The effectiveness of the invention "JR System" in protecting the occupant in side impact collision

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ABSTRACT

This study is the preliminary evaluation of the potential usefulness of the invention called "JR System", International Application No.PCT/PL04/000018, to protect the occupants during side impact collision. The new system reduces the friction force between the target car and the road surface by raising the wheels just before the impact and thus the better protection of the target car passengers is expected. The analysis was based on the computer simulations performed in the MADYMO v6.2 software environment and the basic test conditions comply with the Euro-NCAP side impact test protocol. To widen the evaluation range of potential application of the new system the different set-up test configurations were simulated with different bullet car mass and speed and also with different methods of elevating the target car.

INTRODUCTION

Though a contemporary car is equipped with the sophisticated restraint systems protecting the occupants in side collisions e.g. side airbags, aerial curtains and side reinforcements the statistics (Figure 1) show that the side protection is still unsolved problem in the vehicle passive safety.

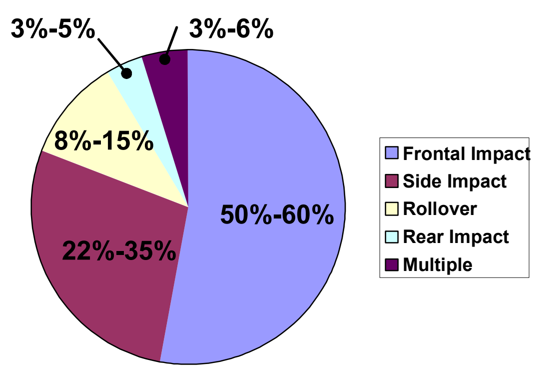

Figure 1. Collision types for car occupant fatalities.

The total number of fatalities in the World in road accidents reaches 700 thousands a year and over 200 thousands only in side collisions. The main reason for such enormous fatality toll in side impacts is that the design requirements for cars locate an occupant close to a relatively thin door and thus the space which can be exploited to dissipate impact energy is very limited and much smaller than in case of frontal collisions. Another problem is the incompatibility issue, especially the situation when the target car is the passenger car whilst the bullet car is the SUV, Pick-up or another vehicle with the high frontal bumper. In this case the target car is hit above the side sill in the more compliant part of the car body which may result in very significant inside intrusion and serious injuries as a result.

The considered idea "JR system" proposes to eliminate part of the energy, which has to be absorbed by the car body, by reducing the friction forces acting on the wheels of the target car during the collision and thus lowering the work done by friction forces which has to be balanced by dissipation energy in the energy preservation principle for the whole system. To reduce the friction forces the system of four airbags placed under the target car is activated just before the side collision so that the wheels lose contact with the road and the car is contacting the basis only by the deployed airbags.

MATERIALS AND METHODS

The current research into the side impact safety focuses on the door reinforcements and restraint systems or on making big cars more compatible with passenger cars by changing front bumper construction. The assumptions of the "JR system" idea differ significantly from the standard approaches mentioned above and thus require more thorough explanation.

DESCRIPTION OF THE INVENTION

The “JR System” idea is aiming at improvement of the safety of the occupants by reducing the deformation of the car body in side collision. The main element of the protection system is the set of four airbags (Figure 2) attached either directly to the car body or to the car’s suspension (depending on the considered technical approach). The integral parts of the protection system are also the radar detectors which activate the undercarriage airbags when the unavoidable collision has been recognized, and the side airbags protecting the head and the thorax of the driver.

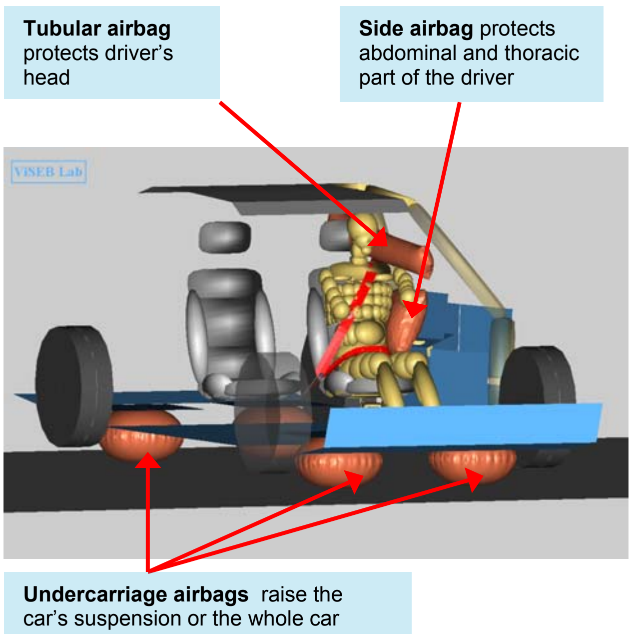

Figure 2. Elements of the proposed side protection system.

