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In-Depth Accident Investigation of Rollovers as a Basis for the Development of New Testing Procedures

Abstract

In-depth road traffic accident research in Spain is a fairly recent activity. In the past, only accident data that had been retrospectively processed by the national and regional traffic police forces was available. In 1999 Applus+IDIADA set up a permanent accident research unit to carry out in-depth analysis of road accidents in Spain. Since then accidents involving cars, motorcycles, coaches and vulnerable road users have been thoroughly studied. The Applus+IDIADA accident research team has carried out work for the various traffic polices in Spain and it is currently involved in several research projects in which accidentology is one of the main tasks. The working methodology of the team is presented in the first part of the paper.

In the framework of the European research project "Rollover" (GRD2-2001-50086), Applus+IDIADA has collected data, inspected scenarios and performed virtual reconstructions of twenty-six of the total seventy-six rollover accidents studied. The second half of the paper describes how these accident investigations were used to develop a test procedure for identifying possible improvements to the vehicle structure which augment occupant protection in a rollover scenario. In particular, a proposal for a new drop test for rollover assessment is presented. The cases were analysed for severity, in terms of injury to the occupants and damage to the vehicle, and taking into account whether a seatbelt was worn or not. The worst possible cases were identified as those that had severe occupant injuries and sizable damage to the occupant compartment when seatbelts had been worn. The most severe cases were then analysed further for impact position (roll and pitch angles) and the impact velocity. With these parameters taken into account, the most representative combinations could be found. This resulted in a series of configurations for possible drop tests. The results of the tests indicate where passenger vehicle structures need to be improved in order to increase occupant safety in the event of a rollover crash.

Background

Vehicle safety development is completed through engineering and homologation. Safety developments are carried out through vehicle crashworthiness, restraint system integration and pedestrian protection assessment. Vehicles are tested for their crashworthiness in all directions of impacts. Restraint system testing and development are carried out according to the various standards using simulation techniques as a complementary tool to sled tests and full scale crashes. Pedestrian protection development and testing utilise free-flight and guided impact test devices to carry out physical simulations for the verification of virtual pedestrian crash simulations and calculations. At the final stage of vehicle safety development, the team dedicated to homologation ensures that engineering developments conform to the required standards (figure 1).

On the other hand, accident investigation forms the basis for the current test procedures for vehicle safety development. However, a number of factors such as improved crashworthiness of recent vehicles, widespread introduction of smart restraint systems and even significant changes in the vehicle fleet – for example, increasing presence of sport utility vehicles – makes it necessary to periodically review test procedures and to provide the appropriate feedback from real world conditions. This can only be done by means of accident research. This paper is concerned with accident analysis with the aim of acquiring

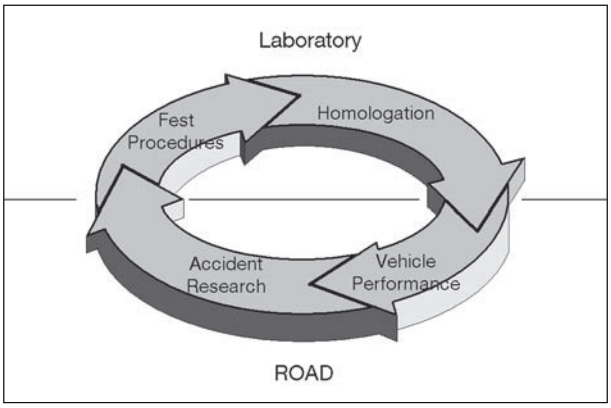

Fig. 1: The vehicle safety development process

enhanced vehicle safety development techniques for the particular typology of rollover accidents.

The Applus+IDIADA Accident Investigation Unit

Introduction

In 1999 a permanent accident research unit was set up to carry out in-depth analysis of road accidents in Spain. Since then accidents involving cars, motorcycles, coaches, lorries and vulnerable road users have been thoroughly studied. Applus+IDIADA collects data, inspects scenarios and performs virtual and physical reconstructions of accidents. The team consists of three full-time accident investigators working very closely with an experienced group of project engineers of different areas (homologation, active safety, passive safety, computer simulation). The working methodology of the Applus+IDIADA accident research team is conducted in a methodical and precise manner to ensure that all possible information has been obtained and used to carry out the most accurate of studies. The investigation stages consist of preparation, practical investigation, processing and analysing the results.

