Final Public Report
July 2002 – December 2005

Date
18-05-2006

Report period
July 2003 – December 2005

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Also seen by
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Contract №
G3RD-CT-2002-00802

Number of pages
22

Number of appendences
1

Number of figures
-

Number of tables
-

Confidentiality:
Public
Final Public Report

Contract №: G3RD-CT-2002-00802
Proposal №: GRD2-2001-50086
Acronym: ROLLOVER
Title: Improvement of Rollover Safety for Passenger Vehicles
Project Co-ordinator: Graz University of Technology
Partners: ESI GmbH, (ESI)
MIRA Ltd. (MIRA)
Netherlands Organisation for Applied Scientific Research (TNO)
Motor Vehicle Research Institute (UVMV)
Magna Steyr Fahrzeugtechnik AG & Co KG (MSF)
Idiada Automotive Technology SA (IDIADA)
Ludwig-Maximilians-Universitaet Muenchen (LMU)
Concept Technologie GmbH (CONCEPT)
Gesamtverband der Deutschen Versicherungswirtschaft e.V. (GDV)
Bolton Institute of Higher Education, (BOLTON)
Ford Werke AG (FORD)
Regienov - Renault Recherche et Innovation (REGIENOV)
Delphi Deutschland GmbH (DELPHI)
TRW Occupant Restraint Systems GmbH & Co. KG (TRW)

Reporting period: from July 2002 to December 2005
Project start date: July 1st 2002 Duration: 42 month
Date of issue of this report: 18.05.2006

European Commission
5th Framework
COMPETITIVE AND SUSTAINABLE GROWTH

Contract №: G3RD-CT-2002-00802
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1. Executive publishable summary

A summary page (non confidential) in a form suitable for publication should give the most significant aspects which describe the project: objectives, clear description of the results, their usefulness and possible applications and indications on the exploitation plans. This page will be used to update your current record in CORDIS.

Objectives

Based on the background of the European Vehicle Passive Safety Network a consortium of 15 European Research Institutes, Universities, suppliers to the car industry and car OEMs was formed to investigate the field of current passenger vehicle rollover accidents as well as to propose new cost effective virtual and experimental methodologies to decrease the injury risk for the car occupants.

In the EU 15 approximately 1.7 million persons are injured and 40 000 people are killed in road accidents a year. Although rollover accidents cover approximately 5-10% of all vehicle accidents, up to 10-20% of all seriously injured occupants and fatalities were involved in an accident where the car rolled. Such accidents cover collisions, single accidents as well as “normal” driving manoeuvres with elements of rollover.

Due to the main investigation aims, the project was split into 6 work packages and a management part.

Clear description of the results

Statistics show a rollover share of 5-10% of all accidents. Looking at fatalities the figures vary between 10-20%, depending on the country. Thus related to the number of accidents rollover is a risky event. Analyses are performed with respect to various investigations (driver, passenger, roll direction, injured body regions, …).

Rollover accident library – A case library for in depth studies was created. It includes general data for 150 accidents from Germany, Austria, Spain, and the United Kingdom. The structure of the case library is based on the STAIRS protocol (EU project). It includes collected data such as sketches, vehicle damage, medical reports and expertises.

Rollover in-depth accident reconstruction – By means of computerised accident reconstruction 75 cases were analysed and the results are included in the case library.

Rollover occupant movement – Based on the in-depth reconstruction, studies of the occupant movement were performed. To ensure typical movements of occupants at the beginning and during a rollover a set of volunteer tests was performed under different conditions typical for rollover scenarios. This study shows a significant difference between the movement of volunteers and existing
ATDs. Especially in the pre-roll and first phase of a rollover an influencing muscle activity could be found. It could also be proven that the characteristics of the motion, performed by the volunteers were repeatable.

Rollover scenarios in Europe – As a next step four main rollover scenarios were derived, which allow an identification and categorisation of all rollover events:

- impact induced
- ramp objects induced
- skidding & yawing induced
- others

This categorisation was used for further analysis in the project.

Rollover full scale reconstruction – The analyses performed for full scale reconstruction of real world accidents shows that reproduction of real rollover events is very difficult. Minimum changes in initial- and boundary conditions, strongly influence the vehicle motion.

Numerical analyses of occupant movement – By means of simulation methods it was possible to investigate and to support the cause of injury investigations. Also the influence of belt pretensioning on the head clearance could be analysed. A basic human body model without activity was used to identify injury mechanisms with sufficient accuracy. By including muscle activities this model could be further improved.

