

A Component Test Methodology for Simulation of Full-Vehicle Side Impact Dummy Abdomen Responses for Door Trim Evaluation

2011-01-1097

Published
04/12/2011

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doi: [10.4271/2011-01-1097](https://doi.org/10.4271/2011-01-1097)

ABSTRACT

Described in this paper is a component test methodology to evaluate the door trim armrest performance in an Insurance Institute for Highway Safety (IIHS) side impact test and to predict the SID-II's abdomen injury metrics (rib deflection, deflection rate and V*C). The test methodology consisted of a sub-assembly of two SID-II's abdomen ribs with spine box, mounted on a linear bearing and allowed to translate in the direction of impact. The spine box with the assembly of two abdominal ribs was rigidly attached to the sliding test fixture, and is stationary at the start of the test. The door trim armrest was mounted on the impactor, which was prescribed the door velocity profile obtained from full-vehicle test. The location and orientation of the armrest relative to the dummy abdomen ribs was maintained the same as in the full-vehicle test. An aluminum honeycomb of a pre-determined crush strength and cross-sectional area attached to the base of the assembly of two abdominal ribs was used to simulate the lumbar shear force, to capture the effect of lower torso loading on the upper torso. The test methodology was developed and validated to a full-vehicle test and the sensitivity of the methodology to different armrest designs was also evaluated. The results show good correlation to full-vehicle test, thus indicating that this component test methodology has good potential to evaluate different armrest design alternatives across various vehicle programs.

INTRODUCTION

In a full-vehicle side impact test, various factors affect dummy responses such as door/side structure velocities, door sheet metal compliance, geometry and stiffness of the intruding door trim, size and stiffness of the EA foams packaged behind the

door trim, dummy seating position, and presence of inflatable restraints such as side and curtain airbags. Different body regions of the dummy are impacted by different parts of the vehicle interior, and the mutual stiffness between the dummy and interior governs the momentum exchange [1]. In the IIHS side impact moving deformable barrier test using 5th percentile SID-II's deflection-based dummies to assess occupant and structural performance, the upper torso injury metrics (average and peak rib deflections, rib deflection rates, V*C and shoulder deflection) and its importance on overall vehicle rating have placed more emphasis on robust component/subsystem evaluation of door trims and restraints [2]. A plethora of component and sub-system test methodologies for side impact assessments have been developed over the last three decades, gradually evolving in complexity based on their ability to capture full-vehicle test parameters [3]. These component and sub-system test methodologies were primarily focused on evaluation of door trims, restraints, and simulation of occupant performance. As noted by Chou et al (2007), the primary aim of the component test methodologies was to develop an up front assessment tool for the evaluation of countermeasures and provide design direction early in the vehicle development process. However, the ability to capture full-vehicle physics of many existing component test methodologies was limited.

The component test methodology presented in this paper has been developed to evaluate and verify various metrics of door trim armrest performance. The component test methodology uses the SID-II's abdomen ribs and aims to capture the impact conditions and kinematics of the full-vehicle test. The component test methodology is not only capable of assessing rib deflections, but also rib deflection rates and V*C.

TEST METHODOLOGY

THEORY

The test methodology for armrest evaluation is based on simulating the full-vehicle physics at a component level as illustrated in [Figure 1](#). This test methodology can be used both as a target setting tool in the early phase, and as a verification tool (when prototype parts become available) in the later phase of vehicle development. Referring to [Figure 1\(a\)](#), in a full-vehicle test, the SID-II's abdomen ribs are primarily impacted by the door trim and/or armrest, which accelerates a portion of the spine box mass, being referred herein to as the 'effective spine box mass', along the lower spine acceleration (T_{12}). Additionally, acceleration of the effective spine box mass may be influenced by the lumbar shear force due to differential loading between the lower torso and upper torso, caused by either the offset in contact time or differences in stiffness. In this test, the lumbar shear force is measured by the lumbar loadcell located at the base of the lumbar spine. The door trim armrest is mounted on the linear impactor and is prescribed a predetermined velocity profile from full-vehicle test. The dummy contact velocity and velocity-time history of the armrest impactor follows the door velocity profile measured on the door inner sheet metal in the vicinity of armrest. The effective mass of the spine box that is accelerated by the two abdominal ribs is approximated by dividing the mass of entire upper torso (~13 kg) by the total number of ribs (six ribs including the shoulder). Thus, the full-vehicle physics is isolated and simplified to a component as shown in the schematic of [Figure 1\(b\)](#). The input to the component model is the door velocity time-history and lumbar shear force while

the corresponding outputs are the abdomen rib deflections and lower spine acceleration (T_{12}) as shown in [Fig. 1\(b\)](#).