Up to now, the accident investigation unit has been working on specific research projects with the traffic authorities in Spain at local, regional and national level. In the period 2000-2001 Applus+IDIADA carried out at national level an in-depth study of 10 accidents in which buses and coaches were involved. This work was commissioned by the Spanish Home Office through the State Traffic Office. In the same way, since the setting up of the team Applus+IDIADA has conducted several accident reconstructions for both the Catalan Traffic Office (regional level) and City Council of Barcelona (local level).

Currently, Applus+IDIADA continues to work with the regional and local traffic authorities carrying out new accident reconstructions. In the same way, Applus+IDIADA acts as a consultant to the different traffic authorities in Spain either conducting specific studies or giving advice in the preparation of their road safety campaigns. On the other hand, Applus+IDIADA is currently taking part in two EC funded projects within the 5th Framework Programme (‘Child’ and ‘Rollover’). Its contribution to these projects consists, among other tasks, of accident data collection and physical and virtual accident reconstruction.

Set-up of Accident Investigation Projects

There are three main bodies involved in Applus+IDIADA accident studies; these are the accident investigation department, the traffic police and the local health care services and hospitals. With a mutual interest in reducing the number of road traffic accidents and injuries, resources are pooled to provide an accurate, detailed investigation; hence the completion of a precise reconstruction can be carried out.

At the beginning of a new project all of the associates that will be involved are informed. For this preparation a kick-off meeting is held with representatives of the involved divisions. Here the new project is outlined and discussed. The meeting is designed to inform the traffic police and healthcare services concerning the intentions of Applus+IDIADA in the project, to convey the general overview of the study and indicate to the other factions the information that will be required.

After the traffic police have investigated the scene of an accident and formalised their report, they select the case suitable for Applus+IDIADA studies based on the information and specifications of the project given in the meeting. The traffic police send a summary of the report, designed as a result of the meetings, to Applus+IDIADA technical centre. The accident investigation department analyses the accident with regards to the project criteria and makes the final decision on whether the case is appropriate. If the case is deemed to meet the criteria then a request for further information is made.

The information delivered comprises the police investigation into the accident and additional information specifically required by Applus+IDIADA. The police investigations can have varying levels of content depending on the circumstances of the accident but a typical file contains the following:

- Summary
- Description of the location
- The persons involved in the accident
- Interview extracts from driver/passengers/other
- Vehicle specifications

- Impact details – position
- Point of crash
- Trajectories before and after the point of impact
- Various Studies (these vary depending on the circumstances of the accident)
- Causes of the accident
- Various hypotheses for the accident
- Photographs of the scene of the accident and the vehicles involved
- A plan of the accident in the form of a step diagram

Practical Investigation Methodologies

The practical investigation is begun with a general vehicle investigation entailing the visual inspection of the vehicle – important characteristics are observed such as deformation, intrusion and restraint systems for their presence, use and their activation.

Observations precede general measurements of the vehicle. The general measurements provide an instant hard copy of information regarding the deformation. Examples of deformation and intrusion measurements recorded are: side sill reduction, wheel base reduction, A-pillar intrusion, foot well intrusion, maximum front and side deformation. These measurements are taken using an accurate laser distancemeter.

After the general over-viewing measurements have been recorded an accurate detailed study of the deformation is carried out using a theodolite to take numerous points at the impact position. Theodolites are instruments primarily used in trigonometric surveying: for the accurate measurement of horizontal and vertical angles. For accident reconstructions they are used to create a three-dimensional map of points in space for an accurate representation of objects and shapes.

The first measurements to be taken are the reference points. These are required to generate the system in which the points will be referred to. Once the reference has been defined the points are taken. A particular methodology is used for this in order to make processing the results easier. The points are taken in a particular sequence that follows the profile of the deformation being measured. The reasoning behind this is that when the points are entered into the CAD software they are joined in the same consecutive sequence as they were taken. The sequence will therefore create a map in space that will outline the shape of the vehicle and visibly indicate the deformation. The deformed shape can therefore be entered into CAD software and compared with another vehicle of the same make and model to calculate the deformation. Finally, the forms defined by the project are filled to conclude the vehicle investigation.

