Development of use tests for automotive components

Helios de Rosario Martínez*, José S. Solaz Sanahuja*, Elisa Signes i Pérez*, Ángel Valera Fernández, Pedro Huertas Leyva*, Luis Garcés Pérez*, Isidro Campo Becares*, Victor Primo Capella***

*Instituto de Biomecánica de Valencia
**Instituto de Automática e Informática Industrial (ai2)

Automating durability tests for products is one effective way of guaranteeing repeatable results and reducing costs in the product value chain, but their definition becomes complex when the forces to which the products are subjected depend on human interaction and the mechanical properties of the material. This problem frequently occurs with automobile components. To solve it for the wear of second-row seats, an automated use test has been developed, based on a series of actual measurements of ingress and egress movements, performed by the Instituto de Biomecánica de Valencia, plus an industrial robot system with force control, programmed and set up by the Instituto de Automática e Informática Industrial (ai2) of the Universidad Politécnica de Valencia, which reproduces a pattern of movements and forces calculated from the real observations.

Introduction

One of the goals of product design is to ensure that the characteristics of the product and the materials used in its production are suitable for its intended use, guaranteeing comfortable interaction and an adequate level of wear throughout the useful life of the product. For this reason, it is common practice to perform durability tests via cyclic repetition of the movements and forces to which products will be subjected during regular use.

It can be quite complicated to define this type of tests for products with which people interact by contact, since human movements are often complex and difficult to emulate by simple machines. One application that has sparked the interest of the industry is the wear tests performed on vehicle seats in relation to ingress/egress movements.

Conventional methods for this type of tests consist of applying cycles of loads to the seats, proportioned according to the weight of the potential users or, sometimes, the normal pressure distributions observed in instrumented seats. However, the greatest contributor to the wear of textile materials is the tangential force which causes friction with the lower limbs when the user is moving to sit or stand. This type of force, which is difficult to measure directly, is produced by a combination of the weight and the movement of the pelvis and legs of the user when in dynamic contact with the seat. Therefore, the best way to define the testing method consists of accurately knowing the pattern of this movement and the simultaneous dynamic actions, and reproducing these conditions using dummies.

In order to attain this goal, the IBV has carried out a series of tests involving users, aimed at measuring the biomechanical variables associated with the ingress/egress movements in the second row of seats in an automobile and, based on these results, it has defined a pattern of movements and forces to be applied to standardised dummies. These patterns were integrated in an industrial robot programmed with a force control algorithm by the ai2 Institute of the *Universidad Politécnica de Valencia*.

Methodology

In order to capture the ingress/egress movements, a series of tests were performed on users in a real car. These tests used the Kinescan/IBV photogrammetry system with four cameras and a pressure-recording system placed on the seat and the backrest of the second row of the vehicle, recording the actions of the user with a sampling speed

>

> of 20 frames per second (**Figures 1 and 2**). The position of the system had previously been calibrated in the space of the photogrammetry system.

Figure 1. Testing stage and photogrammetry system.

Figure 2. Pressure blanket on seat.

