PERFORMANCE OF THE PROTOTYPE WORLDSID DUMMY IN SIDE IMPACT CRASH TESTS

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ABSTRACT

A new, highly biofidelic, advanced side impact crash test dummy is being designed within the international WorldSID project. This world-wide project was initiated with the aim of developing a new mid-size male dummy which, it is hoped, by responding to the needs of potential users around the globe, could be adopted universally for side impact crash testing and for future harmonised regulatory test procedures as defined by the International Harmonized Research Activities (IHRA).

The prototype WorldSID dummy has been subjected to a series of demanding car environment crash tests sponsored by the Department of Transport and Regional Services of Australia. This testing constitutes the first phase of a multinational programme to evaluate the dummy's biofidelity along with its directional sensitivity and verification. Any necessary modifications will be made, following which a second, comprehensive and world-wide evaluation programme will be undertaken.

This paper presents and discusses the performance of the dummy as observed during the initial testing in Australia. This testing consisted of a mobile deformable barrier (MDB) test, two sled tests, a car-to-car test and verification testing. During the testing the dummy was equipped with a complete set of its purpose-designed instrumentation yielding a considerable quantity of data. Along with the dynamic responses, aspects such as the kinematics, positioning and handling of the dummy will be addressed.

BACKGROUND

Although the Hybrid III dummy is used universally for frontal impact testing, several different dummies are used in side impact, each with its own advantages and disadvantages. Eurosid-1, DOT-SID, Biosid and SID-IIs are all commonly used side impact dummies. The adoption across the globe of a single, adult side impact dummy would be advantageous for all involved in the crash safety field for a number of reasons. Firstly, the adoption of a harmonised dummy would be highly desirable if harmonised regulatory test procedures were to be adopted throughout the world, as is the objective of the International Harmonised Research Activities (IHRA). Secondly, car manufacturers could avoid the additional work of developing cars to pass different regulatory tests, with different dummies, when they are to be sold in several markets. This process is costly to the manufacturers and has no benefit to passive safety.

It is also true to say that the existing side impact dummies are limited in their biofidelity and cannot always be instrumented as required. There is therefore, aside from harmonisation aspects, also a need for an improved side impact dummy.

It was with the double objective of developing a harmonised and advanced dummy that, in November of 1997, the International Organisation for Standardisation (ISO) initiated the international WorldSID (World-wide Side Impact Dummy) project which was to operate under the auspices of the ISO working group on anthropometric test devices: ISO/TC22/SC12/WG5 [1]. This group was made up of participants from car manufacturers, governmental organisations, research institutes, test houses and dummy and instrumentation manufacturers from around the world.

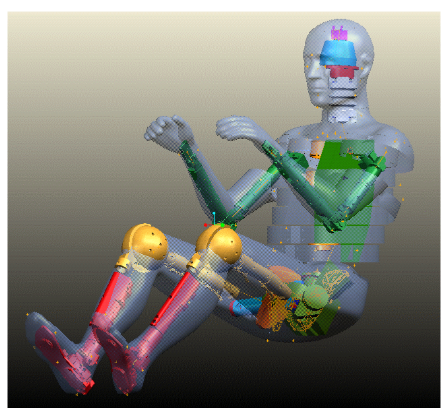

FIGURE 1 CAD image of the WorldSID prototype dummy

The group has always striven to include all involved in passive safety and, to this end, three regional groups for Europe, Asia-Pacific and the Americas, were created to facilitate the participation of interested parties around the world. The WorldSID Task Group brings together, on a regular basis, delegations from the three regions. The Task Group contracted a design team, consisting of dummy manufacturers, instrumentation manufacturers and members of the European Commission (EC) sponsored SID-2000 project consortium, to carry out the development work. A project manager was also contracted to co-ordinate the development activities and to liase between the Task Group and the Design Team.

The project has been financed, up to delivery of the first prototype dummy, by contributions from all three of the regions. The United States, Japanese and European car industries have made large direct contributions to funding through their industry organisations: OSRP, JAMA and ACEA respectively. The European Commission has also made a significant contribution through the participation in the development of the dummy of the SID-2000 consortium. Contributions from Transport Canada, the Australian Department of Transport and Regional Services, the U. S. National Highway Transportation and Safety Administration and the European Commission supported SIBER consortium are contributing to the funding of the the first WorldSID prototype evaluation testing. Furthermore, all costs related to the participation of Task Group and Regional Advisory Group members are met by the individual participating organisations.

The WorldSID dummy is being developed to meet the dynamic response requirements laid out in the document ISO TR9790 [2]. The target performance that has been specified is a rating of “good” to “excellent”, on the scale contained in TR 9790, for all segments of the dummy. A report identifying new such requirements was, at the time of writing, being finalised by the IHRA. The group will ensure that future versions of the dummy also meet these IHRA requirements.

A single prototype dummy has been fabricated. Following the evaluation of the prototype, an improved, pre-production dummy will be developed and it is envisaged that several will be built for extensive testing around the world. Once the development of the dummy is complete, full specifications will be released into the public domain. This release is planned for March 2004.

INTRODUCTION

The WorldSID Task Group organised a workshop in December 2000 to mark delivery of the prototype dummy. The workshop, hosted and funded by the Department of Transport and Regional Services in Australia, provided an opportunity to perform full dummy tests with the prototype for the first time. This allowed the Task Group to check that the newly delivered hardware was functioning correctly and to obtain test data for an initial assessment of the dummy’s performance.

Only several weeks preceding the first test the component parts had been delivered for assembly of the full dummy after design and manufacture by several companies in the United States and in Europe. The dummy was assembled, instrumented and wired, then verification tests were performed. The dummy was shipped to Melbourne where two full-scale tests and two sled tests were performed with the dummy fully instrumented. Following this initial testing, the dummy was shipped to another test site to begin a full evaluation of its biofidelity.

This paper presents the results of the initial testing performed during the WorldSID workshop and discusses various aspects of the dummy’s performance and handling based on the observations made during this testing.

DESCRIPTION OF THE WORLDSID PROTOTYPE DUMMY

The WorldSID prototype dummy (see FIGURE 1 and FIGURE 2) is representative of a mid-size male with an overall mass of 77.3 kg and a stature of 1753 mm. Its anthropometry is based on a study carried out expressly for the automobile occupant[3], having first checked this data against all known pertinent data sources for the world population [4].

FIGURE 2 The WorldSID prototype dummy.

The head is made up of a one-piece polyurethane skull, with bonded skin, which fits over a central instrumentation core. The neck is of similar design to that of the ES-2 dummy and is adjusted to give a biofidelic response in flexion and extension in addition to its lateral biofidelity. The thorax is composed of three Nitinol® super elastic alloy ribs (see FIGURE 3). Each rib consists of an outer band and a secondary inner band which contributes to giving the thorax a biofidelic response. Two abdominal ribs and a shoulder rib, all of a similar design to that of the thorax, bring the total number of ribs to six. The pelvis (see FIGURE 4) is a totally new concept which includes a polymer pelvic bone incorporating the form of the pelvic girdle and giving humanlike flexibility of the pelvis structure. The lumbar spine (see FIGURE 5) is a radically new design allowing de-coupling of the thorax and pelvis segments to be achieved. The lower extremities have been developed expressly for the WorldSID dummy and include purpose-designed, instrumented side impact knees (see FIGURE 6) and integrated shoes.

FIGURE 3 View of the WorldSID prototype shoulder, thorax and abdomen ribs

The dummy can be equipped with a stub arm for general testing but a full instrumented upper extremity has also been developed as an option for uses such as airbag interaction testing. A full set of load cells and accelerometers has been developed and each of the six ribs is equipped with an IR-TRACC (Infra-Red Telescoping Rod for the Assessment of Chest Compression) sensor [**5**] to measure rib displacement. An optional, in-dummy data acquisition system (DAS) has also been developed. This system consists of seven units that can be mounted at various locations (thoracic spine, pelvis and femur) inside the dummy and which together have enough capacity for the entire instrumentation of the dummy (up to 212 channels in total). The dummy is equipped with integrated wiring for the sensors and has a purpose designed suit with removable, full-length sleeves and legs.

FIGURE 4 Pelvic structure and pelvis flesh (insert).

FIGURE 5 Lumbar spine

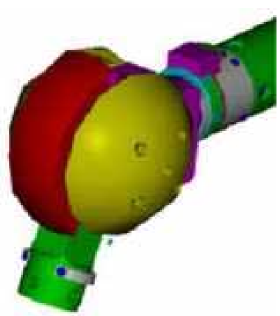

FIGURE 6 CAD image of knee.

METHOD

Verification Tests

A number of tests have been defined in order to allow verification of the prototype dummy dynamic responses. Tests are based, as far as possible, on existing certification tests for other dummies. The verification process includes visual inspection of parts, certification of instrumentation, sub-system tests and full dummy tests.

For the head, a lateral drop test and a frontal drop test have been specified. The test procedure for the neck is still being considered. Until a procedure is specified, the ES-2 test is being used. This test is itself similar to the Eurosid-1 test.

Pendulum tests on the assembled dummy have been specified for verification of the shoulder, the thorax and the pelvis. Since the dummy has been designed for use with an occupant seated posture, and since the lumbar spine is more flexible than that of other dummies, the dummy is seated on a bench for pendulum testing rather than being placed in an upright seated position as with other dummies. The bench, which is shown in FIGURE 2, is fitted with Teflon sheets on the seat and backrest. The pendulum used is 23.4kg in mass and has an impacting face 152mm in diameter. The details of the verification tests have yet to be confirmed. However, the tests described were used to verify the responses of the WorldSID prior to the workshop testing and although some adjustments need to be made the results were very promising.

The responses of the dummy will be fully evaluated during biofidelity evaluation testing.

Mobile Deformable Barrier Test

Test type:	based on EU 96/27/EC procedure (mobile deformable barrier)
Struck vehicle:	Ford AUII Falcon
Impact velocity:	50km/h
Impact angle:	0° (no crab)
Sled mass:	950kg
Restraint:	standard three-point belt (no airbag)

The WorldSID dummy was seated in the driver position of the Falcon, which is a medium-sized passenger car sold on the Australian market (note that the car was right-hand drive). The test was set up as per the European regulatory test procedure (European Union Directive 96/27/EC) with the centre-line of the barrier aligned with the R-point of the car.

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FIGURE 7 WorldSID barrier test.

The Falcon is 96/27/EC compliant but no side airbag was fitted. For this test, as for the other tests described below, the dummy was fitted with its optional full arm, fully instrumented on the struck side. The decision to fit this arm, rather than the stub arm option, was made in order to verify that the upper extremity instrumentation was functioning correctly. FIGURE 7 shows the impact.

The dummy, dressed in its standard suit (see FIGURE 8), was positioned using the draft procedure developed by the Design Team specifically for this dummy. The seat was positioned at the mid-point of the rail and the back rest was set to 20°. The test was run without glazing in the driver's door window. FIGURE 9 shows the car after the barrier test.

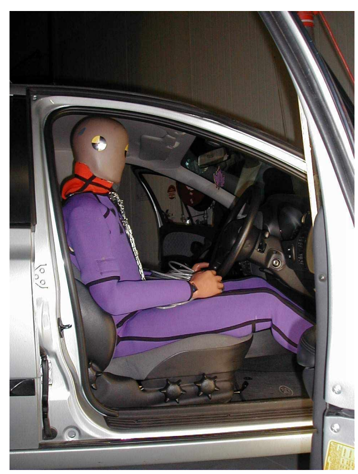

FIGURE 8 WorldSID dummy seated in Falcon prior to final positioning.

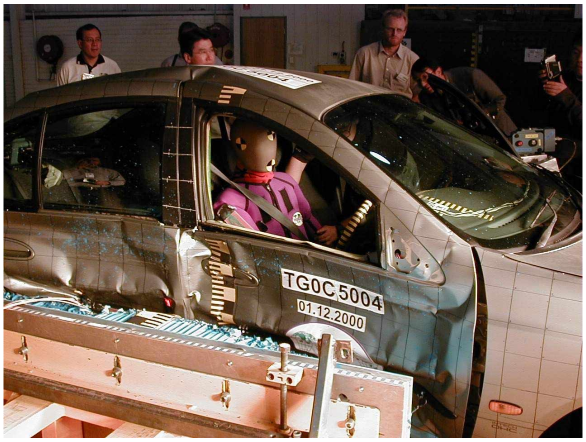

FIGURE 9 Falcon after MDB test

Sled Tests

Sled: "Heidelberg" type (modified)
Test type: rigid wall (no padding)
Impact velocity: 6.8 m/s

The two identical sled tests were based on thorax test 5 and pelvis test 7 of the ISO TR 9790. The rig for this type of test consists of a rigid, bench-type seat at one end of which is a rigid, vertical wall (see FIGURE 10). Two rectangular load plates are mounted on this wall via load cells, one at each corner of each plate. When the sled is subjected to a deceleration, the dummy slides along the bench, into the load plates as shown in FIGURE 11.

FIGURE 10 WorldSID on sled.

The test type was selected with the intention of providing some initial information on the biofidelity of the dummy. It should be noted that modifications had been made to the test rig so the configuration differs from that of the original tests from the University of Heidelberg (dimensions of the original buck can be found in TR 9790). The main differences between the two configurations are in the angle of the seat back (less reclined at 69° compared to 65° in the reference tests) and the positions of the load plates on the sled. The load plates had been re-positioned to maintain the same positions relative to the seat back. In addition, for the WorldSID tests, there was no headrest and no footrest. For the WorldSID tests, stiff plastic sheets were fixed over the complete surfaces of the seat and seat back and a Teflon sheet was placed under the feet.

