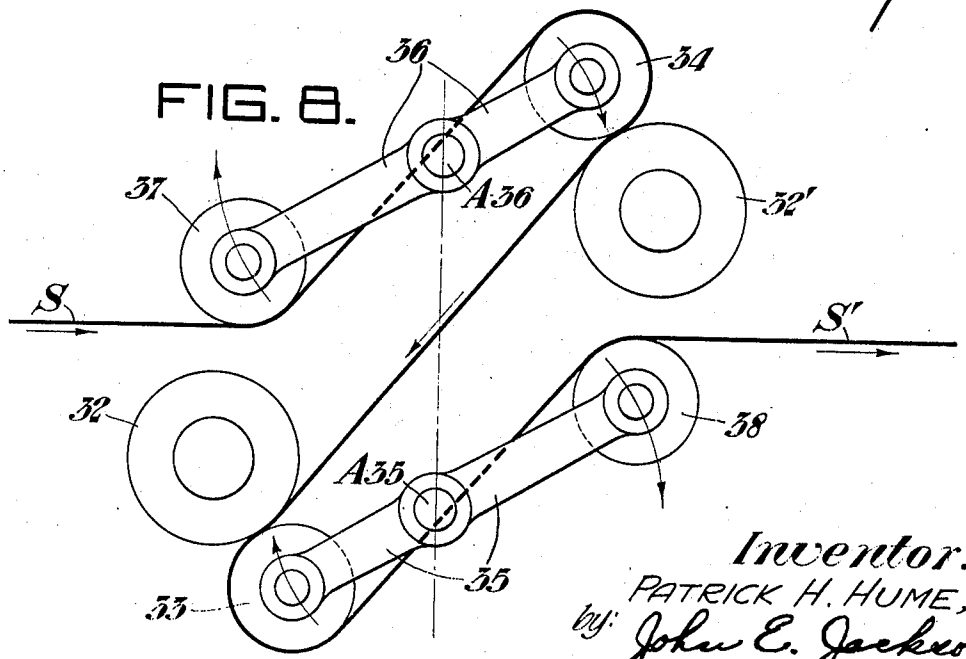


FIG. 8.



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Oct. 26, 1943. P. H. HUME 2,332,796

REDUCTION OF ELONGATED BODIES

Filed Jan. 25, 1941 3 Sheets-Sheet 3

FIG. 9.

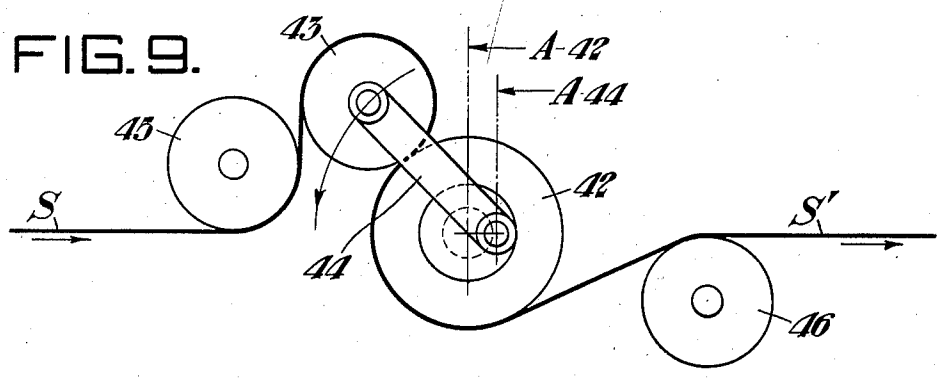


FIG. 10.

