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EFFECT OF SPEED OF PULLING JAWS ON THE TENSILE STRENGTH AND STRETCH OF LEATHER

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ABSTRACT

The purpose of this investigation was to obtain data on the effect of the speed of the pulling jaws of the testing machine on the tensile strength and stretch of leather. In practice, speeds as low as 0.25 in./min and as high as 12 in./min have been used in different laboratories. In this study, 1,900 measurements of strength and stretch were made at 6 different jaw speeds, using a horizontal Scott machine of 800-lb capacity. The tensile strength increased with jaw speed, the rate of increase being least between 6 and 12 in./min. The change in stretch with jaw speed was erratic; the average difference between the stretch at 0.5 in./min and that at 20 in./min was 1 percent, or no greater than the smallest interval of stretch measured.

CONTENTS

I. INTRODUCTION

Among the physical properties of leather which are most frequently measured are its tensile strength and stretch. The importance of their measurement is indicated by the fact that 10 of the 12 Federal specifications for different types of leather include requirements for these properties. The 10 specifications are those for bag, belting, case, chamois, harness, hydraulic packing, lace, rigging, strap, and upholstery leathers. The specifications for sole and welting leathers alone contain no requirements for strength and stretch.

In view of the widespread use of these measurements, it is desirable that the methods used in different laboratories should give concordant results and that the results in any laboratory should not vary excessively from time to time. Some factors may affect the results seriously. Among them are the method of selecting samples for the test, the temperature and humidity of the atmosphere to which the samples are exposed before and during the test, and the kind of testing machine and manner of using it. This study deals with one phase of the last factor, namely the effect of the speed of the jaws of one type of testing machine.

In different laboratories the jaw speeds that are used vary greatly. In some, the speed of the pulling jaws is as low as 0.25 in./min; in others, as high as 12 in./min. When the machine is operated by hand, the speed of the jaws may change from time to time.

This work was undertaken for the purpose of obtaining data that would show the magnitude of the effect of the speed of the pulling jaws on tensile strength.

II. DESCRIPTION OF LEATHERS USED

The heavy leather used for the main part of this work was made in the experimental tannery at the National Bureau of Standards. The equipment used has been described by Bowker in a recent article.[1] Six steer hides which had been limed and unhaired were obtained from a commercial tannery. They were washed in clean water, bated, and then tanned with a blend of approximately one-third chestnut, one-third cutch, and one-third sulfited quebracho. The pH of the tanning liquors was originally about 5.4, and was reduced at the rate of about 0.05 pH unit per day until it was about 4.0, using acetic acid when necessary. After tanning, the leather was washed thoroughly with fresh water, swabbed with sperm oil, allowed to dry, then dampened again and rolled. No filler or finishing material was used. The completed leather had a pH of about 3.9 and a shrinkage temperature of about 78° C.

Smaller quantities of two commercial leathers were available. One was a vegetable-tanned sole leather, the other a light, snuffed-grain, chrome-tanned leather.

III. PLAN OF THE EXPERIMENTS

In the main part of this study, it was planned to make measurements of tensile strength and stretch at six different jaw speeds, 0.5, 1, 3, 6, 12, and 20 in./min. The method of dividing the leather into the six groups which were necessary was devised with the purpose of making the six groups as nearly uniform as possible. Two sources of variability in the leather were considered, namely the differences between hides and the differences caused by location in the hide.

From each hide were cut 12 blocks for tanning, each block about 14 in. wide by about 16 in. long. After tanning, each block was cut in half along a line parallel to the backbone. This gave 24 pieces from each hide. From each piece were cut 12 tensile-strength test specimens, the lengths of which were perpendicular to the backbone. Thus, there were 288 test specimens from each hide, or a total of 1,728 from the six hides.

Figure 1 represents the location of the test specimens in a hide. The numbers which were given to the 24 pieces for identification are placed on the corresponding pieces. The division of each piece into 12 specimens for tensile-strength measurements is also indicated. The meaning of the shading on some of the strips will be explained later.

