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Motorcycle Suits: Uniaxial and Biaxial Tensile Tests of Leather

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Abstract. This paper describes uniaxial and biaxial tests of leather samples. The tests were conducted on non-standardized samples. The uniaxial test was performed on 100 samples. The biaxial test was done on 20 samples. The aim of the uniaxial test was to obtain a reliable value of the leather ultimate strength, on a large population of samples. Additionally, this test revealed the differences in the ultimate strength between two relative perpendicular directions of cut. The biaxial test was used to obtain the stress-strain relationship and the ultimate strength. The stress-strain relationship will be used in the future to improve the constitutive material model of the leather. The biaxial test was conducted under four logarithmically graded clamps separation speeds (1, 10, 100, 1000 mm/min).

Introduction

A natural leather is the most commonly used material in motorcycle suit industry [1]. Potential reduction of the rider's injuries by personal protective equipment makes the assessment of the drivers clothing a very important topic in powered two wheelers safety research [2]. The manufacturers and developers of motorcyclist outfits often follow the standardized test procedures [3] during the examination of materials provided by their suppliers. However, these standards do not take into account non-isotropic nature of the biological material. In previous research, the authors identified Ogden's material parameters of the leather [4]. This paper presents the progress in the author's leather tensile testing procedure.

Tensile test methodology

The tensile tests were conducted on the 574LE2 Biomechanics and Tissue Tester from TESTRESOURCES Company. The tests were held in temperature equal to 23±1 °C and relative humidity 50±6 %.

The uniaxial test was designed to measure differences in the ultimate strength between relative perpendicular material directions. The five standardized samples [3] (S samples) were cut randomly from the motorcycle suit. Then, 20 samples were cut from each S sample. The first half of them were cut along the S sample axis (0 degrees angle), the rest were cut in the perpendicular direction (90 degrees angle). The uniaxial samples (U samples) had dimensions 40 x 4 mm with average thickness 1.24 mm. The U samples (Fig. 1) were exposed to a uniaxial strain described by Fig. 2 (the loading continued up to the ultimate strength).

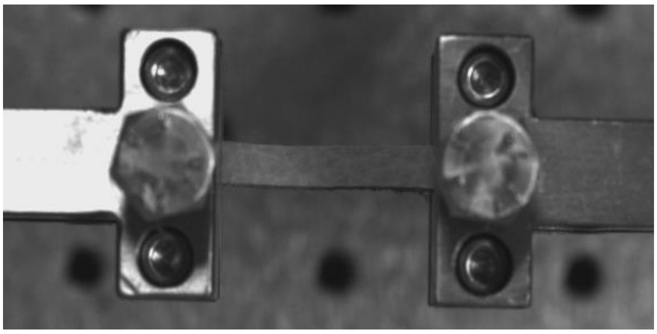

Fig. 1 Clamped uniaxial sample.

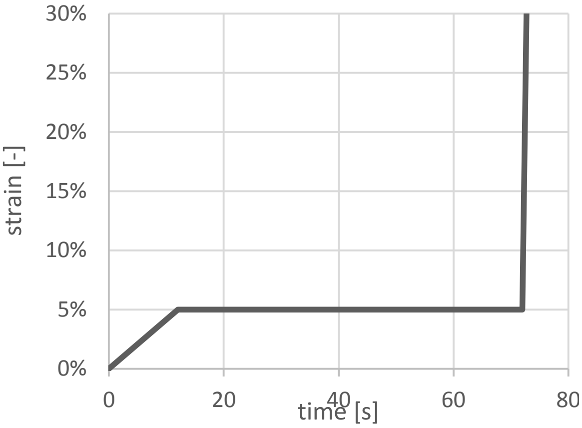

Fig. 2 The testing machine control signal.

To obtain data for the more reliable calibration of the hyperelastic material model, the biaxial test was performed (Fig. 3). The biaxial samples (B samples) were cross-shaped with 12.5mm radius in the corners (Fig. 4). This shape allowed to avoid the stress concentrations in the cross corners. The B samples were cut randomly from a motorcycle garment leather. The B samples thickness wavered between 1.017 mm and 1.468 mm, with an average of 1.283 mm.