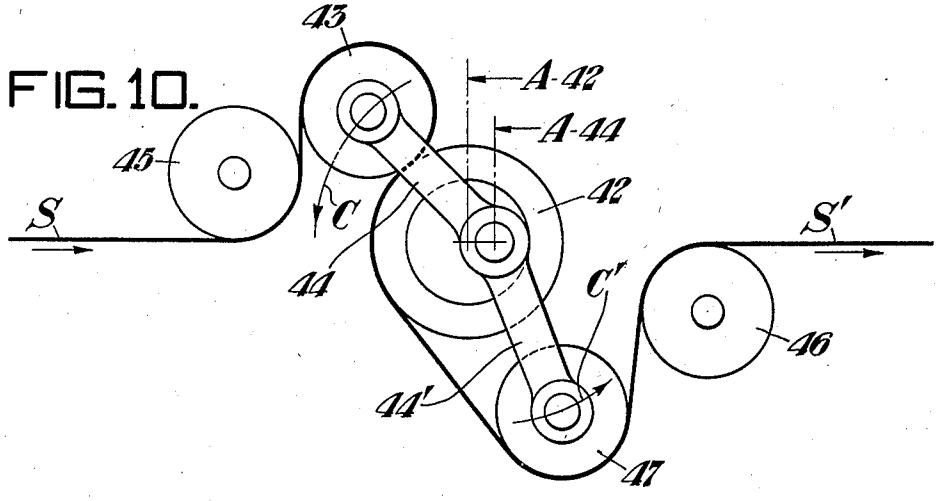
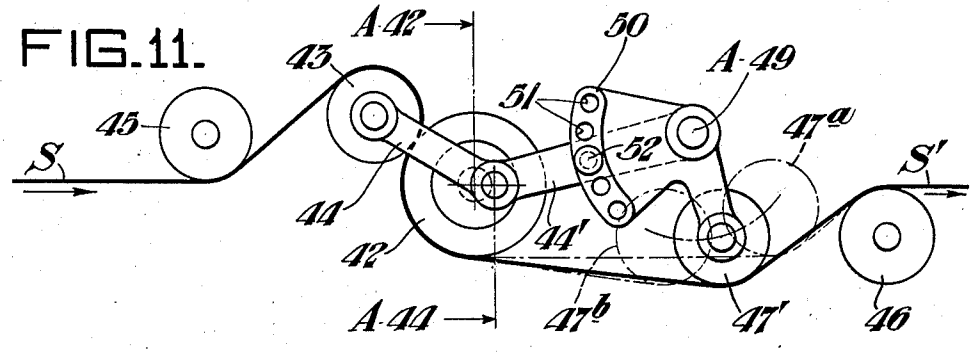


FIG. 11.



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UNITED STATES PATENT OFFICE

2,332,796

REDUCTION OF ELONGATED BODIES

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Application January 25, 1941, Serial No. 376,001

27 Claims. (Cl. 80—32)

This invention relates to the reduction of long metal bodies, and, more particularly, to the compressive rolling of metal sections so as to reduce the thickness thereof.

The invention is applicable to the production of any material capable of plastic deformation that has a longitudinal dimension of sufficient extent in relation to its cross sectional area as to be flexible and capable of extending through the reducing means provided therefor. It has particular applicability in the reduction of metal sections such as, sheets, strip, rods, wire, and the like, which, for purposes of this description, may be regarded synonomously.

Heretofore sheet, strip, wire, etc., have, in the metal industries, been produced by movement through a compressive means such as rolls or dies, to reduce the metal section an amount provided by such dies. In some instances, the stock being reduced has been subjected to a tension throughout its extent, while being acted upon by such dies, partially to alleviate the compressive stresses at this point, and to bring about a more efficient operating condition. In the case of wire, or very narrow strips, tension in excess of the yield point of the material has been used with some success without the aid of dies. In all other cases, the tension has been applied incidental to the application of the compressive forces, which, for any given reduction, usually remains substantially constant. The stretching of wire without the benefit of compressive dies has not proved to be desirable in all instances because of the lack of control over the "necking-down" of the material, which is inclined to take place at mechanically weak portions of the wire to cause breakage of the stock before contiguous portions have been reduced the required amount.

With respect to the application of tensile forces where compressive dies are used, the amount of such forces has, in the past, been more or less arbitrary, with no definite correlation of the compressive forces to the tensile forces, or vice versa, to give effect to the most efficient condition for reduction. Thus, in the reduction of strip, tension is applied without direct regard to the compressive force being exerted by the work rolls upon the material, and usually remains constant throughout the operation, irrespective of the screw-down pressure by which the work rolls are forced to bear upon the strip. More or less reduction is, therefore, made by adjustment of the roll screw-downs without effecting any change in the tension of the strip. In wire drawing operations, the apparatus employed is usually such as to give a predetermined tension for any wire drawing operation, even though each operation necessarily varies as the size of the wire being drawn, and the size of the dies through which it is being drawn, vary.

It is, thus, possible to tear a strip in half during the rolling operation by applying to it the same tension formerly used satisfactorily in the reduction of a heavier section, or with less screw-down pressure, since the tensile force, when combined with the augmented compressive force, causes the strip to rend in two. Similarly, in wire drawing, the tension applicable for one set of conditions may be inacceptable for an altered set of conditions. In either case, it is possible that the material would be subjected either to a tension overload, causing its failure, or would be given too little tension, which is improvident of the most efficient reducing action.

Similarly, in reducing operations wherein compressive dies are employed, which are adjustable to vary the amount of reduction effected, as in rolling mills, it has heretofore been virtually impossible to preset the mill in accordance with all known factors to give the precise reduction in thickness, and extension in length, required in any given operation. To circumvent this difficulty, many elaborate and costly mechanisms have been devised to gauge the amount of the reduction by measuring the thickness of the material before and after reduction or to measure the extension of the material resulting from the reduction, or to compare the rate of movement of the reduced material with the rate of movement of the unreduced material, from which the reduction can be computed. Such instrumentalities are, at best, suitable only for the empirical determination of a reducing operation then in progress, but are of no assistance in presetting a mill to give a stock having the precise cross-sectional area and length desired.

