Jan. 27, 1942. W. M. McCONNELL 2,271,459

ROLLING MILL

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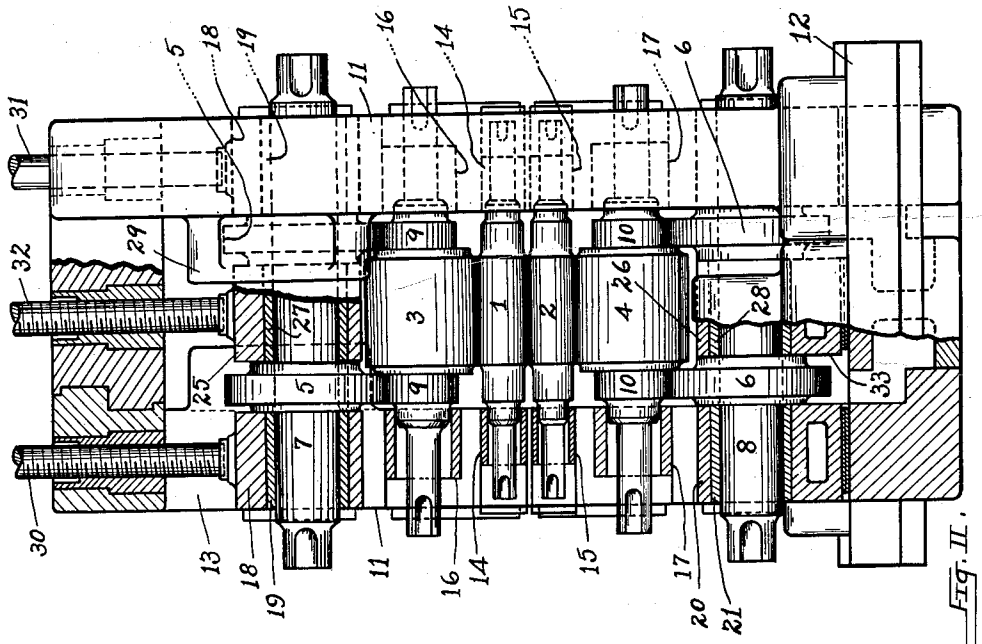


Fig. II.

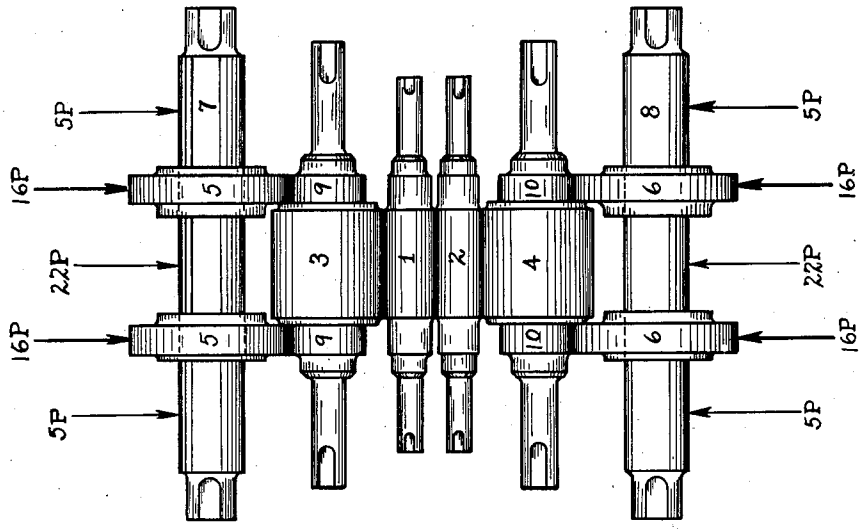


Fig. I.

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Fig. IV.

