CRASH-TEST RESULTS TO ANALYSE THE IMPACT OF NON-PROFESSIONAL REPAIR ON THE PERFORMANCE OF SIDE STRUCTUR OF A CAR

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ABSTRACT

Non-professional repairs can have a negative influence on the deformation behaviour of a vehicle involved in a crash. The introduction by OEM's of new materials and production techniques in cars makes it increasingly important that the repair of such cars is carried out with appropriate techniques and quality. These are the aims described in a project named "Fair Repair", to which this paper is linked. This research project deals with the influence of non-professional repairs, on the behaviour of a car's structure in an additional crash. KTI, with the support of the OEM (VW) tested the side structure of a VW Passat, MY 2005.
With a side impact at 50 km/h (Euro NCAP standard) it was shown that a non-professional repair of a vehicle previously damaged in the same side impact scenario results in negative influences on the crashworthiness and protection afforded by the structure. The repair of the damage caused by the first crash was carried out using incorrect repair methods and equipment, e.g. welding machines. It is evident that the safety of such a vehicle after the non-professional repair is not to the same high level as that of the original build, or to the standard of a professionally repaired vehicle.

INTRODUCTION

Increasingly, over the last 10 years we have seen new generations of materials introduced by the OEM's. Aluminium, Magnesium, Plastics and Fibre Reinforced Composites in combination with newly developed high strength and ultra-high strength steels have been introduced to save weight and secure a stronger body shell at the same time. A modern Body-in-White is normally made up of a number of modern steels (Figure 1).
The new materials mean that body shops must continuously ensure that they are conversant with the requirements for new tools, procedures and information about the repair processes. New welding machines need to be used, training is required and OEM information has to be accessed to make sure that the correct repair methods will be applied. Without this knowledge it is likely that an inadequate repair will be the result, potentially placing the car and its occupants at much higher risk in a later crash.

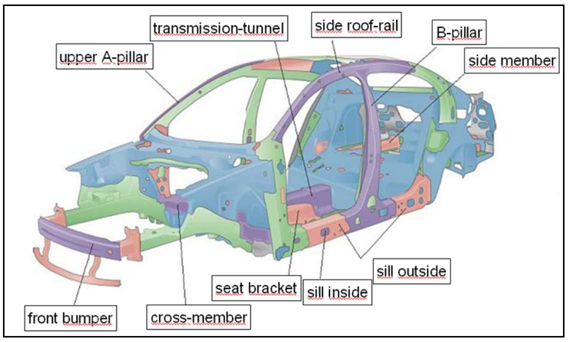

Figure 1. Distribution of steel in a VW Passat B6 (Source - VW)

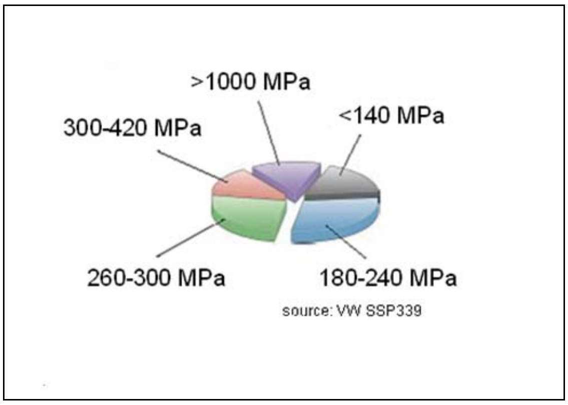

Figure 2. steel grades in a VW Passat B6 (Source - VW)

In parallel to the introduction of new materials, single component parts of earlier vehicles have been replaced by highly integrated, multi-material components on more recently designed cars. The production of a modern Body-in-White is characterised by complex manufacturing processes and bonding techniques.

Taken together, the technical progress made by the OEM's has resulted in corresponding new challenges for the repair shops. Repair shops must ensure they have well trained staff and are equipped with appropriate tools to cope with the techniques needed for professional repairs on today's cars when they are damaged in an accident. If such techniques and knowledge are not available, a non-professional repair may lead to a significant reduction in the safety and quality of these cars.