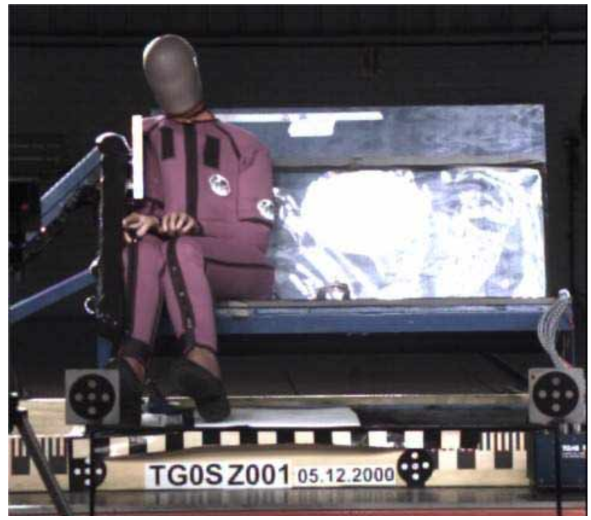

FIGURE 11 Dummy impacting load wall in sled test

It was observed that, in the first sled test, the dummy was leaning slightly away from the load wall, as it slid along the bench, having shifted slightly during acceleration. This altered the position of the dummy on impact. For the second test the shoulder was taped lightly to the seatback to maintain an upright position for the second test.

The dummy was dressed in its standard suit with full-length trouser legs. The full instrumented arm was fitted.

Car to Car Test

Test type: car- to-car
Struck vehicle: Ford AUII Falcon
Striking vehicle: Land Rover Freelander (Light SUV)
Impact velocity: 50 km/h
Restraint: standard three-point belt
Impact angle: 0°
Striking vehicle mass: 1475kg

For this test, the stationary struck car was a Falcon identical to the one used in the previous MDB test (see FIGURE 12). The test configuration was also similar, except that the MBD was replaced by a Land Rover Freelander light SUV.

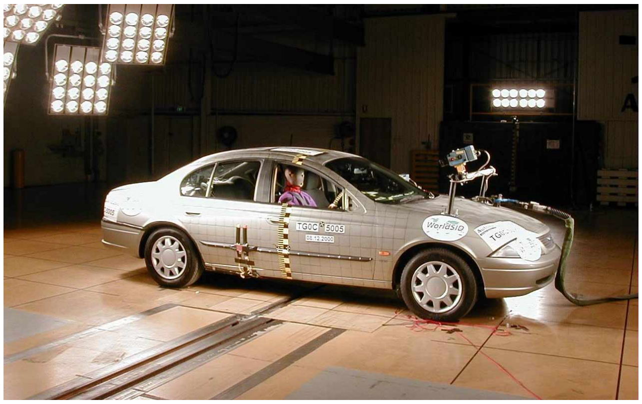

FIGURE 12 Dummy in Falcon prior to impact

The dummy was positioned again in the same manner and in the driver position. Once again, the instrumented full arm was used. The centre axis of the striking car was aimed at the R-point position of the struck car. The test was run without glazing in the struck car driver's door window. The test is shown in FIGURE 13 and a view of the vehicles after impact is shown in FIGURE 14.

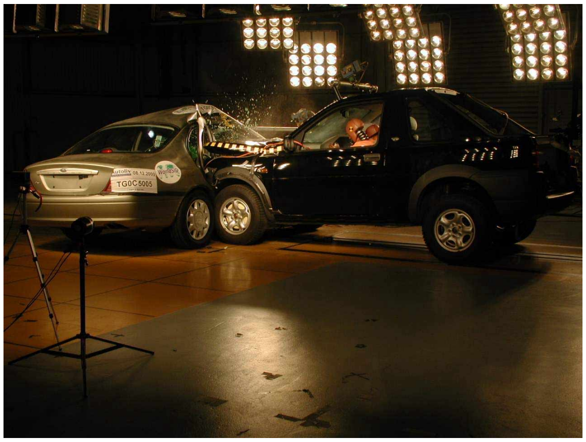

FIGURE 13 Falcon with WorldSID impacted by the Freelander.

Dummy Instrumentation and Data Collection

The dummy was equipped with the same 170 data channels for all vehicle and sled tests. The full list of instrumentation is shown in APPENDIX A. The instrumentation used is also summarised below:

<u>Tri-axial linear accelerometers:</u>
head, T1, T4, T12, thorax, shoulder and abdomen ribs, pelvis, wrist, elbow

<u>rotational accelerometers:</u>
head, T4

<u>load cells:</u>
upper neck, lower neck, shoulder, sacro-iliac joint, lumbar spine, pubis, proximal and distal femur, femur neck, knee, proximal and distal tibia, arm and forearm

<u>displacements:</u>
shoulder, thorax, abdomen

<u>rotations:</u>
elbow, knee, ankle

FIGURE 14 Falcon and Freelander post test.

All data was collected through the seven, thirty-two channel in-dummy DAS units. All data was successfully retrieved in all but the final test. For this test, the data was successfully recorded by all DAS units, however, the Ethernet drivers for two of the units failed after the test, preventing retrieval of the corresponding data (32 channels per unit). Post-test analysis revealed the units to be fully functional in every other aspect. The two units concerned were located in the right femur and in the spine box.

RESULTS

Plots of the test results can be found APPENDIX B. It should be noted that since four tests are described, each with 170 data channels or more, only a selection of data is included. The SAE J211 sign convention and filters apply.

Head (see FIGURE B 1; FIGURE B 2)

All linear and angular accelerations from the head were recorded successfully and no problem was encountered with these sensors.

In the second sled test, a 60G spike in the z acceleration occurs at 140ms corresponding with a peak of 6000 rad/s^2 in the angular acceleration about the z axis. The x and z accelerations peak at around 53G and 77G respectively at less than 50ms into the car-to-car test. These peaks are accompanied by angular accelerations of 13,200 rad/s^2 about z and 6000 rad/s^2 about the x axis.

Neck (see FIGURE B 3 to FIGURE B 6)

As with the head, all upper and lower neck data was recorded successfully and the sensors functioned correctly.

The highest upper neck forces measured were the Fz measurements ranging from just over 1.3kN at 110ms in the first sled test to around 1.8kN in the car-to-car test. In the car-to-car test, Fx peaks at almost -900N, whereas in the other tests this load never exceeds about -400N. Mx values reach around 60Nm just before 80ms into the MDB test and at around 115ms in the second sled test. My and Mz maximum values are greater for the Falcon tests than in the sled tests.

At the lower neck, Fz positive peaks correspond with those measured at the upper neck and peak values are similar except in the MDB test where the lower neck value reaches only 1.3kN. The principal peaks in the lower neck Mx range from –100Nm to –180Nm and these moments remain negative for about 100ms in each test. As with the upper neck values, My and Mz reach greater magnitudes in the Falcon tests. My ranges from 125Nm to –80Nm in the car-to-car test.

Shoulder, Thorax and Abdomen
(see FIGURE B 7 to FIGURE B 11; FIGURE B 22; FIGURE B 23)

A drop out occurs on the three thoracic rib deflection channels in the first sled test (see FIGURE B 7). This is not caused by a malfunction of the sensors, as can be seen by the fact that the dropout occurs at the same instant on the three channels, but rather by a power supply problem which will be further described in the discussion.

In FIGURE B 7, the rib displacements from the MDB test are shown with the shoulder rib displacement from the car-to-car test for comparison (the other deflections from the latter test having been lost due to the DAS Ethernet driver failure). Not surprisingly given the type of test, the shoulder displacement is significantly higher in the second of these tests, reaching a peak of 60mm (from a maximum of 75 mm available). As shown in FIGURE B 7, in the second sled test the shoulder displacement bottomed out at 74mm having peaked at 74mm in the first sled test. The uppermost thorax rib also peaks at 74mm of deflection in the second sled test.

In the MDB test, the maximum rib deflections are progressively lower from the shoulder to the lowermost thoracic rib, then progressively greater again to the lower abdominal rib.

Although the lowermost IR-TRACC unit data contained numerous, short duration spikes, no prolems were encountered with the other units throughout the testing.

T12 accelerations from the car-to-car test were lost due to the DAS problem mentioned above. All of the other data from the thoracic spine acceleration channels was successfully retrieved.

T1 and T4 y-axis accelerations were highest in the car-to-car test with peak values reaching 72G and 79G.

Lumbar Spine (see FIGURE B 12; FIGURE B 13)

The lumbar load cell functioned correctly and all data was successfully recorded.

In each test Fy peaks negative, at around –1.5kN and 40ms for the Falcon tests and at –700N and –1.2kN around 100ms in the sled tests. Following this the load goes positive in each case. For the MDB test, a peak positive load of 1kN is measured, compared to 1.9kN for the car-to-car test. The positive peak values do not exceed 500N in the sled tests. Peak Fz loads of 1.5kN and 2.5kN are recorded for the MDB and car-to-car tests respectively. Lumbar moments about the x axis are considerably higher in the Falcon tests than in the sled tests: values reach 110Nm and –70Nm to –100Nm compared to 30Nm and –30Nm.

The lumbar spine functioned well throughout the testing and no damage to it was reported.

Pelvis (see FIGURE B 14; FIGURE B 15)

The pelvis was instrumented with a tri-axial linear accelerometer, a six-axis pubic symphysis load cell and a sacro-iliac sensor consisting of two six-axis load cells, one on the left and one on the right hand side. All this instrumentation functioned correctly and all data was recorded.

Pelvis y axis acceleration peaks reach almost 100G in the sled tests and 70G to 80G in the Falcon tests at between 30ms and 40ms. FIGURE B 15 shows all y-axis loads measured on the pelvis. Pubic loads peak at 4kN in the MDB test, almost 5kN in the car-to-car test and at between 5.4kN and 5.8kN in the sled tests. The right-hand sacro-iliac y-axis peak loads reached 4.8kN in the MDB test, almost 5kN in the car-to-car test and 4.4kN and 4kN in the sled tests.

Lower Extremities (see FIGURE B 15 to FIGURE B 21)

A selection of lower extremity loads is shown in the above figures. Lower extremity data was lost in the final test due to the DAS problem described above.

The highest right hand side femur neck peak loads were measured along the y axis. Values reached 4.3kN in the MDB test and around 8kN in the sled tests. Right side and left side upper femur loads are shown. The highest Fy peak load occurred in the second sled test with a value of –1.6kN. In the sled tests, Fy peaks were higher for the right femur than for the left, and in the MDB test left and right values were of a similar magnitude. Fz peak values were higher for the left femur in each test.

The knee load cells have a capacity of 5kN. Peak knee Fy loads were far in excess of this value for the last three tests. The load cells were very severely overloaded in the last two tests and were physically damaged in the car-to-car test.

Several sharp peak loads can be seen on the upper tibia Fy and Fz plots from the sled tests. These peaks range from 500N to 1.3kN in magnitude. Very short duration, high amplitude spikes can be observed on the Fy and Fz data from the left tibia in the car-to-car test.

Upper Extremities (see FIGURE B 24 to FIGURE B 26)

Selected data is presented in the above figures. Apart from some of the elbow data, all upper extremity channels were successfully recorded.

Very high, short-duration spikes can be seen on the sled test elbow accelerations. In the MDB test, the elbow y-axis acceleration reached a peak of almost –140G at around 25ms. In the sled tests, the Fz values measured in the arm remained well below 50N throughout the tests whilst peak values reached almost 1kN in the car-to-car test.

DISCUSSION

Dummy Performance

The testing showed that the dummy functions very well overall. No major problems were encountered and the dummy successfully completed the test programme and was subsequently sent for further testing at another site.

In the second sled test, it can be seen from the peak at 140ms that there is a head contact. Also, in the car-to-car test, the right side rear of the head impacts the forward edge of the B-pillar between 40ms and 50ms into the test. The head comes close to the impacting car bonnet but does not strike it. There is also a light head contact with the same area of the B-pillar in the MDB test.

It is seen that the shoulder deflects up to a measured 74mm corresponding to a theoretical maximum deflection of 75mm. The high shoulder deflections obtained in the sled tests would seem to indicate that the shoulder rib may be somewhat soft. This will be further investigated during the full biofidelity evaluation.

It is reported that similar deflection trends are seen on the Eurosid-1 dummy in the same type of test, although the WorldSID values in this test tend to be a little higher. This difference in magnitude comes as no surprise as the WorldSID was designed to have a more biofidelic thorax.

No permanent deformation of the Nitinol super elastic alloy ribs resulted from the testing despite the high deflections to which they were subjected.

The relatively low loading of the lumbar spine indicates a relatively high degree of decoupling between the thorax and the pelvis. This may require adjustment after further testing has provided additional information.

Pelvis load levels seem somewhat high. This may be an indication of too much decoupling of the thorax and pelvis.

Use of the full arm was particularly incompatible with the sled tests as the extremity is caught between the thorax and the load plates. However, all four tests were to be performed with the same upper extremity. The tri-axial elbow accelerometer and elbow load cell made direct contact with the load wall, which can be seen by the sharp spikes on the elbow accelerometer data. The elbow made contact between the two load plates.

Above a certain elbow angle the tri-axial accelerometer and elbow load cell are no longer covered by skin and flesh. These sensors, therefore, were exposed to direct contact with the load wall. The elbow potentiometer is mounted on the inside of the joint to protect it from impact. It may be necessary to take steps to better protect the instrumentation in the elbow area which will often be exposed to severe interaction with deploying airbags.

The only damage sustained by the dummy itself was some minor wear to the suit and flesh around the knee, the ankle and the shoulder.

Although data from the car-to-car test was lost, it would seem that there was significant loading of the knees when the right leg made contact with the left leg which then became trapped against the centre console.

Although the optional half-arm was not tested during this programme, it is not thought likely that there will be any problem with this assembly as it relatively simple.

Instrumentation and Data Collection

The in-dummy DAS was examined by the manufacturer at the test site immediately after testing, and then further at the manufacturer's own site. Having identified the cause of the Ethernet driver problem, the implementation of improvements began immediately.

Although the data was successfully collected for the test in question, the Ethernet link failure precluded communication with the DAS modules. As the data is stored in DRAM, which requires power to keep the data intact, it was not possible to retrieve the data. It was found that the Linux network services could occasionally be lost during the A/D process. Extensive testing on the modules failed to identify any other failure modes such as shock, temperature etc.