The 12 test specimens from each piece were assigned to the 6 groups in pairs, that is, the first and twelfth specimens to one group, the second and eleventh to the next group, and so on. Table 1 shows this assignment for the two pieces, one on either side of the backbone, nearest the tail of hide 1. The speed numbers in table 1 are merely identifying numbers of the groups of specimens, not the actual speeds

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[1] Hide and Leather 97, No. 23, 11 (1939).

used. Since the tensile strength within a piece tends to change regularly from one end of the piece to the other, this assignment of specimens minimizes the variation caused by differences within the piece as a factor affecting the average tensile strength of a group of specimens.

It is still necessary, however, to make allowance for the variation caused by differences in location in the hide. To do this, data obtained from measurements of tensile strength, not yet published, were

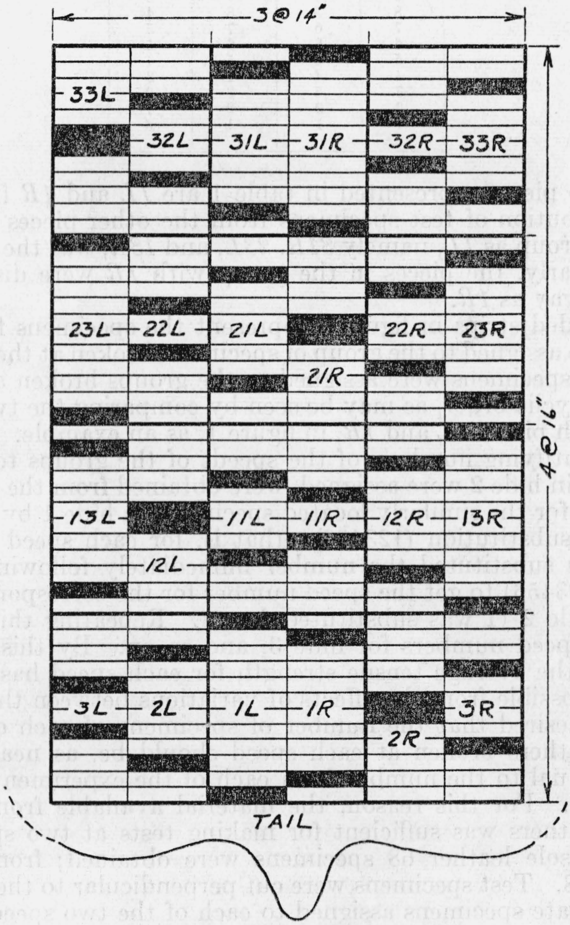

FIGURE 1.—*Method of dividing a hide, with assignment of test specimens to one speed.*

used as a basis for dividing the 24 pieces into 6 groups of 4 pieces each, such that the average tensile strength of each of the 6 groups would be approximately equal to the average strength for the whole hide. The groups of pieces were as follows:

1. 33L, 21R, 12L, 2R.
2. 32R, 22L, 11R, 3L.
3. 32L, 22R, 11L, 3R.
4. 33R, 21L, 12R, 2L.
5. 31L, 23R, 13L, 1R.
6. 31R, 23L, 13R, 1L.

TABLE 1.—*Method of assigning specimens from a block to groups for different speeds*

1L		*1R*	
Strip No.	Speed No.	Strip No.	Speed No.
12	1	12	6
11	2	11	1
10	3	10	2
9	4	9	3
8	5	8	4
7	6	7	5
6	6	6	5
5	5	5	4
4	4	4	3
3	3	3	2
2	2	2	1
1	1	1	6

The two pieces represented in table 1 are *1L* and *1R* from hide 1. The distribution of test specimens from the other pieces of hide 1 in the same group as *1L*, namely *31R*, *23L*, and *13R*, was the same as for *1L*. Similarly, the pieces in the group with *1R* were distributed in the same way as *1R*.

The shaded strips in figure 1 represent the specimens from hide 1 which were assigned to the group of specimens broken at the first speed. The other specimens were assigned to the groups broken at the other speeds in cyclic order, as may be seen by comparing the two pieces in table 1 with pieces *1L* and *1R*, in figure 1, as an example.

