Interpretation of Stiffness Change over the Trunk Side of a Vehicle upon a Re-accident after Repair Its Former Rear Impact Collision Accident

Sungho Kim and HaengMuk Cho*
Department of Mechanical Engineering, Kongju National University, Cheonan campus, South Korea
Email: sungho.kim@gm.com, hmcho@kongju.ac.kr

***Abstract*—Since automobiles have become a major means of transportation, there have been high risks or frequent actual occurrences of accidents due to drivers' negligence. In general, accidents between vehicles result from collisions at the front, rear, or side sections. In the case of frontal collisions, the safety of passengers may be protected to some extent because of the frontal frame and engine room while in the case of broadside accidents, the stiffness of doors and pillars is a deciding factor in terms of passenger safety. In the case of rear side collisions, the trunk and pack panel protects passengers by absorbing impact. However, most vehicles except large-sized automobiles have no separate frame, involving vulnerable sections structurally. After an accident, the affected vehicle is repaired at a car repair shop. For trunk deformation, the welding section is removed employing a drill and the trunk is replaced, which is followed by welding over the connecting sections. As a result, major parts may be damaged, depreciating the vehicle. Further, vehicle performance may be degraded after the repair, causing safety concerns. This study accordingly includes collision tests simulating rear-side collision accidents after repair to examine the actual damages upon a collision just as in a real accident. Additionally, the vehicular condition after repair from a collision was interpreted and analyzed through a commercial program. Factors were then interpreted and compared with one another about the F-D curve, effective plastic strain, and force depending on the speed.**

***Index Terms*—accident history, body damage, body repair, deformation, depreciation, re-accident, trunk, welding**

I. Introduction

Since automobiles have become a major means of transportation, there have been high risks or frequent actual occurrences of accidents due to drivers' negligence. In general, accidents between vehicles result from collisions at the front, rear, or side sections. In the case of frontal collisions, the safety of passengers may be protected to some extent because of the frontal frame and engine room while in the case of broadside accidents, the stiffness of doors and pillars is a deciding factor in terms of passenger safety. In the case of rear-side collisions, the trunk and pack panel protects passengers by absorbing impact. However, small or middle-sized vehicles have no separate frame, exposing vulnerable sections structurally [1][2][3][4]. After an accident, the affected vehicle is repaired at a car repair shop. For trunk deformation, the welding section is removed by means of a drill. The trunk is replaced, followed by welding over the connecting sections. As a result, major parts may be damaged, depreciating the vehicle. Furthermore, the vehicular performance may be degraded after the repair, causing safety concerns [5][6].

As part of this study, experiments were conducted where one semi-midsized vehicle being used was selected to simulate a rear-impact collision just as in an actual vehicle accident in the reflection of the vehicle's material, drawing, and data of production. In this simulation, the damaged part and general status of the vehicle after the simulated collision were examined, and the vehicular condition after the collision repair was comparatively analyzed based on the definite interpretation by means of commercial software programs LS-DYNA and HyperWorks.

Changes in the vehicle's condition with the trunk replaced after the accident were interpreted, and so changed in the stiffness of the vehicular body, specifically in the F-D diagram, effective plastic strain, and force depending on the speed.

The trunk section of an automobile was strengthened with multi-layered iron plates that were bent or overlapped and connected to the side and rear panels in order to maintain the stiffness of the body. This is the typical monocoque, all-in-one body type. In a vehicle assembly plant, vehicular bodies are mass-produced by means of jigs and through a series of assembly and welding procedures. Since a body is required to bear the vehicle's load and absorb vibration, materials are reinforced in order to secure the stiffness. The main structural parts—frames and panels—are affected when both the internal and external parts of the body are deformed due to an accident.

In the repairing process after a vehicular accident, the body section involving deformation is pulled or stretched by means of a jig in order to restore the vehicle's original form. The damaged part is then spread and the deformed section is cut off or welded via such instruments as saw, cutter, or welding machine. Replacements undergo certain processing steps such as CO2 welding or SPOT

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Corresponding Author: HaengMuk Cho, hmcho@kongju.ac.kr

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welding and then mounted onto the place where the former parts used to be. In the ordinary repair work process, the surface of a welding section undergoes grinding for smoothing, which is followed by plugging with putty and then coating [7][8][5].

In the event that a pre-accident occurs while the vehicle is in operation after being repaired for a former rear-side collision accident, the stiffness of the body and passenger safety factors of the repaired vehicle may be changed, causing the vehicle's condition to become different from the original state. Thus, this study includes experiments to compare the vehicle's condition before and after such re-accidents [9][10][11][12].

II. Vehicle Collision Testing

A collision test aims to examine the stability of a vehicle by moving it towards a fixed wall or pillar or moving an obstacle to hit the vehicle to the extent that it is damaged or deformed. During this test, the extent of damage and deformation or the force applied to passengers is examined and determined. Basically, human injuries and vehicle damages are assessed and determined during this type of collision test. The basis for collision testing is not the vehicle's body itself but the passengers or pedestrians at the time of the vehicle collision. The impact on the dummy upon a collision is calculated in order to examine and determine the extent of the impact. For example, a frontal collision causes passengers to be catapulted out of the car, and the area wrapped by the safety belt is oppressed. In this frontal collision test, a dummy is used to measure the chest displacement or any damage to the head [13][14].