Additional code has now been written into the firmware to automatically shut down the Linux network services after the unit is armed, thus protecting the circuit from any test related anomalies. The DAS has now been thoroughly tested with no further failure occurring.

Additional modifications will allow critical test data to be written to flash memory so that the DAS can be rebooted without loss of data. Also, the RS232 communication path will, in future, be available as a back-up to the Ethernet path.

The IR-TRACC sensors measure the rib deflections by relating irradiance from an infra-red LED to the distance between the emitter and an infra-red phototransistor. The spikes on the lower abdominal rib deflection channel were caused by an intermittent open circuit which turned off the IR-TRACC's light source sending the output high. This problem was caused by a bad connection which has now been repaired and reinforced.

The longer duration drop-out on the thorax deflection channels in the first sled test was caused by a brief power supply problem. The three sensors were connected to a common excitation voltage and so a temporary short circuit in either the supply or in one of the sensors would effect all three sensors. It is expected that power isolation circuits will be added in the future to avoid this type of problem. It should be noted that, once the problem did occur, the channels recovered quickly which testifies to the protection and fast recovery characteristics of the DAS unit power sources.

Following the overloading of the knee contact load cells the manufacturer was in the process of increasing the capacity of these sensors. One knee contact load cell was damaged beyond repair, the load cell structure having been deformed.

One elbow accelerometer was damaged in the first sled test due to the direct contact with the load plate. The WorldSID Task Group will decide whether any modifications should be made to better protect the elbow instrumentation.

The WorldSID Task Group had been concerned about the amount of heat that could be generated by the sensors in a fully, or highly, instrumented WorldSID and by the in-dummy DAS units. There was no indication during the testing that the instrumentation generated a great amount of heat. Checks on the DAS revealed that virtually no additional heat was generated by these units. Further, more detailed checks on this aspect of the dummy will be carried out later in the evaluation programme.

Handling and Positioning

The four tests described above provided an opportunity to judge the handling and positioning aspects of the dummy. In addition to the preparation of theses tests, the workshop participants spent some additional time positioning the dummy in several different cars and in front and rear seat positions. A positioning procedure had been written by the Design Team prior to testing and improvements were made to this in the light of the experience gained during the workshop.

One concern with the current version is that great care is needed in handling the dummy in order to avoid damaging the lumbar spine and neck which are not reinforced with steel cables. This was, of course, foreseen by the designers and much attention has been paid to designing a lifting harness to prevent damage occurring. Improvements to this have also been carried out taking into account the experience of the workshop. It should be noted that the European side impact test procedure currently states that it must be possible to remove the dummy from the car after testing, without removing any part of the car. For the current version of the WorldSID, removing a component such as a centre console may often be recommended in order to ensure that the lumbar spine is not damaged.

A number of possible minor modifications to the dummy were identified following the testing. These may improve certain handling aspects of the dummy during assembly and dis-assembly.

CONCLUSIONS

The WorldSID prototype dummy was delivered to the WorldSID Task Group at the end of the first development phase of the project. A full set of documentation is being supplied to accompany the dummy including a user manual, verification procedures, a full set of drawings and a full dummy CAD model

The prototype dummy was subjected to initial verification testing, an MDB test, two sled tests and a car-to-car test with a light SUV as the impacting vehicle.

The dummy, its instrumentation and data acquisition system performed extremely well in this testing and it was demonstrated that the dummy was apt for use in crash testing.

Initial indications are that the shoulder, thorax and lumbar spine may need to be slightly stiffer. However, full evaluation of the dummy's biofidelity will provide further information on these aspects.

Only minor damage occurred to the dummy and its instrumentation during the testing.

Experience has been gained in the handling of the dummy and this experience will serve to further develop the positioning procedure and handling equipment.

FURTHER DEVELOPMENT

The WorldSID Task Group and Design Team have begun the process of evaluating the dummy and identifying modifications that may be required. The prototype dummy will be tested at a limited number of test sites in North America, Europe and Japan to evaluate mainly its biofidelity and verification and directional sensitivity aspects. The basis for biofidelity evaluation will be ISO TR9790 but it is planned that evaluation to any new requirements defined by IHRA will also be carried out during this phase of evaluation. Any necessary modifications identified will be incorporated into a pre-production dummy to be designed and built subsequently. Several of these dummies will be manufactured and then comprehensively evaluated around the world.

ACKNOWLEDGEMENTS

The WorldSID Task Group extends its thanks to the Department of Transport and Regional Services for organising and sponsoring the testing and workshop.

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The WorldSID Design Team members are Denton ATD Inc, Diversified Technical Systems Inc, Endevco Corporation Inc, First Technology Safety Systems Inc, R. A. Denton Inc and SID-2000 (represented by INRETS, TNO and TRL). The Project Management task was performed by Biokinetics and Associates Ltd.

CEESAR and the principal author participate in WorldSID on behalf of LAB PSA Peugeot Citroën - Renault

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2. ISO/TR 9790: 1999(E), Road Vehicles – Anthropomorphic side impact dummy – Lateral impact response requirements to assess the biofidelity of the dummy

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APPENDIX A
WORLDSID PROTOTYPE DUMMY INSTRUMENTATION

Head
2 tilt sensors
1 tri-axial linear accelerometer at CG
3 angular accelerometers
1 upper neck load cell

Neck
1 lower neck load cell
1 T1 tri-axial accelerometer

Shoulder/thorax/abdomen
6 IR-TRACC modules
6 tri-axial rib accelerometers
1 shoulder load cell
2 angular accelerometers
1 T4 tri-axial linear accelerometer
1 T12 tri-axial linear accelerometer
2 tilt sensors
2 DAS modules

Pelvis
1 lower lumbar spine load cell
1 sacro-iliac load cell module
1 pubic symphysis load cell
1 tri-axial linear accelerometer
2 tilt sensors
1 DAS module

Lower extremities (per extremity)
1 upper femur load cell
1 lower femur load cell
1 femur neck load cell
2 knee load cells
1 knee rotation sensor
2 DAS modules
1 upper tibia load cell
1 lower tibia load cell
3 ankle rotation sensors

Half arm (per half arm)
1 upper tri-axial linear accelerometer
1 lower tri-axial linear accelerometer

Full arm (per full arm)
1 arm load cell
1 fore-arm load cell
1 tri-axial elbow linear accelerometer
1 tri-axial wrist accelerometer
1 elbow rotation sensor
1 elbow load cell

APPENDIX B
SELECTED TEST DATA

In order to limit the number of pages required, a selection only of the test results is shown on the following pages

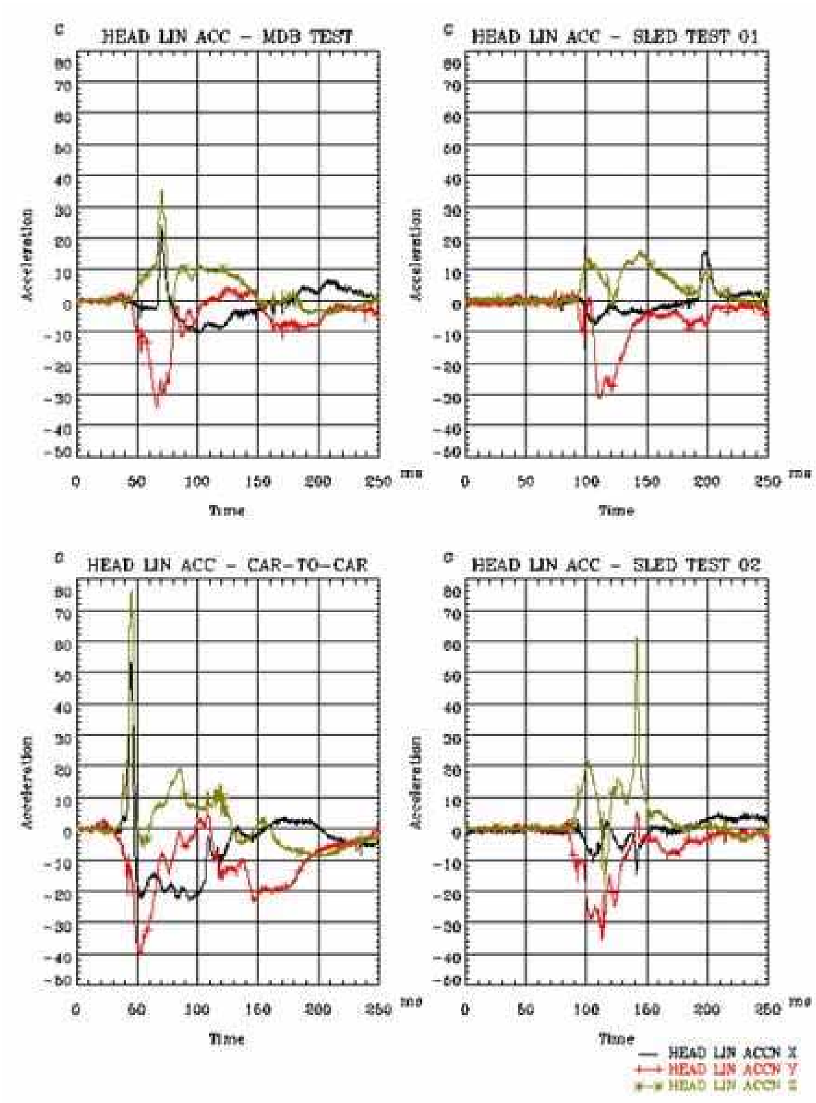

FIGURE B 1 Head linear accelerations (CFC 1000)

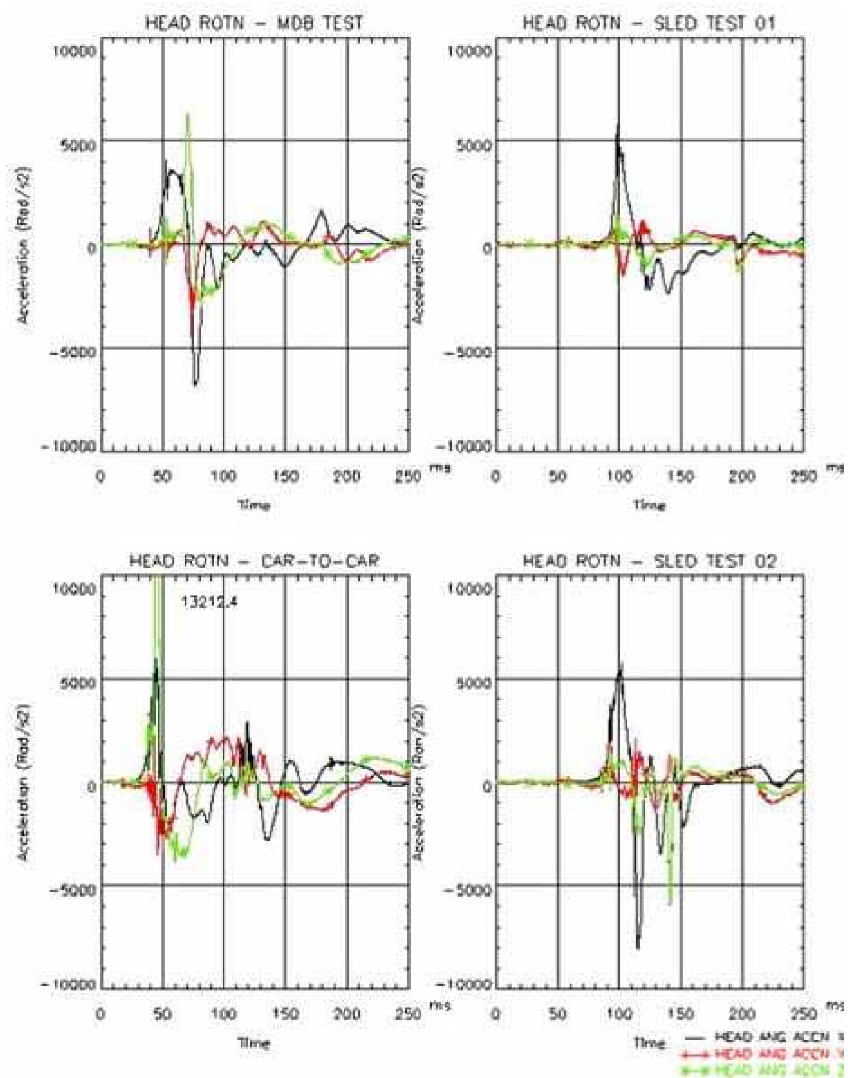

FIGURE B 2 Head angular accelerations (CFC 1000)

