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Experimental investigation of interaction between a vehicle and its occupants

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Abstract

This paper presents some results of measurements performed on a probant in a vehicle during selected manoeuvres. The main objective of these experiments is to obtain data on the behaviour of a human body with and without visual information and in different contact configurations with vehicle. The probant played both roles of a passenger and a driver as well.

About twelve signals on vehicle states consisting of different accelerations, vehicle absolute velocity, directional deviation and roll as well as yaw angles have been measured.

The probant's motion was captured by two cameras and furthermore nine accelerations were measured on the probant. In order to get the information on the probant's muscular activity during the manoeuvres sixteen electromyography sensors have been placed on his body.

The measurements presented in this paper should give a basis for a model of a so-called "mechatronic dummy", which is a computer dummy with a feedback controlled musculature.

Keywords: comfort, vibration, electromyography, vehicle design

1. Introduction

The methods of virtual product design with the aid of computer simulation particularly in the design of road and railway vehicles made significant progress during the last decade. Virtual prototypes comply very well with reality in vehicel stability domain. However there are still cases in the product assessment process, in which experiments with human probants are unavoidable, since objective measures have not been developed yet, [4, 5], and simulation models are not enough advanced. Ride comfort counts to such cases despite some trials for objective measures exist, e.g. ISO 2631-1:1997 / VDI 2057, British Standard BS 6841:1987, [3], or SAE-J 1013. However, the fulfilment of the objective measures does not guarantee in all cases that the vehicle is really subjectively comfortable. It is one of the reasons why almost every company dealing with comfort evaluation developed its own in-house procedures, which are, however, not public accessible.

Current vehicles are designed in order to satisfy a wide range of not just purely technical design objectives [5]. Among the others the ride comfort objectives are emphasized not only for luxurious limousines. The reasons for the design of comfort cars and trucks are connected with the safety of the road traffic. The vehicle vibrations result in tiredness and alertness reduction of the driver.

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Previous studies e.g. [1] deal with on one hand very sophisticated computer dummies usually based on finite element models. However, on the other hand, these dummies are more or less passive. Contrary to the real human being they were not able to actively react on the motion or even visual cues. Very important seems to be the state of the muscular system of the human body, ie if the agonist-antagonistic muscles are simultanously activated, the body is more stiff and the frequency responce differs from relaxed state as shown in [6].

The measurements presented in this paper should give a basis for a model of a so-called "mechatronic dummy", which is a computer dummy with a feedback controlled musculature, [8]. The main design objective of the mechatronic dummy is to contribute to the methodology for the comfort evaluation of virtual prototypes. The mechatronic dummy contains models of active muscles, which react on outer cues such as motion or visual cues. The mechanical states of the dummy and additionally the muscle tension will be than evaluated in order to classify the comfort or tiredness of the passenger or driver.

The main objective of the presented measurements is to collect data for the identification of the behaviour of the mechatronic dummy. The experiments presented in this paper are focused on the investigation of visual information about the manoeuvres on the passenger behaviour. During the experiments several ride manoeuvres have been performed and data have been collected from both the vehicle on-board sensors and sensors on the human probant. The measurements have been done with the first generation of Renault Scénic 1.6 16V (2002), see fig. 1. This vehicle has been selected, because it is a test vehicle, which has already been modified for the experiments, e.g. the vehicle is equipped with a security cage or camera and instrumentation holders. The experiments have been performed in collaboration with TÜV UVMV during three days in June 2006 on the former military airport nearby Mimoň, the Czech Republic, [7].

Fig. 1. Test vehicle.

2. Measurements on the vehicle

In order to record the vehicle motion, the vehicle is equipped with a set of different sensors as indicated in tab. 1. The signals are measured together with three A/D converters National

Instruments DAQ 6036 installed in two computers. The converters are denoted as 1.x, 2.x and 3.x.

Together with the vehicle states the vertical acceleration of the sprung mass above every wheel is measured. These accelerations are measured from another reason; they are not connected with the identification of the mechatronic dummy. These measurements are complementary, in lower frequency range provide information about rotational motions of the car (and thus of the seat), in higher frequency range provide information about flexible (vibrational) behaviour of the car body.

