VOLVO

Investigating the friction properties of the XSENSOR vest

Katarina Bohman, Joakim Risberg

Volvo Cars Safety Centre, Gothenburg ,Sweden.

Summary

A total of 61 tests were conducted to compare coefficients of friction of the XSENSOR vest material with the standardized clothing of the HIII dummy. In addition, two additional materials called 'jacket' and 'XSENSOR mat', were included. A Volvo designed test rig was used, which utlized standardized seat belt webbing as the counterpoint material to measure the coefficients of friction. The belt was positioned in three different orientations (0˚, 45˚ and 90˚).

The tests revealed that the XSENSOR vest has lower coefficients of friction compared to the standardized clothing of the HIII dummy.

Background

The company XSENSOR has developed pressure mats that enable continuous pressure measurement during crash tests. IIHS has integrated the XSENSOR pressure vest into their assessment of the shoulder belt interaction with the HIII 5th female during the offset barrier test. Consequently, it is of interest to investigate whether there are any variations in coefficients of friction between the XSENSOR vest and the original HIII clothing, and to further understand how the direction of shoulder belt movement relative to the chest may contribute to differences in friction.

The aim was to compare the coefficients of friction of the original HIII clothing, XSENSOR vest material, and two additional fabric samples, called 'jacket' and 'XSENSOR mat'.

Method

Test procedure

The test method involves a sliding mass moving along an inclined plane, as seen in Figure 1. To determine the coefficient of friction, the measured acceleration was compared to the theoretical gravitation pull. The test sample was placed on the angled plate with tape around the edges. Pieces of the belt webbing were attached to the bottom of the sliding mass with thin double adhesive tape and with tightening bolts in the upper and lower edges of the plate. The belt orientation was tested in three directions: 0˚, 45˚ and 90˚ (see Figure 2).

The test starts by releasing the electromagnets holding the sliding mass in place. The pulling weight then accelerates the sliding mass for a distance of 110 mm, after which the mass continuous to move freely. Eventually, a mechanical braking systems halts the sliding mass.

Three accelerometers were attached to the sliding mass (Figure 3). To calculate the acceleration, a specific interval was chosen to represent only the free moving phase. Short cut triggers were utilized to mark this interval, typically around 100 ms, which includes the moment the pulling weight contacts the ground or when the brakes are engaged. The acceleration data was filtered using CFC600 and the average acceleration during the selected interval was calculated.

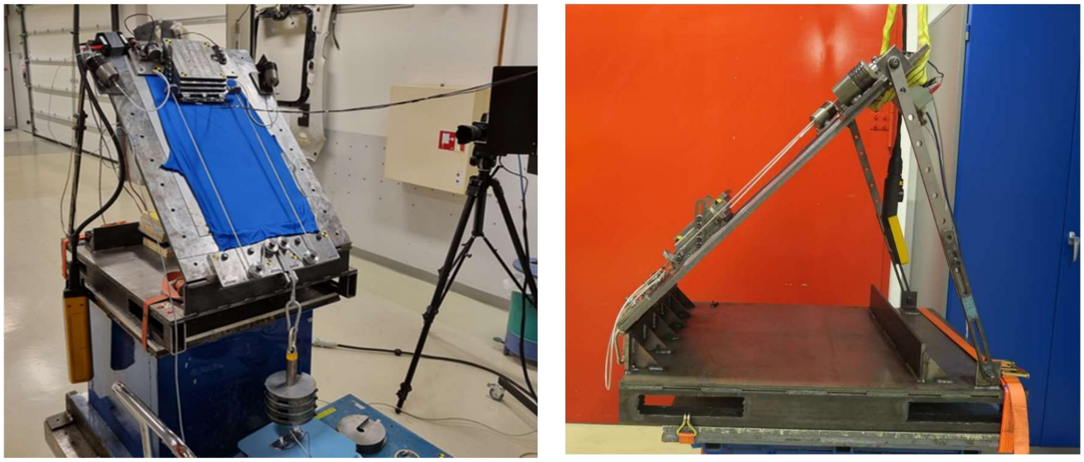


Figure 1 Friction test rig observed from oblique and side view.

