

Oct. 19, 1971

R. W. DENT ET AL

3,613,445

FABRIC CHARACTERIZING APPARATUS

Filed Dec. 3, 1969

2 Sheets-Sheet 1

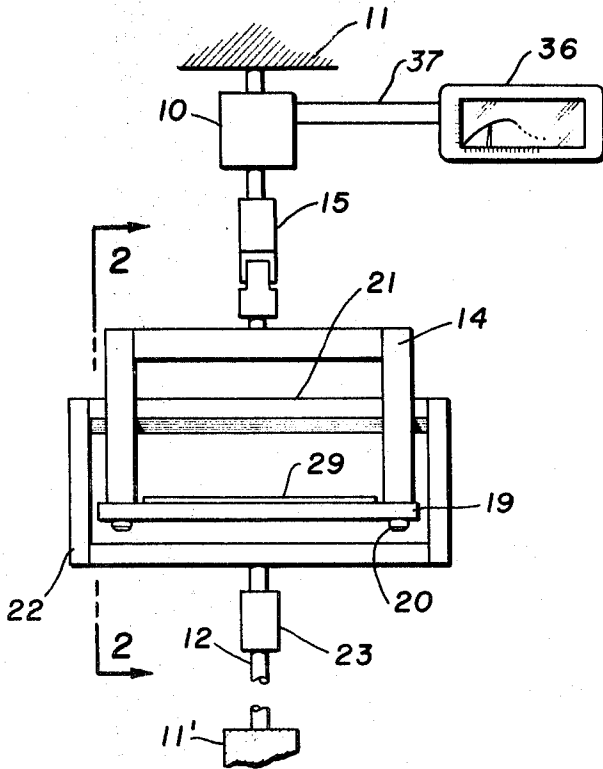


FIG. 1.

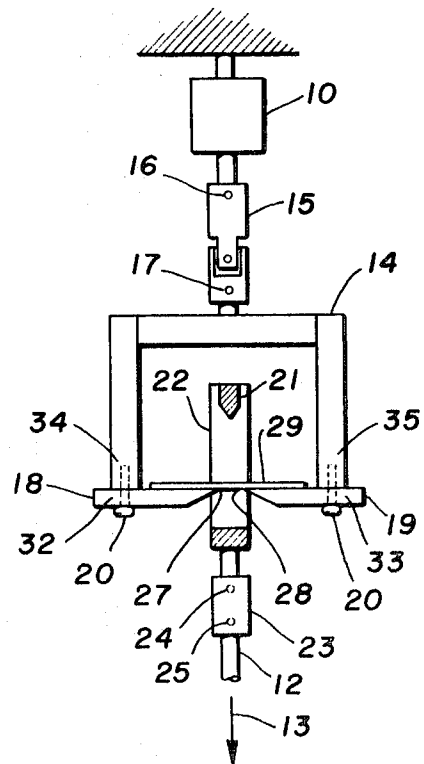


FIG. 2.

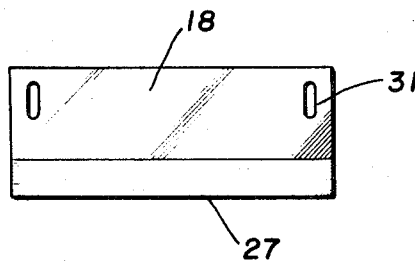


FIG. 3.