The signals 3.1, 3.2 and 3.3 are measured by a stabilised table RMS FES 33/1. The signals 3.4 and 3.5 are measured by a sensor Corsys SCE and the vertical accelerations are measured by transducers Endevco Isotron.

Furthermore a binary synchronisation signal (signal number 3.10) from an optical gate is captured. Since three A/D converters together with two camcorders are used, the synchronisation signal is a very important issue. The synchronisation is performed with optical gates, which are installed on predefined position on the track and captured with Corrsys WL24-B2331 device from the vehicle. Further accelerations are measured with the thriaxial Brüel Kjær transducer 4504A on a frame of the probant's seat in all three directions (signals 2.11, 2.12 and 2.13).

No.	*Signal*
3.1	Lateral acceleration
3.2	Yaw rate
3.3	Roll
3.4	Directional deviation
3.5	Vehicle absolute velocity
3.6	Acceleration above right front wheel
3.7	Acceleration above left front wheel
3.8	Acceleration above right rear wheel
3.9	Acceleration above left rear wheel
3.10 2.13	Synchronisation
2.10	Acceleration on seat frame longitudinal
2.11	Acceleration on seat frame lateral
2.12	Acceleration on seat frame vertical

Tab. 1. Signals measured on the test vehicle.

3. Measurements on the probant

The human probant is monitored by three kinds of information. Acceleration transducers are fixed on the pre-defined probant's body positions. Further measurements are captured by electromyography electrodes device and the third type of information on the probant originates from two camcorders.

The acceleration measurements are summarized in tab. 2 and fig. 2. All the accelerations are measured with triaxial transducers Brüel Kjær 4506.

Electromyography (EMG) system Motion Lab Systems MA300-16 measures electrical signals proportional to the activation of the muscle fibre. The measuring locations are presented in tab. 3 and fig. 2.

No.	*Signal*
2.1	Acceleration of head longitudinal
2.2	Acceleration of head lateral
2.3	Acceleration of head vertical
2.4	Acceleration of chest longitudinal
2.5	Acceleration of chest lateral
2.6	Acceleration of chest vertical
2.7	Acceleration of seat longitudinal
2.8	Acceleration of seat lateral
2.9	Acceleration of seat vertical

Tab. 2. Acceleration measurements on the probant.

No.	*Signal*
1.1	EMG upper left leg - front
1.2	EMG upper left leg - rear
1.3	EMG upper right leg - front
1.4	EMG upper right leg - rear
1.5	EMG abdomen - left
1.6	EMG abdomen - right
1.7	EMG back - left
1.8	EMG back - right
1.9	EMG biceps - left
1.10	EMG triceps - left
1.11	EMG biceps - right
1.12	EMG triceps - right
1.13	EMG forearm - left
1.14	EMG forearm - right
1.15	EMG neck - left
1.16	EMG neck - right

Tab. 3. EMG signals measured on the probant.

The probant is furthermore recorded by two camcorders. The first camcorder takes the probant's body motion from the front and the second from the right hand side. In order to evaluate the motion of the probant from the camcorder frames in post-processing the probant has black markers (table tennis balls) on his body as well as reference black balls are mounted on the vehicle itself. The black markers on the probant and on the vehicle are shown in fig. 3.

The measuring equipment such as amplifiers and computers with the converters is placed in the boot and on instead of rear seats, which have been removed, as shown in fig. 4. The measuring devices have power supply independent of the board net of the vehicle. Two converters 12 V DC/230 V AC are used to supply the devices which cannot be supplied from 12 V DC.