The group of 20 B samples was divided into four sub-groups. Each sub-group was exposed to biaxial strain with various strain rate. The elongation control signal had the ramp shape. The slope of the ramp was logarithmically graded (1, 10, 100, 1000 mm/min). During this test, four independent force-cells were used (one force cell for each clamp).

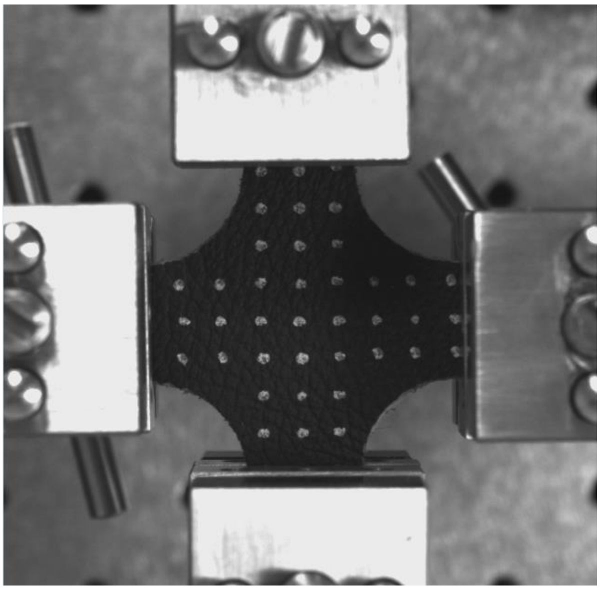

Fig. 3 Clamped B sample before the test.

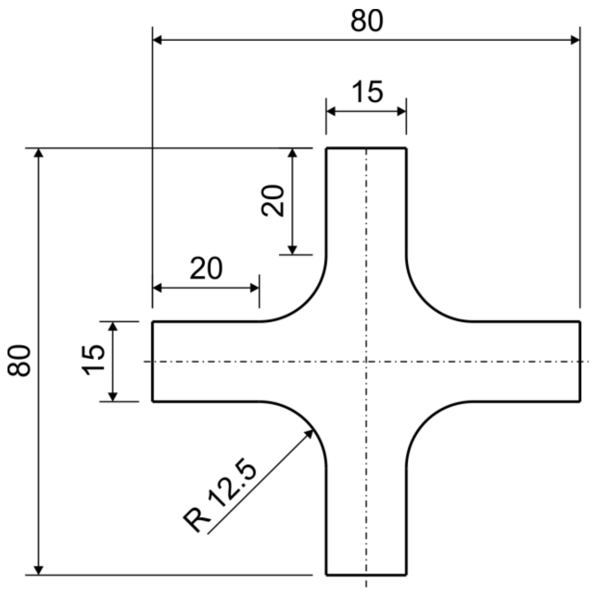

Fig. 4 The B sample dimensions.

Uniaxial tensile test results

The conducted test brought the ultimate damage force with last 20 data points before the samples damage, for the each U sample. These data were presented in the charts below (Fig. 5- 9). Each S sample had a specific color (black, green, blue, red and white). Following this nomenclature, figures 5-9 had the corresponding color. We assumed that the color corresponds to a different cowhide. On the Fig. 5- 9 solid lines represents U samples cut along the S sample axis, while dashed lines represent the U samples cut in the perpendicular direction. The samples cut from white S sample (Fig. 9) shows the smallest dispersion in ultimate damage force.

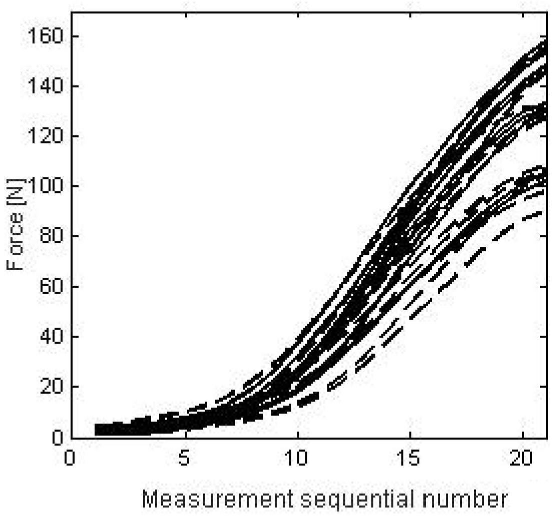

Fig. 5 Last 20 measurements for black samples.