It is the primary object of the present invention to provide a method and means for reducing a cross-sectional area of, and for elongating, materials of the class described in a manner that removes all of the uncertainties and objections experienced heretofore in similar operations.

It is another object of the present invention to provide a method and means for effecting such reductions in a manner that effects correlation between the tensile and compressive forces existent during the reducing operation so

as automatically to establish the most efficient operating conditions.

It is another object to improve upon present-day rolling mill technique by simplifying the operations, and by affording absolutely uniform rolling contact throughout the extent of a work-piece being acted on, while maintaining a balance between tension and rolling pressure to which the work-piece is subjected.

It is another object to simplify reduction practices so that a work-piece may be produced having the precise dimensions desired, whether resulting from a drastic reduction or a very slight reduction in dimension, by the exercise of but one simple control.

It is still another object to improve upon the existing modes of reducing long sections of flexible material, such as steel strip, so that the operation is carried out with the maximum efficiency and convenience, whereby a better product as to physical properties and surface finish is realized. Still other objects and advantages are implicit in the following presentation.

In the accompanying drawings several diagrammatic representations of apparatus for giving effect to the present invention are shown. Thus, Figure 1 is a schematic illustration, as viewed at side elevation, of a rolling mill designed to illustrate the principles of the invention.

Figures 2 to 5, inclusive, are views corresponding to Figure 1, which illustrate modified forms of the invention.

Figures 6 to 9 show the principles hereof as applied in slightly different forms from that contemplated in the foregoing figures, but corresponding in viewpoint to the latter.

Referring now more particularly to the drawings in which like reference characters are used to identify like parts throughout:

In the embodiment of the invention shown in Figures 1, 2 and 3, there is provided idle work rolls 1, 2 and 3, to which a supply of material S, capable of plastic deformation, such as steel strip, is delivered from a coil 4 in such a manner that it is caused to pass beneath the roll 1; thence, upwardly between the rolls 1 and 2; around the periphery of the latter; downwardly between rolls 2 and 3, and, thence, around the latter to a take-up 5.

The rolls 1 and 3 are mounted upon stationary axes of revolution, which may be adjustable backwards and forwards in the direction of the arrows 6 to vary the spacing therebetween. The work roll 2 is supported by the rolls 1 and 3, and, thus, is free to move in vertical directions indicated by the arrow 7. From this arrangement, it will be appreciated that, as the strip is moved in either direction between stations 4 and 5, any tension therein will be transmitted throughout the length thereof to cause the work roll 2 to move downwardly to compress the strip between itself and the relatively stationary rolls 1 and 3. If the tension in the strip S is increased, the compressive forces to which the strip is subjected between the several rolls is increased in direct proportion thereto; and as the tension is lessened, the compressive force with which the roll 7 bears upon the rolls 1 and 3 is likewise lessened, and, except for the weight of the parts, amounts to zero at zero tension.

This provides a simple, and yet effective, correlation between the rolling pressures and the tension to which a body being reduced is subjected, and leaves only one control, i. e., that of adjusting the tension, to give the precise reduction required. Although there is no limitation as to which direction the mill in Figure 1 might run, and might well be designed as a reversing mill, it has been assumed for the purposes of this description that the strip S is passing from the station 4 to the station 5. Let it be assumed that it is desired to reduce the strip being delivered from the station 4 twenty per-cent. It is but necessary to fix the rate of delivery at the station 4 an amount equal to four-fifths of the rate of take-up at the station 5 to result in the precise dimension desired in the finished size of the strip as at S'. For 50% reduction the delivery rate at 4 would only be half of the take-up rate at 5. Similarly, as is frequently desirable in the temper rolling of strip steel, where 1% reduction is a desideratum, it would be necessary only to correlate the drives between the stations 4 and 5, so that the former delivers strip at a rate that is 99% of the rate of the take-up 5.

If a different rolling condition is desired, some adjustment may be effected by moving the rolls 1 and 3 apart to some positions 1', and 3', as shown in broken lines in Figure 1. The central work roll 2 would, under these conditions, be caused to settle downwardly in a vertical direction to assume some lower position, as is indicated by the broken lines 2' in this figure. It is believed that the most efficient reducing condition occurs when those radii of the central roll 2, which, if produced, would pass through the centers of the rolls 1 and 3, respectively, are disposed 120° apart. Less angularity than this would, in all probability, effect some lightening of the compressive action for a given amount of tension, whereas the increase of this angularity substantially in excess of 120° would cause a corresponding increase in compressive action up to the point where a binding action might arise, with an attendant tearing of the stock.

The apparatus diagrammatically illustrated by Figures 2 and 3 comprises stationary rolls 1 and 3, subject to the same adjustment as described above in connection with Figure 1, and the central floating roll 2, which, in this case, is of small diameter to lessen the arc of contact between the work and adjacent rolls along the lines of highest compression. Figure 3 is a similar arrangement except in this case the work rolls 1 and 3 are smaller than the floating roll 2 for the same reasons. Figures 2 and 3 have been included to show that the invention embraces any combination of rolls of different size, irrespective of dimension.