The whole process of activating the system can be described in the following steps:

1. Identification of the approaching bullet car and recognition of unavoidable side collision by the special detectors.
2. Activation and deployment of the undercarriage airbags.
3. The car is elevated over the road by the deployed airbags.
4. The wheels lose contact with the road and the car is contacting the basis only by the undercarriage airbags, thus the friction forces between the car and the road are significantly reduced.
5. The target car is hit by the bullet car.
6. Activation and deployment of restraint systems inside the car – side airbags.
7. Stage of deformation the target’s car body and the front of the bullet car.
8. The pressure inside airbags is decreasing and the wheels start contacting the basis again.

MODELLING

To evaluate the effectiveness of the described system the analyses of the side collision corresponding to the Euro-NCAP Side Impact Protocol was performed in the MADYMO v6.2 environment.

<u>Target car model</u>

The target car is the general model for side impact tests, based on the example from the MADYMO database with the deformable impacted side of the car (doors, pillars and sills) modelled as multibody structure. Additionally the car model was equipped with the simplified suspension, modelled as translational joints between the wheels and the car body with the characteristics of the springs presented in the Figure 3 and damping velocity function. The suspension model enables the upwards-downwards motion of the wheels and thus the intended working of the JR protection system. The car is also equipped with the ellipsoid model of the driver’s seat attached to the car body with the Cardan joint which enables simulating more real-like behaviour of the seat during the collision. The values of the friction coefficient between the wheels and the road amounts to μ=0.8 and between the undercarriage airbags and the road the coefficient is assumed to be reduced to μ=0.1.

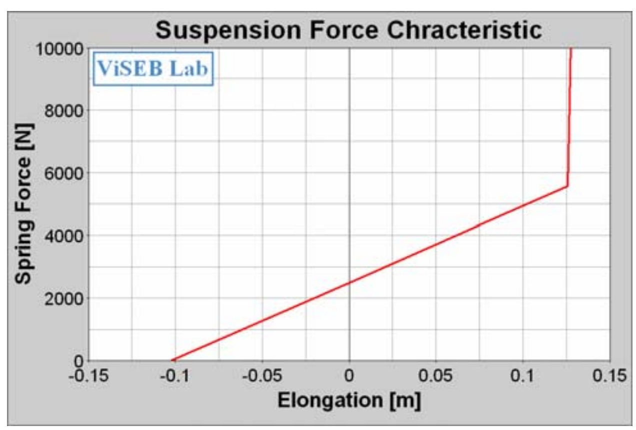

Figure 3. Suspension characteristic.

Another part added to the standard car model is the system of four airbags attached either directly to the suspension as the first technical approach, in which the airbags elevate the wheels at first and then the car, or to the car body as the second approach, in which the car is elevated at first and then the wheels. The two approaches are considered in the study and are described in the results paragraph. The undercarriage airbags are modelled by using the standard driver's frontal airbag with default gas and deployment parameters with the permeability definition equal 0.01.

The model of the car is also equipped with the two side airbags which are integral elements of the JR protection system. One airbag protects the thoracic and abdominal parts and one tubular airbag protects the driver's head.

Occupant model

The driver model is the ellipsoid EuroSID-2 side impact dummy taken from the MADYMO v6.2 database, fastened with the standard 3-point FE seatbelts. The magnitudes of ellipsoids representing the outer surface of the dummy's ribcage were partly modified to improve the contact between the dummy and the FE belts.

Bullet car model

The bullet car is the ellipsoid EEVC WG13 side impact mobile deformable barrier model taken from the MADYMO v6.2 database. The mass and appropriate inertia properties were varied to model different types of the impacting cars. To simulate the SUV type of car the frontal deformable elements: honeycomb bumper and honeycomb block were elevated by 0.1m with respect to the trolley body.

RESULTS

The three different types of side protection were compared:

1. Car with standard side protection – only side airbags.
2. Car equipped with the JR System side protection with undercarriage airbags attached to the car's suspension.
3. Car equipped with the JR System side protection with undercarriage airbags attached directly to the car's body.