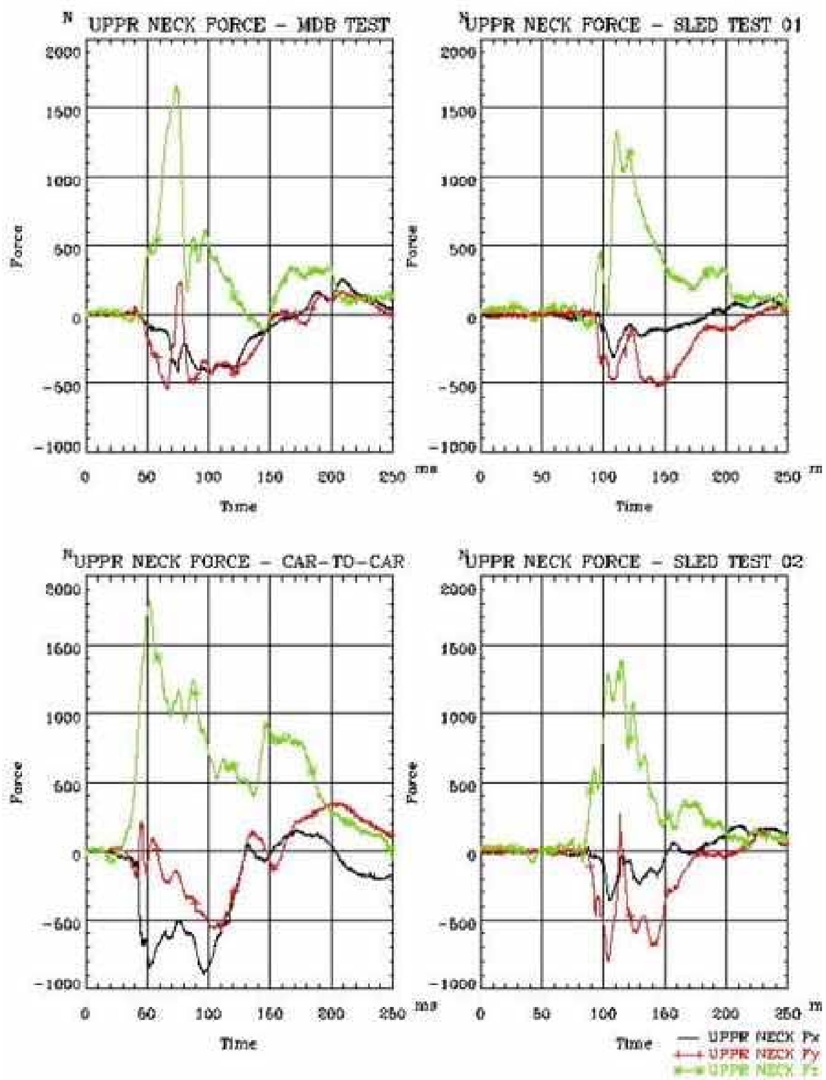

FIGURE B 3 Upper neck loads (CFC 1000)

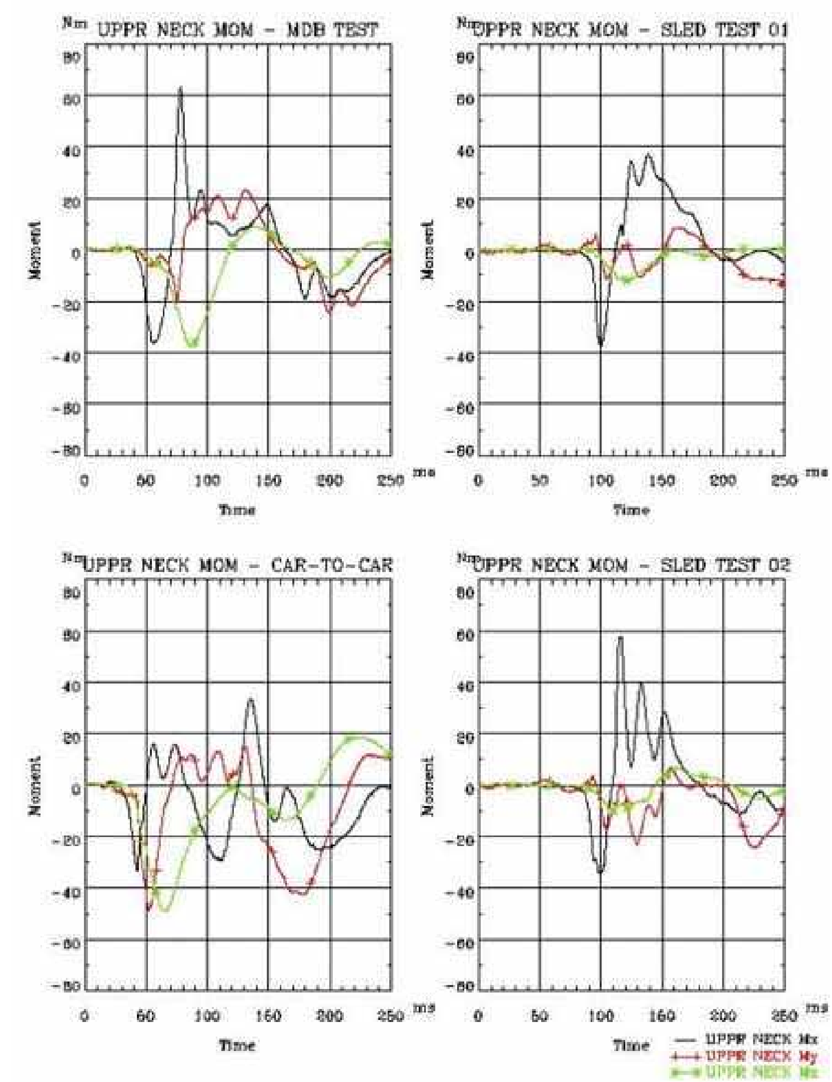

FIGURE B 4 Upper neck moments (CFC 600)

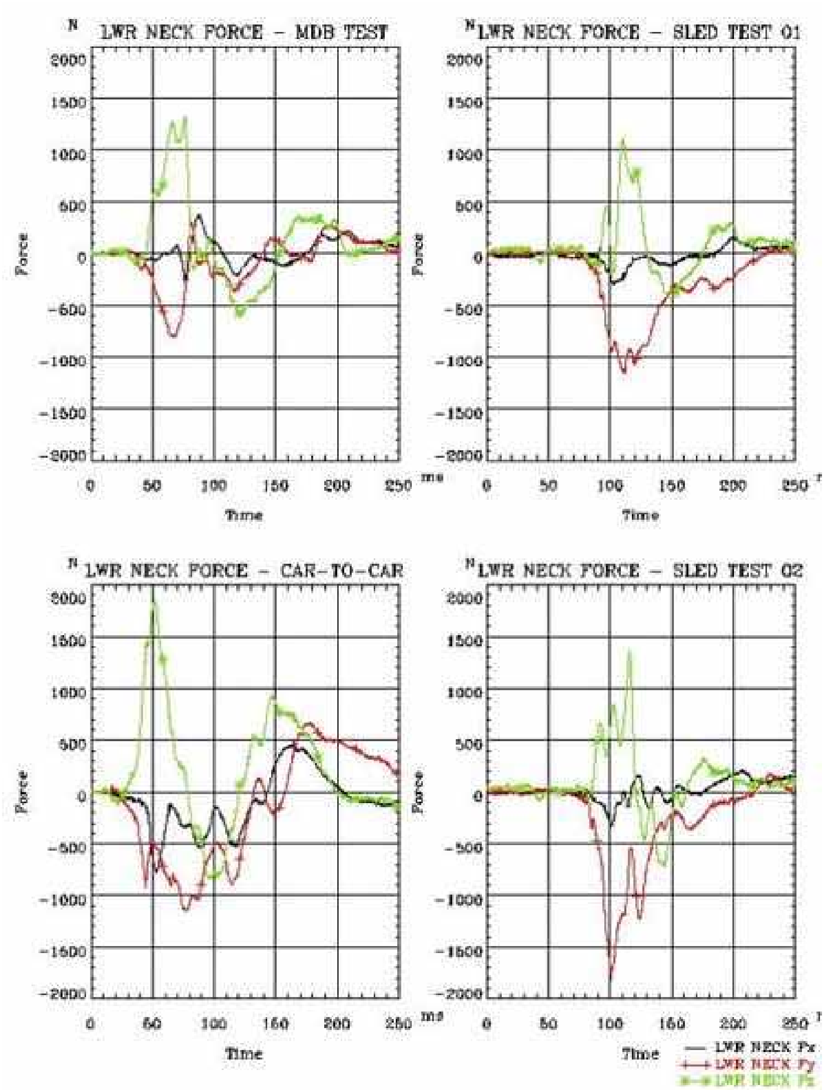

FIGURE B 5 Lower neck loads (CFC 1000)

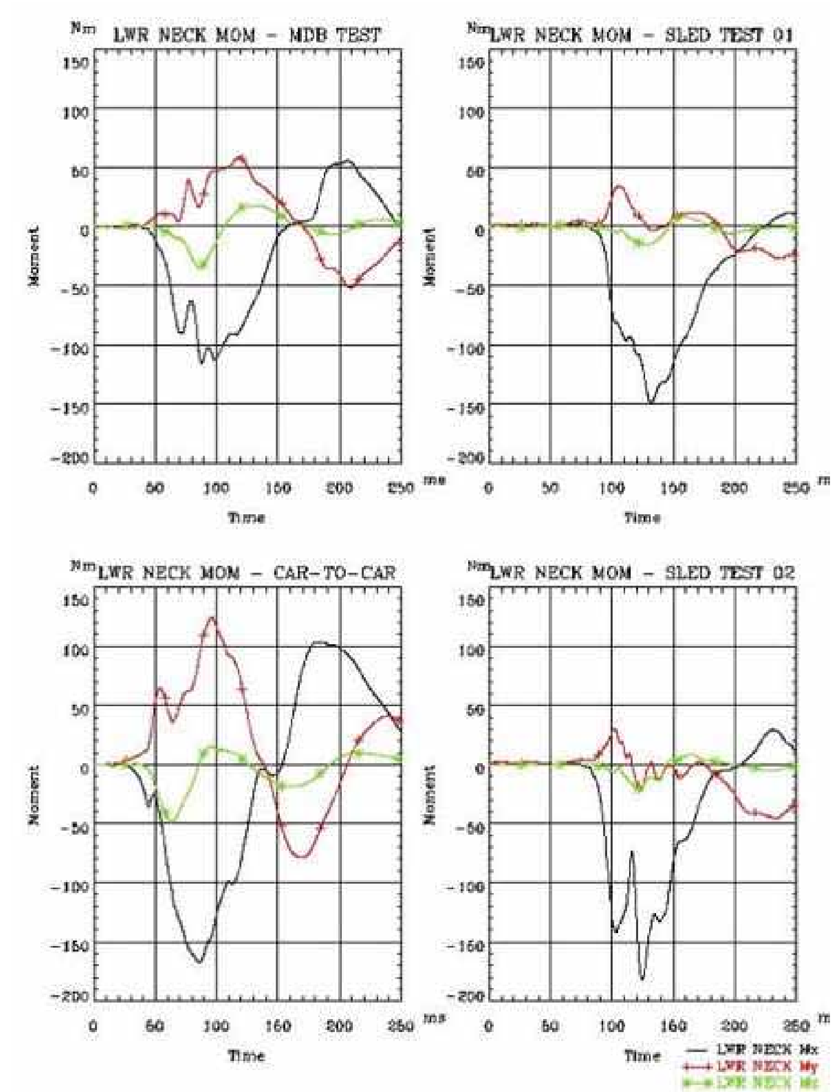

FIGURE B 6 Lower neck moments (CFC 600)

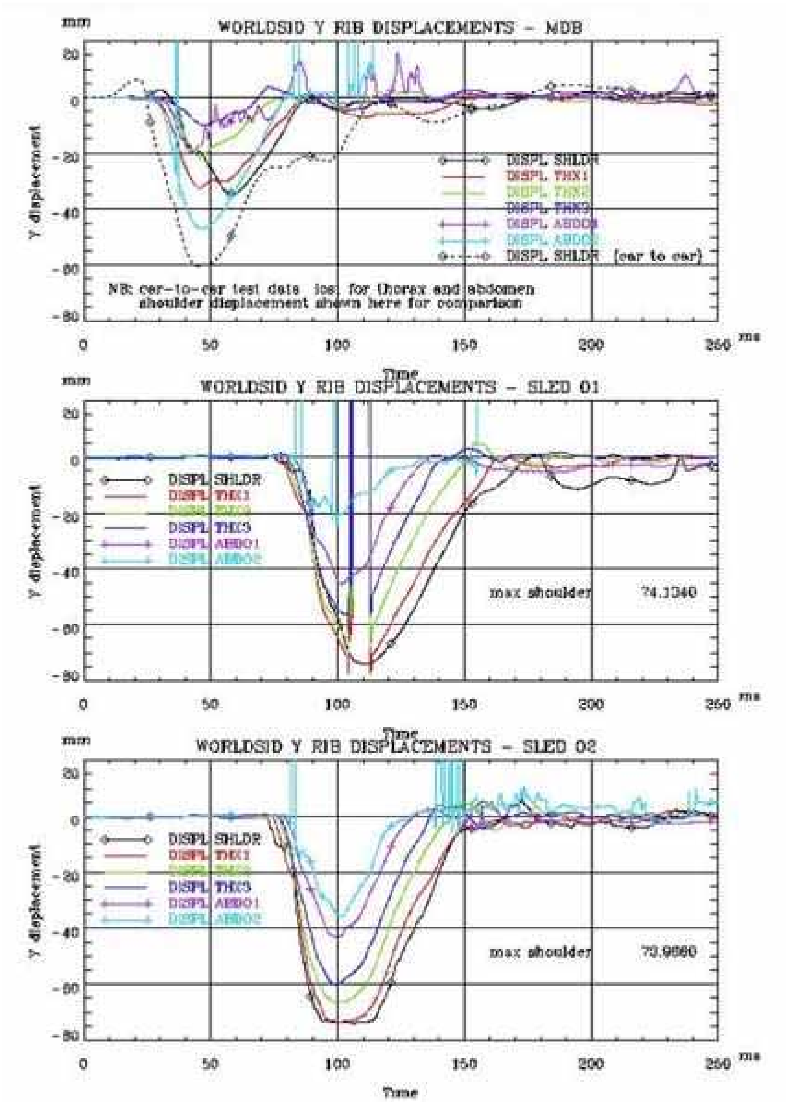

FIGURE B 7 Rib displacements (CFC 600)