Unprofessional repairs may result from of all or any of the following:

- Incorrect method and/or sequence of repair
- Poor assembly of correct/incorrect spare parts, components and sub-systems
- Fitment of low-quality spare parts, components and sub-systems
- Incorrect assembly and connection of electrical/electronic systems and sub-systems
- Absence of correct, special or custom tools
- Repair of damaged parts when actual replacement is necessary

PRELIMINARY CONSIDERATION

The following scenario, including two high-speed crash tests was carried out, and then analysed:

1. The car was damaged by a side impact similar to an intrusion by the front of another car into the passenger side of the test vehicle, according to the side-impact tests of Euro NCAP.
2. A repair was carried out as if done in a car body shop or garage with no information about the correct way to repair this particular car and without the correct tools or welding machines. The repair conforms to a typical standard carried out about 10 years (two car generations) ago. This would be considered as a non-professional repair by today's standards.
3. After the repair, this vehicle was involved in a follow-up crash simulation in the same configuration i.e. a side impact on the repaired passenger side, at the same speed.

In this project KTI wanted to examine and describe the effects of non-professional repairs on modern, state-of-the-art cars in order to highlight/picture reasons why using OEM information is necessary. The focus of the tests is on the side of a car because a small intrusion distance in the deformed area results in a higher risk for the occupants than in frontal or rear-end impacts at similar speed.

The baseline was a crash test according to Euro NCAP - Side Impact- according to EU issue 96/27/EG and ECE-R95 that guaranteed reproducible results. The exemplary vehicle, a VW Passat model B6 variant was chosen for the tests as its structure represented state of the art car bodies with several high-strength and ultra high-strength steels with one of the highest torsional stiffness values of about 30,000 Nm/° in its segment of mid-size cars.

As depicted in Figures 2 and 3 (the first crash test setup), the car was positioned relative to the carriage with its deformable barrier. The test was carried out at a speed of 50 km/h (+/- 1 km/h).
A Dummy, ES-1, 50% male, 72 kg (+/- 1.2 kg) was positioned on the front passenger side seat and weight dummies of 76 kg on the back seat. The restraint systems were active.
After the crash, the damaged car was repaired with recognized methods of car repair, but without specific information for this model i.e. non-professional repair. Subsequently the Passat underwent a second crash test in the same configuration. Finally, differences in deformation behaviour between the two crashes were analysed to determine the implications for passenger safety.

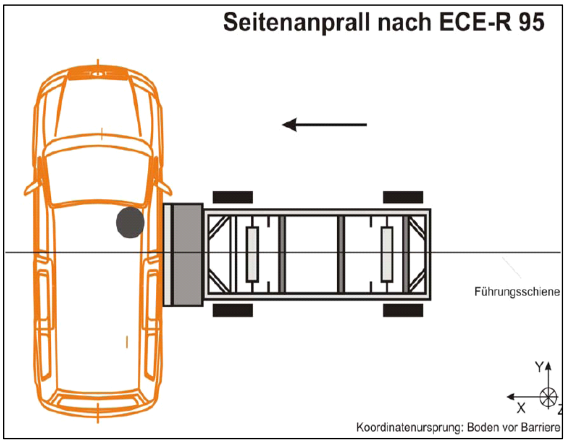

Figure 2. Test setup

Figure 3. Positioning the mobile barrier

CRASH TEST 1

After the side impact the car was severely damaged on the passenger side, as intended. The sill and the floor/undercarriage behind it were particularly distorted. Additionally, the doors and the B-pillar were considerably damaged (Figure 5). There was no damage to the screen pillar or windscreen glass. The pyrotechnic protection/restraint systems (Front and rear passenger side airbags, front passenger belt pre-tensioner and passenger side curtain airbag) were correctly deployed. Overall the car body structure deformed and behaved as expected. As well as the visual analysis, electronic measurement of the car body was carried out. This showed the maximum intrusion to be 161 mm.

Figure 4. Head-on view

Figure 5. Damage to passenger side

NON-PROFESSIONAL REPAIR

The damaged car was repaired with an older spot welding machine with fixed pressure and 6.4 kA maximum current.
It is recommended that an Inverter type welding machine is used with 10 kA maximum current and a variable pressure (maximum 10 bar) to join the high strength steel safely. The deformed inner sill, made from ultra high strength steel, was re-shaped and partially replaced on a bench then re-fitted using a MAG welding process. Figures 6 to 9 show the non professional repair being carried out.
The “Professional” repair would include complete renewal of the B-Pillar and other deformed structures with components made from high strength steel. A partial repair of such steels is not acceptable, as the structure and therefore the strength of the material will be severely degraded while welding and reforming.