It will be appreciated that the invention as embodied in the foregoing description is, perhaps, better adapted in effecting light drafts, such as are encountered in the temper rolling of strip steel, than for effecting heavier reductions. This is because strip is elongated between the rolls 1 and 2, and elongated again between the rolls 2 and 3, which, since the strip is maintained at all times under tension, causes the strip to travel at different speeds past the rolls. The rolls, being idle, must likewise travel at different speeds, resulting in surface slippage between the rolls 1 and 2, and between the rolls 2 and 3. The central roll 2 must, in any case, accommodate itself to the relatively slow surface speed of roll 1, which latter is perhaps accelerated to some extent thereby, and to the faster speed of the advance roll 3, which is, in turn, tending to be slowed down by the roll 2. The resolution of

these several rates of travel occurs as slippage between the several surfaces, a function which is facilitated by the spacing between the roll surfaces themselves afforded by the metal being reduced. It is conceivable, however, that in drastic reductions this slippage could become so aggravated as to impair the efficiency of the operation and damage the surface of the strip, particularly, in view of the large arc of contact between the strip and the central roll 2. The constructions of the following figures in the drawings are provided to alleviate or obviate altogether this condition.

In Figure 4 there is shown a device comprised of rolls 1 and 2 arranged to revolve about stationary axes, which are capable of being horizontally adjusted, as has been previously explained in connection with Figure 1. In this case the central roll 2 is journaled for rotation in a vertically movable floating frame 8, which carries in addition to the roll 2, auxiliary rolls 9 and 10. As the strip moves under tension, the tensile force is resolved in a downward component of the roll 2, as is transmitted through the rolls 9 and 10 and the frame 8 in a manner similar to the action of the floating roll discussed in Figures 1, 2 and 3. The advantage derived from this arrangement is attributable to the fact that this material is held substantially out of contact with the floating roll 2, whereby the large arc of frictional engagement over the back of the roll is avoided. This brings about a better operating condition, whereby the speed differentials of the several rolls can be better accommodated, but does not obviate altogether the slippage attendant upon the elongation of the material between the several rolls.

This latter condition is completely overcome in the arrangement shown in Figure 5, in which the stationarily journaled rolls 1 and 3, as previously described, are matched with floating work rolls 2—2′ carried in a frame 8′, which may be constructed with guide rolls 9′, 10′, arranged in the manner of the device illustrated in Figure 4 and for like reasons, or may be provided with one central roll 11, as shown in broken lines in Figure 5, for guiding the strip S^2. Alternatively, the guide rolls 9′—10′ may be omitted, and the strip passed directly between the work rolls 2—2′, as indicated at S^3, to the same effect. In these arrangements, the surfaces of the rolls 2—2′, 9—9′, or 11, are maintained in spaced relation so that they are each free to follow the surface speed of the strip at the point where it comes into engagement therewith, without regard to the speed of the other rolls. Herein, as in the constructions previously described, the tension in the strip is resolved into a downward component of the frame 8′ which, in turn, is transmitted through the journals of the rolls 2—2′ to compress the strip confined between the latter and the rolls 1 and 3, respectively. As in the foregoing case cited, the pressures here are directly proportional to the tension in the strip; so that a thousand pounds tension would give a downward component of the frame 8′ an amount equal to two thousand pounds to be borne at the two points of bearing between the rolls 1 and 2, 2′ and 3, giving a compressive force at each of one thousand pounds.

In Figure 6 is illustrated another manner in which to give effect to the principle embodied in Figures 1 to 3, inclusive, but in this case by making the central roll 12 stationary with the complementary work rolls 13 and 14 movable with respect thereto. The roll 13 is carried upon arms 15 which are pivoted for rotation upon a center A^{13} that is eccentric relative to the stationary axis of revolution A^{12} of the central roll 12, so that, when the roll 13 is lifted along the arc C, it will ultimately come into tangential engagement with the surface of the work roll 12. The work roll 14 is correspondingly journaled for movement upon arms 16, which, in turn, are pivotally mounted upon a center A^{14}, eccentrically disposed relative to the axis of revolution A^{12} of the roll 12, so that, when the roll 14 is raised, as is indicated by the arc C′, it will be brought into tangential engagement with the surface of the center roll 12.

In this arrangement the strip S is caused to pass about the several rolls in the manner previously described in Figure 1. As the strip is tensioned, the rolls 13 and 14 are urged upwardly into engagement with the roll 12, so as to compress the strip therebetween.