The investigation of the scene is carried out in a manner comparable to the vehicle. Initially the crash scene is examined for indications as to where the point of impact and final rest position may have occurred. This entails finding distinct markings in the immediate surroundings of the accident, for example, marks left by the police on the road and vehicle fragments. Once the scenario has been established, the scene is quantified using the theodolite. The theodolite positioning is important here; it is located in such a way that it is possible to view the entire scene from a single point. When a satisfactory position has been obtained the points are taken. Measurements are then recorded at regular intervals along the road side starting with an initial reference point. This method creates points in space that represent the road plan when the points are joined, indicating relief and shape. The final part is to fill the forms defined by the project to conclude the scenario investigation.

As for the the occupants of the vehicles involved, if it is possible to contact them for further information they are interviewed in an objective manner following specifically designed questionnaires.

Processing of Data

The points that were recorded using the theodolite are processed into a format that is readable by CAD, using the tools contained in the software the vehicles and scenarios are rendered appropriately. The roadway file is imported into PC CRASH® for use in the virtual reconstruction. The deformed vehicle model is used for taking further accurate deformation measurements by a comparison with a non deformed model of the same type.

The complexity of PC CRASH® depends on the case. Reconstructions use the information and parameters gained from police reports, and from the inspections and analysis of measurements as a basis. The investigation engineer uses experience and understanding of the case to identify the unknown parameters. In order to have an accurate reconstruction, any parameters that are selected are chosen for a reason.

Every step of the reconstruction can be analysed for numerous results and analysis. Examples are shown below; the two graphs indicate acceleration and velocity respectively after an oblique collision when two vehicles attempted to join the same path at the same time.

Reconstructions are used to establish a clear picture of the accident scenario and to make use of the data that the software formulates as a result of the inputs. The use of the data varies from project to project. For example on the one hand, in the European 'Rollover' project, Applus+IDIADA were to define a new test for structural analysis in case of rollover, this entailed developing the drop test. For this the roll and pitch impact positions were identified using the virtual simulations in PC CRASH®. On the other hand, for the European project 'Child', the kinematics of the vehicle and the occupants are important for any point in the accident sequence. One of the objectives of this project is to determine if the biomechanical behaviour of the child anthropomorphic dummies is representative of real children.

Different projects require the collection of different information, however, the general objective of such studies is to improve the protection for all road users, both occupants and pedestrians. In order to develop protection measures for occupants and pedestrians it is very important to obtain information on the injury mechanisms and hence the injuries. Applus+IDIADA gains this information from healthcare services and hospitals. The information provided is in terms of the scientific injury. Every feasible injury has been assigned a code on the Abbreviated Injury Scale (AIS). This facilitates understanding of the injury severity.

The accident investigation unit in association with the traffic police and the health care services and hospitals carries out investigations effectively and thoroughly in the development of safety for all road users in various projects on a local regional national and international scale.

Development of a New Drop Test Procedure within the 'Rollover' Project

Introduction

Applus+IDIADA has been engaged in the European 'Rollover' project (GRD2-2001-50086) since June 2002 and will continue to be involved until 2005. The overall aim of the project – a research activity within European Commission 5th Framework Programme – is to assist European sensor system developers and restraint and vehicle manufacturers to develop effective rollover protection systems in a cost effective manner. The project is a common effort of the following 16 partners: TUG, ESI Group, MIRA, TNO, TUV UVMV, MAGNA Steyr, LMU, Concept, GDV, Bolton Institute, Ford Renault, Delphi, TRW and Applus+IDIADA.

Applus+IDIADA has been involved in five of the six work packages in the project but largely, as work package leaders in one particular work package, associated with various aspects of rollover physical testing and development. The work package is divided into four subtasks: structural, interior, restraint and sensor developments. Applus+ IDIADA are task leaders for structural testing and development within this work package, largely due to the specialised skills of the workforce in the field and the facilities available to carry out the tests.

Rollover accidents are complex situations to reproduce in a crash test laboratory. The nature of the accident itself, the unpredictable behaviour of the tyres and suspension systems – thus influencing the number of rolls – are difficult variables to control in a full-vehicle dynamic test. Currently, the only vehicle standard which includes a rollover condition – transversal rollover – is the American FMVSS 208 [1]. This test configuration however presents the problems mentioned above. An attempt to overcome these issues was made with the introduction of the inverted drop test procedure (SAE J996) [2]. This SAE recommended practice establishes a standardized test procedure to obtain as closely as possible deformation of a vehicle roof which occurs in a vehicle rollover. The procedure is intended to provide reliable and repeatable results and to permit valid comparisons between various vehicle models. Structural deformation from a drop test is more readily reproducible than the deformation from rollover tests due to extreme variations and the unpredictability of rollover tests.