4. Maneuevres

The manoeuvres selected for the experiments should excite the probant in all three directions, i.e. longitudinal, vertical and lateral. In some experiments, the probant is in both passen-

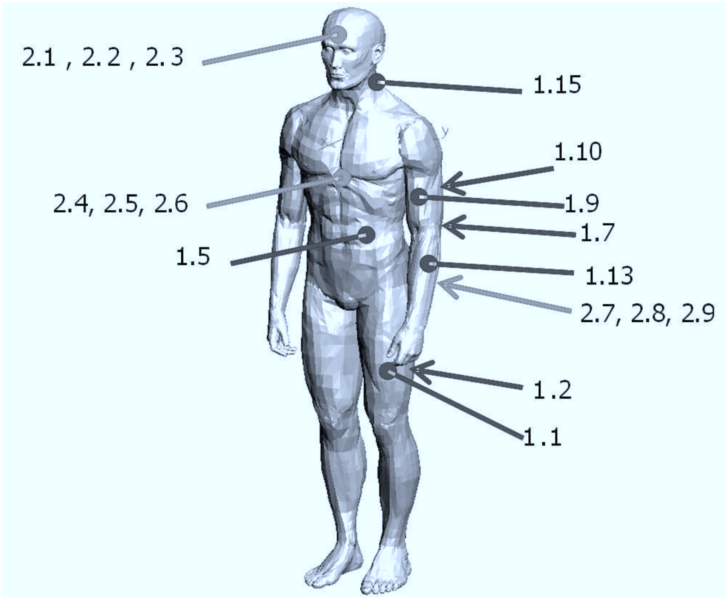

Fig. 2. Measurement of EMG (1.x) and acceleration (2.x) on the probant.

Fig. 3. Probant and vehicle with black markers.

ger and driver role. The list of manoeuvres is presented in tab. 4. Because of the repeatability, every experiment is run three times. The symmetrical double lane change modified from ISO 3888-2 (VDA-test) is chosen as a lateral manoeuvre, see fig. 5. The manoeuvre is chosen both as left and right. In such a case the passenger does not know the manoeuvre direction and thus has no chance to prepare the musculature and must react on the current unknown motion. Emergency full braking from 100 km/h with ABS-cycling is selected as a longitudinal manoeuvre and last but not least the crossing of a rumble strip at velocity of 60 km/h is considered as a vertical excitation.

Fig. 4. Instrumentation in the vehicle.

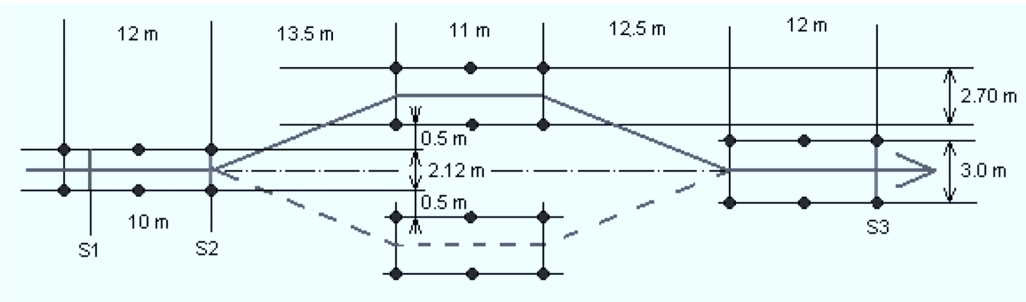

Fig. 5. Symmetric double lane-change manoeuvre, [2].

Experiments			Double lane change	Double lane change mirrored	Rumple strip	Emergency braking
Passenger	Hands in lap	w visual info	3	3	3	3
		w/o visual info	3	3	3	3
	Hands on holder	w visual info	3	3	3	3
		w/o visual info	3	3	3	3
Driver	Hands on steering wheel	w visual info	3	3	3	3

Tab. 4. Number of manoeuvres.

5. Evaluation of the influence of visual information

Together 39 signals are captured for each of 60 valid experiments, which result in a large amount of data. In order to study the influence of visual information on the passenger behaviour, the lateral manoeuvres are studied in this paper. fig. 6 presents an example of the captured and cropped signals from a lateral manoeuvre with right hand on the holder with visual information after post processing. Since the right hand supports the probant's body position, the right hand