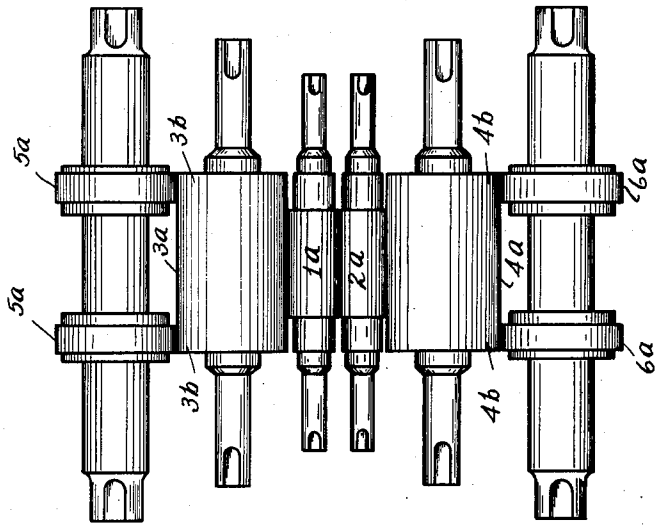
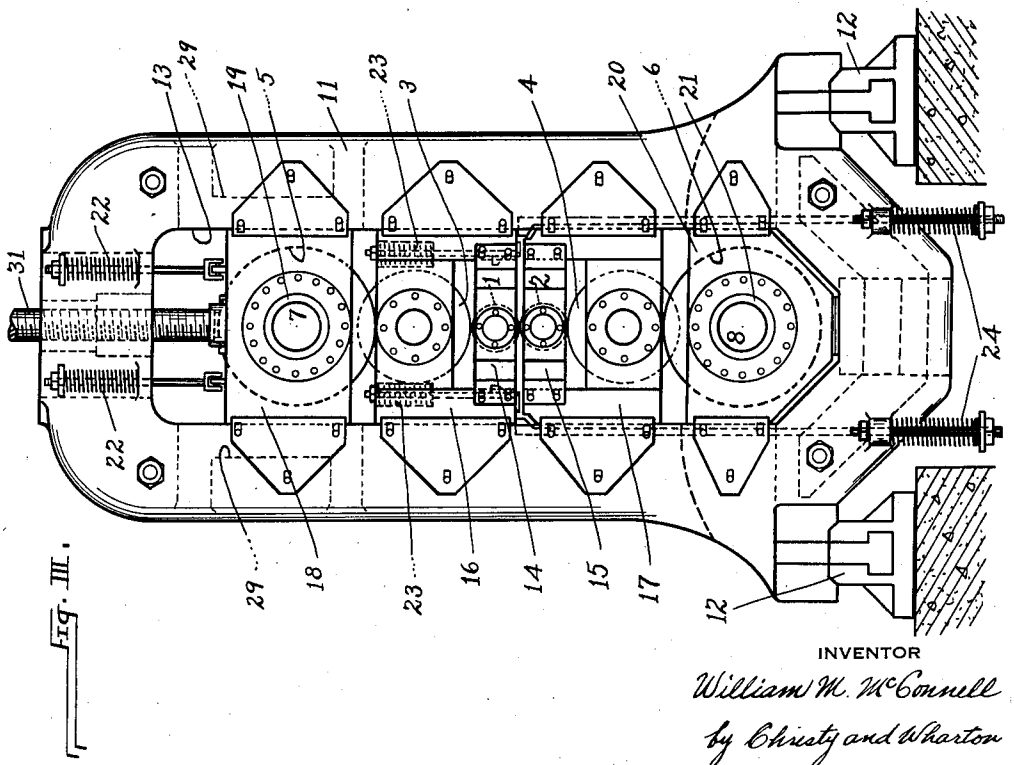


Fig. III.



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ROLLING MILL

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Application June 14, 1939, Serial No. 279,045

8 Claims. (Cl. 80—38)

This invention relates to rolling strip and sheet metal.

