This invention relates to a load cell and stretch forming machine combination and particularly to a load cell for the purpose of controlling the tension applied to a length of stock being stretch-formed about a rotary die. One of the principal objects of the present invention is to provide a load cell so mounted that it is maintained substantially free from stresses and strains of any nature except those directed axially of the load cell itself.

Another object is to provide a load cell comprising two members movable relatively toward and away from each other and so interconnected in spaced locations along their length that they are constrained from movement relative to each other in all directions transversely of their length, but have negligible resistance to movement for short distances in at least one direction lengthwise, and an elastically deformable load element operatively connected at its opposite ends to the members so as to be deformed thereby upon relative movement of the members in the one direction, with means at the ends of the members for connecting the members to force applying means of which the applied force is to be sensed.

Another object of the invention is to provide a load cell which is especially adapted for use in connection with stretch forming machines in which stock is stretch-formed about a side face die.

Still another object is to provide, in such a machine, a stretch forming assemblage for stretch forming stock and a load cell so combined as to provide advantages in intensity of the signal obtained and to limit the signals substantially to those due to components of force parallel to the length of the load cell.

Other objects and advantages will become apparent from the following description wherein reference is made to the drawings, in which:

FIGS. 1, 2, and 3 are a top plan view, side elevation, and a vertical sectional view taken on line 3--3 of FIG. 2, respectively, showing a stretch forming machine and load cell combination of the present invention;

FIG. 4 is an enlarged fragmentary top plan view of a portion of the present machine with the load cell of the present invention installed;

FIG 5 is a fragmentary enlarged side elevation of the structure illustrated in FIG. 4, part thereof being shown in section for clearness in illustration;

FIG. 6 is a vertical cross sectional view taken on the line 6--6 of FIG. 4; and

FIGS. 7, 8, and 9 are vertical cross sectional views, respectively, taken on lines 7--7, 8--8, and 9--9, respectively of FIG. 5.

Referring to the drawings, the load cell is shown as combined with a stretch forming machine of a general character shown in United States Letters Patent No. 2,514,830, issued to Cyril J. Bath on July 11, 1950, but modified to obtain the full advantage of the combination of a machine of this type with the present load cell.

The machine shown for purposes of illustration is one such as disclosed in the copending application of George H. Perkins, Serial No. 792,304, filed February 10, 1959, now Patent No. 2,974,707, and comprises a longitudinal frame 1 on which a turntable 2 is mounted for rotation about an upright axis 3. The turntable 2 is driven through a ring gear 4 coaxial therewith, a driving gear 5, a reduced speed gear transmission 6, a secondary gear transmission 7, and a pair of hydraulic motors 8 to which pressure fluid is supplied by a variable delivery pump 9, driven by a motor 10, so that the speed of the table 2 can be accurately controlled.

Mounted on the frame 1 is a stretch forming piston and cylinder assemblage 12 comprising a reciprocable carriage 13 driven by a double ended piston 14 having rods 15 and 16, respectively, and reciprocable in a cylinder 17. The ends of the rods 15 and 16 are fixedly connected to the frame 1, as indicated at 18 and 19. The cylinder 17 is secured to the carriage 13 for movement therewith longitudinally of the frame 1 and extending parallel to the path of movement of the carriage. In order to allow for any possible misalignment of the carriage and cylinder, the cylinder is connected to the carriage for limited relative rocking movement to permit compensation for irregularities in the carriage trackway.

For this purpose, a suitable bracket 20 is fixedly connected to the cylinder 17 and to frame rods 21 is connected to a fitting 22 which, in turn, is connected to the carriage 13 so that at the point of connection of the carriage and fitting, they can rock relative to each other about horizontal axes.

The carriage 13 is mounted on the frame on suitable trackways 25 and 26 by means of rollers 27 and 28, the rollers 27 rolling on top of the trackway 25 and rollers 28 rolling on the underside of the trackway 26, so as to prevent tilting of the carriage, about an axis extending transversely of its path, by the longitudinal pull imposed on the carriage by the stock being stretch formed.

In order to supply pressure fluid to the carriage 13, so as to yieldably resist movement thereof toward the turntable 2 during the stretch forming of the stock as it is wrapped on the forming die from a source located on the carriage 13 and may comprise a hydraulic pump 30 driven by a motor 31. The pump is connected to the cylinder 17 at opposite sides of the piston 34 through suitable conduits and a conventional remote control reversing valve by which, in selected positions, the fluid supplied by the pump 30 can be supplied to either end of the cylinder, selectively, or, blocked so as to prevent supply of pressure fluid to the cylinder while connecting the ends of the cylinder to each other.