Since one of the aims of the ‘Rollover’ project is to develop suitable test procedures for enhancing rollover protection, a proposal for a new drop test procedure is presented. This test procedure intends to update the test configuration of the SAE J996 protocol and is particularly addressed to the European vehicle fleet.

Data Collection and Processing

Applus+IDIADA began work in the project by acquiring the cases for the rollover project database. The work policy at Applus+IDIADA is to select new cases specifically for the project after it has been defined, rather than to have a database of cases from which appropriate cases are selected. This ensures that the specific data required for the current project is present and available and the cases are as up to date as possible and representative of the current vehicles on the road. Carrying out the research in this manner also ensures that the Applus+IDIADA’s rollover research database will continue to expand. The process of accident investigation for the rollover project proceeded in the same methodical manner as usual.

The traffic police were informed regarding Applus+IDIADA’s involvement in the new project and its aims through meetings. Applus+IDIADA specified the subjects of information that would be required for the project so that when the traffic police were next called to a rollover accident scenario, the specific information could be obtained. The accident summary and information was faxed to the Applus+IDIADA technical centre in Tarragona after the traffic police inspection. If the criteria defined by the rollover project were present the case was accepted. If accepted a further request was made for the traffic police full report. With the information now available concerning the locations of the scene and the crash vehicle(s) Applus+IDIADA carried out a full investigation. During the inspections all the information specified by the project was gathered where possible. For example, all vehicle information: type, make, model, various deformations. All occupant information: number of, age, gender, seatbelt, injuries. All scenario information: what happened, how, where, what type, weather condition, time of day, etc.

When the ‘Rollover’ database was finalised there were seventy-six cases reconstructed of which Applus+IDIADA had completed twenty-six. The accident scenes and vehicles were inspected and quantified using the theodolite, the three dimensional maps indicated with points were transferred from data into an Auto CAD file where the maps were finalised to create a three-dimensional rendered visualisation of the scene and the vehicle(s). The Auto CAD file was imported into PC CRASH® for an accurate and detailed reconstruction. The screen shots below (figures 2a and 2b) provide an example of such a transformation.

The points taken for the crashed vehicle(s) were used to measure particular deformations and intrusions. The points are taken using the theodolite and transferred into the Auto CAD software. An example of the process is shown below (figure 3).

The required data files were transferred into the PC Crash® program and the reconstruction commenced. To begin with the basic parameters were input. For example: the car, make, model,