Cause of injuries – Looking at the medical reports and the simulations of the occupant movement four distinct injury causation mechanisms were established: Localised injuries caused by a direct impact to a body part (Localised Injury), Remote and diffuse injuries caused by a direct impact to a body part (Global Injury), Load based injuries produced by indirect loading associated with an impact to another body (Indirect Load Injury) and Crush based injury produced by crushing of the body part between deformed vehicle structures and/or outside structures (Crush Injury).

Numerical methods – Different numerical methods were investigated for analysing:

- the vehicle structure
- the restraint system
- the sensing system

Two finite element codes were analysed with respect to their applicability to rollover. The major difference between rollover simulation and conventional crash simulation lies in the long duration of the event and thus necessary simulation time. New methods were developed to speed up the simulation by switching between different numerical models. Detail simulation of laminated glass was also investigated and proved to be of great importance for rollover events. Guidelines for the simulation of restraint and sensing systems were developed. The new “tool chain” method integrates the vehicle dynamic simulation with the restraint analysis for rollovers. A special software tool was also developed to simulate the sensing system and to determine the trigger times.
Experimental methods – For the vehicle structure an inverted drop test was defined. It allows the evaluation of the structural stiffness in a repeatable and simple environment. In combination with numerical analysis a development strategy was derived, to find the severest loading case. Additional test procedures based on Low-G sled and driving tests were developed. They proved to be simple and reliable for the evaluation of sensing systems. Some of these methods also allow evaluation of restraint systems.

Performance criteria – Performance criteria for the following three categories were defined and evaluated:

- structural design (head clearance and structural stiffness)
- restraints (belt and airbag performance)
- sensing (type and trigger performance)

Design instructions – Design instructions resulting from this project are based on countermeasures against ejection, intrusion of the roof and occupant impact against interior parts, taking into account the timing of activation of protection systems (e.g. belt reminder, belt location, padding …).

Demonstrator – A physical demonstrator was built to show improvement on rollover performance through belt pretensioning. A prototype of the newly developed rollover measurement device “Rolland” was built in hardware. It allows improved quantification of survival space after a drop test. The effectiveness of improved belt and seat system was shown using numerical demonstrators.

Cost-benefit analyses – Using cost benefit methods the impact of rollover on European economy was estimated and opposed to the potential costs of vehicle improvement. Due to the lack of comprehensive European rollover data (statistics) no clear general statement could be given.

Indications on the exploitation plans

The technical achievements can be summarised as follows:

- Statistical overview of rollover accidents with respect to probability and accident mechanics
- Electronic Database of well documented and reconstructed rollover cases
- Definition of Representative Rollover Scenarios which allow categorisation of different rollover mechanisms
- Tool for simulation of occupant movement up to first phase of rollover
- Cause of injury summary
- Definition of efficient numerical rollover test methods
- Definition of efficient experimental rollover test methods
- Design instructions and performance criteria for Rollover performance of vehicles
• Hardware and virtual demonstrator

These achievements should be used to provide new knowledge to the industry, suppliers and research institutes in the European automotive sector. The new methodologies for numerical and experimental simulation of passenger vehicle rollovers should provide an effective way in terms of quality of the results and costs for development and finally lead to safer vehicles.
2. Objectives of the project

The ROLLOVER project responds to KA 3 - Land transport and Marine Technologies - under the Development of Critical Technologies focussing on the priority of the development of advanced vehicle safety. Specifically it addresses the goals of Objective 3.1.2 Innovative and safe road and rail transport vehicle concepts, by encompassing the development of safety related systems for passenger cars.

The socio-economic issue addressed is the fact that traffic-related accidents are still a major threat to life in the European Union, especially when the low average age of the victims is taken into account. Illustrative in this respect is the annual road toll of more than 40,000 people killed and 1.7 million injured (EU 15), which represents an unacceptably high burden on Europe’s society and economy. This means that 1 in 80 European citizens will end their lives on average 40 years too early in a road accident and 1 in 3 will need hospital treatment during their lifetime as a result of a road accident. The social costs of these accidents are currently evaluated at some 160 billion Euros per year in the European Union alone. If the additional road tolls of approx. 23,000 persons killed each year in EU's associated states are taken into account, the annual socio-economic cost will be around 250 billion Euros.