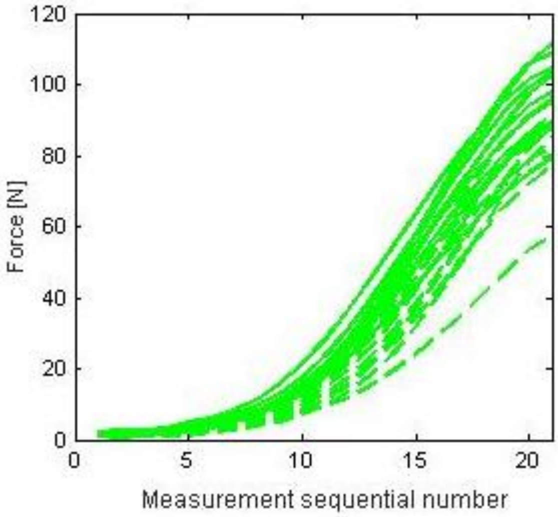

Fig. 6 Last 20 measurements for green samples.

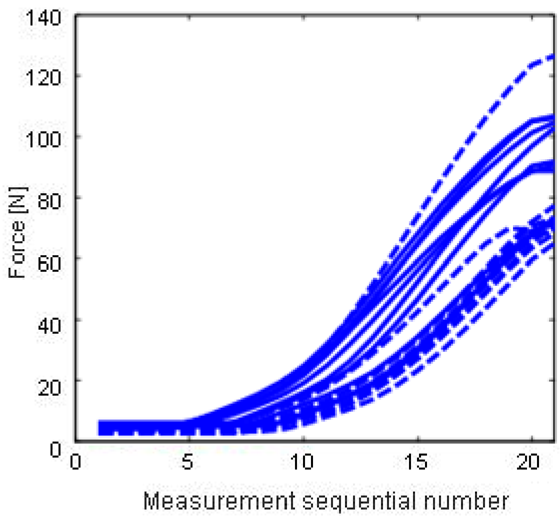

Fig. 7 Last 20 measurements for blue samples.

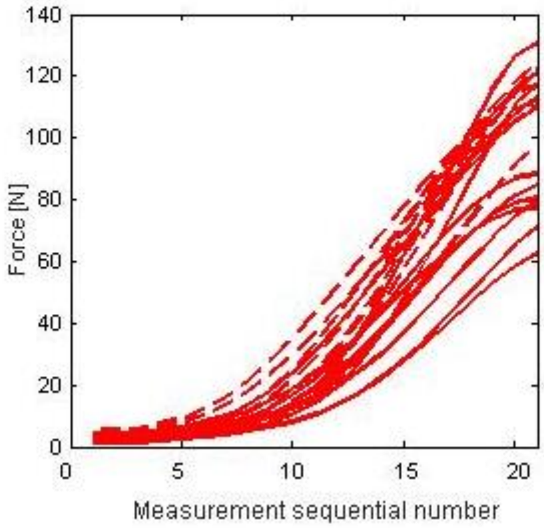

Fig. 8 Last 20 measurements for red samples

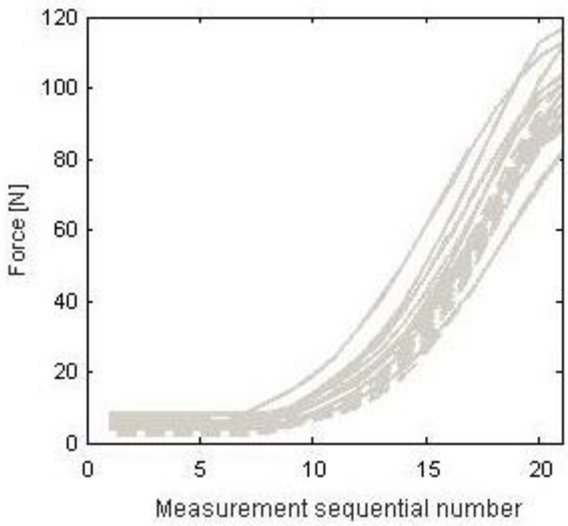

Fig. 9 Last 20 measurements for white samples.