Figure 6. MAG-welding the inner sill

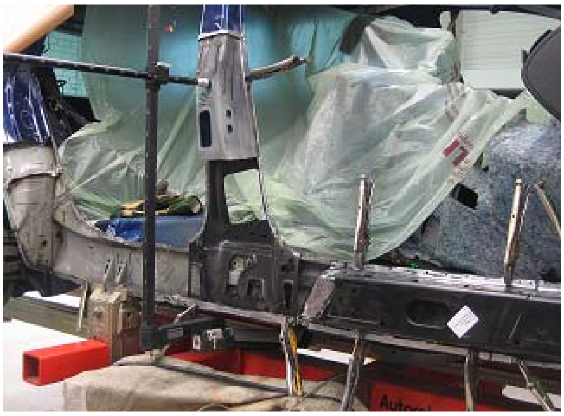

Figure 7. Adapting the lower end of the B-pillar

Figure 8. Positioning the outer panel

Figure 9. The completed repair

CRASH TEST 2

After completing the repair the car was crashed again under the same conditions as the first test in order to make a fair assessment on equal terms. It was immediately evident that there was a substantial difference, with far more comprehensive deformation of the car body after the second impact. The B-pillar had noticeably higher intrusion into the passenger compartment in comparison with the first crash, especially at the lower part at the connection with the sill (Figures 10 and 11). Note: Later measurement of the car body confirmed there was 60 mm more intrusion after the second test, compared to the first crash.

Other differences were noticeable at the cant rail/roof and the transmission tunnel which both displayed severe deformation not seen in the first crash. It seems that the load paths were quite different in the second crash. It was also notable that the top right corner of the windscreen was damaged in the second crash, further indication of changed load paths. These comparisons made it evident that a change of load paths and therefore of the energy dissipation was due to the un-professional repair. The pyrotechnic protection/restraint systems (Front and rear passenger side airbags and the front passenger belt pre-tensioner) were correctly deployed but the passenger side curtain airbag failed to operate.

Figure 10. Damage after second crash

Figure 11. Higher intrusion to passenger compartment

RESULTS

To make clear the differences between the two tests, we compared photographs, sequences of high-speed crash-movies and electronic measurement of the car body.
With the help of the time analysis in the high-speed crash-movies we can for instance compare the time of highest intrusion (Figures 12 and 13). The analysis clearly shows higher intrusion at the same moment in time in the second crash test.

Figure 12. Crash 1

Figure 13. Crash 2

The higher deformation of the B-pillar has an important influence on the intrusion of the doors, which moved further into the seat area of the passenger compartment, increasing the bio-mechanical stress on the occupant, the co-driver in this case (Figures 14 and 15).

Figure 14. Side structure after first crash

Figure 15. Side structure after second crash

Figure 16. B-pillar and sill after first crash

Figure 17. B-pillar and sill after second crash

After removing the doors and the sill trim panel the deeper intrusion can be clearly seen on the side frame (Figures 16 and 17). The movement of the sill has reduced the normal distance between the B-pillar/door and the co-driver's seat dramatically (Figures 18 and 19). Additionally, although the front passenger's side airbag deployed, it was restricted by the close proximity of the seat to the pillar. Consequently a controlled deployment of the bag was not possible because the space between B-pillar and seat was too small, too early in the deformation process.

Figure 18. Passenger seat after first crash

Figure 19. Compressed seat after second crash

After removing all the seats and necessary trim the deformation of the transmission tunnel after the second test was clear to see. The cross-member which supported the front seat had pushed into the transmission tunnel, distorting it severely. In comparison, there were no measurable changes at the transmission tunnel during the first attempt. (Figures 20 and 21).

Figure 20. Front seat anchor cross member/ transmission tunnel after first crash

Figure 21. Front seat anchor cross member/transmission tunnel after second crash

The deformation differences between Crash 1 and Crash 2 can also be represented by measurements taken after both crashes (Figure 22 and Table 1). At each measuring point the range of movement and deformation depth was measured. The table shows differences in movement up/down (Height), forwards/rearwards (Length) and Intrusion (Width). As an example, at point 1 which is nearly 100 mm above the sill on the B-pillar, the electronic measurement shows an important difference in Intrusion of 60 mm. The difference in deformation has enormous effects on the bordering body-parts which in turn have broader repair consequences, above all affecting passenger safety.