In rolling steel strip, or sheet, whether it be hot or cold, and particularly in cold-rolling steel strip in temper mills to a gauge so light that it is usable as deep-drawing stock, rolling pressures are very high. When entering the strip in cold mills, or temper pass mills, it is necessary to start up slowly under load in order accurately to set the gauge of the strip. Also at the end of the coil or strip being rolled, the mill must again slow down. During these intervals rolling pressure becomes excessive and indeterminate. Also during the normal cold rolling of strip and sheet steel, the reaction to the rolling pressure at the two necks of the same back-up roll may vary greatly. This variation may be such that the reaction at one of the roll necks may be as much as four times the reaction at the other, without seriously affecting the gauge to which the stock is rolled. It is, therefore, of importance that rolling mills be capable of sustaining the high rolling pressure incident to such work without deformation or variation of the roll pass, and there is great advantage in having them capable of sustaining pressures even higher than those which heretofore have been attempted.

When rolling strip in 4-high mills in accordance with modern practice, the work rolls are of small diameter, and are supported along their working faces by back-up rolls of greater diameter and weight. In existing 4-high mills the maximum endurable rolling pressure is limited by the strength of the roll necks on the back-up rolls, and by the strength of the bearings associated with the roll necks. Since all the rolling pressure must be transmitted by a back-up roll through the roll neck bearings to the screw-downs, these bearings must not only carry the load caused by the normal rolling pressure of the mill but also must compensate for any abnormal load caused by deflection of the back-up roll neck incidental to the rolling action of the mill on the work.

In service, and this is particularly the case if there be even slight roll misalignment, the necks and bearings of the back-up rolls are subjected to stresses, incident to the high pressures used, which stresses are frequently of a destructive order. Since roll failure has presented a serious problem in strip, and sheet, rolling, it has been attempted to inhibit it by increasing the strength of the roll necks and the anti-friction bearings associated with them. Frequent roll failures have, however, persisted, and it has been found that when either a neck or a bearing fails, its failure is frequently followed by the failure either of the bearing or the neck associated with it. This would appear to indicate that under the exacting conditions of strip and sheet rolling, it is impossible in conventional roll arrangements to provide an adequate balance in the factors of safety of both the necks and bearings of the rolls.

My invention is purposed in a practical manner to make such accommodation to the very high rolling pressures incident to the rolling of strip and sheet steel, and particularly in cold-rolling steel strips and sheets accurately to light gauge, that the bearings and necks of the rolls are both largely relieved of the stresses caused by such pressures, which pressures are assumed by structures designed particularly for the purpose of enduring them without failure. To this end I employ an ultimate backing structure which bears upon a back-up roll of a set, or directly upon a work roll as in the case of a 2-high or 3-high mill, in regions between the roll necks, and outwardly beyond the normal working faces of the work rolls.

In the accompanying drawings I have shown my invention as embodied in a four-high mill, otherwise of conventional structure and arrangement. These drawings, exemplary of my invention, I herein briefly describe as follows:

Fig. I is a diagrammatic elevation of a set, or stand, of rolls together with backing structures constructed, and arranged with the rolls, in accordance with my invention. Fig. II is a view of a rolling mill assembly partly in front elevation and partly in vertical section, showing the mounted arrangement of the set of rolls and backing structures shown in Fig. I. Fig. III is a side elevation of the rolling mill shown in Fig. II. Fig. IV is a front elevation of a set, or stand, of rolls and backing structures similar to Fig. I in its general arrangement, but showing modification in the arrangement of backing rolls and backing structures.

Fig. I illustrates my invention in a stand of two work rolls 1 and 2 against the faces of which bear respectively the faces of the back-up rolls 3 and 4. Upon the back-up rolls 3 and 4, and laterally beyond the contact faces of these rolls, are pairs of wheels 5 and 6. The wheels 5 contact back-up roll 3 on both sides of the median portion in which it is in contact with the face of work roll 1, and the wheels 6 similarly contact the back-up roll 4. The pairs of wheels 5 and 6 are carried respectively on relatively heavy shafts 7 and 8, so that the backing structures

have a general spool shape. For reasons which will appear, the wheels should preferably be made integral with, or otherwise be fixed to, their carrying shafts.