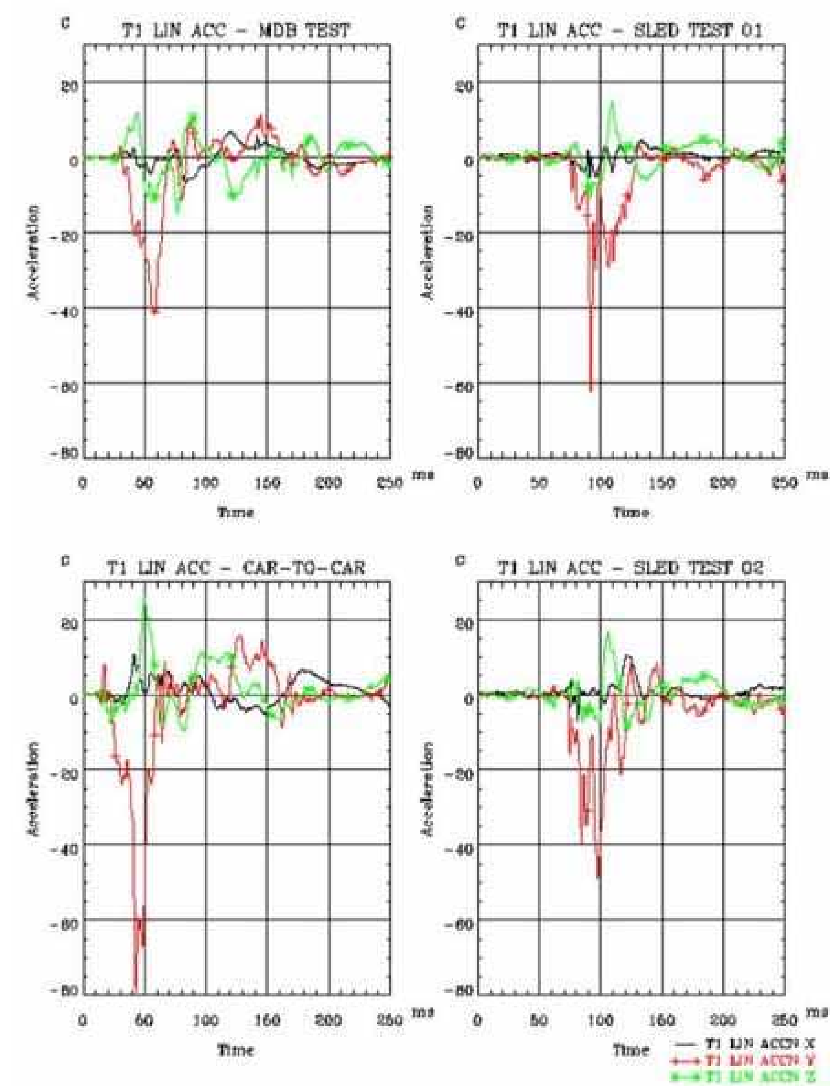

FIGURE B 8 T1 linear accelerations (CFC 180)

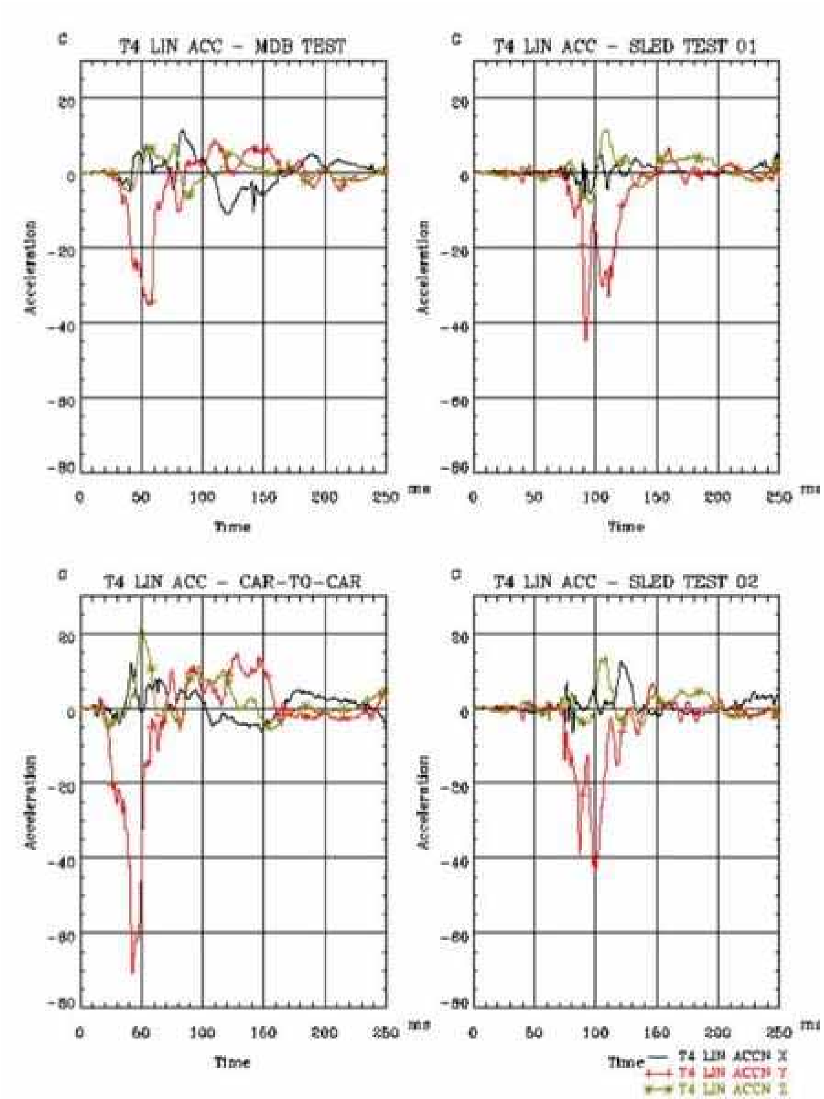

FIGURE B 9 T4 linear accelerations (CFC 180)

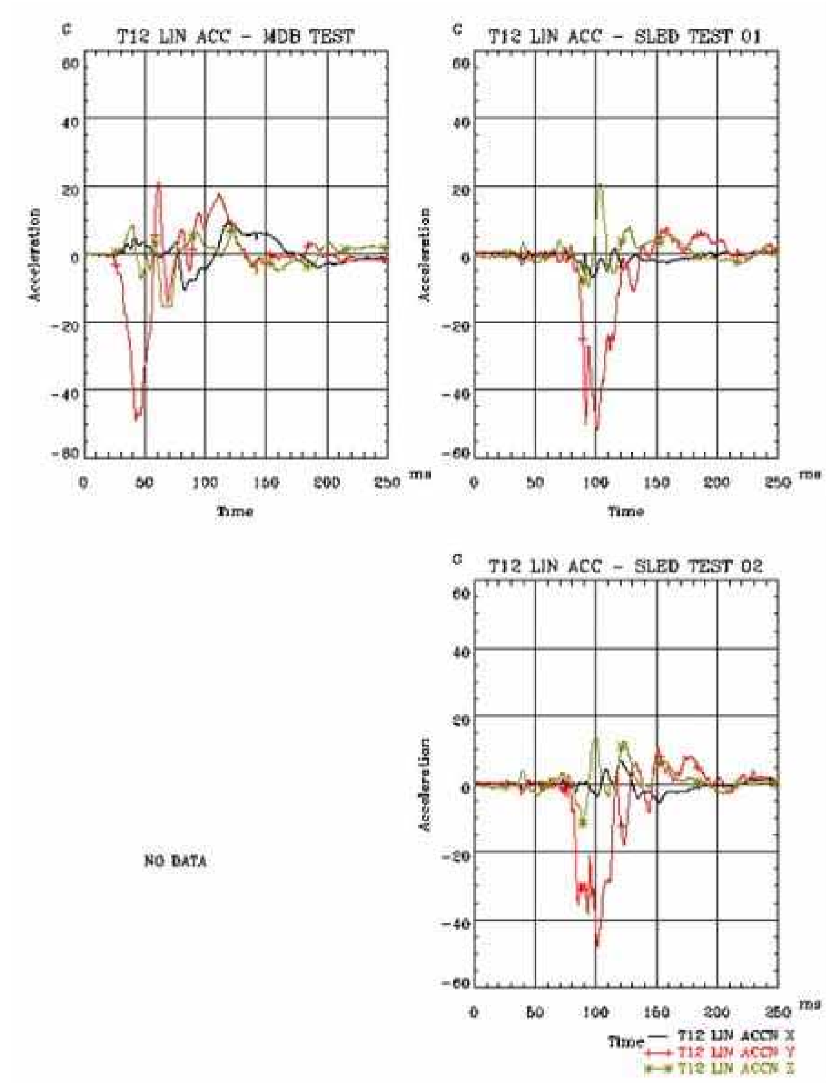

FIGURE B 10 T12 linear accelerations (CFC 180)

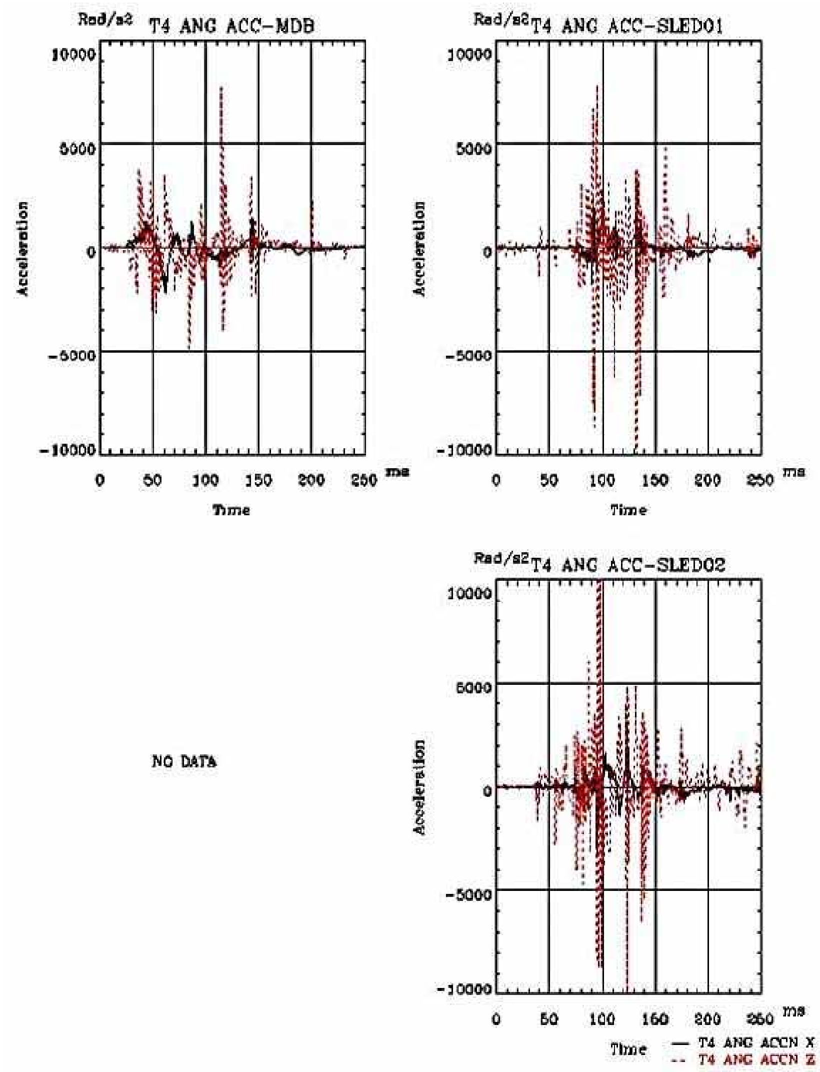

FIGURE B 11 T4 angular accelerations (CFC 600)

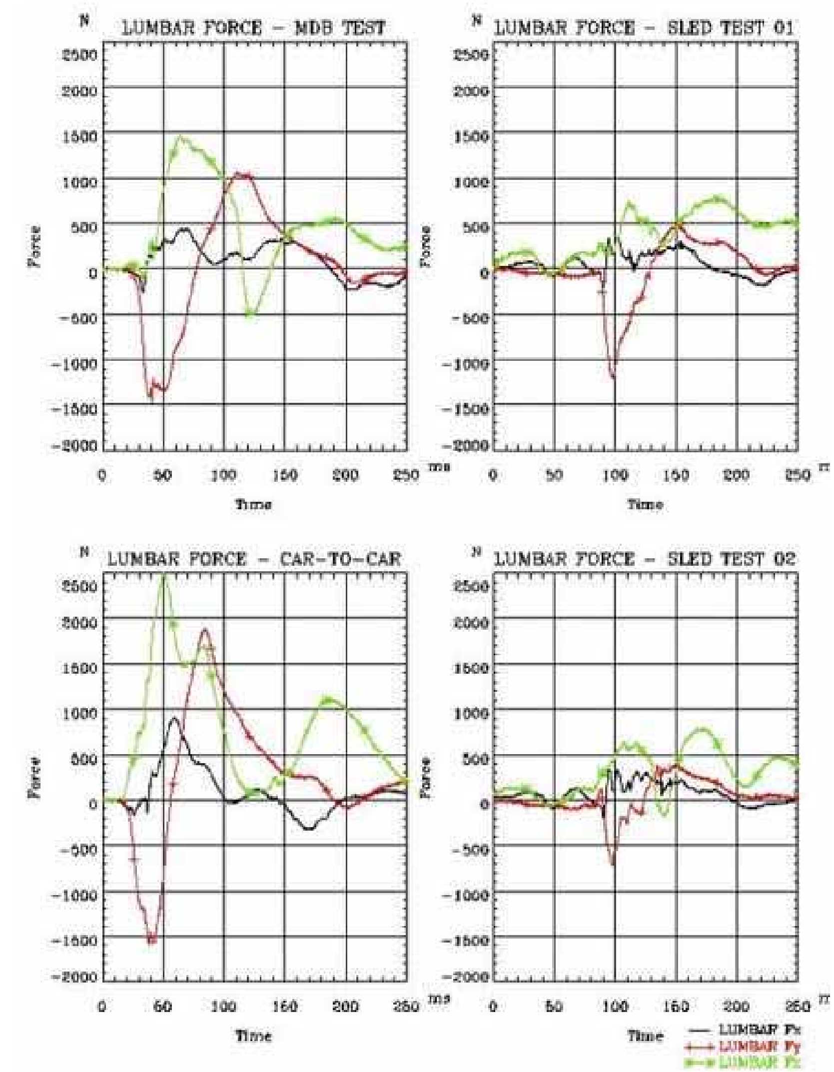

FIGURE B 12 Lumbar spine loads (CFC 1000)