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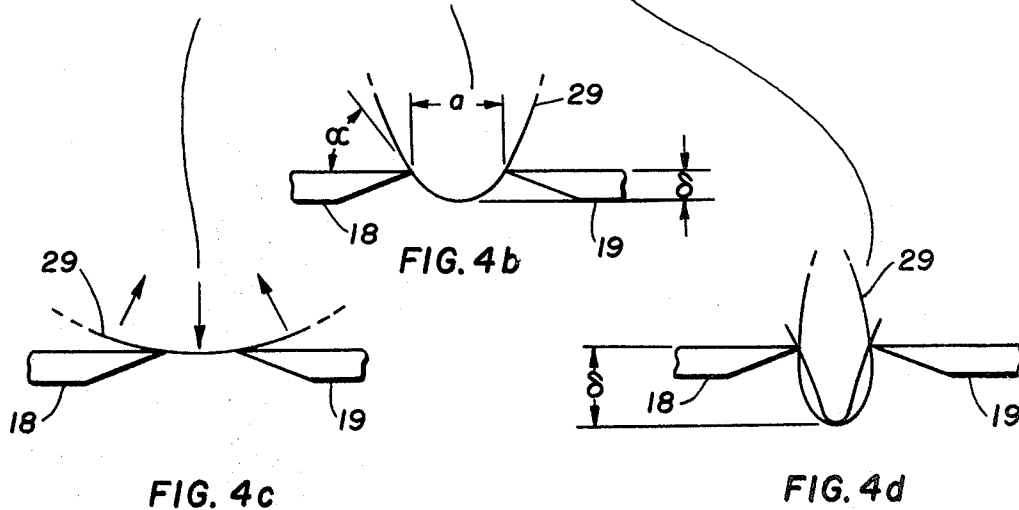
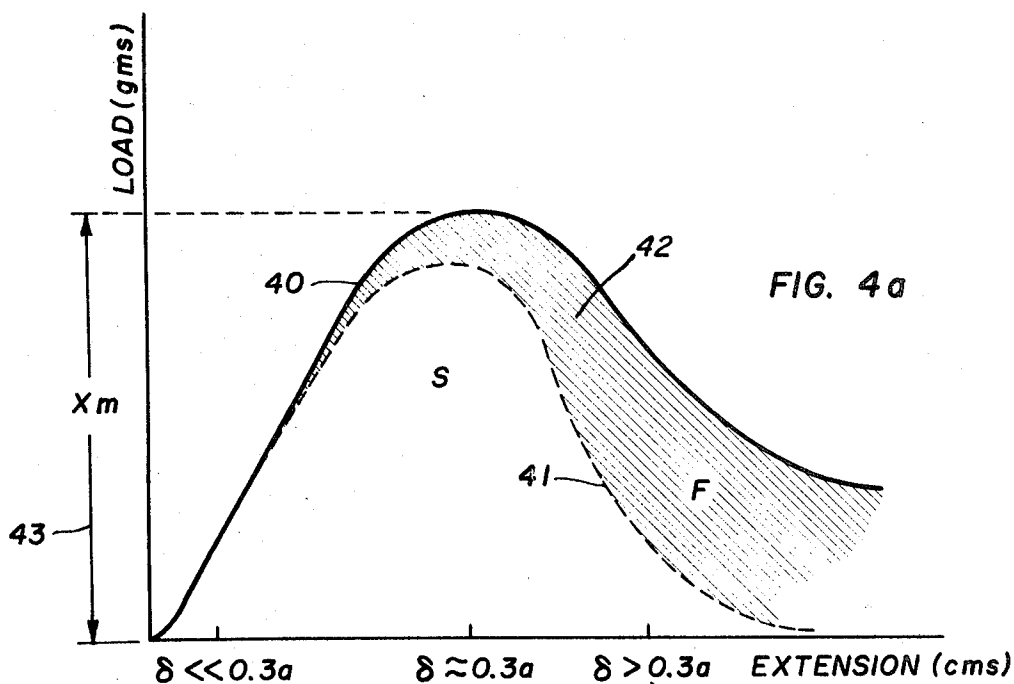
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FABRIC CHARACTERIZING APPARATUS

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2 Sheets-Sheet 2



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FABRIC CHARACTERIZING APPARATUS

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Filed Dec. 3, 1969, Ser. No. 881,790

Int. Cl. G011 5/10

U.S. Cl. 73—159

3 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus and method for determining the roughness and stiffness components of the hand of a fabric from a load-extension curve are provided. The test fabric is forced vertically downward through a slot at a constant speed for a distance which is at least greater than one-half the width of the slot. A signal is generated in proportional response to the load incurred in moving the fabric into and through the slot while simultaneously measuring the distance through which the fabric moves. A load-extension curve is generated by plotting the signal as a function of the distance. Smoothness and stiffness (as well as "hand") are obtained from this curve.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to an apparatus and method for determining the hand of a fabric. More particularly, the present invention relates to an apparatus and method for determining the roughness and stiffness components of the hand of a fabric.