By consideration of Fig. I, it will be seen that the spool-form backing members relieve the necks of the back-up rolls, and their associated bearings, from the rolling pressure sustained by the back-up rolls. These backing members have in the assembly the specialized function of receiving and enduring the high stresses incidental to the rolling pressure, and they are, therefore, specifically adapted to that purpose. Thus the shafts 7 and 8 may be designed for great strength, and a high factor of safety may be provided both in the shafts and in their associated bearings.

The structural arrangement of my spool-shaped backing members tends to distribute reaction to the rolling pressure symmetrically along the beam formed by the shafts and wheels, and provides both end and intermediate bearing spaces of relatively great length, both outwardly of, and between, the wheels. In the assembly shown, in which the bearings and screw-downs are symmetrically located, and equidistant with respect to the pressure transmitting wheels on shafts 7 and 8, the arrangement will tend to balance the rolling pressures on the mill, by tending strongly to centralize reaction to those pressures. In Fig. I of the drawings there is illustrated the relative loads on the wheels and shafts forming the ultimate backing structures, when the rolling pressure is uniform throughout the entire width of the stock being rolled. An inherent characteristic of the backing structure is that it tends, in accordance with the principle of a continuous beam, to centralize reaction to the rolling pressure of the mill. It thus functions also to decrease inequality in reaction to non-uniformly distributed rolling pressure, by its tendency to resolve the reaction toward a central line.

The value of thus centralizing reaction to rolling pressures is most striking when considered in connection with the conditions which exist in the use of a conventional 4-high mill. In such practice there are usually changing and highly unbalanced loads on the opposite necks of each of the back-up rolls, resulting from the reaction of those rolls to the rolling pressures in the mill.

It will be apparent that the backing members relieve the necks and bearings of the back-up rolls both from the normal stresses incident to rolling at high pressure, and also from abnormal stress caused by slight roll deflection or misalignment, or from inequalities in the initial gauge of the stock being rolled. Since in rolling strips and sheets in my apparatus no direct load is carried by the necks of the back-up rolls, or the work rolls, the anti-friction bearings associated with them need only be large enought to take the end thrust, and the sidewise thrust due to the rolling process. The apparatus arrangement reduces to a minimum deflection of the back-up rolls, and hence tends to maintain an accurate-to-gauge pass between the work rolls. That is, the organization is such that the pass between the work rolls is maintained accurate within a very narrow tolerance in resistance to the tendency to deform the pass resulting from marked irregularity in gauge transversely of the strip or sheet being rolled.

As shown in Fig. I of the drawings, the back-up rolls 3 and 4 are shouldered to provide respectively in the two back-up rolls peripheral surfaces 9 and 10, against which the pairs of wheels 5 and 6 respectively bear. There is substantial advantage in such a structure of the back-up rolls, in that it provides a progressive decrease in angular velocity from the work rolls upwardly and downwardly of the roll stand to the shafts 7 and 8. Thus, the work rolls, being of lesser diameter than the back-up rolls, the back-up rolls will be driven less rapidly than the work rolls, and the back-up rolls being formed, as shown, with a diameter less than that of the wheels which they contact, there is a further drop in angular velocity from the back-up rolls to the shafts 7 and 8. This decreased angular velocity further simplifies the bearing problems for the pressure-receiving spools, since the peripheral speed of the shafts 7 and 8 may thus be brought within the range where sleeve bearings are satisfactory. Also if anti-friction bearings are used on the shafts 7 and 8, their capacity and life will be increased.