TEST SET-UP

[Figure 2](#) shows the test set-up of the component test methodology described above. The spine box with the two SID-II's abdomen ribs assembly is mounted on a linear bearing and is allowed to translate during impact. The spine box with the assembly for two abdominal ribs is rigidly attached to the sliding test fixture, and is stationary at the start of the test. To achieve the desired effective mass (approximately 4.5 kg) for the assembly of two abdominal ribs, a new aluminum SID-II's spine box was fabricated, while maintaining the same design and attachments as the original spine box. However, due to practical limitations, the final effective mass of the rib assembly was approximately 7.5 kg. The door trim armrest is mounted on the impactor, which is prescribed the door velocity profile obtained from the full-vehicle test (from time of dummy contact till separation). However, the door velocity profile in the component test was approximated to a constant deceleration by using an aluminum honeycomb. The location and orientation of the armrest relative to the dummy abdomen ribs is maintained the same as in the full-vehicle test. An aluminum honeycomb of a predetermined crush strength and cross-sectional area attached to the base of the assembly of two abdominal ribs is used to simulate the lumbar shear force, to capture the effect of lower torso loading on the upper torso. The aluminum honeycomb has a mating surface on the impactor, and its length can be adjusted depending on the time difference between contact of abdomen ribs and pick-up of lumbar shear force. In this test set-up, in order to compensate for the additional mass of the rib assembly, the

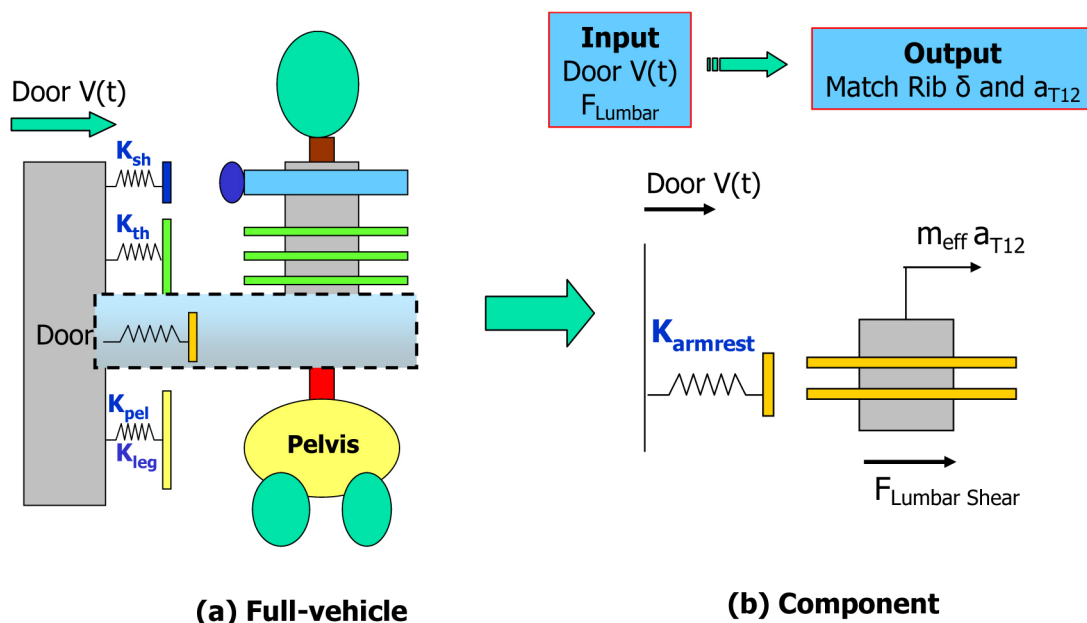


Figure 1. Schematic of component methodology for armrest evaluation using SID-II's abdomen ribs assembly