Discussion of the prior art

The feel or "hand" of fabrics is of great interest to paper and textile manufacturers due to their need to maintain quality production standards. Some of the early attempts to maintain production standards utilized experienced individuals who handled the fabrics and, from the field, determined the degree in which the desired qualities such as, for example, softness were present. The inconsistencies that resulted in this subjective approach are self-evident, since opinions as to hand determined from the feel of the fabric obviously would vary between individuals. The large margins of error made it extremely difficult to maintain the desired standards of quality control.

More recently the subjective approach has been replaced by an objective one due to the development of various devices which can provide a numerical value for hand. The devices have been highly successful as they have enabled manufacturers to maintain a reasonable consistency and reproducibility in the manufacture of paper and textile fabrics, particularly non-woven fabrics.

One of the more successful devices is one in which a sample fabric is pushed through a slot in a fabric supporting table. The maximum load necessary to push the fabric a predetermined distance through the slot is measured by a means such as strain gauge. The fabric is then assigned a numerical value related to the measured load. The numerical values which are assigned the various fabrics provide relative indications of the hands of each and thus make it possible to consistently reproduce fabrics having substantially the same hand.

Further refinements in the manufacture of paper and textile fabrics have dictated a need for a more complete description or characterization of fabrics. That is, it is desirable to determine those parameters which determine hand. For the most part, hand depends primarily upon the stiffness and roughness of a fabric. Generally, the devices of the prior art while quickly determining that one

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fabric has a different hand from another do not indicate whether the difference between the two is due mainly to roughness, stiffness or a combination of the two. It is therefore a primary object of this present invention to provide for an apparatus which determines the values necessary to define both roughness and stiffness of various textile fabrics and papers.

BRIEF DESCRIPTION OF THE PRESENT INVENTION

When a fabric sample is forced through a slot by a contacting means, two factors affect the movement of the means through the slot, flexibility (stiffness) and surface friction. A stiff fabric resists the motion of the contacting means more than a flexible fabric; a rough fabric resists being dragged over the edge of the slot more than a smooth fabric. Some of the prior art devices detect the combination of the two resistances with a means such as a load cell which register the resulting load on a calibrated meter. The number read off the meter represents a value which may be assigned to the sample fabric as its hand value or index.

It has been noted, however, that both a roughness and a stiffness index may be determined for a given fabric sample from a load-extension curve generated in accordance with the present invention. These indices make it very easy to characterize a multiplicity of fabrics as to roughness and stiffness. The advantages of such characterization are readily evident, particularly, when two fabrics may have approximately the same hand but different roughness and stiffness parameters.

Briefly, the present invention comprises a support means having a surface for supporting a fabric to be tested. The surface of the support means has a slot which is necessarily longer than the width of the fabric to be tested. Positioned above the slot is a means for contacting the fabric and forcing it through the slot a distance preferably greater than the width of the slot. The contacting means is constrained to move vertically downward at an essentially constant speed along a line which is substantially perpendicular to the surface and passes through the center line of the slot. Attached or coupled to the contacting means is a load cell which measures the load required to push the fabric through the slot. A recording means electrically connected to the load cell of the contacting means records the output signal generated by the load cell as the force required to push the fabric through the slot, thereby generating a load extension curve. The load extension curve as detailed more explicitly hereafter is readily resolved into roughness and stiffness indices.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention which are desired to be protected are pointed out with particularly in the appended claims. The invention itself, together with further objects and advantages thereof, may be best understood with reference to the following description taken in connection with the appended drawings in which:

FIG. 1 is a side view of a fabric evaluation apparatus in accordance with the present invention.

FIG. 2 is a partial section of the apparatus taken along line 2—2 of FIG. 1.

FIG. 3 is a plan view of one of the adjustable fabric supporting plates seen in FIGS. 1 and 2.

FIG. 4 is a graph of a typical load-extension curve generated by the apparatus of FIG. 1.

FIGS. 4b, 4c, 4d are geometrical illustrations of a fabric being forced through a slot in correspondence with different extensions as demarcated on the horizontal axis of FIG. 4a.

