A Study on the Coefficient of Dynamic Friction between Dummy and Seat by Test Method

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I. INTRODUCTION

For accurate finite element (FE) sled simulation, usually some important data (or factors) is needed – for examples, precise dummy, seat, restraint system model, and interaction rule between dummy and seat, or dummy and seat belt system, etc. This is a sequential study to help FE sled simulation enhancement. The aim of this study was to get the coefficient of dynamic friction between dummy and seat. However, it is not easy to find the announced values or documents about the coefficient of dynamic friction between various / flexible materials, as well as testing methods. Therefore, a newly specified test method was devised to reveal the relationship between dummy and seat. In this study, the effect of bulk friction was not considered.

II. METHODS

When the testing block moves straight on a flat plate with constant velocity, the coefficient of dynamic friction can be calculated from acquired forces, or accelerations (moving, and normal directions).

$$\mu_D = \frac{F_D}{F_N} = \frac{a_{moving\_direction}}{a_{normal\_direction}}, \quad (1)$$

where, μ_D is dynamic friction, F_D is the median of the dynamic frictional force, and F_N is the normal force, $a_{moving\_direction}$ is acceleration in moving direction, and $a_{normal\_direction}$ is acceleration in normal direction (those accelerations are acquired from accelerometers).

For the test, a propulsion system, testing block (weight), small metal plate (sled) under testing block, long-span metal plate onto test table, three sensors, and some specimens were prepared.

The pedestrian test device (Fig. 1) was used as a propulsion system with *upper legform carrier plus pusher (friction test exclusive)*. It was reliable for constant velocity and direction.

Before the main test, some pre-tests were performed to decide adequate weight for the testing block. Among various weights, the 2 kg block (Fig. 2) showed most stable results in terms of acquired accelerations, and reliable propulsion system.

For the data acquisition, the three sensors were attached to the testing block – one load cell for monitor pushing-force, two accelerometer for moving, and normal direction (Fig. 3). For presenting the dummy and seat materials, some specimens were prepared. In detail, the dummy skin (rubber), and dummy clothes (fabric) were attached under a small metal plate (Fig. 4), and typical seat cover materials (fabric, fabric with silicon patch, leather), and dummy clothes were attached to a long-span metal plate (Fig. 5).

Fig. 1. BiA impact system

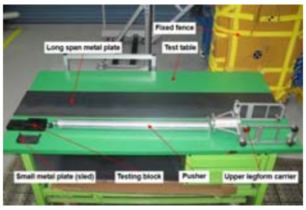

Fig. 2. Test devices

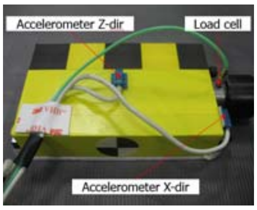

Fig. 3. Testing block with sensors

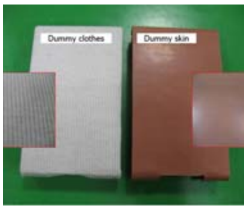

Fig. 4. Dummy skin, and clothes

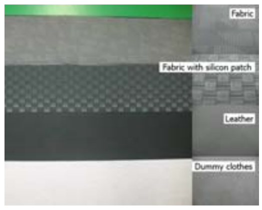

Fig. 5. Seat covers, and dummy clothes

Each test was repeatedly performed over five times under controlled conditions in a chamber (temperature: 18~20℃, humidity: 55~60%). Before and after the tests, each specimen was examined for defect and damage by visual and tactile inspection. Through result analysis, some data (selected to test deviation) were excluded.

TABLE I

TEST MATRIX AT SAMPLING VELOCITIES – 1.0, 1.5, 2.0, 3.5, 5.5, 7.5 m/s

Testing block	Long-span metal plate	Testing block	Long-span metal plate
Dummy clothes (fabric)	Seat cover (fabric)	Dummy skin (rubber)	Dummy clothes (fabric)
	Seat cover (fabric with silicon patch)		Seat cover (fabric)
	Seat cover (leather)		-

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III. INITIAL FINDINGS

In Fig. 6, the coefficients of dynamic friction were displayed as scattered data which were calculated by Eq. (1). The ‘$a_{moving\_direction}$’, and ‘$a_{normal\_direction}$’ were the mean value of acceleration from *target test velocity - 0.1* to *target test velocity + 0.1*. Those acceleration values were analysed and calculated in accordance with ‘*ISO 6133 – analysis of multi-peak traces*’.