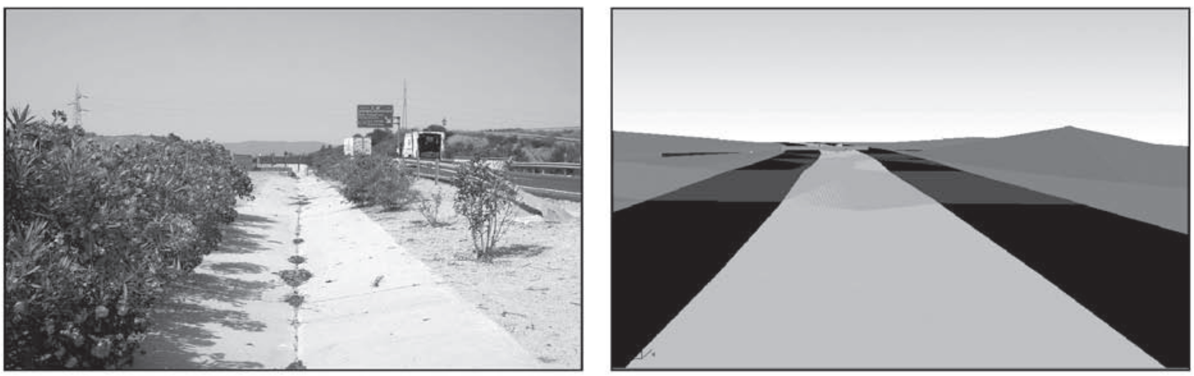

Figure 2a Figure 2b

Figure 2

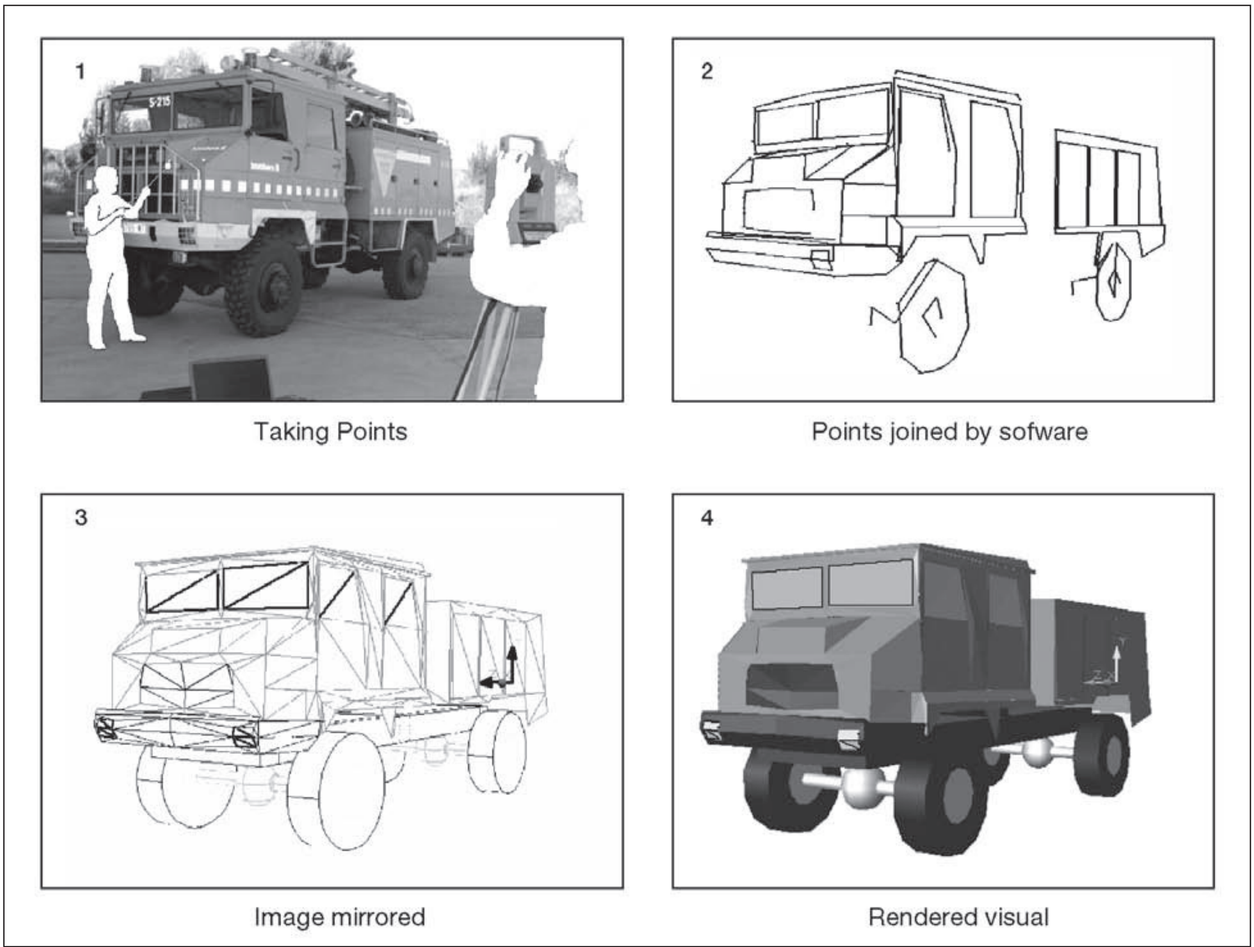

Fig. 3: Example of vehicle 3D-measurement process

settings and height of the centre of gravity and the number of passengers, the latter two being very important for rollover reconstruction. The sequences were defined after the basic parameters had been entered. These are the sequence of events that occurred during the accident based on the information obtained by the traffic police. For example, using the estimated velocities, the weather conditions and the sequenced diagram of events given in the report, the chain of actions was defined.

Once all the information available has been entered a preliminary simulation is initiated, this initial reconstruction may need to be modified to improve the accuracy. The engineer uses the numerous options and tools contained in the software and his experience in using this. For example, the vehicle may do too few or too many rollovers. The friction of the surface on which the vehicle is travelling greatly affects the rolling behaviour of the vehicle. Applus+IDIADA has researched the friction coefficients of several surfaces and therefore defined rules for applying some standard frictional coefficients to a surface. Other variables can also be altered in order to render accurate results, these changes are required to have reasoning behind them to ensure the accurate representation of the real accident.