3 DESCRIPTION

A typical apparatus constructed in accordance with the present invention may be seen in FIG. 1. A load cell 10 is fixed to the stationary upper frame 11 of the tensile tester. Rod extension 12 is fixed to the movable lower crosshead 11' of the tensile tester. The directional arrow 13 indicates the movement of rod extension 12.

Beneath load cell 10 is a support bracket 14 which is secured to load cell 10 by a universal joint 15 and pins 16 and 17 (seen in FIG. 2). Support bracket 14 provides a mounting for plate 18 and plate 19 (also seen in FIG. 2) which is secured thereto by screws 20.

Mounted in cooperating relationship with plates 18 and 19 is knife-edged member 21 which is fixed in the U-shaped bracket 22. Bracket 22 is in turn fixed to the rod extension 12 by coupling 23 and pins 24, 25. As best seen in FIG. 2, plates 18, 19 are also provided with facing knife edges 27, 28 respectively. The knife edges facilitate contact with the fabric 29 shown in outline when the apparatus is in operation.

As seen in FIG. 2, the width of the slot between plates 18 and 19 may be adjusted by loosening screws 20 which engage bracket 14 through slots 31 (seen in FIG. 3). The width of the slot between plates 18, 19 may be determined by graduated lines 32, 33 disposed on plates 18, 19 in respective cooperation with lines 34, 35 on bracket 14.

Load cell 10 is connected to a recorder 36 through leads 37. Recorder 36 functions to generate the load-extension curve for fabric 29.

In operation, the fabric 29 is placed over the slot between plates 18, 19. Bracket 22 is so disposed that the downward movement of knife-edged member 21 engages or contacts the upper surface of fabric 29 along the center line of the slot. The continued constant rate of descent of member 21 pushes or forces fabric 29 through the slot. The force required to push fabric 29 through the slot is imposed upon load cell 10 which in turn generates a signal conducted by leads 37 to recorder 36. Thus, recorder 36 generates a load-extension curve in response to the signal.

FIG. 4a is a graph of a typical load-extension curve generated when utilizing the apparatus as depicted in FIG. 1. Curve 40, the load-extension curve, is the resultant of a stiffness load-extension component 41 and frictional (or roughness) load-extension component denoted by the shaded region 42. Line 43 represents the maximum load, X_m , recorded by the recorder means. The maximum load is also a function of stiffness component 41 and frictional component.

It has been found that the maximum load X_m occurs when the angle α (as shown in FIG. 4b) is approximately equal to 45° . The angle α is the angle between fabric 29 and the upper surface of plate 18. It may be shown that the distance δ which fabric 29 extends below the upper surface of plate 18 at an angle α of 45° is approximately equal to $0.3a$ where a is the width of the slot between plates 18 and 19.

At $\delta \leq 0.3a$, the load is mainly due to the stiffness component 41. A qualitative explanation may be made by briefly viewing FIG. 4c. As seen therein, fabric 29 is starting to bend under the influence of the contact means (not shown), but has not begun to slide significantly over the knife edges which results in a resisting frictional force. The magnitude of δ in FIG. 4c is very small. This is also seen in FIG. 4a which indicates that for small extensions the frictional load component F is very small.

As fabric 29 is continually forced between plates 18 and 19, the frictional force increases. FIG. 4d illustrates that the amount of bending required by fabric 29 for further extension between plates 18 and 19 is small for $\delta \gg 0.3a$. FIG. 4a indicates this by showing that the frictional load component F rapidly becomes the larger of the two components beyond $\delta > 0.3a$.

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It has been found that the stiffness and roughness of a fabric may be conveniently represented by the following indices:

$$(1) \quad \text{stiffness index} = \frac{a^3 Y}{w}$$

$$(2) \quad \text{roughness index} = \frac{X_m}{a Y}$$

where

a is the width of the slot;

X_m is the maximum amplitude of the load-extension curve;

Y is the slope of the initial linear portion of the load-extension curve; and

w is the width of the fabric measured along the center line of the slot.