Since the cylinder is exceedingly long, it is desirable that it be supported for movement longitudinally of the frame 1. For this purpose, the cylinder 17 is provided at the end adjacent the carriage with a yoke 32 which, at its ends, has rollers 33 which ride on suitable trackways 34 extending longitudinally of the frame. At its opposite end, the cylinder has a roller 35 which is arranged to ride on a track 36 extending longitudinally of the frame. As mentioned, the piston rods 15 and 16 of the assemblage are fixedly connected at each end to the frame 1. Thus, by admitting fluid pressure to opposite ends of the cylinder, the carriage 13 and cylinder 17 can be reciprocated as a unit lengthwise of the frame 1.

For completing the stretch forming assemblage, a tension means, an extended arm 40 is mounted on the carriage for swinging about an axis parallel to the axis of the table. One end of the arm is connected to the carriage 13 by an upright post 41 so that the arm can swing about the upright axis of the post 41. The arm 40 extends from its pivotal connection with the post 41 back in the direction toward the table 2 and is relatively long. As its forward end the arm 40 is supported on suitable slide pads 42 and 43, respectively, so as to relieve the arm from binding stresses.
Further, positioning rollers 45 are arranged to reduce friction and maintain the carriage in proper alignment transversely of the frame I. Carried on the end of the arm 40 which is the nearer to the table is a stretch forming head 46 adapted to engage one end of a length of stock for applying tension thereto endwise. The arm 40 is movable along with the head 46 toward and away from the table 2 while such movement is resisted by yieldable resisting force due to the pressure fluid supplied to the cylinder 17 from the pump 9.

Mounted on the table for movement therewith is a clamp 47 which is adapted to engage the opposite end of the stock and hold it in fixed relation to the side face die D.

In the stretch forming of the stock with the structure above described, one end of the length of stock is secured to the clamp 47 for rotation in fixed position relative to the die D. The opposite end of the length of stock is gripped by the head 46. Accordingly, when tension is applied to the stock 5 by rotation of the table, the wrapping of the stock on the die D is opposed by the arm 40 which moves endwise relatively toward the table while being resisted by predetermined tensioning force as a result of the ram 12. The arm 40 is elongated and extends from its pivotal connection with the post 41 back toward the table 2 a substantial distance and, as mentioned, the end of the arm which is nearer the table is supported on suitable slide plates or slid plates 42 and 43.

As disclosed in U.S. Patent No. 2,549,048, issued August 26, 1948, it is desirable to control the tension applied endwise of the stock by signals derived from a suitable load cell responsive to the endwise tension applied to the stock. Furthermore, it is desirable that this load cell be subjected substantially only to force components directed endwise of the stock and be substantially free from any force components directed transversely of the stock.

For this purpose, the load cell of the present invention is provided, the use of this load cell being made particularly effective by the elongated arm 40. The specific details of the load cell and arm are best illustrated in FIGS. 5 through 9, to which reference is now made.

The arm 40 is an elongated rigid structure which may be in the form of two oppositely facing channels 50 disposed with their open sides toward each other and held in rigidly fixed spaced relation to each other by suitable tie bolt 58 and spacing sleeves 53, or otherwise. At the end of the arm 40, attached to the post 41, the channels 50 are welded to a suitable sleeve 53. The arm is further reinforced at the top by means of a tie plate 54a which extends part way from the sleeve 53 toward the free end of the arm, and at the bottom by a plate 54b which extends the full length of the channel members 50. To the underside of the plate 54b, near the free end of the arm, the skid pad 42 is secured.

Carried on the arm 40 is a suspended arm 55 which is supported in laterally spaced telescopic relation to the arm 40 midway between its channels 50 by suitable tension isolation supporting means which constrain the suspended arm 55 from movement in all directions transversely relative to the arm 40, but which permit the arm 55 to move a limited amount linearly of the arms while resisted only by negligible flexure of the supporting means and while free from any frictional binding forces. The arm 55 is shown as a rigid I-beam. A gripping head support 56 is secured to that end of the arm 55 which is closer to the table and is adapted to support the stretch forming head 46. By this arrangement, any pull exerted on the stock is applied by the head 46 directly to the arm 55 and urges it generally endwise relative to the arms 40 and 55.

A very simple and effective tension isolation supporting means for providing this suspension comprises a plurality of sets of tie bolts, the tie bolts 58 of one set being arranged in a rectangular pattern, one at each corner of the arm 55, and the tie bolts 59 of the other set being correspondingly arranged. Each of the tie bolts 58 is arranged in the same manner as the other tie bolts 58 with respect to the arms, and each tie bolt 59 is arranged in the same manner as the other tie bolts 59 with respect to the arms, only one of each set of tie bolts is described herein in detail.