The embodiment of Figure 7 works similarly to the Figure 6 construction in that the central roll 22 is journaled to revolve about a relatively stationary axis A^{22}, with the cooperating work rolls 23 and 24 being journaled for rotation upon oscillatable arms 25 and 26. The difference, however, is that the arms are pivoted upon a common center A^{27}, eccentric to the center of the revolution of the roll 22. In this instance the strip is passed between the rolls 23—24, and beneath the central roll 22, instead of over the top thereof. When the strip is tensioned the rolls 23 and 24 are urged toward each other along arcuate paths C and C′, respectively, to confine and compress the strip against the central roll.

In Figure 8, there is shown stationarily journaled rolls 32 and 32′ against which movable rolls 33 and 34, respectively, are adapted to bear. The rolls 33 and 34 are carried at the extremities of arms 35 and 36, respectively, which are provided with guide rolls 37 and 38 at their outer extremities. The arms 35 and 36 are pivoted for rotation upon stationary pivot bearings A^{35} and A^{36}, respectively. The strip enters the arrangement as is shown at S and leaves the arrangement as is shown at S′. Tension on the strip exerts a lifting force upon the roll 37, which is transmitted by the arm 35 to the roll 34 to compress the strip against the stationary work roll 32′. This compressive action is assisted by the downward moment resulting from the tensioned strip passing over roll 34. Similarly, in Figure 8, the roll 33 is lifted to bear against the roll 32 by the lifting moment the tensioned strip imparts to the roll 33, and the downward force exerted upon the roll 38. The leverage afforded by the arms 35 and 36 can be arranged to give a compressive force in relation to the tensile force at a ratio of greater than one to one.

In Figures 9, 10 and 11, the invention is illustrated as applied to a mill designed with but one movable work roll cooperating with one stationary work roll. Thus, in Figure 9, the strip is passed over a movable work roll 43, and downwardly beneath a relatively stationary work roll 42. The movable work roll 43 is carried at the extremity of arms 44 pivoted for rotation upon a center A^{44} that is eccentrically disposed relative to the axis of revolution A^{42} of the stationary work roll. Stationarily journaled guide rolls 45 and 46, are provided to lead the strip to the work rolls, and to remove it therefrom along paths provident of the greatest mechanical advantage,

looking toward maximum compression at minimum tension.

The device illustrated in Figure 10 is similar to that illustrated in Figure 9 in that the stationarily journaled work roll **42** is arranged to cooperate with the movable work roll **43**, which is carried upon an arm **44** pivoted upon a center A^{44}, eccentric to the axis of revolution A^{42} of the stationary work roll **42**. In this case, however, an extension of **44'** of the arm **44** is provided upon the far side of the pivotal axis A^{44} from the work roll **43**, the extremity of which extension is provided with a guide roll **47**. The stationary rolls **45** and **46** are placed in the most desirable locations respecting the entry and exit of the strip to the mill, the same as in the Figure 9 embodiment. Tension on the strip S urges the work roll **43** downwardly in the direction indicated by the arc C, and urges the guide roll **47** upwardly, as indicated by the arc C', and effects a compressive action upon the strip passing between the rolls **42** and **43**. The compressive force may be made greater than a one to one ratio in proportion to the tensile force by increasing the length of the arm extension **44'**. In these single roll embodiments, the "block-and-fall" action of the strip upon the movable work roll, which is provident of a force equal to twice that of the tensile force in the strip, is realized in substantially its full value, and multiplied by the effects of similar action on the guide roll **47**, as augmented by the lever **44'**. In the embodiments shown in Figures 1 to 7, inclusive, the "block-and-fall" action is distributed between the two points of bearing the central roll makes with the other work rolls, whereby the downward moment of the central roll (equal to twice the tensile force) is reduced to a value substantially equal to the tension at each bearing.

Figure 11 is a modified form of the device shown in Figure 10 comprising, as in the latter, stationarily journaled strip guide rolls **45** and **46**, a stationarily journaled work roll **42**, and a movable work roll **43** cooperating therewith. The latter is carried on an arm **44** with a leverage extension **44'**. In this case, however, the extremity of the extension **44'** is provided with a bell crank **48** which is adapted for pivotal movement relative to the extension **44'** upon a pivot A^{49}. The bell crank upon one side of the pivot A^{49} is provided with a roll **47'**, and upon the opposite side of the pivot is provided with an arcuate segment **50** having a plurality of holes **51** adapted to cooperate with a hole (not shown) in the extension **44'**, into which a pin **52** is removably disposed. By withdrawing the pin, the bell crank may be turned and fixed at any of the several positions allowed by the holes **51** to increase the leverage, as when the roll **47'** would be extended to position 47^a, shown in broken lines, or to decrease the leverage as when the roll of **47'** is made to assume the position indicated by the broken lines 47^b. This arrangement is intended as a schematic representation only for the purpose of illustrating the idea of changing the moment of force by which the movable roll **43** is made to bear against the stationary roll **42** as a result of the tension in the strip. Any suitable means for accomplishing this purpose are within the contemplation of the invention.