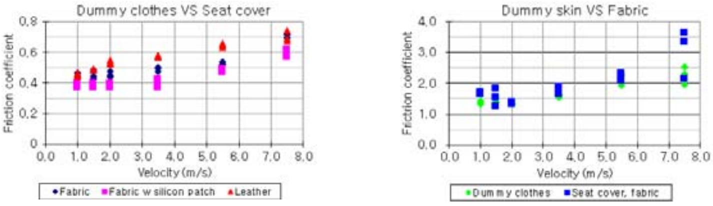

Fig. 6. Test results by scattered data

From these results, ‘friction models (dependent on sliding velocity)’ were derived through analysis of dynamic friction data (Eq. 2)

$$\mu_D = f(v), \tag{2}$$

where, μ_D is the coefficient of dynamic friction, and $f(v)$ is the curve referenced to *friction coefficient versus relative sliding velocity*.

Two types of friction models are suggested. MODEL #1 (Fig. 7) has one slope curve by linear regression. MODEL #’ (Fig. 8) consists of two slope curves by linear regression. Their break points were selected as the slope of the connecting line (between mean values in each velocity) was the most obvious changing point.

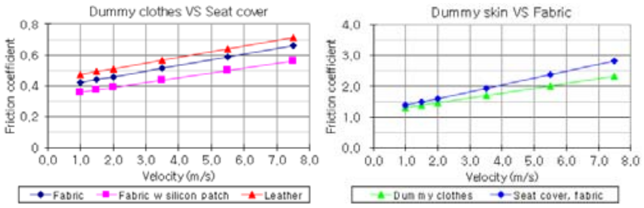

Fig. 7. MODEL #1, one slope curve by linear regression

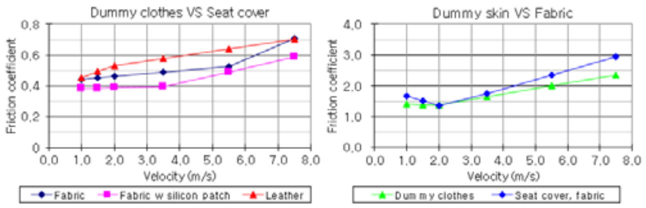

Fig. 8. MODEL #2, two slope curves by linear regression

These simplified and standardised models are helpful to understand the tendency of friction coefficients, and to apply in sled simulation.

IV. DISCUSSION

Generally, each test result showed uniform data distributions (low dispersion rate) in every velocity. However, sometimes it produced unpredictable results under uncontrolled (but, subtly changed) humidity, because the rubber and fabrics were severely sensitive in humidity. Moreover, the *dummy skin (rubber)* didn’t show consistent results in some velocities, and a new dummy skin appeared to behave slightly different to a used one. To get over these obstacles, the test chamber was carefully controlled, and pre-tests were performed over 10 times.

Overall tendency of friction coefficients shows that the higher the test velocity (and the less surface roughness), the higher the coefficient of dynamic friction. In case of *dummy skin vs dummy clothes*, and *dummy skin vs fabric seat cover*, all values over 1.0 – almost cling to each other. It means that the concerning interaction (between dummy and seat) is not only *dummy skin vs dummy clothes*, but also *dummy clothes vs seat covers*.

It will be expected that *friction models (dependent on sliding velocity)* facilitate more precise and better behaviour than usual *constant friction* in FE sled simulations, or different kinds of occupant analysis. Furthermore, the test method used in this study will be helpful to figure out the characteristic friction coefficient between other different kinds of flexible materials.

V. REFERENCES

[1] ISO 6133, Rubber and plastics – Analysis of multi-peak traces obtained in determinations of tear strength and adhesion strength (Page#2~5 – Procedure, and Trace-analysis)
[2] Internet: http://www.bia.fr (Products > Autumotive Safety > Impact Simulation)
[3] Internet: http://www.kistler.com (Products > Components > Force Sensors, Accelerometer Sensors)