The simulations completed by the partners involved were submitted with all other data to the ‘Rollover’ project database.

Applus+IDIADA used the information and the reconstructions from the database for their next main role in the project – structural testing.

Research and Analysis

Structural testing began with researching current rollover test methodologies, analysing and evaluating them with respect to specific criteria, such as repeatability and representation of ‘real world’ accidents, defined by Applus+IDIADA. These criteria were based on the research and the views of the accident reconstruction engineers. The result of the research was the signifying of the

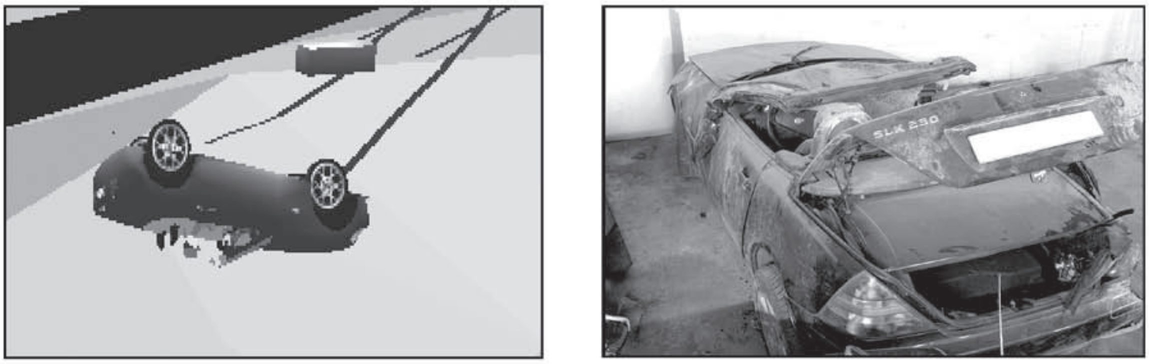

Fig. 4a Fig. 4b

Figure 4

‘Drop test’ that met all the criteria set with the aim of investigating vehicle structures in the event of rollover.

The ‘drop test’ is a simple procedure and regarded as representative of ‘real world’ cases due to the flexibility of possible test configurations. The drop test was developed with the aim of increasing its representation of known ‘real world’ cases i.e. the cases in the ‘Rollover’ project database. This development involved deeper analysis of the cases using PC CRASH®.

The ‘Rollover’ project database consisted of seventy-six PC CRASH® reconstructed cases when complete. However an initial development phase of the twenty-six Applus+IDIADA reconstructed cases was employed to make certain that the development of the seventy-six cases would reap useful results. The development was designed to systematically identify the most representative and severe Drop test roll and pitch angle configurations. The developments consisted of several stages:

The first consisted of summarising each of the accidents in the database, for example, what happened, how it happened and the consequences, by viewing the photos of the crashed vehicles and the AVI files created in PC CRASH®.

The second stage involved in-depth use of PC CRASH® to indicate the actual impact positions in terms of roll and pitch angles (figures 4a and 4b). The reconstruction was run for each case and the results of the calculations generated by PC CRASH® were used to determine where the strongest impact position may have occurred. The software tools gave the roll and pitch angles at these positions.

The third step of the development was to assess the cases with respect to certain characteristics. Essentially the worst cases needed to be identified. The aim of the characteristics was to filter out the ‘less important’ cases and concentrate on those that had the more serious consequences. The crash severity was indicated by stating if the crash resulted in:

- Serious occupant injury. Injury was defined as serious if the AIS was three or higher.
- Serious damage to occupant zone of the vehicle. Due to a lack of deformation data in the database this criterion was based on visual deformation from photographs. This was considered sufficient for the task in hand.

If these two criteria were characteristic of the case it was subjected to a further filter to determine the most serious cases. The final filter considered if the occupant in question was wearing a seatbelt or not at the time of the accident. If indeed the occupant was wearing a seatbelt then the case was classified as serious and was eligible for the final stage of the development. If not the case was excluded because it was not possible to determine whether the severity of the accident was a result of the rollover or the fact that the occupant was not wearing a seatbelt.

The strongest impact and the most severe accidents had now been defined. The development continued by assessing any correlation between impact position and injury severity. It was not possible to conclude this from the test development. The final cases that reached this category were sparse and saw impact positions that were quite varied. This however did not deter analysing the accidents in this way, it simply confirmed that rollover accidents can be very different from one another and that the current protection for occupants in rollovers is on the whole not sufficient. Instead of using one configuration it was decided that two would be used in order to increase this representation.