Because the roughness index utilizes a value for X_m , it is necessary that the fabric be extended to a value at least greater than $0.3a$, preferably equal to or greater than $1.0a$. Such an extension ensures that the maximum load has been reached.

At times, when the thickness (t) varies among a plurality of samples to be tested, it is convenient to utilize still another index called the intrinsic stiffness index as shown below:

$$(3) \quad \text{Intrinsic stiffness index} = \frac{a^3 Y}{wt^3}$$

The intrinsic stiffness index takes in account the variation in thickness and is a more realistic representation of the actual flexibility of the fabric material.

For a more detailed understanding of the present invention, reference is now made to the following examples.

EXAMPLE I

Double knit samples of fabric having a size $4\frac{3}{16}'' \times 4\frac{3}{16}''$ were tested as described above, one each in wale and course, face and back directions with the values of Y and X_{max} being averaged. The fabric samples had previously been subjectively ranked from "soft" to "harsh" (listed in order of 1 to 6 in the subsequent chart) by experts.

All of the following fabric samples utilized fiber processed on a Turbo Stapler made by the Turbo Machine Co. of Lansdale, Pa. except the sample indicated by an asterisk (*) which was a 40/60 preblend processed on a Pacific Converter made by the Swasey Co. of Cleveland, Ohio.

Subjective ranking	1 (soft)	2	3	4	5	6 (harsh)
Thickness, t (cm.)	.236	.249	.244	.240	.249	.254
Density (gm./cm.)	.098	.092	.093	.112	.105	.105
X_{max} (gm.)	11.0	12.2	11.3	14.5	15.1	16.4
Y (gm./cm.)	23.7	25.3	24.1	31.5	32.2	34.1
X_{max}/Y (cm.)	.47	.48	.48	.47	.47	.49
Y/t^3 (gm./cm. ⁴) $\times 10^3$	1.8	1.7	1.7	2.3	2.1	2.1
Fabric sample composition, percent:						
A:						
Relaxed	55	**44	60	*40	0	0
Unrelaxed	45	**36	0	-----	40	0
B:						
Relaxed	0	**11	0	-----	60	55
Unrelaxed	0	**9	40	*60	0	45

Under the heading "subjective ranking 1" the double knit fabric was an acrylic copolymer comprising 92.4 wt. percent acrylonitrile and 7.6 wt. percent vinyl acetate. The copolymer is solution spun as a continuous tow. The tow was then processed on the Turbo Stapler. The Turbo Stapler converts the continuous tow to staple by abrading the continuous filaments of the tow with abrading bars while the filaments of the tow are subjected to tension. After the staple has been formed, 55 wt. percent thereof was placed in an autoclave wherein it was relaxed (i.e. permitted to retract) under the influence of steam at a pressure of 10 p.s.i.g. The remaining 45 wt. percent was not treated in this matter. The aforementioned weight

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percentages were then blended together in the same proportion and the resultant blend was spun into a knitting yarn from which the samples were knitted.

The fabric of the column "subjective ranking 2" consisted of staple spun yarn made by the Turbo process as described above. The resultant yarn consisted of 80 wt. percent acrylic copolymer and 20 wt. percent of a bi-component fiber consisting of 8.4 wt. percent vinyl acetate and 91.6 wt. percent acrylonitrile. The acrylic copolymer after being converted to staple was divided with 55 wt. percent thereof being relaxed by the previously described steam treatment step while the remaining 45 wt. percent was unrelaxed. The 20 wt. percent bicomponent fiber was Turbo processed into staple and 55 wt. percent thereof was relaxed by steam treatment and the remaining 45 wt. percent remained unrelaxed. The total fiber was then recombined in the proportions set forth such that the relaxed acrylic copolymer percentage by weight was $80\% \times 55\% = 44\%$, the unrelaxed acrylic copolymer percentage by weight was $80\% \times 45\% = 36\%$, the relaxed bicomponent fiber percentage by weight was

$$20\% \times 55\% = 11\%$$

the unrelaxed bicomponent fiber percentage by weight was $20\% \times 45\% = 9\%$.

The fiber of the column "subjective ranking 3" in the light of the above discussion is self-explanatory as to that particular knit sample and the same is apparent for rankings 5 and 6.