Whereas it is desirable, and is particularly so under severe working conditions, to stiffen the work rolls by back-up rolls which bear against the work rolls throughout the entire width of their working faces, it is possible for lighter work, or if the work rolls be of unusual stiffness, wholly to omit the back-up rolls, and thus to have the wheels of the pressure-receiving spools bear directly upon the work rolls in zones between the necks and the working faces of the work rolls. In still other arrangements, as in the case of a 3-high mill, the wheels of the pressure-receiving spools may bear directly upon the working faces of the top and bottom rolls in zones between the necks and working faces of the rolls.

Whereas it is desirable that the wheels of each backing structure be fixed on a rotatable shaft; the wheels may be rotatably mounted on a fixed shaft, without sacrificing the principle of pressure centralization, and the relief given the roll necks.

In Figs. II and III of the drawings there is illustrated mounting structure for the roll assembly of Fig. I. The mounting structure shown is preponderantly conventional in its form and arrangement, and comprises roll housings 11 supported by shoes 12 and having therein windows 13. The work rolls 1 and 2 have their necks extended respectively into chocks 14 and 15, and the back-up rolls 3 and 4 have their necks extended respectively into chocks 16 and 17. The necks of the upper spool are carried by chocks 18, each of which is shown as provided with sleeve bearings 19 surrounding the necks of the spools, and the necks of the lower spool are carried by blocks 20 equipped with sleeve bearings 21. Balancing springs 22, 23, and 24, arranged in sets, serve to maintain the rolls in operative contact with each other and with the adjusting means of the assembly. Desirably in large installations, these springs are replaced, in accordance with common practice, by fluid pressure cylinders or counterweights.

The mounting assembly, thus described, is of conventional form and arrangement. There are, however, a chock 25 and a block 26 having respectively sleeve bearings 27 and 28, which are adapted intermediately to support the shaft 7 of the upper spool and the shaft 8 of the lower spool. The bearing block 26 is held against horizontal displacement by a beam structure, 33, which is supported on the mill shoes, 12, and the chock

25 for the upper spool is held against horizontal displacement by means of webs 29 extended from the roll housings 11 at the edges of the windows therein. Screwdowns 30 and 31 bear against the chocks 18, and a third screwdown 32 bears against the chock 25. It is to be understood that power to drive the mill may be directly applied to the work rolls, to the back-up rolls, or to the spools, in the conventional manner, by a suitable pinion stand and drive operating through driving spindles.

Fig. IV of the drawings illustrates a modified arrangement in which the backing rolls are not shouldered. In this modification the wheels 5*a* and 6*a* have contact with the faces of the unshouldered back-up rolls 3*a* and 4*a* in zones 3*b* and 4*b* which lie outwardly of the working faces of the work rolls 1*a* and 2*a*, so that the spool has similarly the effect of straddling the ultimate working faces of the rolls.

It has been explained that great rolling pressure may be endured by the rolls and the backing spools. Because of the distribution and centralization of the reactions to rolling pressures, effected in my stand of rolls (including the backing structures), rolling pressures may be as high as 250,000 pounds for each linear inch of work roll face, and even higher. This is an order of pressure which has not previously been endurable in rolling mills within any practical size limitation. In addition to the advantage in the protection of roll necks and bearings, under loads which have previously been met or approached, and which may be considered to be "normal" pressures, my novel arrangement, because of its ability to withstand "abnormal" pressures and because of its ability to operate at "abnormally" high speed, has utility of a more positive sort.

In cold-rolling strip and sheet steel to the condition of a deep-drawing stock, it has been customary to effect the final reduction, after an annealing operation, in what is known as a "temper pass" under relatively severe pressure and tension. This final rolling results in such structural change in the stock as to adapt it for use as deep-drawing stock. That is, its ultimate yield point is raised and its elastic limit is lowered, permitting the stock to endure without loss of cohesion severe deformation into shapes which it permanently retains. There has been the difficulty that the deep-drawing property of the stock has not been persistent, but that in a relatively short time following a "deadening" operation there will occur such structural rearrangement in the stock that it is not suitable for its intended use, without having more work done on it.