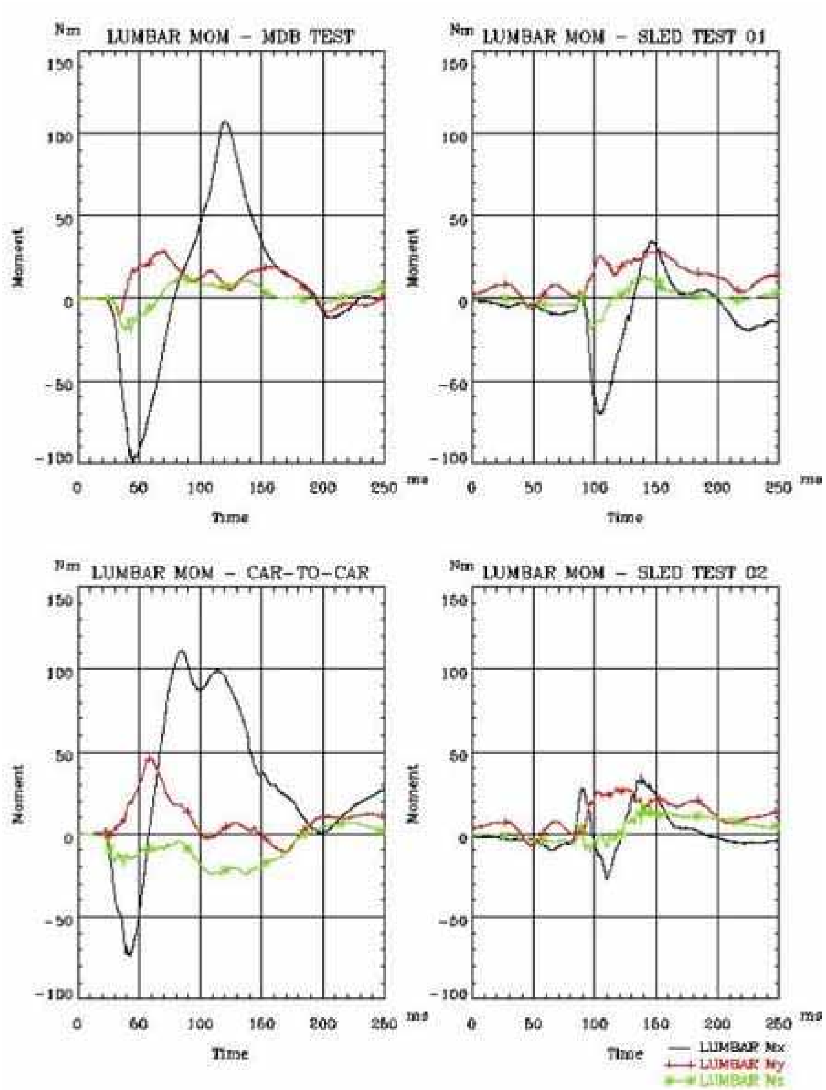

FIGURE B 13 Lumbar spine moments (CFC 1000)

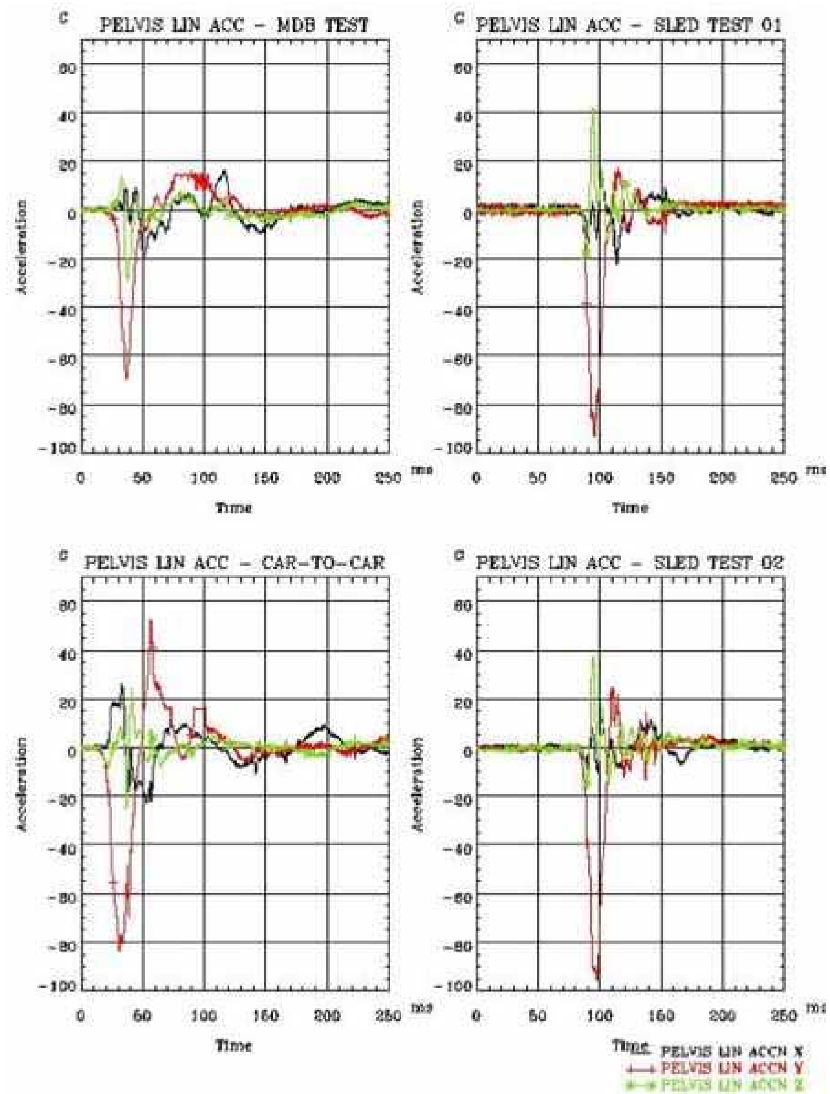

FIGURE B 14 Pelvis linear accelerations (CFC 1000)

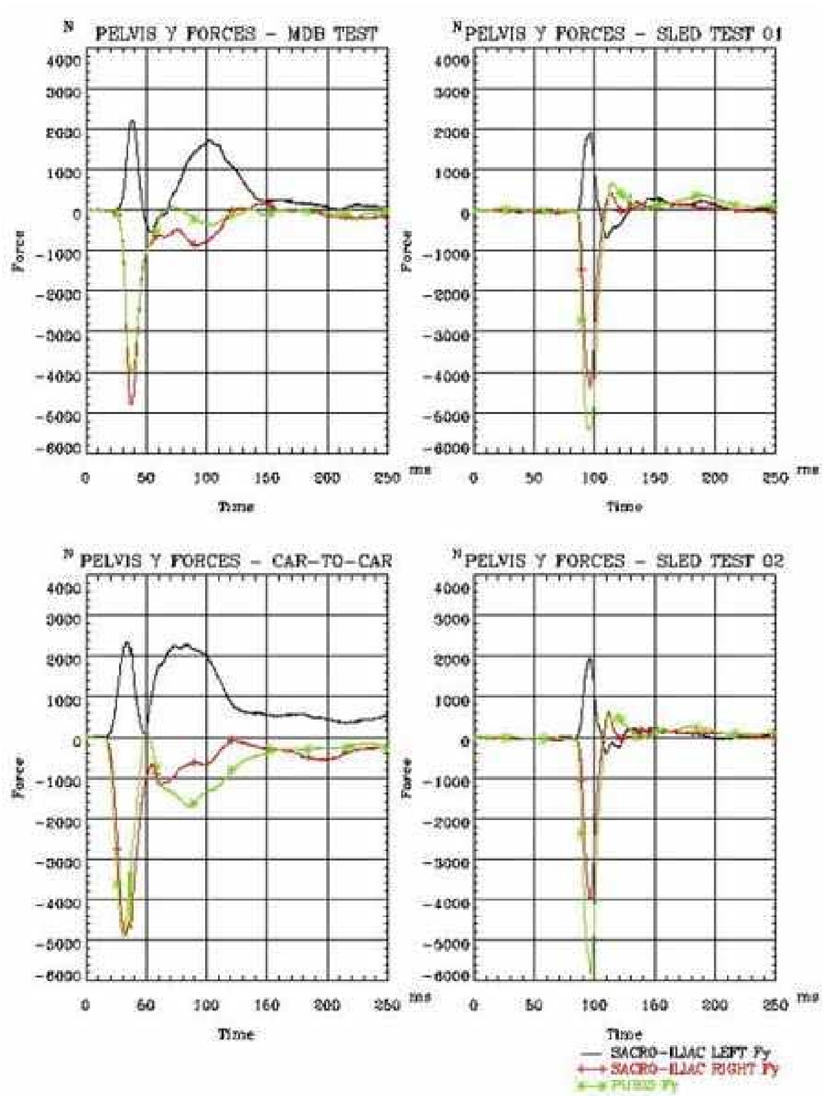

FIGURE B 15 Pubic and sacro-iliac y-axis loads (CFC 600)

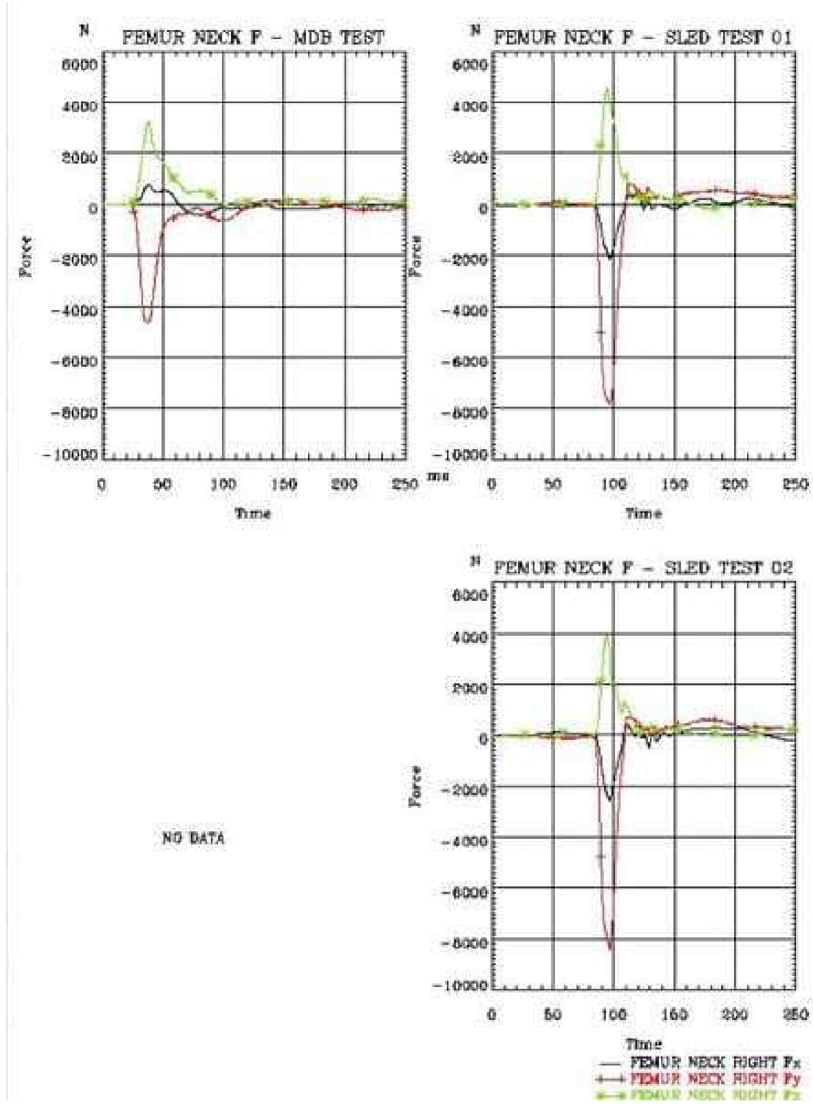

FIGURE B 16 Femur neck loads (CFC 600)

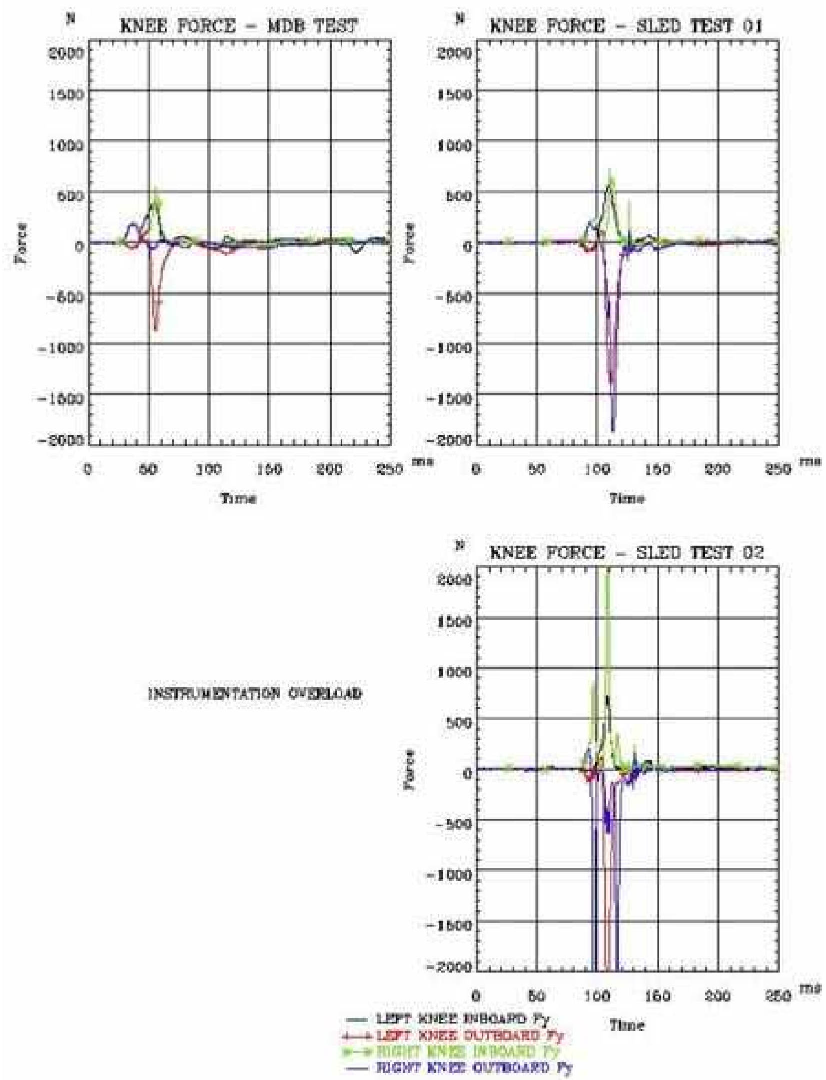

FIGURE B 17 Knee contact loads (CFC 600)