Based on obtained data (Fig. 5- 9) and real dimensions of the U sample, the ultimate strength was calculated (fig 10). The ultimate strength was in the range 11.58- 31.8 MPa. The average ultimate strength difference between the U samples in the two directions was in the range 7– 28 % (Table 1).

Table 1 Average ultimate strength of uniaxial samples [MPa].

Samples belonging to S sample	**Black**	**Blue**	**Red**	**White**	**Green**
0 deg	27.45	18.35	18.20	20.14	19.79
90 deg	24.16	15.35	23.36	18.71	16.80
difference	12.01%	16.33%	28.30%	7.07%	15.09%

The Fig. 10 shows the dispersion in the ultimate strength through all U samples. This graph illustrates that the blue and white samples, cut in the perpendicular direction, are the most homogenized group. Only two measurements (one BL90 and one G90) were out of 99.3 % of result distribution.

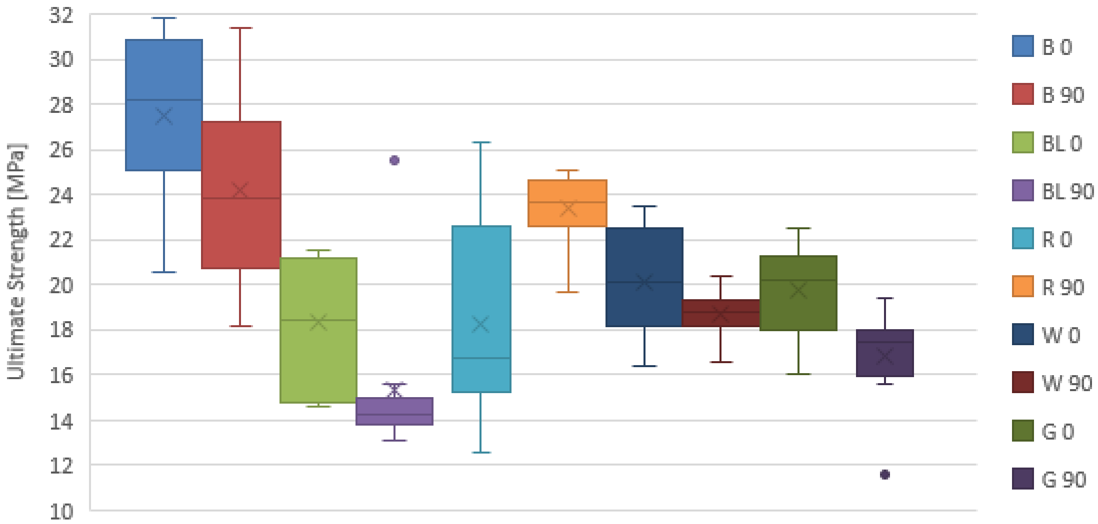

Fig. 10 Box plot of U samples ultimate strength [MPa].

Biaxial tensile test results

The biaxial test was designed to obtain leather stress-strain relationship (Fig. 11). The biaxial load characteristics are necessary for reliable hyperelastic model fitting in terms of Ogden parameters [5]. In paper [4], the authors used the load characteristics from the uniaxial standardized test with the clamp separation speed of 100 mm/min, therefore the biaxial test with the same speed was desirable (Fig. 11).