It is, however, a fact that if the stock in temper working be worked with great violence, there is a very great increase in the persistence of deep drawing properties in the stock. While such persistence in deep-drawing properties may be created by hammering, which is a commercially impractical operation for the purpose, it has not previously been possible to obtain it by a commercially practical cold-rolling operation.

I have appreciated that if strip and sheet steel be rolled at abnormally high speed, and under abnormally high pressure, that is, at a speed and under a pressure not previously attempted in the art, persistent deep-drawing qualities might be obtained; and have found in my roll organization, above described, an instrumentality capable, in commercially practical manner, of imparting to the stock persistence in deep drawing properties in such order that the stock may properly be considered to be a novel commercial product. That is, the order of violence in working which is obtainable by heavy hammer blows must be approached in rolling in order commercially to obtain a persistence in deep-drawing properties analogous to that attainable under a hammer.

It is to be understood that the word "violence" as I above use the term, is descriptive of time-qualified reduction in the stock, or otherwise expressed, it is descriptive of a measure of reduction in the stock as one component and the rate at which the reduction is effected as another component. I have found in rolling, and the analogy to hammer action is here yet pertinent, that the greater the violence with which the reduction is effected, the more persistent will be the deep-drawing qualities of the stock. When the working (i. e. the violence of reduction) is increased well beyond that effected in normal practice, the results are striking. For example, by subjecting the stock to a temper-rolling at a rolling pressure of 200,000 lbs. per linear inch of work roll face and at a speed of 2500 ft. of the stock per minute through the work rolls, the deep-drawing properties of the stock persist for many times the persistence period of stock rolled under the conditions previously employed commercially. Also the proportional permanent retention of deep-drawing properties is far greater than has been obtained in previous commercial practice.

The pressure endurable by my novel roll organization, and we now consider it as a usable instrumentality to provide a temper pass for deep-drawing stock, has been above given and explained. Now to consider the angular velocity of the rolls and backing structures with relation to high speed of the stock through the rolls, with the organization shown in Fig. I of the drawings the work rolls may be driven at an angular velocity of at least 500 R. P. M. to 600 R. P. M., while keeping the angular velocity of the backing spools no higher than between 100 R. P. M. and 150 R. P. M., a speed readily endurable by the backing-spool bearings. As used in a temper pass and with a diameter of the work rolls in the proportion shown, the stock may be rolled at a speed at least approaching 3,000 feet a minute.

Taking into consideration the necessity for proper "bite" of the work rolls with respect to the gauge of the stock which is to be rolled, and the desirability of avoiding excessive height of the mill housings, the contact diameters of the several elements of the roll stand may be so related as to give much higher rolling speed without increasing the angular velocity of the backing spools beyond the point of satisfactory operation.

In speaking of "abnormal" loads, and "abnormal" speed, it may be stated that loads of as much as 150,000 pounds per linear inch have been considered to be higher than normal in temper mills, and it has not been previously attempted to provide temper mills capable of enduring so high a load. Also travel of the strip or sheet steel through temper mills has not previously been attempted at a speed as high as 1500 feet per minute.

It is to be understood that the terms "wheel" and "spool" or "spool-form," as herein used, are terms of description and not of limitation, used for the convenience in description which they provide, and without intent by their use to limit the specification and claims specifically to structure illustrated and described. Without elaboration in description or explanation, the principles

of my invention, and the disclosed embodiment of such principles in novel and useful method and apparatus, will be clear to those skilled in the art to which my invention relates. Several modifications in the structure and arrangement of stands of rolls embodying my invention have been above noted. Another suggested modification, applying more particularly to structure associated with the load-sustaining spools, would be to provide a set of screw-downs in association with the lower spool of the assembly like the set shown and described in association with the upper load-sustaining spool of the assembly. Numerous other modifications will occur to those skilled in the art of metal rolling, within the scope of my invention, as hereinabove explained and as defined in the appended claims.