In all of the foregoing embodiments, and in many other similar arrangements which might be illustrated, the elongation of the work-piece is effected by a tensile force imposed upon the work-piece that is somewhat less, due to the compressive force afforded by the rolls, than would be required to stretch the work-piece without the presence of such compressive force. The possibilities of over-stretching the strip are entirely obviated by virtue of the fact that the compressive force is a function of the tension in the work-piece, and must always bear a direct proportionality thereto. In the preferred embodiment of the invention, the work rolls are idle, and the only motive force applied to the work-piece and mill is that provided by the take-up mechanism. If the take-up is set to a unit pulling force, and is opposed by a force less than unity applied to the work-piece at the entrance side of the mill, the work-piece will be reduced an amount exactly equal to the difference between the pulling and opposing forces. The tensile and compressive forces automatically attain a balance to give only the desired reduction, and over-stressing is entirely obviated.

In conventional types of mills, the work rolls are automatically driven, and are set to some predetermined spacing intended to be provident of the size to which it is desired to reduce the work-piece. In such case, the work rolls divide the strip into two parts with respect to tension applied thereto, since the work rolls provide a bearing behind which tension may be applied largely independently of the amount of tension applied forwardly of this bearing. The opposing forces, in the case of mills having driven work rolls (whether driven directly or driven by contact with driven backing-up rolls), provide a forwarding moment to the strip which is in addition to and combined with the pull of the take-up to advance the work-piece through the mill, even though there may be a force opposing such advancement upon the entrance side of the mill exceeding the pulling force of the take-up, considered by itself. The result frequently is that of breaking the work-piece or causing excessive elongation, since, hitherto, no way has presented itself to correlate these factors, or for making them interdependent.

To obtain the exact amount of reduction desired, be it ever so small or large, and to overcome all of the disadvantages of the prior art, it is but necessary, in practicing the present invention, to proportion the pulling force and the opposing force on the work-piece in such ratio that the latter force has the same relation to the former, as the desired finished dimensions of the material bear to the unreduced dimension thereof, and a work-piece of the desired finished dimensions follows as an inherent function of the device. This may be easily effected by connecting the delivery and take-up stations through differential gearing, by hydraulic drives, or by suitable electrical instrumentalities, so that the rates of delivery may be pre-set before the commencement of the operation to provide the desired reduction. The mill is then threaded up and the power applied. All of the various forces are brought into balance to reduce the work-piece the required amount with extreme accuracy. If, during the reducing operation a greater or lesser amount of reduction becomes desirable, this may be effected by adjusting the one simple control to diminish or increase the ratio of the opposing force to the pulling force, respectively.

There are many ancillary advantages accruing to the use of the present invention, such as absolute uniformity of contact between work

rolls and work-piece, and the automatic alignment of the rolls in operation. In many of the embodiments, the work-piece under tension so encircles the rolls as to resist any tendency of the latter to spring, an undesirable condition which provides a work-piece that is thicker at the center than at the edges.

The manner in which the work-piece is disposed about the several rolls is provident of another distinct advantage not enjoyed in conventional rolling or drawing practices. In the present invention the work-piece is subjected to bending stresses as well as to compressive and tensile stresses, which gives an advantage in overcoming the yield point of the work-piece at the points where the necking-down thereof is effected, as compared with conventional reduction operations that subject work-pieces to tensile and compressive stresses in a straight line.

Although the greatest benefits of the invention may be enjoyed by the use of idle work rolls, it is not intended to preclude the use of driven rolls, since many suitable arrangements are possible by the use of driven rolls should this prove to be desirable. It is recognized that to adapt the present invention to tandem operations, powered work rolls would be necessary to assist the passage of the work-piece through such a mill, and tandem operations are within the purview of the present invention. Similarly, although rolls have been used herein, for purposes of illustration, as preferred forms of working instrumentalities, it will be appreciated that other forms of compressive dies may be employed. Further, it is contemplated that proper lubrication shall be provided in all of those operations wherein there occurs a substantial amount of slippage between the work rolls and the work-piece, as is the case in the embodiments illustrated in Figures 1 to 3, etc.

In cases where it is desired to have a compressive force disproportional to the tension, it will be understood that additional pressure may be applied as by screw-downs to the floating roll 2 or roll frame 8—8', shown in Figures 1 to 5, inclusive, in augmentation of the downward component of these members as provided by the tension in the strip. Increasing compressive force is obtainable by permitting the work rolls 1 and 3, in these same figures, to be displaced away from each other against the resistance of heavy springs so that the greater the displacement the greater would be the compression to which such springs would be subjected, giving an increasing compressive force disproportional to the increase in tension causing this action. Similarly, springs, weights, or screw-downs, could be applied to lift the axes of the rolls 13 and 16 in Figure 6, or to draw the axes of the rolls 23 and 24 together so as to provide an augmented compressive force. Similar adaptations could be effected upon the instrumentalities shown in the other views.