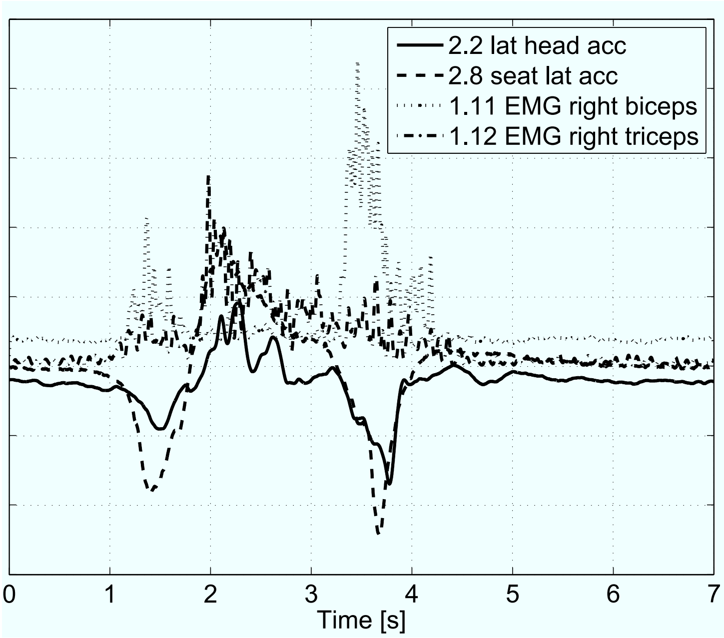

Fig. 6. Example of selected data at the double lane change.

EMG signals from biceps and triceps muscles reflect the human body reaction on the motion and visual cues. The EMG measurements are post processed to get an envelope. The vehicle and passenger acceleration signals are filtered with a low pass filter.

Two features of the captured signals are studied. The first is the level of lateral head accelerations and the second is the time delay between the crossing the synchronisation signal and the action the muscles.

The lateral head acceleration at double lane change with right hand on holder are averaged and compared in fig. 7. A significant difference is observer for the first two peaks, in the first peak is the lateral acceleration lower of about 30 %, the second peak in of about 43 %. The lower level of signal represents the configuration with visual feedback information, the higher level is the configuration with bladed eyes, ie without the visual information which is used to accelerate the reaction of the passenger on the motion cues.

6. Conclusions

The paper presented the measurement of the probant in a personal vehicle at different manoeuvres. The instrumentation of vehicle and the probant is described.

The main objective is to study the influence of the visual cues on the probant's reactions. The double lane change manoeuvre is chosen for these evaluations. The evaluation shows that the visual information accelerates the reactions of the probant's muscular system of about 0.1s and decreases the peak acceleration of the observed head of about 30 % in the first peak and even 43 % in the second peak.

The experiments indicate that the visual information is significant for the reactions of the mechatronic dummy. Due to the visual information the probant is better prepared to the compensation of the motion originating in lateral acceleration.

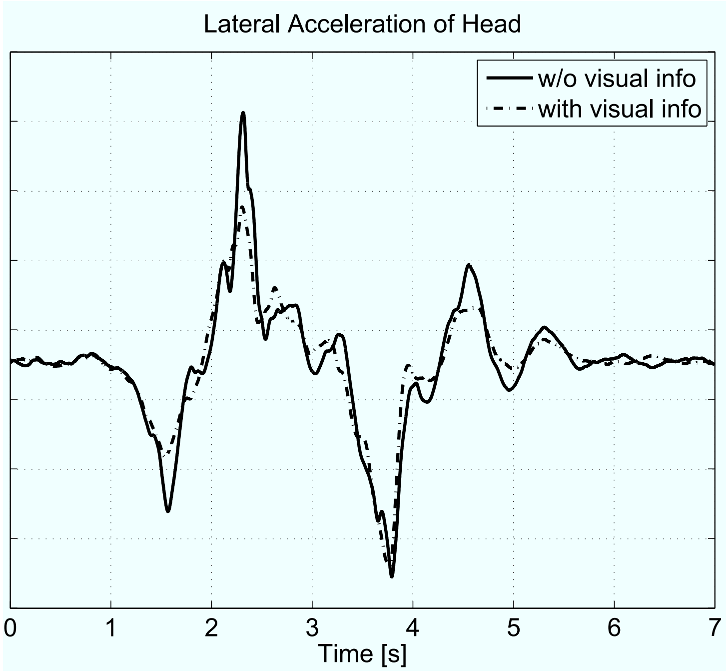

Fig. 7. Averaged acceleration of the passenger head at the double lane change.

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