In general, the impact in a vehicle collision is not directly applied to passengers but absorbed or distributed so that the actual impact applied to passengers is reduced [15].

In this test and the interpretation thereof, the testing method of the Research Council for Automobile Repairs (RCAR) was adopted as shown in Figure 1. This type of test mostly assesses the repairability of the damaged part. It represents common accident types in middle or low-speed sections, such as ordinary driving patterns on city roads, being designed to determine the damage and repairability of a new vehicle. In the same condition of collision accidents, the extent and parts of damage may be varied depending on the car types. Car types involving much damage are classified as having high damageability while those involving less damage are classified as having low damageability [5].

In Korea, the RCAR test is conducted by the affiliated research institute of automobile technology of the Korea Insurance Development Institute in order to estimate the vehicle insurance premium before and after a new vehicle release in Korea. After a 15km/h collision of the front and rear sides against an inclined wall, the damageability and repairability were examined and graded. In complex reflection of the vehicle's damage and repairability, the repair cost is estimated and classified into grades from a minimum of 1 to a maximum of 26 [6]

As the grade is high (close to Grade 26), the damageability and repairability of the vehicle upon a low-speed collision are superior. The grade is determined based on the depth indicator reflecting the damageability and repairability of the vehicle (assessment on the collision, parts, wage, and coating) and the frequency indicator reflecting the damage rate. The depth indicator of a vehicle (reflecting the damageability and repairability) is determined based on the vehicle model's collision characteristics, parts prices, and wages for worktime and coating. In the collision assessment, frontal and rear collision tests against an inclined wall at the speed of 15km/h are conducted on the basis of the RCAR criteria for the indexation of damageability and repair ability characteristics [3] [6].

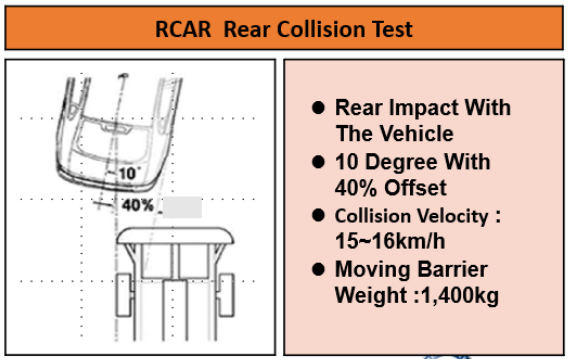

Figure 1. RCAR Rear Collision test

III. Trunk Repairing Method

A. Corrective Method for Trunk Damage

1) *Sheet Metal Correction*

a) The damaged part of a rear bumper or rear panel is disconnected, and the condition of the damaged trunk is examined.

b) For parts workable with sheet metal, tensile force is applied for restoration by means of applicable devices. Heat may be applied for correction by means of an oxygen welding machine or the deformed part is corrected by means of a sheet corrective machine.

c) The length of both sides, adhesion angles, and height from the bottom are corrected.

d) Coating and sealing are performed.

2) When it is unable to restore the damaged part due to trunk damage, the part is replaced as follows:

a) The welding section of the trunk is removed by using a boring machine.

b) After drilling on the welding section, the affected parts are disconnected.

c) New applicable parts are processed with holes in them (same numbers on the same spots) and then combined by way of CO_2 welding or SPOT welding.

d) After grinding and sealing the welding section, painting is performed. Trunk structure and correction method is shown in Fig. 2 and Fig. 3.