In those embodiments providing the floating central roll, it will be understood that suitable vertical guiding means are contemplated to prevent such rollers from lateral displacement, as also are suitable jacks or mill crane appurtenances, for the raising and lowering of such rolls much in the manner of contemporary rolling mill operations.

Although not illustrated in the drawings, it will be appreciated that constant-speed pull-out and pay-off means may be employed between the supply and take-up reels, and the reducing rolls, respectively, to facilitate the constant and uniform tensioning and feeding of the work. This would eliminate from consideration the ever-changing relationship existent between the winding and pay-off reel arbors, occasioned by the stock's unwinding from the latter (thus lessening its effective diameter) and building up on the former (thus increasing its effective diameter).

This purpose may be likewise served by intergearing the pay-off and pull-out reels by automatically compensating fluid, mechanical, or electrical differential mechanism, to the end that, once the device is set, and the reducing operation commenced, the work will be subjected to uniform, constant tension and reducing conditions throughout the entire operation, or until an alteration in the amount of reduction is desired.

Devices for giving effect to this result are so well known in this and related arts as to render more specific illustration thereof superfluous.

It will be understood, therefore, that many modifications of the invention may be made without departing from the scope thereof, and it is not intended that I be limited to the specific embodiment shown, other than as is rendered necessary by the recitations of the appended claims.

I claim:

1. The method of reducing long bodies capable of plastic deformation which includes imposing a tensile stress upon such a body; simultaneously and incident to the imposition of said tensile stress, subjecting a tensioned portion of said body to a compressive stress that is derived from said tensile stress, and effecting relative movement between said body and the points of application of said compressive stress to subject successive tensioned portions of said body thereto.

2. The method of reducing long bodies capable of plastic deformation which includes tensioning such a body while compressing successive portions thereof intermediately of its tensioned extent, and controlling the amount of compression by varying the amount of the tension.

3. The method of reducing long bodies capable of plastic deformation which includes applying tensile and compressive forces to such a body simultaneously and interrelatedly until its yield point has been exceeded, said method being characterized by the fact that the compressive force is derived from the tensile force prevailing in the unreduced portions of the body, and varies directly therewith.

4. The method of reducing long bodies capable of plastic deformation which includes forwarding such a body by a unit pulling force thereupon, resisting said forwarding movement by a force less than unity to tension the material in motion, and compressing successive portions of said moving body intermediately of its tensioned extent by a compressive force which is derived from said resisting force and which varies as said resisting force varies.

5. The method of reducing long bodies capable of plastic deformation which includes forwarding such a body by a unit pulling force thereupon, resisting said forwarding movement by a force less than unity to tension the material in motion, and compressing successive tensioned portions of said moving body by a compressive force applied posteriorly of the point of application of the resisting force which varies as said tension varies.

6. The method of reducing long bodies capable of plastic deformation which includes moving

such a body from a delivery point to a take-up point, fixing the delivery rate of said material at unity, pulling said body toward the take-up point by a force provident of a rate exceeding unity to tension said body, exerting compressive forces upon tensioned portions of said body intermediately of the delivery and take-up points, which forces are derived from the tension and vary in response to variations in the tension, and increasing the pull on the body until its yield point has been exceeded and the desired reduction performed.

7. The method of reducing long bodies capable of plastic deformation which includes tensioning and compressing a body simultaneously, said tension being applied anteriorly of the points of application of the compression, said compression being derived from said tension and varying in response to variations in the tension.

8. The method of reducing long bodies capable of plastic deformation which includes simultaneously imposing tensile and compressive stresses upon such a body, the compressive stress being derived from the tensile stress existing in the body anteriorly of the compression zone so as to vary as the tensile stress varies, increasing said stresses until the combined stresses exceed the yield point of the material which is reduced in thickness thereby, and continuously effecting such reduction upon successive portions of said body lengthwise thereof.

9. Reducing metal strips, wire, and the like, by subjecting successive portions of a length of such material to the action of compressive dies, actuating said dies to compress the material by tensioning it upon its approach side of the dies continuously to reduce the material passing therethrough.

10. In the rolling of metals, the improvement which comprises tensioning the work-piece anteriorly of the rolls, and controlling the rolling pressure by said tension so that the pressure varies as the tension and as a function of the latter.

11. In the rolling of metals, the improvement which comprises passing a work-piece between work rolls, and effecting compression of the work-piece by said rolls by placing the work-piece under tension anteriorly of said rolls; the compression being derived from said tension and varying directly therewith.

12. In the rolling of metals, the improvement which comprises advancing a length of stock through work-rolls by a unit pulling force, resisting the advancement of the stock through said work rolls by a force less than unity to tension the stock anteriorly of the rolls, and causing said work rolls to compress the stock, as a result of the institution of the tension therein, with a force bearing a one to one ratio or greater to the tensile force.

13. In the reduction of metals, the improvement which comprises in moving a length of stock between a movable compressive die element and a relatively stationary compressive die element so that when the stock is tensioned anteriorly of the dies the movable die element is urged toward the stationary element to subject the stock to compressive stress.