The identifying numbers of the speeds of the groups to which the specimens in hide 2 were assigned, were obtained from the numbers of the speeds for the similarly located specimens in hide 1 by performing the cyclic substitution (123456)—that is, for each speed number on hide 1 was substituted the number immediately following it in the symbol (123456) to get the speed number for the corresponding specimen on hide 2 (1 was substituted for 6). Repeating this operation gave the speed numbers for hide 3, and so on. By this method of sampling, the average tensile strength for each speed has been freed as far as possible from the effects of variations between the hides.

It was desired that the number of specimens of each of the commercial leathers broken at each speed should be, as nearly as convenient, equal to the number from each of the experimental hides at each speed. For this reason, the material available from the commercial leathers was sufficient for making tests at two speeds only. From the sole leather 68 specimens were obtained; from the light leather, 108. Test specimens were cut perpendicular to the backbone, with alternate specimens assigned to each of the two speeds selected.

The necessity of measuring the strength and stretch of leather under conditions of controlled humidity was shown by Veitch, Frey, and Leinbach.[2] Accordingly, all work was done in a room where the temperature was controlled at approximately 72° F and the relative humidity at about 65 percent. The test specimens were cut out with a metal die in the standard dumbbell shape [3] (fig. 2). The leather was removed from the conditioning room for a period of time just long enough to cut out the specimens, which were then quickly returned to

[2] J. Am. Leather Chem. Assn. **17**, 492 (1922).
[3] J. Am. Leather Chem. Assn. **32**, 418 (1937).

the conditioning room. The test pieces were then placed in racks allowing free access of air to both sides, where they were allowed to stand for 3 days before the thickness was measured and for at least 3 more days before they were broken.

The thickness of the leather was measured with a Randall & Stickney gage graduated in 0.001 in. and having a contact foot 1 cm in diameter. The load on the foot was approximately 1 lb. The minimum thickness of the reduced section of the specimen was used in calculating the tensile strength. The specimens varied in thickness from about 0.10 in. to about 0.25 in.; the thickness was read to 0.001 in.

Two transverse gage marks were placed on the reduced section of the specimen equidistant from its center, and 2 in. apart. The distance between the gage marks was measured with calipers as the specimen

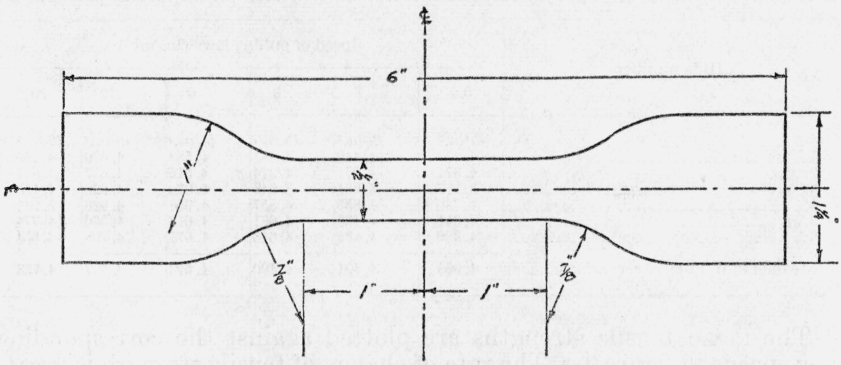

FIGURE 2.—*Size and shape of specimen for test.*

was being stretched; the distance when the specimen broke was recorded to the nearest 0.02 in. This figure was used in computing the percentage elongation.

The machine used for breaking the specimens, which was set up in the conditioning room, is a horizontal Scott machine of the pendulum type, having a capacity of 800 lb. A calibration of this machine showed that the errors of its indicated loads did not exceed 1.4 percent for the range 200 to 800 lb. The pulling jaws are driven by an electric motor, through a belt and pulleys, the size of which could be varied to change the speed of the jaws. The speed of the pulling jaws, which was observed when they were running free, was computed from the time required for a given point on the jaws to travel a measured distance. It is estimated that the measurements of speed were accurate within 1 percent. The speeds chosen for study were 0.5, 1, 3, 6, 12, and 20 in./min, which roughly cover the range of speeds which have been used in practice.

The observed tensile strength depends on the rate of loading of the specimen, and this, in turn, depends not only on the speed of the pulling jaws but also on the capacity of the machine. Therefore, control of the speed of the pulling jaws is not in itself sufficient to ensure duplication of results on different machines. It is also necessary that the capacities of the machines should be the same. When considering the results, then, it should be remembered that they are applicable only to a machine of the type and capacity used in this work.