To widen the range of assessment a few different test conditions were conducted for different barrier speed and mass. Additionally the simulations with the non-standard position of the frontal honeycomb structure of the bullet car were carried out which simulates the collision with the SUV type of a car.

KINEMATICS

The Figure 4 presented below illustrates the working of the JR side protection system during the side collision for the EuroNCAP test configuration. The pictures show consecutive stages of the collision: undercarriage airbag activation, deformation of the target car compartment and side airbags activation and the end of the deformation stage.

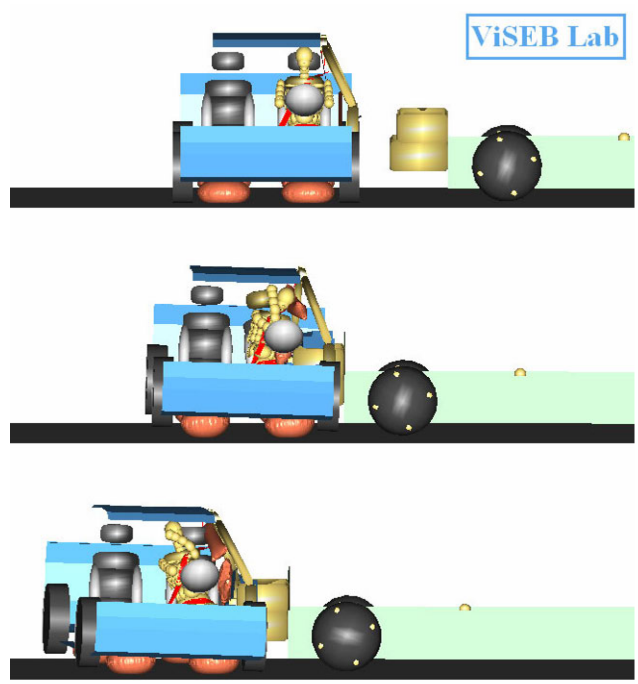

Figure 4. Consecutive stages of the side collision simulation.

To check the possible behaviour of the target car elevated by the undercarriage airbags after the collision several long time simulations (1000ms) were performed in the same calculation conditions as in case of short simulations (200ms). Taking the kinematics into consideration it can be observed that the JR system with the airbags attached directly to the car body is less stable on the road (the car rotates around its longitudinal axis which may lead to the rollover) than the system with the airbags attached to the suspension. The Figure 5 illustrates the differences in behaviour between the two types of JR systems in 400 ms time.

Additional effect observed for the JR systems is the greater rotation of the car around its vertical axis than in case of the car without undercarriage airbags. It results from the differences in mass distribution in the car (centre of gravity is shifted towards the front of the car) and thus lower friction values do not restrain the rotation motion when the car is contacting the basis only by the airbags.

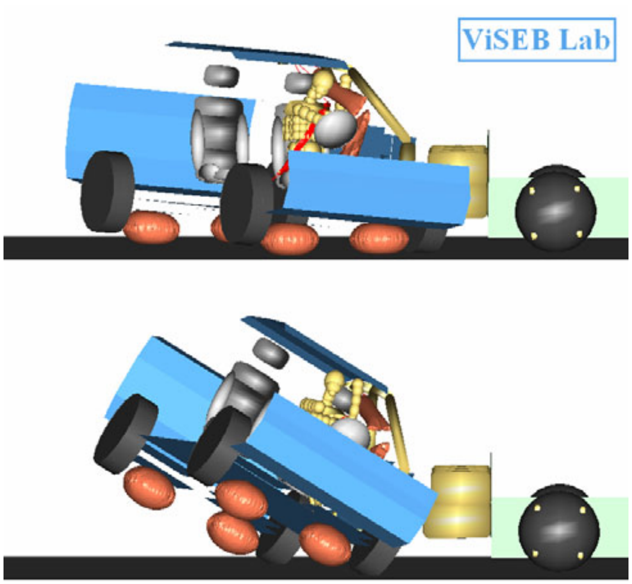

Figure 5. Comparison of the two types of the JR system in 400ms simulation time. Airbags attached to the suspension (upper) and airbags attached to the car body (lower).

The optimization of the inflation parameters of the undercarriage airbags and their location under the car should solve the potential problems with the non-standard kinematics after the collision.