Results

A total of 76 rollover cases were PC CRASH® reconstructed in the European project 'Rollover'. These cases were evaluated with regard to the impact angles and velocity in order to determine a test that represented the vast majority of the most serious rollover scenarios. The aim was to identify the most severe impact positions according to these 76 cases. The cases were analysed in four different ways:

- The first indicated the strongest impact position and showed the severity of the injury that resulted.
- The second used the same strongest impact position as before; however indicated the damage to the occupant compartment that resulted.
- The third used the same strongest impact position, this time indicating both injury and damage to occupant compartment levels; they are not always mutually inclusive.
- A further stage was carried out to indicate if a seatbelt was being worn during the accident. If a severe injury and a high level of damage resulted from the accident and a seatbelt was worn by the occupant, then only the case qualified for a most serious case.

It turned out that in 16 of the 76 cases serious injuries – AIS3 or above – were present and the vehicles were seriously damaged, with large visible intrusions into the occupant compartment. These were identified as the most serious cases.

There were 4 cases that met the injury requirement to be included as serious, however the occupant compartment was not visibly intruded and there was no intrusion data on these cases. These cases were excluded from the study because the aim was to analyse the effect of the vehicle structure on the protection of the occupants.

The 13 most serious cases were then identified (table 1).

The table indicates that 5 of the 13 cases are from the category 'Impact induced rollover (Δv>30kph)' this is therefore clearly the most serious mode of rollover crash. At the end of the table the average roll, pitch and resultant velocities are indicated. There are three averages given for pitch angle: the first is an average of all the most serious cases, the second is an average indicating the pitch in the

Case	Category	Roll [°]	Pitch [°]	Resultant Velocity [km/h]
1	Impact induced rollover Δv<30kph	167	12	36
2	Impact induced rollover Δv<30kph. Not usual cases	178	-26	40
3	Impact induced rollover Δv<30kph. Not usual cases	138	21	1
4	Impact induced rollover (Δv>30kph)	105[1]	1	10
5	Impact induced rollover (Δv>30kph)	125[1]	3	32
6	Impact induced rollover (Δv>30kph)	156[1]	-1	6
7	Impact induced rollover (Δv>30kph)	85	1	9
8	Impact induced rollover (Δv>30kph)	146[1]	6	12
9	Trip induced rollover	178[1]	29	10
10	Turning and rollover. Not usual cases	172[1]	-15	4
11	Special others: Free fall & Rear down tripped. Not usual cases	86	-2	25
12	Other	167	-14	23
13	Other	122	3	41
Average		140	10	19
			-10	

[1] For roll angles the direction has been omitted, the vehicle will be assumed symmetrical

Tab. 1: Selected cases for development of drop test procedure positive direction according to the coordinate system and the third in the negative direction.

- The average roll, 140° only represents (±10°) 15% of the cases.
- The average pitch angles 10° and -10° represent (±10°) 85% of the cases.
- The resultant velocity average 19km/h represents (±5km/h) 8% of the cases.

The individual pitch angles seem to be very representative of these most serious cases. If two roll angles are selected in a similar way more representative results may be identified. By dividing the most serious cases into two roll orientations, 130° and 170°, the representation can be increased to 62%. In conclusion, two drop test configurations are proposed (figure 5).

These roll and pitch angles were then compared with all the cases with necessary information available. For the results, the cases where important data was absent were excluded reducing the field form 76 to 54. The results showed the following:

- 100% of all cases had at least one of the suggested roll or pitch angles.
- 91% of the cases were represented by the pitch angles 10° and -10°. This figure was 81% for the most serious cases.
- 60% of the cases were represented by the roll angles 130° and 170°. This figure was 62% for the most serious cases.
- Approximately 50% of all the cases and the most serious cases were represented by either of the two suggested configurations.