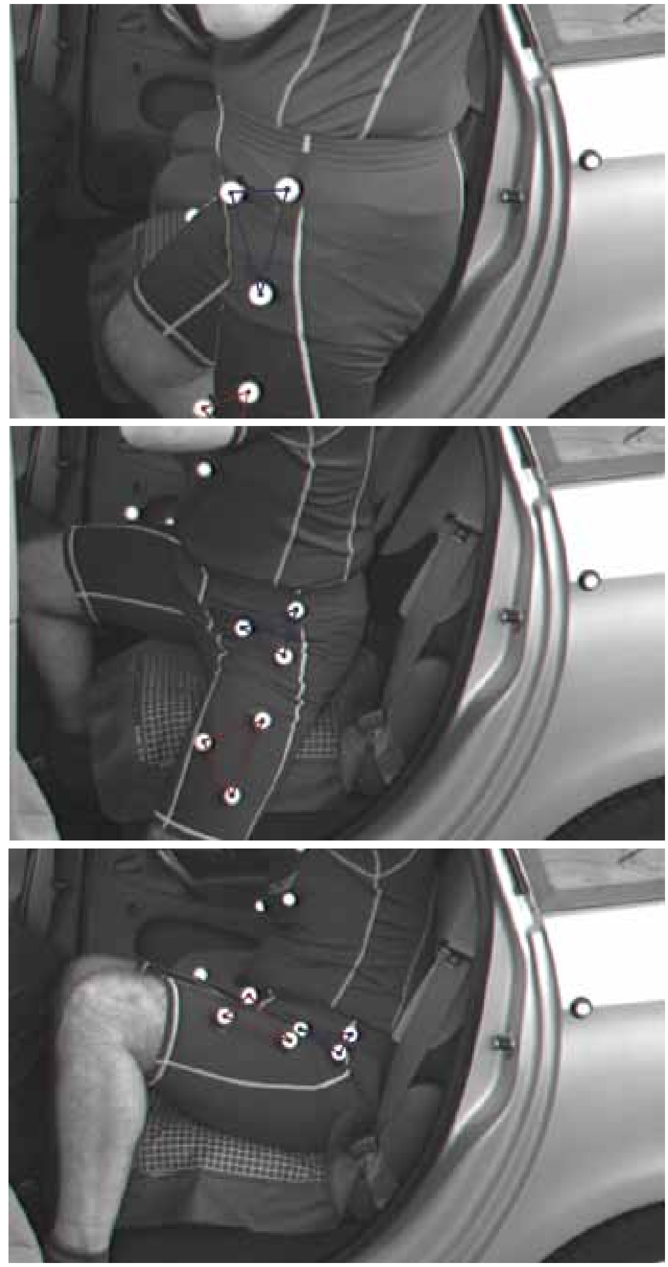

Figure 3. Measurement of the ingress/egress movement.

The movements (position and height) of the legs were simultaneously obtained by three reflecting markers on each leg. The pelvis was measured via a set of six markers. The position of the body parts was defined at each instant of the ingress/egress movements according to the coordinates of said markers, taking the fully seated position as a reference (**Figure 3**). The anatomical reference used to define the movements was the "H-point" (a point halfway between the hips), which is used as a standard reference in the automotive industry.

The movement of the H-point and the rotation of the legs were measured by mean of the photogrammetry records, also obtaining the force exerted on the seat by integrating the pressure measured on the seat. These data were used to obtain the average movements of three people: one women in the fifth percentile and two men in the 50th and 95th percentiles, each of whom performed three repetitions of the test. To obtain the average pattern, an advanced functional data processing technique was applied, regularising the position, orientation and force curves recorded in each test, and defining average curves at a standardised speed, in order to even out the duration and the phases of the nine measurements (**Figure 4**).

In addition to the movements of the persons and the forces they exerted on the seat, in order to develop the test platform, it was necessary to obtain the force/seat movement calibra-

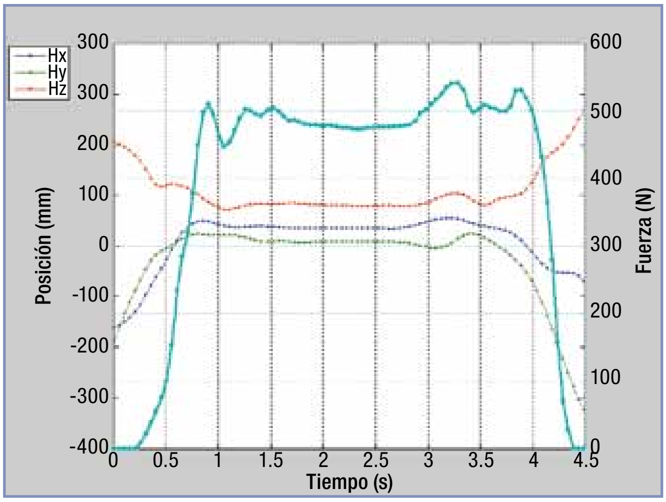

Figure 4. Pattern of force and movement of the H-point.

tion curve. This curve is required in order to establish the force control, since it allows us to determine the movement of the seat when a given force is applied. These tests of automobile seat firmness have been developed in accordance with the UNE-EN 1957 procedure.