Table 1.
Differences in body movement

	Measurements of the lower parts of the car body					Measurements of the upper part of the car body											
Point Number	13	14	16	17	18	1	2	3	4	5	6	7	8	9	10	11	12
Length (mm)	5	6	4	1	5	0	23	1	25	39	17	1	2	0	0	2	1
Width/Intrusion (mm)	4	9	49	17	39	60	61	7	27	1	6	3	21	75	50	9	9
Height (mm)	0	0	24	5	25	2	0	0	2	20	1	0	1	1	35	0	1

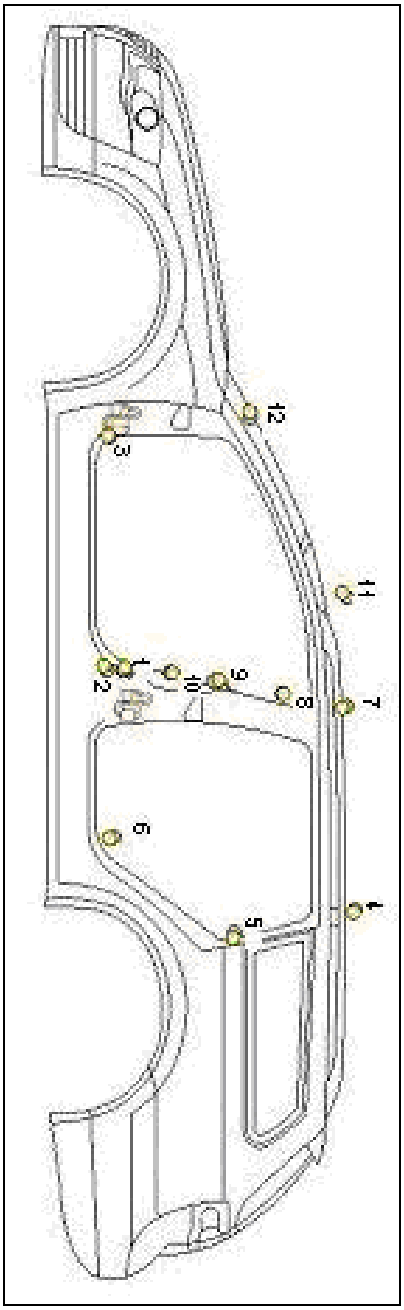

Figure 22. Measurement points

OEM information was not used during the repair after the first crash. Figures 23 and 24 show the disruption at the joining points after the second crash. These are positions where the inappropriate spot welding machine was used. The disconnection between inner sill and floor panel shows that the spot welds have not withstood the impact and were destroyed. The spot welds need to have a minimum diameter of 4.9 mm at a sheet thickness of 1.5 mm. The optimum would have been 6.7 mm diameter. It is clear that the spot welds were inadequate.

Figure 23. Disconnection of the sill after second crash

Figure 24. Disconnection of the inner sill after second crash

The connection of the B-pillar with the inner sill was joined with MAG welding. The structure of the high-strength steel parts was changed by the welding process and re-shaping. The welded seam was totally broken after the second crash, being unable to withstand the stress and the distortion (Figures 25 and 26).

Figure 25. Disconnection between lower B-pillar

Figure 26.Disconnection between lower B-and inner sill after first crash

pillar and inner sill after second crash

SUMMARY

From the results obtained by this project it is clear that only a repair carried out according to the OEM's information could be described as Expert and Professional. The information would describe the recommended methods and joining procedures, including possible partial repairs in order to guarantee that a repair would have no adverse effect on the protection afforded to passengers in the event of a later collision.

REFERENCES

[1] Bürkle, Heiko et al.: Relevanz der Kompatibilität im realen Unfallgeschehen heute in Verkehrsunfall und Fahrzeugtechnik, 7-8, 2006, S. 193

[2] Kramer, Florian: Passive Sicherheit von Kraftfahrzeugen, Vieweg Fachbuch 2. Auflage, S. 37 ff

[3] Watson, Brock et al.: Study of vehicle dynamics and occupant response in side impact crash tests, ESV 2009 Stuttgart

[4] Bröckerhoff, Markus: Karosserie-Strukturverbesserungen für den seitlichen Pfahlaufprall, Dissertation an der RWTH Aachen, 2006, S. 14

[5] Der Passat '97 - Die Vorstellung - Konstruktion und Funktion, Selbststudienprogramm 191, Volkswagen AG

[6] Der Passat Modelljahr 2001, Selbststudienprogramm 251, Volkswagen AG

[7] Der Passat 2006, Selbststudienprogramm 339, Volkswagen AG, S. 10 und 11

[8] Der neue Passat, Sonderausgabe ATZ/MTZ, April 2005, S. 45

[9] http://www.euroncap.com, Stand November 2009

[10] Rusch, Hans-Jürgen: Reparaturschweißen, Vogel Fachbuchverlag, Würzburg 2005, S. 34