The proposed development of improved or new restraint system for rollover scenarios is a response to the societal need for safe cars as described above. An overall objective of the project is to pave the way for the realisation of a new generation of road vehicles, which are both cost-efficient and safe. The focus of the project is on occupant safety during rollover scenarios. The target vehicles are passenger cars, including SUV, MPV and Minivans.

Another overall objective of the project is to assist European restraint and vehicle manufacturers to develop effective rollover systems in a cost efficient manner. As such systems are implemented, this should provide increased protection to members of European society who travel by car. The project will cover various types of rollover accidents including injury mechanisms and protection methods.

The scientific research objectives are:

- To review existing European and US accident data and publications, to assess the potential effects of rollover protection systems on the European and US accident statistics. Based on this knowledge the importance of different rollover scenarios with respect to injury risk can be quantified.

- To obtain a database of in-depth studies of rollover accidents which can be used to determine various representative accident scenarios. This database will contain all available information regarding causation, vehicle movement, deformations and injuries. In addition detailed accident reconstructions will be included for several cases. This database will form the basis for the
categorisation of rollover types and for the validation of newly
designed restraint systems.

- To identify impact / occupant scenarios worthy of detailed study and
to evaluate the issues and likely effects of new restraints on those
scenarios. Through categorisation of rollover scenarios the amount
of necessary testing can be reduced to a minimum.

- To demonstrate the efficiency of an optimised rollover protection
system through a demonstrator system.

Industrial/ Societal objectives are

- To investigate the effects of pre-impact occupant kinematics, (for
example under pre-roll impact) to determine worst case occupant
"impact start positions". This investigation guarantees that Out of
Position scenarios will be taken into account from the beginning.

- To identify, create and use advanced computer models that allow
the effective evaluation of such scenarios. Through the optimum
combination of FE and MB models simulation time can be reduced by
at least a factor of 5 for typical scenarios

- To define physical test methods for an effective evaluation of sensor
and restraint systems

- To generate standard guidelines to define and evaluate the
functional requirements of rollover restraints. Guidelines will help to
develop new rollover protection systems a lot faster.

- To create new knowledge for the development of improved restraint
systems.

- Improved vehicle designs could offer a substantial reduction in
fatalities if they are adopted within the EU community

These objectives are vital for the European Road Vehicle Safety Policy.
The listed objectives of the proposed project directly refer to Key Action 3:
LAND TRANSPORT AND MARINE TECHNOLOGIES of theme 3: Competitive
and Sustainable Growth.
3. Scientific and technical description of the results

This section is the main part of the report and comprises different technical chapters covering the research approach and the work performed within the project and highlighting the main results achieved. Tables, figures or charts should be used where appropriate.

The detailed description of the results can be found in the annex. All tasks are listed with their results.
4. List of deliverables

The list of deliverables of any tasks completed during the project, and which constitute contractual deliverables, should be given with indication of the references and issue date in comparison with the project planning.

The following deliverables are planned within this project:

### Table 1  Overview of deliverables

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<td>Report on design guidance for numerical models used in the assessment of restraint systems</td>
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<td>Report on design guidance for numerical models used for the assessment of sensors and for rollover detection and triggering</td>
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<td>Report on summary of rollover performance criteria for structural stiffness, interior design, restraint systems and triggering</td>
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<td>04/2005</td>
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<td>Report on summary of rollover design instructions for structural stiffness, interior design, restraint systems and triggering</td>
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<td>Final assessment</td>
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5. Results and Conclusions

Results

Rollover statistical data – The investigation of accident databases and statistics results in a rollover share of 5-10% of all accidents. Looking at fatalities the figures vary between 10-20%, depending on the country. Thus related to the number of accidents rollover is a risky event. Analyses are performed with respect to various investigations (driver, passenger, roll direction, injured body regions, …).

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Cost-benefit analyses – Using cost benefit methods the impact of rollover on
European economy was estimated and opposed to the potential costs of vehicle
improvement. Due to the lack of comprehensive European rollover data
(statistics) no clear general statement could be given.

Conclusions

Rollover Statistics - Analysis of National databases suggest that 5 -15% of all
accidents involve Rollover. The significance of Rollover appears to be different
in different countries. The lack of availability of a comprehensive uniform
European accident database including information on Rollover makes the
evaluation of rollover on an EC wide basis impossible. It’s recommended to
enforce the setup of a uniform European accident database, including more
detailed information.