The fiber of "subjective ranking 4" is a blend of acrylic copolymer and bicomponent fiber in the ratio of 40 wt. percent acrylic copolymer and 60 wt. percent bicomponent fiber. This fiber was converted to staple fiber by the Pacific Converter. The continuous length tow bundle having a denier of up to 1.8 million is cut by running through the nip of helically grooved roll and solid plain surface roll.

The subjective harshness determination correlates very well with the $X_{\max}$ value, the composite measure of hand. The values of the smoothness index $X_{\max}/Y$ were virtually constant so that difference in hand is due primarily to the stiffness and thickness effects. The values of Y confirm this, as they correlate with the harshness ranking. The values of the smoothness index $X_{\max}/Y$ were virtually stiffer materials, due to the higher densities, while the thicknesses then determine the orders in the two groups 1, 2, 3 and 4, 5, 6. These two main groupings were commented upon in the subjective judgments. The effect of the B fiber in the fabric clearly determines the harshness.

EXAMPLE II

Four jersey knit fabrics having a size of $4\frac{3}{16}'' \times 4\frac{1}{16}''$ were tested as described previously. The results are tabulated below:

Sample.....	1	2	3	4
Sample composition, wt. percent:				
A.....	60	30	70	35
B.....	0	30	0	35
C.....	40	40	30	30
Thickness t (cm.).....	.091	.093	.087	.091
Density (gm./cc.).....	.56	.55	.59	.58
$X_{\max}$ (gm.).....	24.4	23.0	20.9	21.9
Y (gm./cm.).....	69.9	65.5	63.4	57.5
$X_{\max}/Y$ (cm.).....	.35	.35	.33	.38
Y/t^3 (gm./cm. ⁴) $\times 10^5$	0.93	0.82	0.97	0.76

NOTE. Yarn A was of 5 den./filament acrylic copolymer fiber; Yarn B was of 3 den./filament acrylic copolymer fiber; Yarn C was a 65 single wool yarn.

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The $X_{\max}$ figures show that the hand increased in softness in the order 1, 2, 4 and 3. In the above tabulation Y/t^3 shows that fabrics 1 and 3 were basically the stiffer fabrics due to the inclusion of component A. However, thickness differences between the fabrics then increase the rigidity of fabric 2 and markedly reduce that of fabric sample 3 relative to the fabrics 1 and 4. This latter effect is further enhanced by the lower smoothness index value of fabric sample 3. Fiber C has the effect of reducing the fabric density but is shown not to significantly affect the intrinsic stiffness.

While the invention has been set forth with respect to certain embodiments, many modifications and changes will readily occur to those skilled in the art. For example, although the present invention has been described for use in measuring stiffness and roughness components of fabric, it could conveniently be utilized to measure the same components of a yarn. Accordingly, the appended claims are meant to cover all such modifications and changes which fall within the true spirit of the present invention.

We claim:

1. An apparatus for determining roughness and stiffness of a fabric comprising:

- a support means having a surface for supporting the fabric and including a pair of plates having adjacent facing knife edges defining a slot, said slot having a length greater than the width of the fabric;
- a fabric contacting means spaced above said surface and constrained to move at essentially constant speed along a line which is substantially perpendicular to said surface and passes through the center line of said slot, whereupon said contacting means forces the contacted portion of the fabric downward through said slot a distance not less than one-half the width of said slot, said contacting means comprising a member having a knife edge which is positioned substantially perpendicular to said plates; and
- measuring means coupled to said contacting means for continuously generating a signal in proportional response to the load incurred by said contacting means in forcing the fabric into and through said slot; and
- a recording means for generating a load-extension curve in response to said signal and to the distance through which said contacting means moves the fabric into and through said slot.

2. The apparatus of claim 1 in which said measuring means comprises a tensile tester having a stationary upper frame and a movable lower cross-head, and a load cell secured to the upper frame wherein said support means is coupled to said load cell and said contacting means is attached to said lower cross-head.

3. The apparatus of claim 2 wherein said plates are secured to the respective legs of a U-shaped bracket which is coupled to said load cell, said plates being adjustable with respect to each other thereby allowing the width of said slot to be varied.

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