I claim as my invention:

1. For incorporation in a roll stand as a structure ultimately receiving and reacting to rolling pressure therein, a spool-form element composed of a continuous shaft and laterally spaced-apart wheels on said shaft, said shaft having bearing spaces laterally beyond each of the wheels and between the said wheels, and bearings for rotatably supporting the said spool form element mounted in each of the said bearing spaces.

2. In a roll assembly the combination of a mounted set, or stand, of rolls, and two load-sustaining structures, one rotatably in contact with the uppermost roll of the set and one rotatably in contact with the lowermost roll thereof, both said load-sustaining structures being constructed and arranged in contact with the rolls of the set at two spaced points beyond the work faces of the rolls, and load-distributing structures mounted in the mounting structure of the said set or stand of rolls and bearing at three spaced points on each of the said load-sustaining structures so that the said load-sustaining structures are enabled to function as continuous beams.

3. In a roll assembly the combination of a pair of work rolls, a pair of back-up rolls in face-to-face contact with said work rolls, and two load-sustaining spools each composed of a continuous shaft and having two laterally spaced apart wheels thereon constructed and arranged each to bear against one of the back-up rolls in two laterally spaced zones outwardly beyond the contact faces of the work rolls; the relative contact diameter of the work rolls with respect to that of the back-up rolls and the relative contact diameter of the back-up rolls with respect to that of the spools being so apportioned as to give a reduction in angular velocity from the work rolls to the back-up rolls and from the back-up rolls to the spools in operation of the assembly.

4. In a roll assembly the combination of a set, or stand, of rolls, two load-sustaining spools each composed of a continuous shaft having laterally spaced apart roll contacting wheels thereon, and bearings around the shaft of each of the two said spools at the ends of the said shaft and in the region of the said spaced apart wheels.

5. In a rolling mill, a housing structure, a rolling assembly including in combination a set, or stand, of rolls, two load-sustaining spools, each composed of a continuous shaft having laterally spaced apart roll-contacting wheels thereon, bearings arranged at both ends of each said shaft and in the region of the said wheels thereon for supporting the said spools rotatably to contact one the uppermost and one the lowermost roll of the set or stand, and load-distributing structures mounted in the said housing structure and arranged to receive and distribute the reaction to the rolling load in the several spaced bearings associated with each of the said spools.

6. In a rolling mill, a housing structure, a rolling assembly including in combination a set, or stand, of rolls, two load-sustaining spools, each composed of a continuous shaft having laterally spaced apart roll-contacting wheels thereon, bearings arranged at both ends of each said shaft and in the region of the said wheels thereon for supporting the said spools rotatably to contact one the uppermost and one the lowermost roll of the said set or stand, and load-distributing structures mounted in the said housing structure and arranged to receive and distribute the reaction to the rolling load in the several spaced bearings associated with each of the said spools, the load-distributing structures associated with at least one of the said spools being regulable in their load-distributing effect.

7. In a rolling mill, a housing structure, a rolling assembly including in combination a set, or stand, of rolls, two load-sustaining spools, each composed of a continuous shaft having laterally spaced apart roll-contacting wheels thereon, bearings arranged at both ends of each said shaft and in the region of the said wheels thereon for supporting the said spools rotatably to contact one the uppermost and one the lowermost roll of the set or stand, and load-distributing structures mounted in the said housing structure and arranged to receive and distribute the reaction to the rolling load in the several spaced bearings associated with each of the said spools, the load-distributing structures associated with at least one of the said spools being composed of chocks embracing each one of the bearings on the spool and adjusting screws mounted in the housing structure of the rolling mill and connected with the said chocks.

8. For incorporation in a roll stand as a structure ultimately receiving and reacting to rolling pressure therein, a spool-form element composed of a continuous shaft and laterally spaced-apart wheels on said shaft, said spool-form element having bearing spaces around the said shaft at the ends thereof and in the region of the said wheels, and bearings for rotatably supporting the said spool-form element mounted in each of the said bearing spaces.

WILLIAM M. McCONNELL.