14. In the reduction of metals, the improvement which comprises in moving a length of stock between a movable compressive die element and a relatively stationary compressive die element so that when the stock is tensioned anteriorly of the dies the movable die element is urged toward the stationary element to subject the stock to compressive stress, pulling the stock through said die elements by a unit pulling force, and opposing the movement of the stock to said die elements by a force less than unity.

15. In the reduction of metals, the improvement which comprises in moving a length of stock between a movable compressive die element and a relatively stationary compressive die element so that when the stock is tensioned anteriorly of the dies the movable die element is urged toward the stationary element to subject the stock to compressive stress, pulling the stock through said die elements by a unit pulling force, and opposing the movement of the stock to said die elements by a force less than unity, said opposing force being in the same proportion to the pulling force, substantially, as the reduced dimension of the material is to the unreduced dimension thereof.

16. In the reduction of metals, the improvement which includes moving a length of stock between relatively movable compressive die elements so that when the stock is tensioned anteriorly of the dies the die elements are urged together to compress the stock therebetween, tensioning the stock, and effecting relative movement between the stock and die elements to subject successive portions of its length to the compressive action thereof.

17. In the reduction of metals, the improvement which includes disposing a length of stock between relatively movable compressive die elements so that when the stock is tensioned anteriorly of the dies the die elements are urged together to compress the stock therebetween, tensioning the stock, and effecting relative movement between the stock and die elements to subject successive portions of its length to the compressive action thereof, the compressive force exerted upon the stock by said die elements being equal to or greater than the tensile forces by which the stock is tensioned anteriorly of the dies, and varying as the latter vary.

18. Apparatus of the class described, a delivery station; a take-up station; means for tensioning a length of material between said stations; relatively movable compressive dies constructed and arranged to bear upon said material within the tensioned portions thereof actuable in response to the tension to exert a compressive force proportioned to the tension in the material and varying as the latter.

19. Apparatus of the class described, means for tensioning a length of material between two stations along its length; means responsive to the tension in said material and varying as the latter varies for compressing the latter at tensioned portions thereof, and means for moving said material past said last-named means while under tension.

20. Apparatus of the class described comprising means for simultaneously and interdependently tensioning and compressing a metal body, the tensioning means being effective to tension the body anteriorly of the compressing means, and the latter means being actuable in direct response to the anterior tension to compress the material proportionally to the tension.

21. A rolling mill comprising a plurality of relatively movable rolls; means for moving a length of stock in cooperative relation to said rolls under tension; said rolls being constructed and arranged to bear upon said stock with a force at least equal to the tensile force to which the

stock is subjected upon the approach side thereof, and in response thereto.

22. A rolling mill comprising a plurality of relatively movable rolls between some of which stock to be reduced is adapted to pass, and about some of which said stock is passed before and after, respectively, reduction; said mill being characterized by the fact that the compressive force exerted by the rolls upon the stock is a function of tension in the stock which varies as the tension varies.

23. A rolling mill for reducing long lengths of metal stock comprising a plurality of rolls; a mounting for said rolls including means responsive to tension in the stock anteriorly of said rolls for urging the rolls together to compress the stock.

24. A rolling mill for reducing long lengths of metal stock comprising a plurality of rolls journaled on relatively movable axes of revolution; means for moving and tensioning stock in reducing engagement with certain of said rolls, including means responsive to tension in the stock for urging said rolls together to compress the stock; said means allowing the compression of the stock between separate groups of rolls, while effectively maintaining the compressive groups of said rolls, and contiguous portions of the stock under compression, in spaced relation.

25. A rolling mill for reducing long lengths of metal stock comprising a plurality of work rolls; two of said rolls being relatively stationarily journaled; two other of said rolls being adapted for cooperation respectively, with said stationary rolls, and being journaled in a housing movable relative to said stationarily journaled rolls, whereby, when a work-piece is positioned to extend between adjacent portions of the cooperating relatively stationary and movable rolls, respectively, and is tensioned, the movable rolls are urged toward the stationary rolls to compress contiguous portions of the work-piece.

26. A rolling mill for reducing long lengths of metal stock comprising a relatively stationary roll, and a movable roll; a mounting for the movable roll allowing the latter to approach and recede from said stationary roll; and means on said mounting for engaging a work piece in the mill, whereby, when the work-piece is tensioned said means urges the movable roll against the stationary roll to compress contiguous portions of the work-piece.

27. The method of reducing long metal bodies which includes: continuously advancing lengths of such a body to compression means; tensioning the body upon the approach side of the compression means to stress it; compressing said body by said means with a force derived from and proportional to the tensile stress prevalent in the approaching body; increasing the tensile stress to effect simultaneous increase in the compressive force until the coacting stress and force combined exceed the elastic limit of the body an amount sufficient to impart the elongation and reduction in area thereto desired.

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