INJURY CRITERIA AND INTERNAL INTRUSION

To evaluate the effectiveness of the new solution a maximum door internal intrusion of the target car and the following injury criteria were considered:

- HIC – Head Injury Criterion - 36ms time interval
- TTI – Thoracic Trauma Index
- VC Rib – Viscous Injury Response
- Rib deflection

Notification:

V0_B50kmph_1t – Stationary target car, bullet car speed amounts to 50km/h, bullet car mass 1.0 tone.

V0_B50kmph_1,5t - Stationary target car, bullet car speed amounts to 50km/h, bullet car mass 1.5 tone.

V0_B50kmph_2,0t - Stationary target car, bullet car speed amounts to 50km/h, bullet car mass 2.0 tone.

V0_B30kmph_1t - Stationary target car, bullet car speed amounts to 30km/h, bullet car mass 1 tone.

V10_B50kmph_1t – Target car travels at 10km/h, bullet car speed amounts to 50km/h, bullet car mass 1 tone.

V0_B50kmph_2t_SUV - Stationary target car, bullet car speed amounts to 50km/h, bullet car mass 2 tones.

V0_B80kmph_1t - Stationary target car, bullet car speed amounts to 80km/h, bullet car mass 1 tone.

Test conditions	HIC		
	Standard	JR sys. susp	JR sys. body
V0_B50kmph_1t	108,41*	94,50	59,76
V0_B50kmph_1,5t	131,77	128,90	90,48
V0_B50kmph_2,0t	140,96	148,00	99,20
V0_B30kmph_1t	22,50	19,60	9,77
V10_B50kmph_1t	56,59	58,30	73,74
V0_B50kmph_2t_SUV	190,01	134,80	163,02
V0_B80kmph_1t	501,18	481,26	538,84
Threshold value	1000	1000	1000

* - red coloured numbers are the highest values obtained

Table 1. HIC comparison.

Test conditions	VC Rib up [m/s]		
	Standard	JR sys. susp	JR sys. body
V0_B50kmph_1t	1,16	1,21	1,04
V0_B50kmph_1,5t	1,18	1,13	1,14
V0_B50kmph_2,0t	1,50	1,49	1,22
V0_B30kmph_1t	0,11	0,08	0,06
V10_B50kmph_1t	0,77	0,73	1,12
V0_B50kmph_2t_SUV	2,70	1,45	1,99
V0_B80kmph_1t	3,03	3,19	2,86
Threshold value	1,3	1,3	1,3

Table 2. VC Rib up comparison.

Test conditions	TTI [g]		
	Standard	JR sys. susp	JR sys. body
V0_B50kmph_1t	145,94	154,56	151,48
V0_B50kmph_1,5t	142,50	159,17	162,47
V0_B50kmph_2,0t	163,96	177,42	159,43
V0_B30kmph_1t	78,00	81,76	77,64
V10_B50kmph_1t	128,06	130,70	153,20
V0_B50kmph_2t_SUV	211,76	174,20	203,71
V0_B80kmph_1t	256,70	265,79	272,41
Threshold value	85	85	85

Table 3. TTI comparison.

Test conditions	Rib Deflection up [m]		
	Standard	JR sys. susp	JR sys. body
V0_B50kmph_1t	0,0470	0,0448	0,0404
V0_B50kmph_1,5t	0,0485	0,0468	0,0426
V0_B50kmph_2,0t	0,0532	0,0512	0,0442
V0_B30kmph_1t	0,0171	0,0168	0,0082
V10_B50kmph_1t	0,0343	0,0333	0,0381
V0_B50kmph_2t_SUV	0,0586	0,0582	0,0570
V0_B80kmph_1t	0,0579	0,0579	0,0588
Threshold value	0,064	0,064	0,064

Table 4. Rib up deflection comparison.

It was expected that some injury criteria, which are based on the acceleration characteristics e.g. HIC criterion, may result in less profitable results for the JR protection system than for standard side protection system. The reason for this is that the global acceleration acting on the target car is grater when the friction effect on wheels is reduced. However the results obtained show that in some test configurations, e.g. when the bullet car is the SUV type of car, the acceleration based criteria HIC and TTI are significantly reduced when the JR protection systems were applied. Although in most cases the TTI criterion is higher for the JR protection system. But it should be emphasised that this results were obtained only when the standard protection systems (side airbags) act simultaneously to the undercarriage airbags. Also the results obtained for the ribcage dummy part – velocity based criterion VC Rib and Rib deflection are improved in most cases by application the JR system.