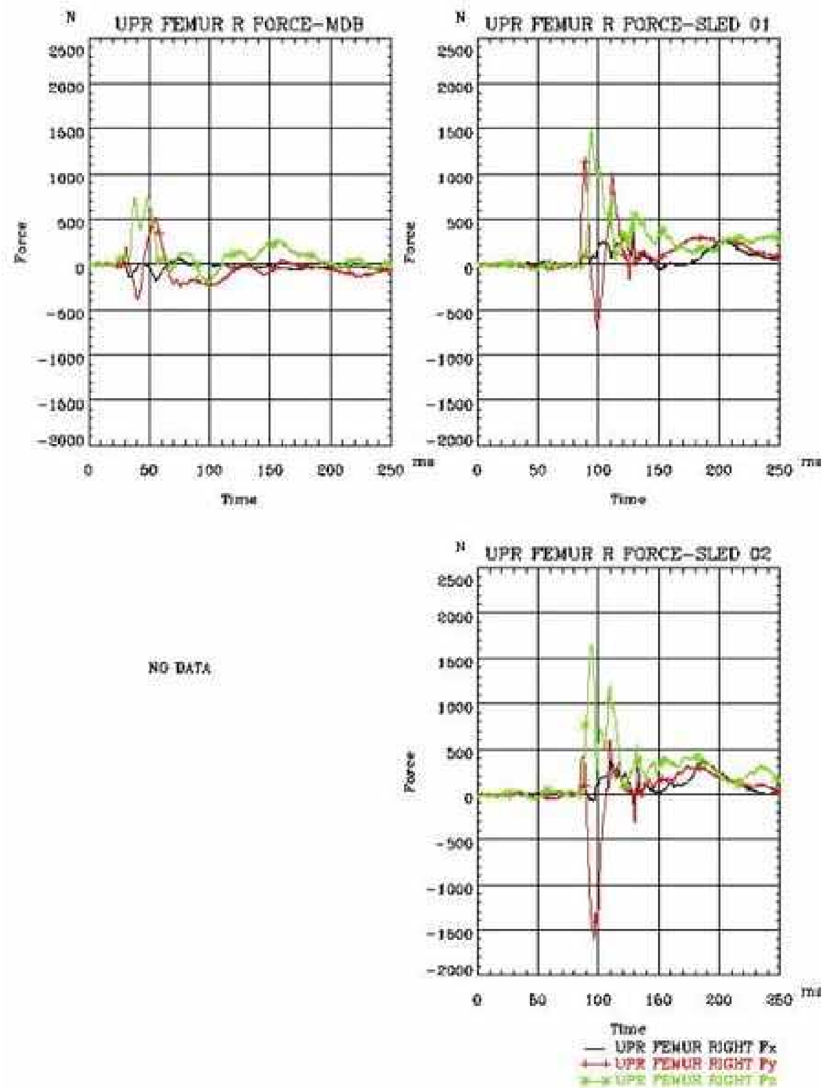

FIGURE B 18 Right upper femur loads (CFC 600)

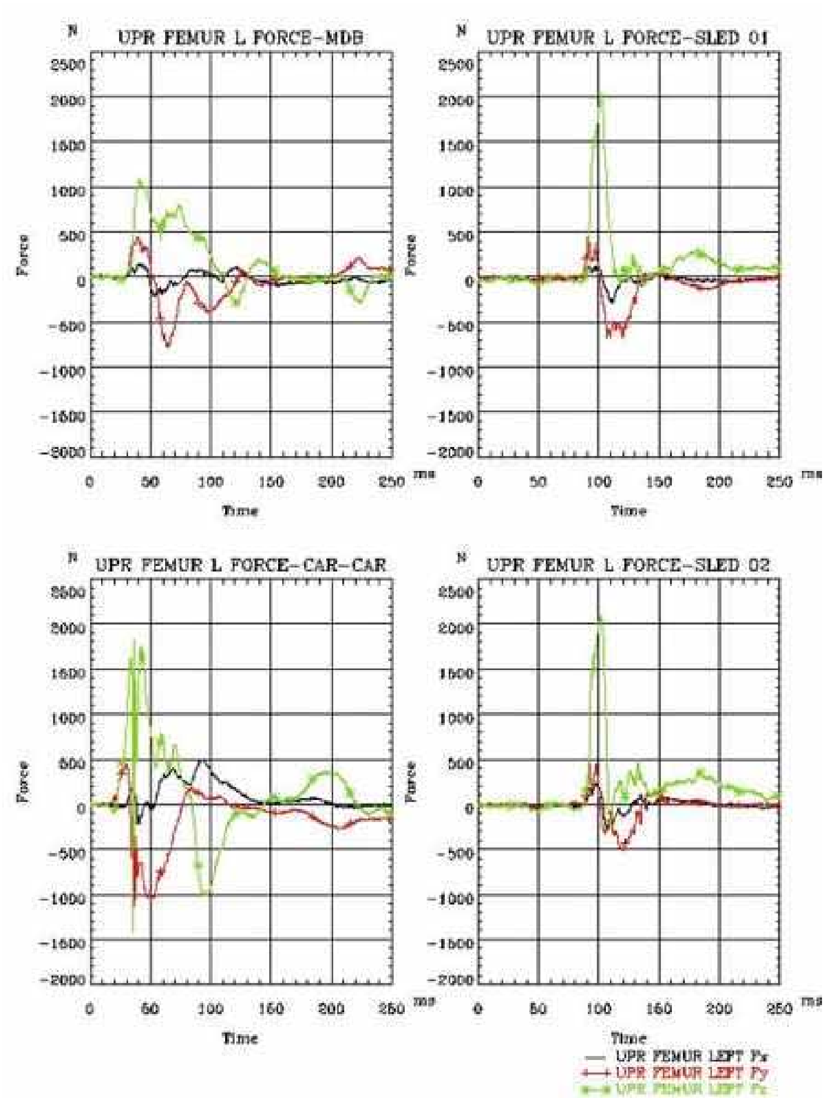

FIGURE B 19 Left upper femur loads (CFC 600)

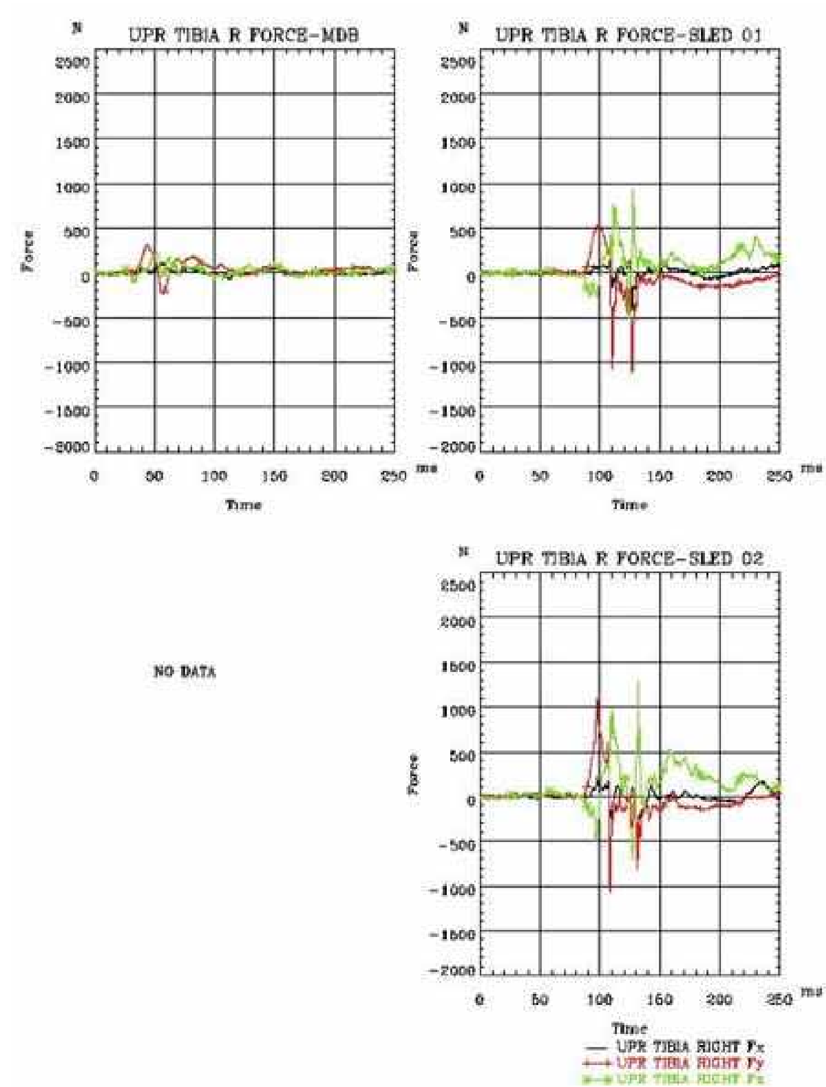

FIGURE B 20 Right upper tibia loads (CFC 600)

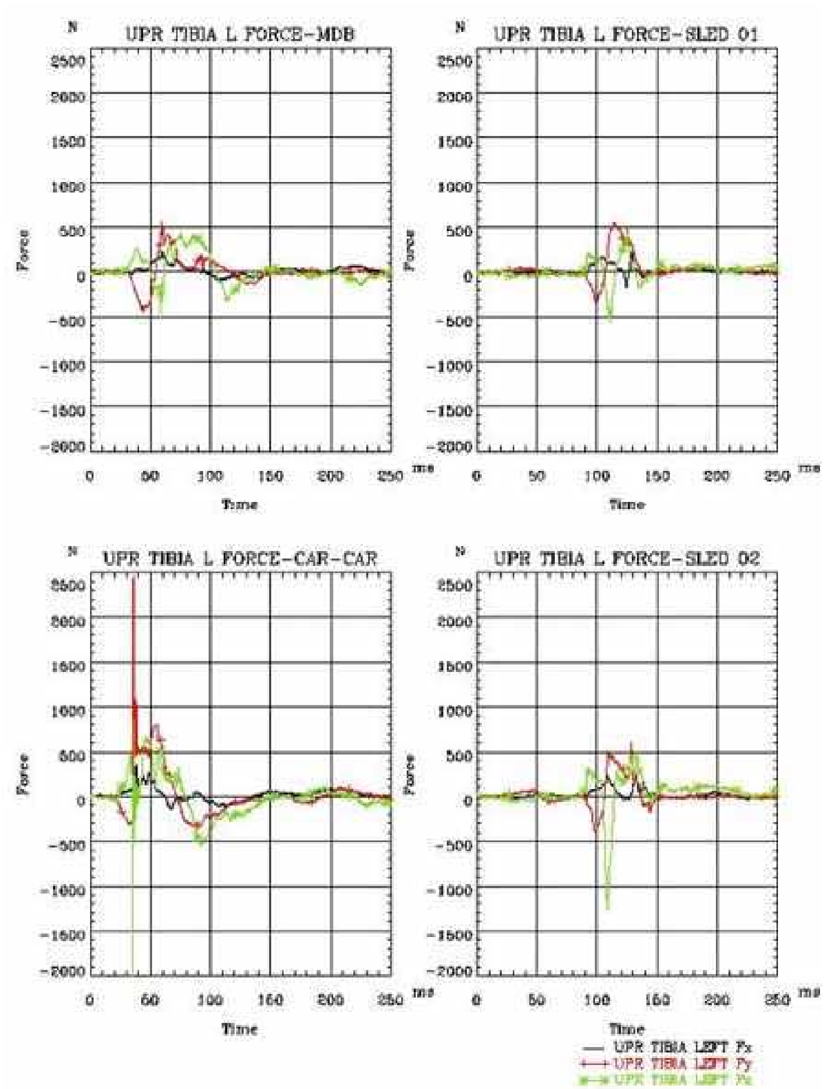

FIGURE B 21 Left upper tibia loads (CFC 600)