Rollover injury analysis – Many injuries are caused by roof-head-contacts
during rollover. Belt excursion showed to be a critical factor with respect to
partial ejection. The study also shows that the complex occupant motion in a
rollover event can be sufficiently analysed by means of virtual simulation. It is
recommended to enforce the development of active virtual human body models.

Vehicle Structure Testing – Although the US are the only place were rollover
safety must be evaluated on legal requirements the currently used assessment
tools do not seem to be very efficient. Weak repeatability and insufficient
loading of the test could be significantly improved.

Sensing System – New methodologies for virtual testing and development of
sensing systems were introduced and evaluated. Suggested scenarios were
defined which can be used for the evaluation of the sensing system.
Nevertheless OEMs will have to define their own set of evaluation scenarios to
meet their own requests.

Recommendations for further investigations are:

• Set-up of a uniform European accident database (incl. Rollover data
  and scene data). Currently rollover is not defined in most European
data bases.
• Extension of existing human models through integration of active
  muscle models to improve rollover simulations
• Further evaluation of test methods seems necessary (roof strength,
  restraint testing - virtual methods, sensor system test scenarios)
• Discussion of harmonisation and improvement with US regulations

Outlook – These recommendations could be addressed within an additional
research project focussing on:

• Development of further criteria for assessing new vehicle roof
  strength performance
• Development of a rollover sensor test standard
• Extension of the current study on occupant movement and injury severity for restrained active human models
• Extension of the human model to rollover simulations through integration of muscle models
• Is the equipped restraint & interior system capable of limiting critical occupant movements and injury levels?
• Further evaluation of proposed EU rollover standards
• Evaluation of possible reduction of rollover casualties through a proposed EU standard
6. Acknowledgements

The coordinator, Jürgen GUGLER and Hermann STEFFAN from Graz University of Technology like to thank following people for the support and collaboration within the Rollover project (in alphabetic order):

Jiri Adamec Ludwig Maximilians Universität München
José-Manuel Barrios IDIADA AT
Hans-Peter Bausch TRW Occupant Restraint Systems GmbH Co. KG
Jenö Bende Gesamtverband der Deutschen Versicherungswirtschaft e.V.
Farid Bendjellal Regienov - Renault Recherche et Innovation
Erwan Bigot Regienov - Renault Recherche et Innovation
Wilhelm Breitenhuber Magna Steyr Fahrzeugtechnik AG & Co KG
Gary Brown MIRA Ltd.
Clive Chirwa University of Bolton
Anneloes Dalenoort TNO Automotive
Abtin Darvish Delphi Deutschland GmbH
Erwin Deutscher Concept Technologie Ges.m.b.H.
Ewald Dohr Magna Steyr Fahrzeugtechnik AG & Co KG
Miroslav Dvorak TÜV UVMV s.r.o.
Arno Eichberger Magna Steyr Fahrzeugtechnik AG & Co KG
Volker Eis Ford Werke AG
Jacques Faure Regienov - Renault Recherche et Innovation
Paul Fay Ford LtD
Florian Feist Graz University of Technology
Sven Fleischer Delphi Deutschland GmbH
Patrice Fradin Regienov - Renault Recherche et Innovation
Bertram Geigl Graz University of Technology
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Bernhard Greilinger Gesamtverband der Deutschen Versicherungswirtschaft e.V.
Sabina Hannemann Delphi Deutschland GmbH, Vehicle Safety Laboratory Berlin
Jens Haun Delphi Deutschland GmbH
Wolfram Hell Ludwig Maximilians Universität München
Klaus-Ulrich Heller Delphi Deutschland GmbH
Joaquim Huguet IDIADA AT
Cees Huijskens TNO Automotive
Thomas Hummel Gesamtverband der Deutschen Versicherungswirtschaft e.V.
Sven Jansen TNO Automotive
Alian Kirk Loughborough University
Michael Klein European Commision
Laurence Lamy Regienov - Renault Recherche et Innovation
Diana Lang Gesamtverband der Deutschen Versicherungswirtschaft e.V.
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<td>Universität der Bundeswehr München</td>
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<td>Schoeenpflug</td>
<td>Ludwig Maximilians Universität München</td>
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<td>Michiel</td>
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7. Annex

In the annex to the final technical report the detail descriptions of the work performed and the results can be found.