Test conditions	Mid_Pillar_intrusion [m]		
	Standard	JR sys. susp	JR sys. body
V0_B50kmph_1t	0,334	0,315	0,249
V0_B50kmph_1,5t	0,359	0,347	0,273
V0_B50kmph_2,0t	0,370	0,362	0,301
V0_B30kmph_1t	0,197	0,183	0,145
V10_B50kmph_1t	0,325	0,301	0,251
V0_B50kmph_2t_SUV	0,406	0,362	0,380
V0_B80kmph_1t	0,456	0,447	0,449
Threshold value	-	-	-

Table 5. Middle pillar intrusion comparison.

The Table 5 displays that the effect assumed by the JR system inventors was achieved. In all considered test configurations the intrusion of the middle pillar and thus the deformation of the car body is reduced and in some cases the differences are significant. The most distinct improvements are achieved for the JR side protection system with the undercarriage airbags attached directly to the car body. It can be explained by the fact that the car which is elevated by the airbags, in respect to the approaching bullet car, is hit in the lower part of the body (sill) which is more durable. This effect combined with the decrease of friction forces on the wheels results in significant reduction in car deformation. In the standard EuroNCAP side collision configuration (V0_B50kmph_1t) the pillar intrudes 8.5 cm less than in case of the standard side protection which makes 25% reduction.

TIME-HISTORY CHARACTERISTICS

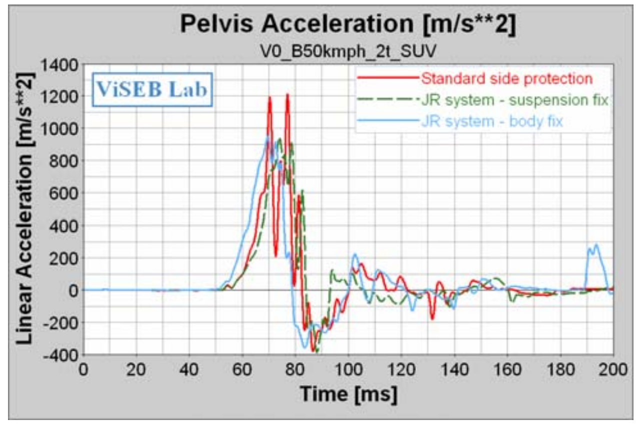

Figure 6. Pelvis acceleration - time history characteristics for three test configurations.

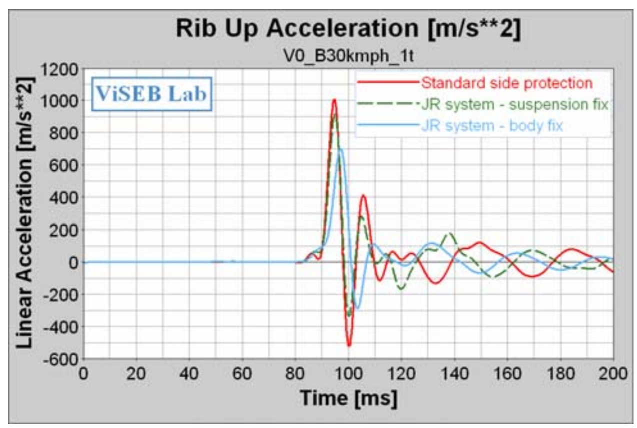

Figure 7. Rib up acceleration - time history characteristics for three test configurations.

The time-history characteristics obtained show wide diversity of results for different test configurations and so it is difficult to observe clear global tendencies and indicate more or less efficient protection system. The two graphs presented above (Figures 6, 7) were chosen as an example in which the reduction of the acceleration acting on the driver's pelvis and clavicle for the JR systems applied can be observed.

CONCLUSION

The results obtained showed that the new side protection system reduces the values of some of the injury criteria (e.g. HIC and VC Rib up) and also reduces the intrusion of the pillar inside the car compartment which improves the occupant safety. However, some of the criteria were not significantly changed or the values were even higher for the case with the "JR system" applied. Therefore, based on the preliminary study with the simplified model it can be stated that the results show some improvements in the occupant protection in particular cases and areas, however the further investigation, with the more detailed models, into this subject should be proceeded in order to prove the hitherto stated thesis and to search for potential disadvantages of the system. Additionally the influence of the gas and deployment parameters of the undercarriage airbags on the kinematics and possible improvements of the system shall be performed.

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