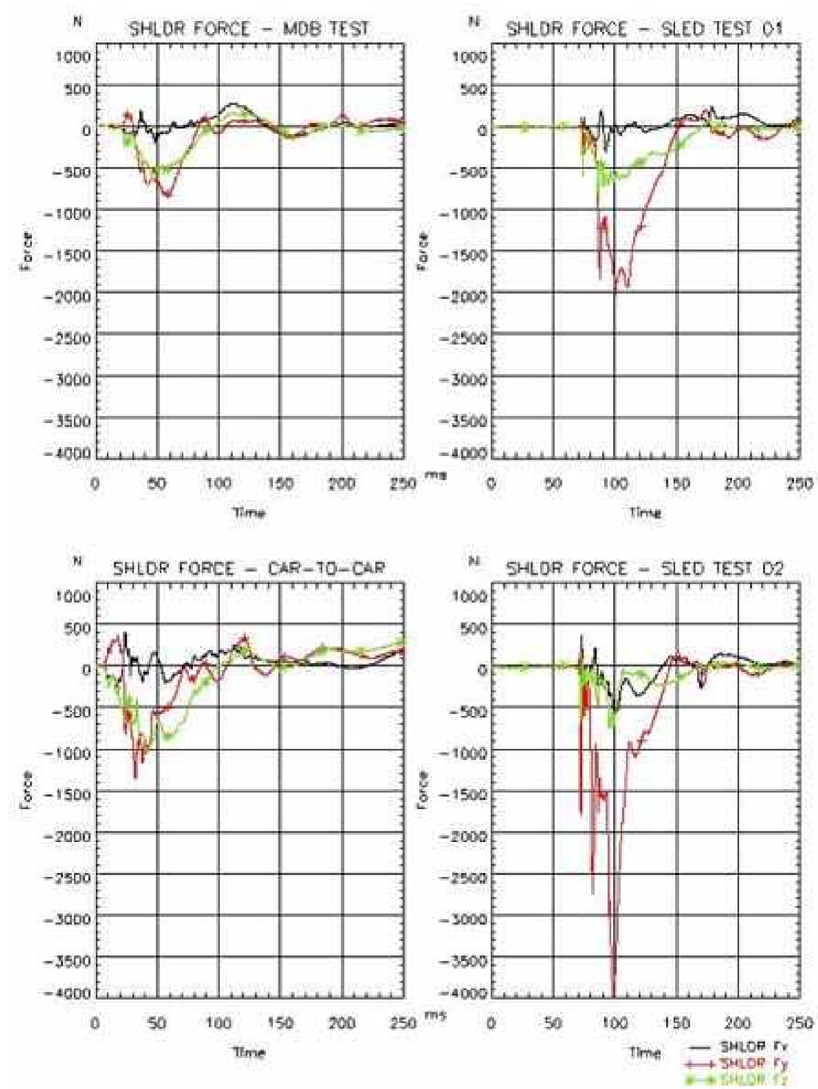

FIGURE B 22 Shoulder loads (CFC 600)

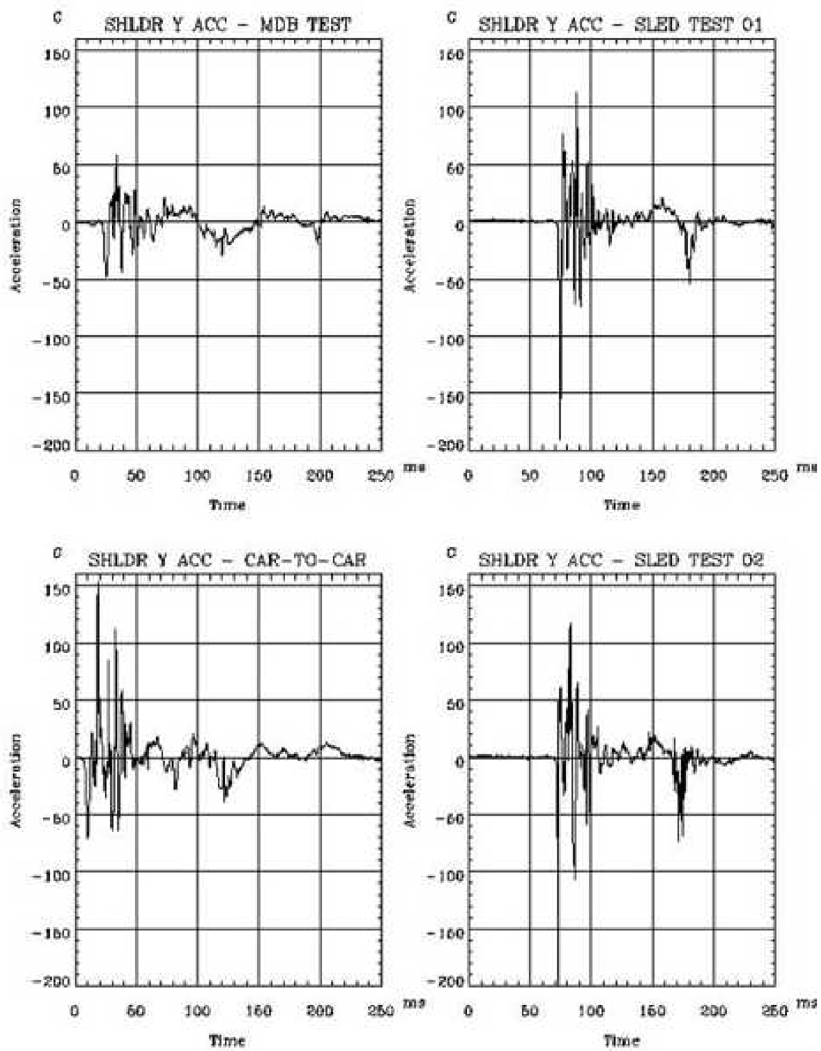

FIGURE B 23 Shoulder y-axis linear accelerations (CFC 1000)

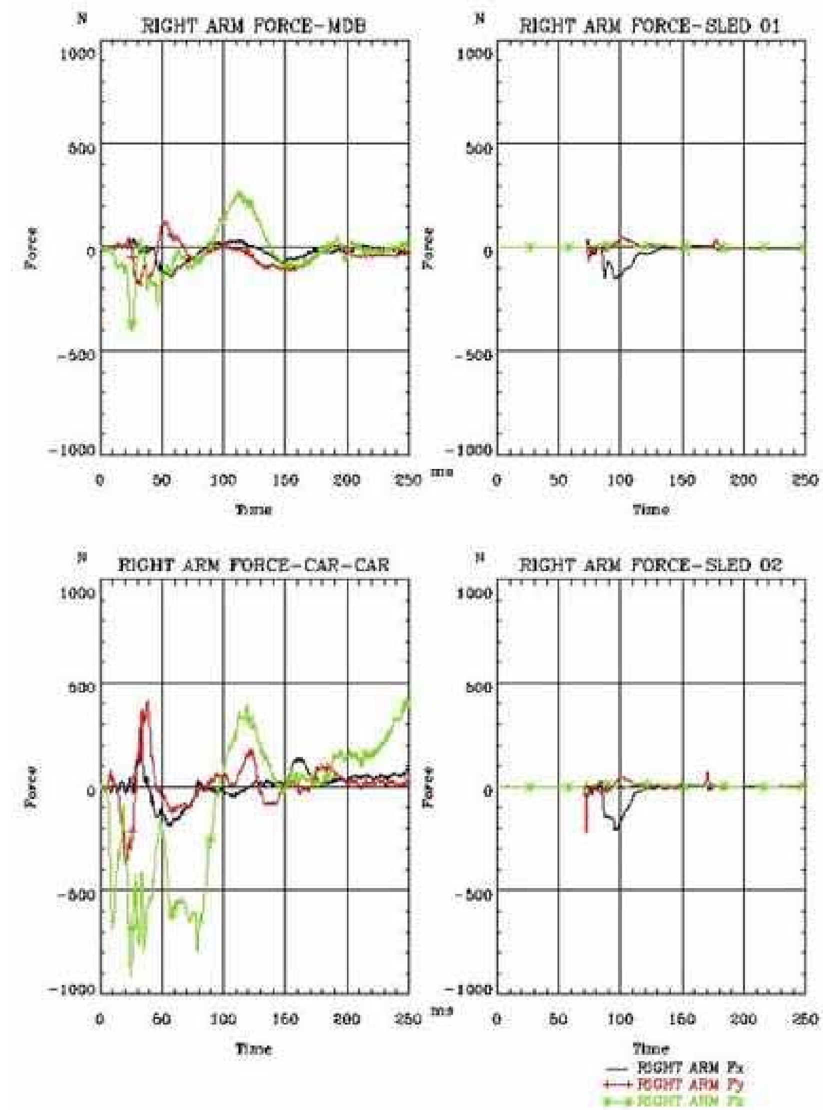

FIGURE B 24 Right full upper extremity - arm loads (CFC 1000)

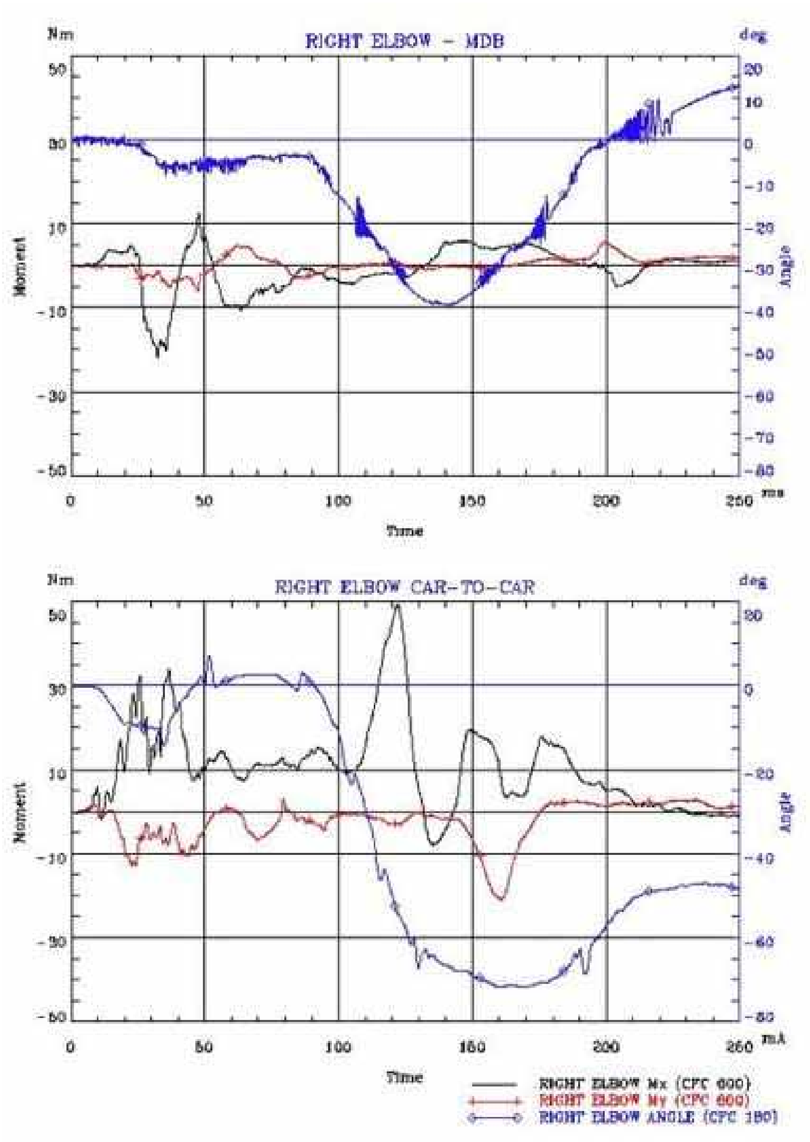

FIGURE B 25 Right elbow angle and moments

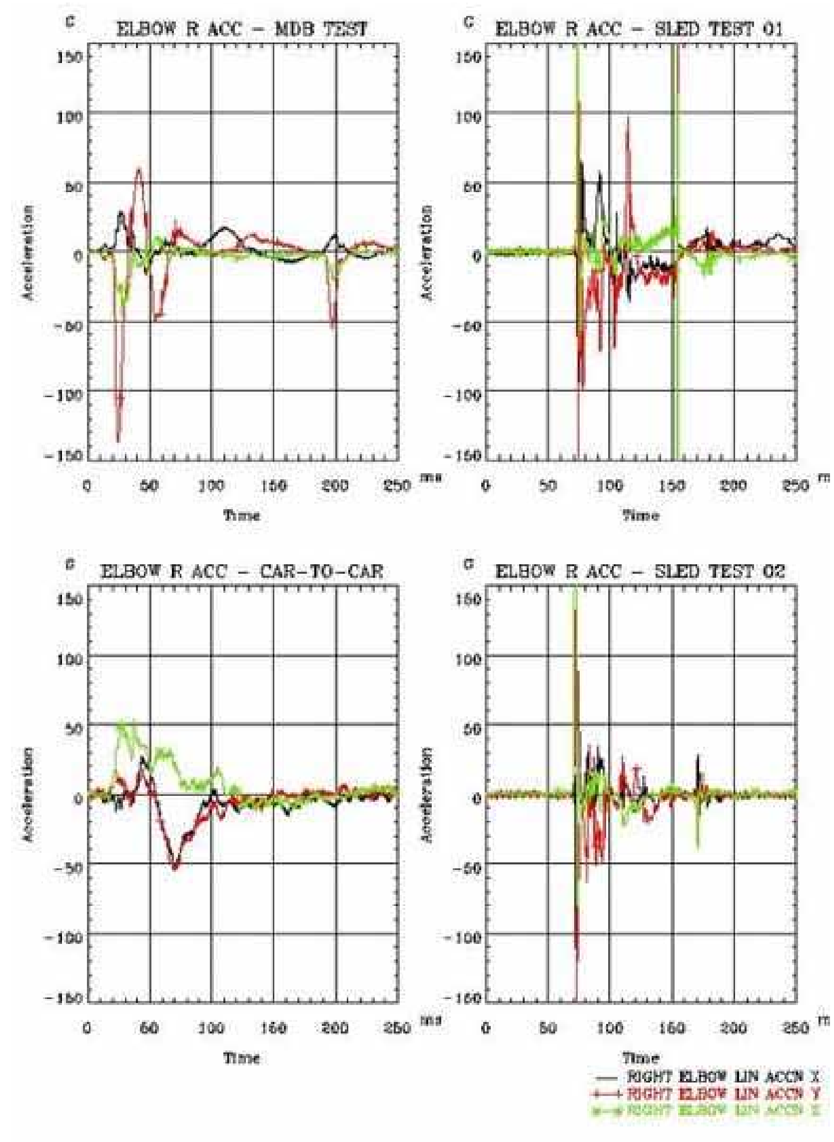

FIGURE B 26 Right elbow accelerations (CFC 1000)