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IV. RESULTS

1. TENSILE STRENGTH OF EXPERIMENTAL LEATHER

The results of the measurements of tensile strength on the leather prepared in the experimental tannery are given in table 2. Each figure in the body of the table is the mean of all measurements on specimens from the indicated hide at the given speed. At the foot of each column is given the mean of all measurements at the given speed. Of the 1,728 specimens, 57 were made worthless by cuts, grub holes, and other flaws in the leather, leaving 1,671 valid observations. Thus, each of the 6 means represents about 278 observations; the minimum was 272, the maximum, 281.

TABLE 2.—*Tensile strength of experimental leather tested at different jaw speeds*

Hide number	Speed of pulling jaws (in./min)					
	0.5	1	3	6	12	20
	lb/in.²	*lb/in.²*	*lb/in.²*	*lb/in.²*	*lb/in.²*	*lb/in.²*
1	4,377	4,440	4,481	4,583	4,699	4,755
2	4,371	4,271	4,374	4,515	4,657	4,857
3	3,987	3,954	3,948	4,080	4,026	4,155
4	4,730	4,855	4,857	4,958	4,926	5,233
5	4,311	4,436	4,681	4,613	4,560	4,774
6	4,386	4,435	4,615	4,677	4,708	4,664
Mean of individual observations	4,368	4,404	4,490	4,573	4,597	4,733

The mean tensile strengths are plotted against the corresponding jaw speeds in figure 3. The rate of change of tensile strength is great-

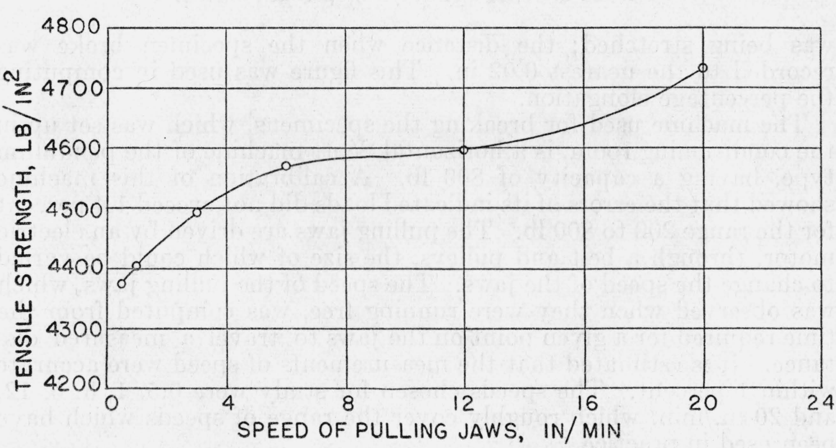

FIGURE 3.—*Effect of speed of pulling jaws on tensile strength.*

est between 0.5 and 1 in./min, and decreases to a minimum between 6 and 12 in./min. Between 12 and 20 in./min it increases.

The question arises whether the observed differences in tensile strength at the different speeds are statistically significant. A test of significance which is frequently used is the comparison of the quantity tested (in this case, the difference in tensile strength), with its standard deviation. The standard deviation of the difference between the mean tensile strengths for any two given speeds may be calculated from the original data as follows. For each block of leather there were two measurements of tensile strength at each speed. The average of each pair of measurements for each speed is taken. The difference between two averages from the same block for any two speeds is an estimate of the difference in tensile strength caused by the difference in speed. Since both of the averages from which the difference was derived represent the same block of leather, the difference is an estimate in which the effect of variation between the hides does not appear and the effect of location on tensile strength has been minimized. One such estimate has little value, but a large number of them may be combined to give a reliable estimate. For these data, there are 144 such differences for each pair of speeds, minus those which must be omitted because of missing observations. From each group of differences the mean difference and the standard deviation of the mean difference were then calculated. The ratio of the mean difference to its standard deviation was then computed. These data are given in table 3. The last column of this table gives the probability, in percent, of the chance occurrence of a difference as large as, or larger than, the given difference; this probability is determined by the ratio in the fifth column. (Tables of these probabilities are given in textbooks on statistics and in chemical handbooks.)