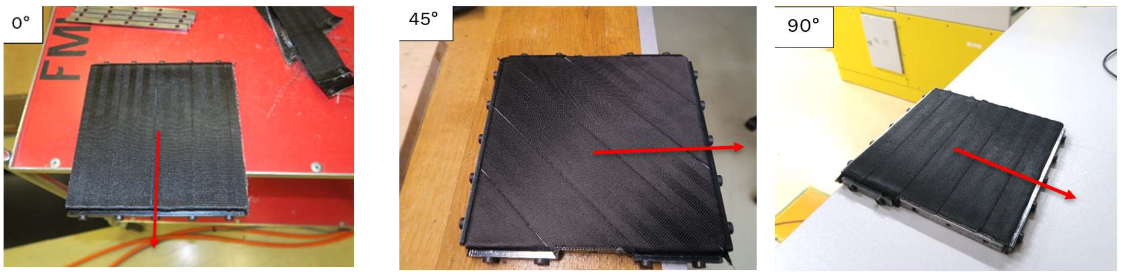


Figure 2 The webbing was *oriented in 0˚, 45˚ and 90˚* relative the direction of the sliding mass (see arrow).

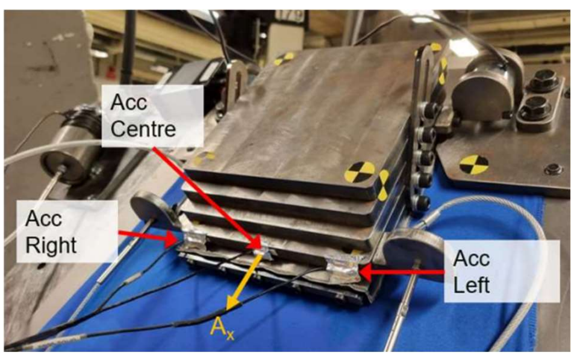


Figure 3 Three accelerometers were attached to the sliding mass, as shown in Figure.

Test material

Four different materials were tested (Figure 4). The materials included HIII clothing (‘HIII fabric’), XSENSOR pressure vest material which was same material used in vest by IIHS (‘XSENSOR vest’), a jacket representing ‘normal clothing’ (‘jacket’) and a pressure mat material (HX210.50.50.05) from XSENSOR that was a different material compared to in XSENSOR/IIHS vest (‘XSENSOR mat’). To ensure a more extensive testing surface, a larger rectangular-shaped material measuring approximately 30x50 cm with identical fabric and surface characteristics as the original XSENSOR vest was selected instead of directly testing the vest itself. Both XSENSOR materials were provided by XSENSOR, while the jacket was supplied by IIHS.

Throughout the tests, standard seat belt webbing was replaced every 15 tests to maintain consistency and accuracy.

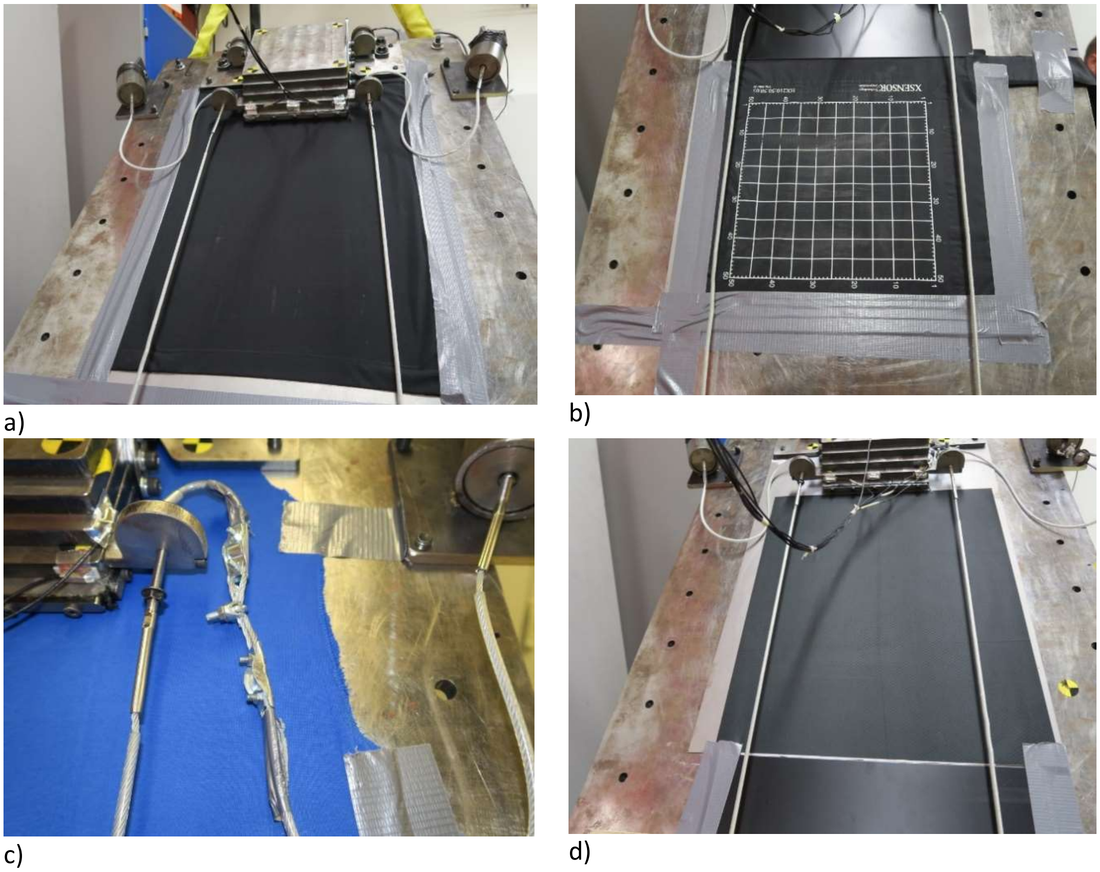
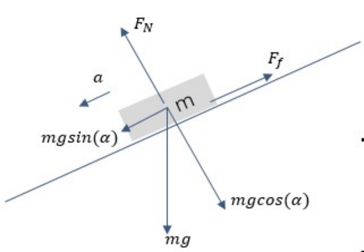