Using the information from the biomechanical and firmness tests, the force and movement pattern to be followed by a dummy was defined in accordance with the SAE J826 and ISO 6549 standards. In this type of dummies the thighs and the pelvis form a rigid block which imitates the bottom surface of a seated person, such that the dimensions of their profile and the connection point with the robot that moves them are defined according to the reference H-point.

Based on the predetermined pattern of force and movement, we first of all created a 3-D computer simulation to ensure that the movement of the dummy in relation to the seat was compatible with the geometrical limitations of the seat, also considering its capacity for deformation (**Figure 5**). Once the adjustments had been made, the pattern was programmed in an ABB IRB 140 industrial robot equipped with a JR3 force sensor (**Figure 6**).

The IRB 140 is a compact six-axis robot with a working space reach of 810 mm and repeatability of ± 0.03 mm. The JR3 sensor amplifies and converts the force signals into a digital representation which can be used to control the movement of the robot when the dummy comes into contact with the surface.

In order to perform the tests on the automotive components, an application has been developed in which the robot is controlled in three separate phases: the first of these is the free movement phase, in which the robot moves up to the contact point in three-dimensional space without any interaction with its environment. Control of the position and/or speed of the robotic system has been established in this phase. The second phase is the impact phase, during which the robot first comes into contact with the environment. Finally, the restricted movement phase, in which the robot applies the force required to perform the entrusted task. This phase uses the measurements provided in real time by the JR3 sensor.

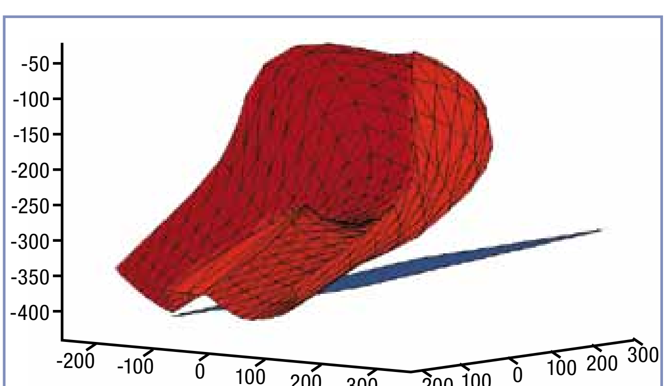

Figure 5. 3-D simulation of dummy movement.

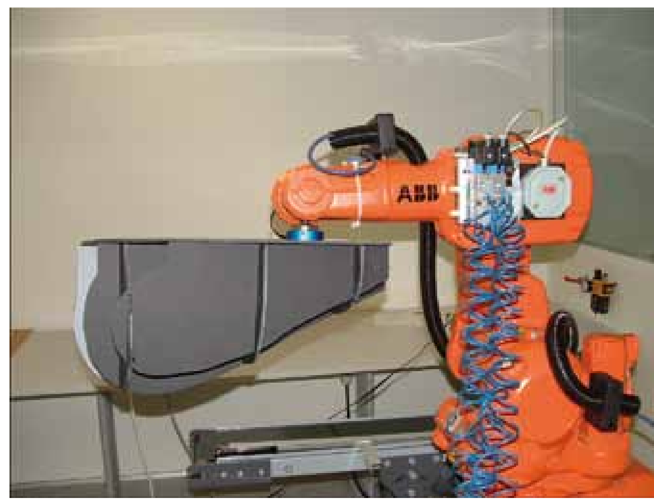

Figure 6. IRB 140 robot used to reproduce the movement.

Conclusions

By analysing human movements in real use tests and by programming a force and movement control system in an industrial robot we have been able to perfect a test for controlling the mechanical effect of ingress/egress movements in the second-row seats of an automobile. This methodology can also be applied to testing other types of mechanical interactions and to other automotive components, for automatically measuring, modelling and reproducing this type of interactions between the user and the product.

ACKNOWLEDGEMENTS

The Institute of Automation and Industrial IT (ai2) of the Polytechnic University of Valencia (UPV) for its participation in the development of an automated use test for studying the wear of second-row seats.