The difference between the mean tensile strength at 12 in./min and that at 20 in./min is undoubtedly significant. The difference between 6 and 12 in./min is probably not significant. For other comparisons, the probability of the differences not being caused by chance is great enough to justify the assumption that the effect of jaw speed may be important. Therefore, measurements of tensile strength should be made at a specified speed. Since the rate of change of tensile strength is least between 6 and 12 in./min, the effect of accidental variations in speed would be minimized by selection of a speed within this range.

TABLE 3.—*Test of significance of differences between tensile strengths at different jaw speeds*

Speeds compared	Number of differences	Mean difference	Standard deviation of mean difference	Ratio of mean difference to standard deviation	Probability
(in./min)					*(Percent)*
0.5 and 1	127	52.3	42.2	1.24	21.5
1 and 3	129	108.3	42.6	2.54	1.1
3 and 6	134	71.6	42.6	1.68	9.3
6 and 12	133	24.2	37.7	0.64	52.2
12 and 20	133	170.0	40.4	4.21	0.0

2. STRETCH OF EXPERIMENTAL LEATHER

The results of the measurements of stretch made on the leather tanned at the Bureau are given in table 4, which is arranged similarly to table 2. From the values for the average stretch at each speed, there appears to be a tendency for the stretch to increase as the jaw speed decreases. However, when the data in table 4 for the different hides are compared, it is seen that they are very erratic. Hides 3 and 6 show the stretch tending to decrease as the jaw speed decreases, and hides 1 and 2 show an increase in stretch only at the two lowest speeds. Moreover, the smallest interval that was read in measuring the stretch was 1 percent, and the six averages lie within a range of 1 percent. For this reason, together with the lack of stability of the data, it did not appear necessary to make a statistical analysis to show that there was no significant effect of the speed of the pulling jaws on the stretch.

TABLE 4.—*Stretch of leather at different jaw speeds*

Hide number	Speed of pulling jaws (in./min)					
	0.5	1	3	6	12	20
	%	%	%	%	%	%
1	32.1	30.3	28.8	29.8	28.7	29.6
2	34.1	31.8	30.7	31.1	30.9	31.6
3	29.5	28.9	28.7	30.1	29.8	29.0
4	29.5	33.0	29.2	30.0	28.6	27.9
5	30.1	30.4	30.4	30.6	30.1	29.0
6	29.0	29.4	30.4	29.5	30.8	31.1
Mean	30.7	30.6	29.7	30.2	29.8	29.7

3. LIGHT LEATHER

One hundred and eight specimens of a light, chrome-tanned leather were broken, 54 at each of 2 speeds, 12 and 20 in./min. The average tensile strength at the lower speed was 4,620 lb/in.^{2}; at the higher speed, 4,800 lb/in.^{2} The difference, expressed as percentage of the strength at 12 in./min, was 3.9 percent. This is comparable to a similarly obtained figure, for the experimental leather, of 3.0 percent.

The average stretch was 38.9 percent at 12 in./min and 36.8 percent at 20 in./min. As in the case of the experimental leather, the stretch is higher at the lower speed, but the difference is not large when compared with the smallest interval of stretch measured.

4. COMMERCIAL SOLE LEATHER

Sixty-eight specimens of commercial vegetable-tanned sole leather were broken, 34 at each of 2 speeds, 0.5 and 12 in./min. At 12 in./min the average tensile strength was 4,290 lb/in.^{2} and the stretch 20.2 percent. At 0.5 in./min the tensile strength was 3,890 lb/in.^{2} and the stretch 22.7 percent. With respect to each property the change was in the same direction as it was for the experimental leather, but the effect seems to have been greater for the sole leather.

V. CONCLUSION

The large differences found between the tensile strengths of leather at different jaw speeds, the capacity of the testing machine being constant, indicate that better duplication of results will be obtained if all measurements are made at the same speed. For the machine used, having a capacity of 800 lb, the preferable speed would seem to lie in the neighborhood of 6 to 12 in./min, since the rate of change of tensile strength is least in this range, and accidental variations in the speed of the jaws would be likely to introduce the least error into the determination if the speed is within this range.

WASHINGTON, June 11, 1940.