Figure 4 Tested fabric attached to test rig a) Hawke & Co jacket, b), XSENSOR pressure mat – HX210.50.50.05, c) HIII fabric and d) XSENSOR vest material.

Calculation

The coefficient of friction is determined by comparing measured acceleration and the theoretical gravitational pull as seen in Figure 5.



$$F_f = \mu F_N$$

$$F_N = mgcos(\alpha)$$

$$mgsin(\alpha) - F_f = ma$$

$$\rightarrow \; mgsin(\alpha) - \mu mgcos(\alpha) = ma$$

$$\rightarrow \; \mu = \frac{\sin(\alpha)}{\cos(\alpha)} - \frac{1}{\cos(\alpha)} * \frac{a_{uppmätt}}{g}$$

Figure 5 Calculation of the coefficient of friction (μ)

In all tests the following values were used:

m = 23.2 kg
g = 9.81 m/s^2
α = 45°

An example of the acceleration and how it is used to calculate the friction is demonstrated in Figure 6. The acceleration is taken from the center position of the sliding mass.

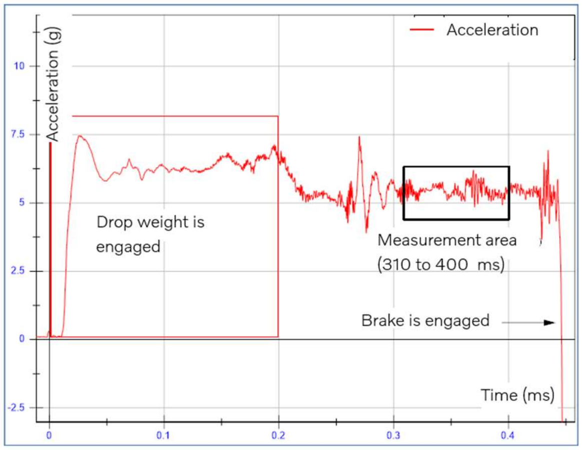


Figure 6 An example of the acceleration vs time, also indication what part is used for 4calculating the coefficient of friction.

Five tests were conducted for each material and test condition, except for the first configuration with the jacket, which was tested an additional time. An average value was calculated for each configuration, for each material.

Table 1 Test matrix

Material	Belt orientation	Number of tests
HIII fabric	0˚	5
HIII fabric	45˚	5
HIII fabric	90˚	5
XSENSOR Vest	0˚	5
XSENSOR Vest	45˚	5
XSENSOR Vest	90˚	5
Jacket	0˚	6
Jacket	45˚	5
Jacket	90˚	5
XSENSOR mat	0˚	5
XSENSOR mat	45˚	5
XSENSOR mat	90˚	5

Results

The results are presented in Figure 7, showing the normalized coefficients of friction compared to HIII fabric, for each test configuration and each tested material. The coefficients of frictions of the XSENSOR vest were lower compared to the HIII fabric, in all three webbing directions. In 0˚ direction, the friction was 4% lower, while in the 45˚ and 90˚ directions, the friction was 30% respective 20% lower, respectively, compared to the HIII fabric.

Both the jacket and the XSENSOR mat demonstrated higher friction compared to the HIII fabric in all tested configurations. The XSENSOR mat showed higher friction relative the HIII fabric, due to its uneven surface. The XSENSOR mat was partly worn out compared to the XSENSOR vest, which was unused prior the tests. The jacket, initially selected to represent low friction clothing, unexpectedly exhibited higher friction than the HIII fabric. The jacket was brand new and had not been used prior to the testing.