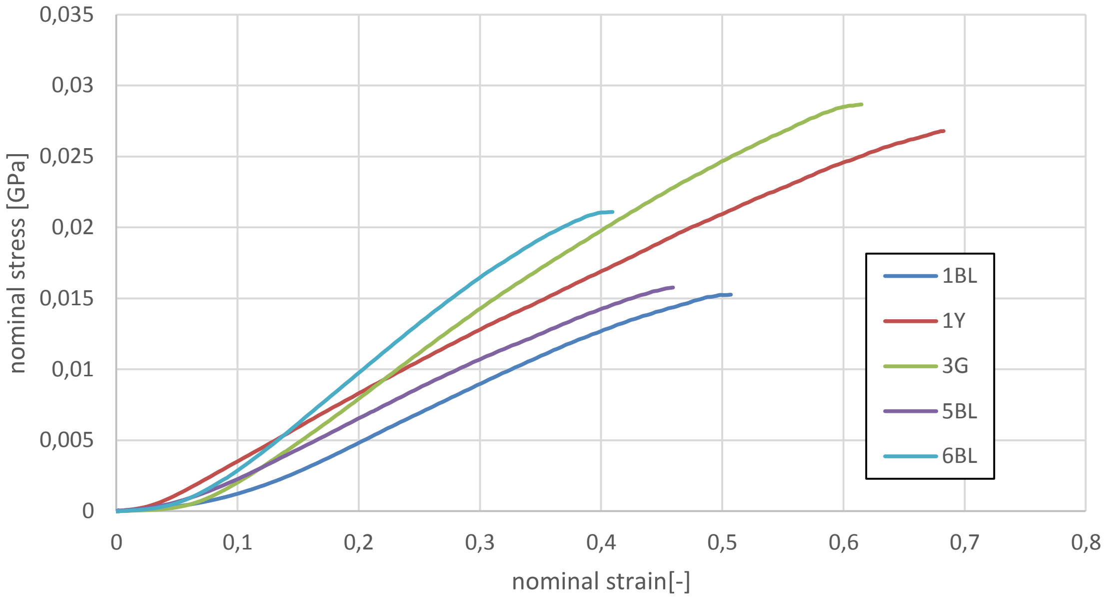

Fig. 11 Nominal stress vs. nominal strain under speed of 100 mm/min

Additionally, the ultimate damage force in the different jaw separation speeds was examined (Fig. 12). The following graph shows that under the speed of 1, 100, 1000 mm/min the average ultimate force is around 500 N. Only for speed 10 mm/min higher average ultimate with the value of 625 N was found.

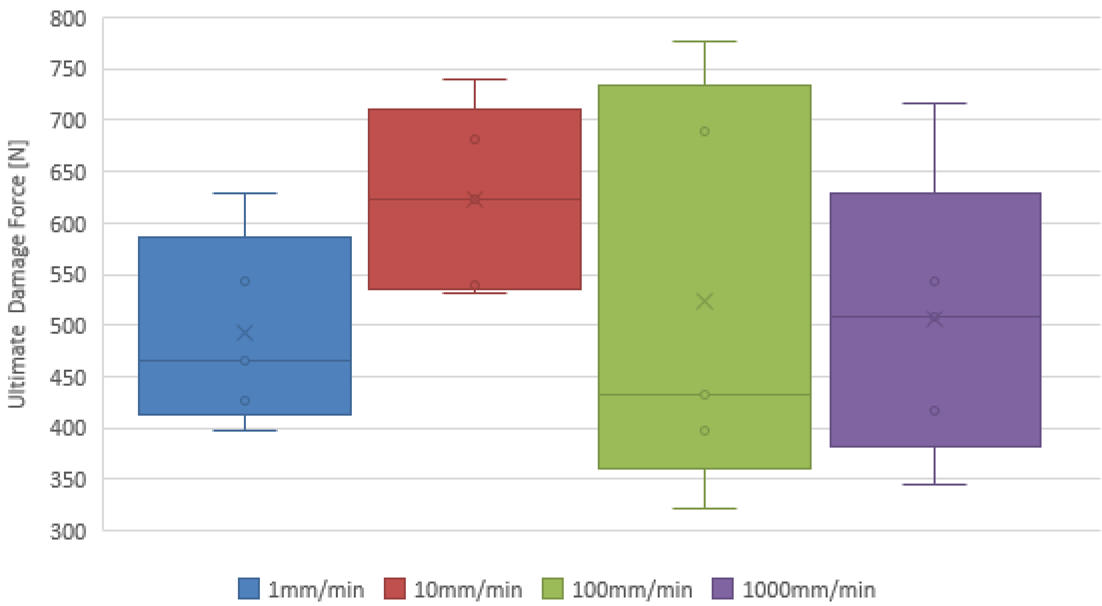

Fig. 12 Box plot of the B samples ultimate force [N].

Conclusions

The ultimate tensile strength under uniaxial loading was in the range 11.58- 31.8 MPa. The average ultimate strength difference between the U samples in the two perpendicular directions was in the range 7– 28 %. The nominal stress–nominal strain relationship and the ultimate damage forces under biaxial load were obtained. The nominal stress-strain relationship will be used in the future to improve the leather constitutive model in terms of Ogden parameters.

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