Each tie bolt 58 is connected at its threaded lower end to the lower flange of the arm 55 and extends upwardly therethrough as shown in FIG. 6 in the upper flange of one of the channels 40, with radial clearance. At its upper end the bolt carries a suitably washer 62 which is disposed between the head 63 of the bolt and the upper surface of the upper flange of the associated channel 50. Normally, when the arms are unstrained, the bolt 58 is preloaded and thereby under tension tending to urge the arm 55 upwardly. Thus, the arm 55 is urged upwardly by a similar bolt 58 arranged one near each of the corners of the arm 55.

Each of the bolts 59 is connected at its threaded lower end to the arm 40 and extends, with radial clearance, therethrough as shown in FIG. 6 in the lower flange of the arm 55, through a passage 67 in the upper flange of the arm 40, and through a passage 68 in the upper flange of the arm 55. The bolt 59 carries at its upper end a nut 69 between which and the upper surface of the upper flange of the arm 55, a suitable gasket 70 is interposed. Thus, when the bolts 59 are tightened and are under tension, they urge the arm 55 downwardly at each of its four corners.

As mentioned, each of the bolts 58 has a screw threaded lower end in engagement with the arm 55 and each of the bolts 59 has a screw threaded lower end in engagement with the arm 40. Further, the bolts have welded thereto, respectively, nuts 71 which are accessible through windows 72 in the arm 40 so that the bolts can be tightened readily to adjust their tension and to facilitate installation.

By this arrangement the arm 55 is tensionally suspended but is free to move axially or endwise a short distance by a transverse flexure of bolts 58 and 59 and thus without frictional resistance. Since this movement is very slight, the bolts offer substantially no resistance to such flexure.

Due to the clearance between the bolts 58 and arm 40 at the passage 61, and to the clearance between the bolts 59 and arm 55 at the passages 66 and 68, and between bolts 59 and arm 40 at the passage 67, neither the bolts 59 nor the bolts 58 can be placed under compression by movement of the arm 55 by extraneous forces in the direction in which it is urged by the tension of the particular bolt. Any tendency toward compression of the bolts 58 by lifting arm 55 is relieved by its head 63 being lifted thereby from the arm 40. Any tendency toward compression of the bolts 59 by pulling downwardly on the arm 55 is relieved by its head 69 being lifted thereby from the arm 55. Thus the arms 40 and 55 are held by the bolts in tensioned equilibrium in their normal laterally spaced relation.

Due to the side face of the die, the arm 40 often must swing about the post 41 under the tension applied to the stock to maintain its alignment with the stock, and hence lateral forces are imposed on the arm 55 which must be transmitted to the arm 40 without imposing any stresses on the load cell which is to be connected between the two arms. For this purpose, transverse bolts 73 are connected to the arm 55 at their inner ends and at their outer ends engage the outer faces of the channels 50. These bolts likewise are placed under tension by preloading and, since they extend directly transversely of the arms, any forces applied tending to pull the members 55 laterally relative to the arm 40 are resisted by direct
tension on the bolts 73. The bolts 73 are readily flexible transversely of their axes. Thus the arm 55 is substantially immovable transversely relative to the arm 40 but is readily movable endwise of the arm 40 by mere flexure of the elongated bolts 58 and 59 and the small diameter tie bolts 73, transversely of their axes.

In order to obtain a signal, a load cell is connected to the arms 40 and 55 so as to be responsive to the relative movement of the arms endwise. For this purpose, a block 75 is fixedly connected to the arm 40 by heavy transverse pins 76 so as to be movable with the arm 40 as a unitary structure. The web of the arm 55 is slotted endwise from its free end so as to provide clearance, as indicated at 77, between the block 75 and the arm 55 so that there is no frictional engagement therebetween.

The load cell or tension member 78 may be in the form of a bar of metal of accurate cross section. It is connected at one end by a pin 79 to the block 75 of the arm 40 and at the other end by a pin 80 to the arm 55 near the support 56. As a result, any pull exerted on the arm 44 by the stretch head 46 is transmitted to the arm 40 through the load cell 78. The load cell is relieved from any transverse and frictional forces due to the bolts 58, 59, and 73. Accordingly, the load cell 78 is responsive substantially only to tension forces directed endwise of the arms, and hence lengthwise of the stock but is subject to the full lengthwise force because the flexure of the rods offers negligible resistance.