Throughout the 76 cases the pitch angles did not vary a great deal, this was the main reason as to why the derived general result for pitch is so very typical of all the cases. The derived roll angles on the other hand were much less representative of

Configuration 1			
Roll (degree)	Pitch (degree)	Resultant Velocity (km/h)	Equivalent Height (mm)
130	10	20	500
130	-10	20	500

Configuration 2			
Roll (degree)	Pitch (degree)	Resultant Velocity (km/h)	Equivalent Height (mm)
170	10	20	500
170	-10	20	500

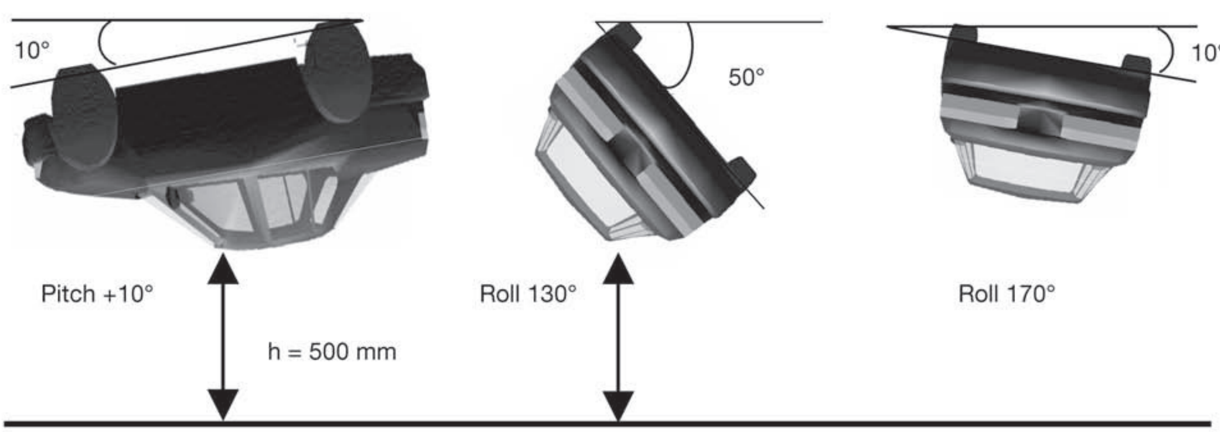

Fig. 5: Proposed drop test configuration

the cases, however they did cover 60% of the cases which indicates that their representation is significant.

If the derived roll and impact angles were both taken into account, then there was a total of four test configurations. These four tests represented approximately 50% of the cases. This is high enough to say that the representation is good.

The roll and pitch angles were determined by the most serious cases, there were no other combinations that could represent the most serious cases any better. It has been shown that these characteristics are represented in all the cases in a similar manner. A satisfactory level of representation has been achieved for a crash situation that can be individual.

The relative considerations that will make an effective test were found to be the following:

- Repeatability: the test is very controlled, roll and pitch angles can be coupled for any orientation, this means that very specific aspects of the vehicle structure can be loaded time after time in a test. This will make it possible to define a series of tests to gain an overall picture of vehicle structural integrity. This key factor is of utmost importance when testing vehicle structures for rollover protection. A repeatable test would enable the creation of an accurate model on which the development of safer vehicles in a rollover scenario can begin.
- Representativity: the test is controlled as mentioned previously, but the test still allows for a realistic representation of a rollover crash in that the vehicle can actually be dropped on its roof from whatever aspect or height deemed necessary. This will essentially represent a wide range of the worst cases, simulating impacts in real crashes.
- Insensitivity to vehicle size: vehicles of different sizes vary in dynamic behaviour when rolling. For example two vehicles of differing size would behave very differently in certain tests where there are rotational and/or translation movements. For example, FMVSS208 and corkscrew, this is due to the height of the centre of gravity of the vehicle. A higher centre of gravity will tend towards greater risk of roll. In the drop test there is essentially only one direction of movement and so the effect of centre of gravity is minimised. This is important to create a standard which can be applied to all vehicles within reason. For example, all passenger vehicles, from small cars to Multi Passenger Vehicles and 4X4 vehicles.

Conclusion

Applus+IDIADA's task for the 'Rollover' project comprised the development of the drop test through virtual reconstruction of a group of representative rollover accidents. The development included the definition of new roll and pitch angles and also the height from which to drop the vehicle to represent the velocity of impact. Two drop test configurations are proposed with roll angle, pitch angle and height being 170° (10º), ±10° and 500mm for the first one and 130° (50º), ±10° and 500mm for the second one respectively.

The resulting combinations of these angles and height represent two thirds of the 'worst' cases in the 'Rollover' project database. They also represent two thirds of all of the seventy six cases involved in the project. The proposed test procedure combines good repeatability, reproducibility and insensivity to vehicle size.

References

[1] 571.208 Standard No. 208; Occupant Crash Protection

[2] Inverted Vehicle Drop Test Procedure – SAE J996 JUN80. SAE Recommended Practice