The standard deviations for each tested material and each test configuration were relatively small, ranging from 0.7% to 5% (see figure 8 for more details). The standard deviation was highest with the XSENSOR mat in 0˚ direction, probably as a result of its uneven surface.

The tests indicated that the belt orientation had an impact on friction, but the extent of this dependence varied depending on the tested material. The XSENSOR vest material demonstrated minimal dependence on belt orientation.

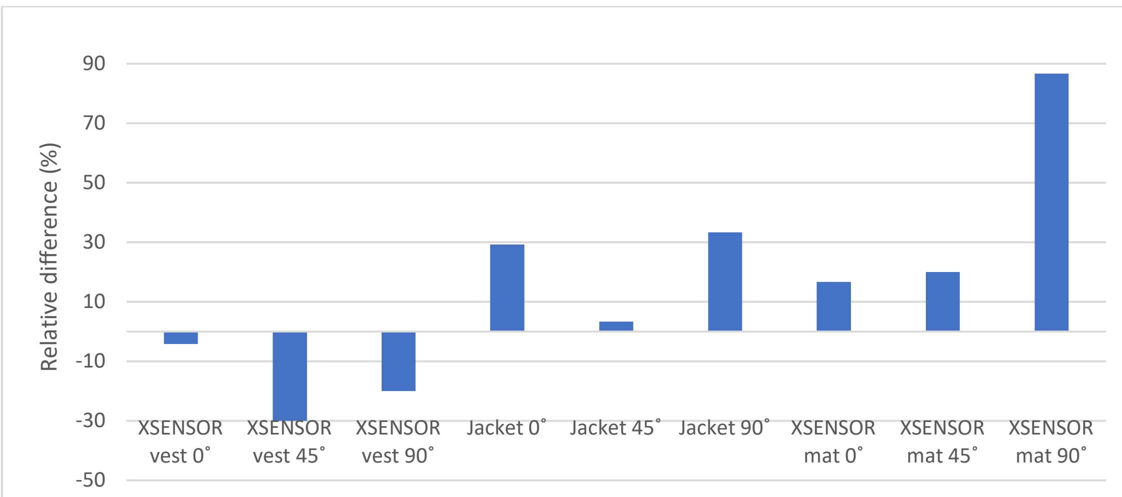


Figure 7 Normalized coefficients of friction using the corresponding HIII fabric coefficients of friction.

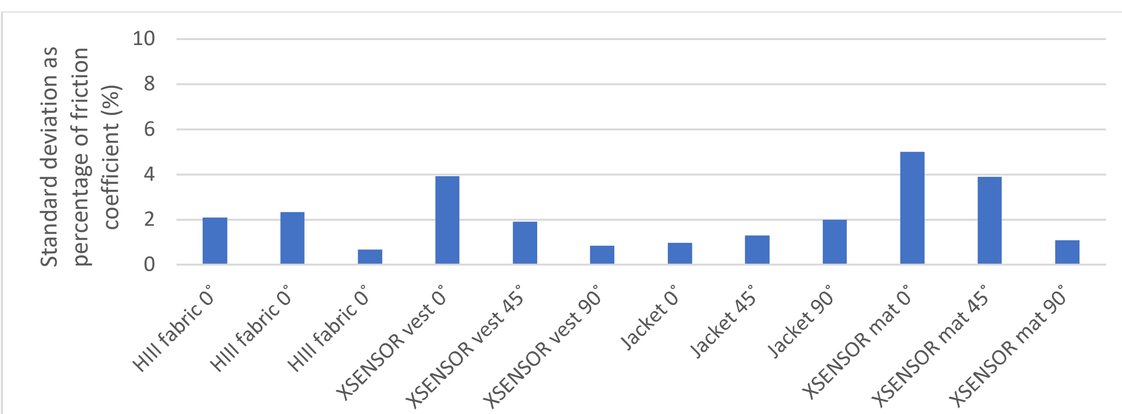


Figure 8 The standard deviation as percentage of coefficients of friction for each configuration and each material.

Conclusions

The XSENSOR vest material exhibited lower friction compared to the HIII fabric in all three configurations, while the other tested materials demonstrated higher friction in comparison with the HIII fabric in all three configurations. Furthermore, the tests revealed that the XSENSOR vest material was less dependent on the belt orientation compared to both the jacket and the HIII fabric.

In general, 45˚ and 90˚ belt orientation resulted in higher friction compared to the 0˚ orientation. The 45˚ belt orientation closely simulates the interaction between the shoulder belt and the occupant in a car, making it a more representative configuration for evaluating coefficients of friction.