As a safety precaution, in event of accidental slipping of the bolt cell 78, an adjustable abutment in the form of a bolt 82 is threadably connected to a suitable sleeve portion 83 fixed on the arm 55 for movement with the arm 55. This bolt is arranged so that its end facing toward the stretch forming head can engage the block 75 which is connected to the arm 40 and thereby arrest movement of the head and the arm 55 endwise relative to the arm 40. Since the normal relative movement of the arms endwise, while the arms are connected by the load cell, are only a few thousandths of an inch, the bolt 82 is set so that the clearance between it and the block 75 is only slightly more than that amount of movement of the arm 55 endwise. Should the load cell break, there can be little axial or endwise relative movement of the arms 40 and 55 before the bolt cell begins to function, thus relieving the parts from excess impact stresses and strains.

In the form illustrated, a suitable tension device 85 is connected to the load cell 78 and is responsive to the elongation of the load cell under stress and thereby reflects the tension being applied to the stock. The signal thus reflected is an extremely accurate signal inasmuch as all frictional binding forces are eliminated and the cell is subjected only to true tension forces directed endwise of the stock.

Any forces transversely of the arms are initially greatly reduced because of the fact that the arm 40 is extremely long and consequently any lateral forces applied to the stretching head by the stock and tending to swing the arm 40 transversely have a substantial mechanical advantage over the frictional forces imposed by the post 41, and hence can swing the arm readily, particularly as the outer end of the arm is well supported on slip pads such as heretofore described. Thus binding stresses resisting swinging of the arm also are greatly reduced.

The strain gauge may be of the so-called patch type, such as disclosed in United States Patent No. 2,649,049, issued August 26, 1956, identified above, or it may be of the transducer or other type.

The signal derived from the signal device may be an electric signal which, in turn, is fed to a conventional tension control unit, such as described in the above identified patent, and which controls the supply of pressure fluid to the stretch forming cylinder in accordance with the reflected signal in the manner set forth therein, and thus maintains the desired tension on the stock.

Having thus described our invention, we claim:
1. A load cell comprising a pair of elongated rigid arm members, tension isolation supporting means connecting the members together at spaced locations along their lengths in telescopic and laterally spaced parallel relation to each other and constraining the members from movement relative to each other in all directions transversely of the lengths of the members while permitting them relatively free movement relative to each other for short distances lengthwise of the members, an elastically deformable tension strain element operatively connected at its ends to the members, respectively, so as to be elastically deformed lengthwise of the members upon said movement of the members lengthwise in one direction, means at the ends of the members, respectively, for connecting the members to force applying members so as to urge the members lengthwise relative to each other in said one direction, said tension isolation supporting means comprising a plurality of elongated, relatively stiff, tensioning elements arranged in groups, one group near each end of the telescoped members, the elements of each group extending generally transversely of the length of the members, each element being operatively connected at one end to one of the members and at the other end to the other of the members, said elements being pre-loaded for applying radial tension directed transversely of the members in directions such that the components of tensioning force of the elements of each group hold the members in tensioned equilibrium transversely of their length in the laterally spaced parallel relation of the members, and constrain the members from substantially relative movement transversely of their length under components of force extraneously applied to one of the members transversely of the length of the members, and each element having negligible resistance to flexure a slight distance transversely of its axis.
2. A load cell according to claim 1 wherein all of the elements are parallel to a plane normal to the lengthwise path of relative movement of the members.
3. A load cell according to claim 2 wherein said elements are relatively straight, metal rods.
4. A load cell according to claim 1 wherein each group comprises two sets of elements, and the axes of the elements of one set define an upright plane, the axes of the elements of the other set define an upright plane parallel to the first mentioned plane and offset therefrom lengthwise of the members, and the axes of the elements of one set extend in a direction at right angles to the axes of the elements of the other set.
5. A load cell according to claim 4 wherein the axes of the elements of said one set are upright and the axes of the elements of the other set are horizontal.
6. A load cell according to claim 1 wherein at least two elements of each group are upright, one for resisting, by tension, movement of one of the members upwardly, and the other for resisting, by tension, movement of said one of the members downwardly, and the connection of each element to the members affords free axial movement of the element relative to at least one of the members when the members are moved by an extraneous force relative to each other in the direction in which urged by said element, whereby the elements operate free from axial compression.
7. A load cell according to claim 6 wherein said one upright element is secured at its upper end to the upper portion of said one member and to the lower portion of the other member, the other of the upright elements is secured at its upper end to said other of the members.
and at its lower end to said one of the members, and each element is connected to at least one of its associated members by extending through a passage therein and is freely movable axially in the passage, and has a portion resting against a face portion of said one associated member facing away from the direction of tension, and is free for movement outwardly from said face upon release of the tension.

8. A load cell according to claim 1 wherein each group comprises two upright elements spaced apart transversely of the members for resisting, by tension, movement of one of the members upwardly, and two additional upright elements spaced apart from each other transversely of the members, and spaced endwise of the members from the first mentioned two members, for resisting, by tension, movement of said one of the members downwardly.

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