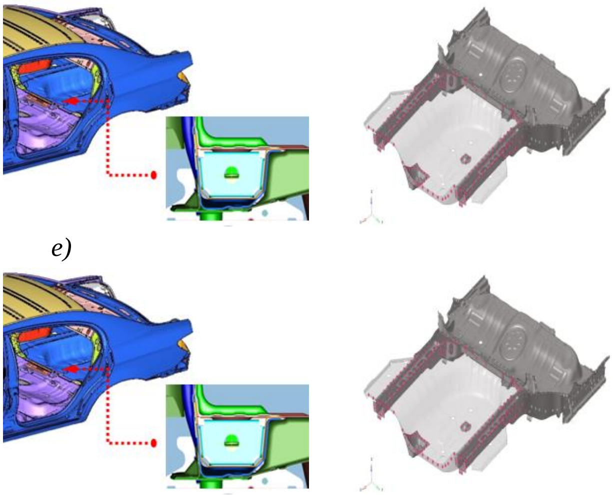

Figure 2. Trunk structure

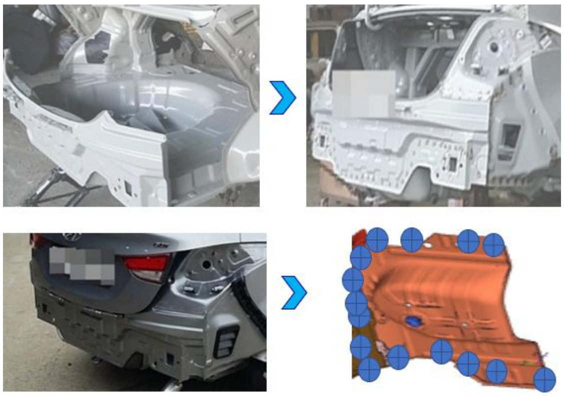

Figure 3. Trunk repair method

IV. TESTING

A. Testing Vehicle Specifications

TABLE I. SPECIFICATIONS OF TEST VEHICLE

Specification	Value
Weight (kg)	1170
Engine Size	1.8L L4
Tire Size	195/60 R15
L*W*H (mm)	4511 * 1745 * 1482
Wheel Base (mm)	2610
Wheel Track (mm) Frt/Rr	1483/1493
CG Reward of Frt Wheel C/L (mm)	1069

The testing vehicle was a normal vehicle being in use on actual roads in Korea. Drawings and specifications were obtained from the manufacturer's research centre. Specification of the test vehicle is shown in in Table I. The parts purchased and applied to the test were the present parts for repairing, which were on sale in an aftermarket. For the test, a skilful mechanic with more than 20 years of working experience at a car repair service centre under direct management was selected to conduct the welding work and produce samples.

B. Interpretation of Finite Elements

To interpret finite elements, modelling was performed for CAD data collection and interpretation. In addition to the test method, vehicle properties, tensile strength test results, and parameters were also applied. A comparative verification was conducted based on collision images and vehicular data. The data were analyzed and assessed in a way corresponding to the testing method, and initial factors of modelling such as speed, thickness, mass, and total weight were simulated just like those of a new vehicle and then applied. The finite element model was interpreted as in the Table II. First of all, CAD data were applied to the entire body of the vehicle in order to extract cleanup and mid-space data. The rear trunk, frontal and rear-side fixed walls, and barriers were simulated. The cells, solids, and elements were checked as well. With the materials, characteristics, and boundary conditions all set, the rear-impact collision test was conducted. In the application of welding properties, the test was conducted in line with collision test criteria. As for modelling, the weight was set to 1,232kg in the finite element interpretation. The other factors are as follows: number of parts: 779; number of nodes: 943,770; number of elements: 1,108,874; number of cells: 901,062; number of solids: 67,469; and 1D: 139443. The vehicle was judged as in the normal condition. After being repaired from an accident, the vehicle incurred thermal deformation during the welding process in general. However, the residual stress was neglected since too many elements could be involved if variables were applied to CAE configuration. The interpretation assumed the same materials of the actual vehicle, and the vehicular condition was compared before and after repair in order to examine the energy absorption rate, stiffness, and F-D Curve. The energy absorption rate was examined to determine the extent that the repair would affect passengers' safety [15] [16].

TABLE II. ANALYTICAL MODELING OPERATION

ANALYSIS CONFIGURATION DIAGRAM	STRUCTURAL MODELING	ANALYSIS SETUP	TEST SETUP	RESULT ANALYSIS
CAD	• Monocoque Body • Geometry Clean up • Mid surface • Rear Trunk	-	• RCAR Rear Barrier	-
CAE	• Modeling (Rear Trunk) - Forward Collision - Shell, Solid, 1D • Element Check	• Material • Property Boundary Conditions • Contacts • Initial Velocity • Control Cards • Modeling Check	• RACR Rear Test - 10 degree, Barrier 40% offset	• Normal Vehicle Collision Stiffness • Stress, Strain rate, energy absorption
VARIABLE	• Specimen tensile test frame (Normal, CO_2) • Governing equation • Vehicle specifications	• Application of weld material to CAE • Assumptions and Boundary Conditions • Collision image comparison	• Collision test method • Driving variable	• Determine the impact on passenger safety • Collision Stiffness Evaluation by Material

C. Tensile Testing

The tensile test was entrusted to Korea Testing Certification. The same trunk parts of an actual vehicle were purchased, and the tensile strength after welding was tested to determine the extent of strength that could be secured in case of a collision based on the material properties. Material samples are shown in Fig. 4 and Fig. 5 shows the universal testing machine.

The normal vehicle's trunk and spot welding area along with the samples of a vehicle repaired after an accident were cut off and tested after welding with CO_2. Result of different welding tensile test have been shown in Table III. Compared to that of the normal trunk, the stiffness of the trunk after welding was weakened by as much as 14%. This result shows that after the vehicular accident followed by welding repair on the cut frame, which is a major part of the body, the vehicular frame's stiffness is weaker than in the initial condition. Although there may be some differences depending on the welding area and direction, the mechanic's technical skills and mechanical stiffness were far weaker than at the time of its release.

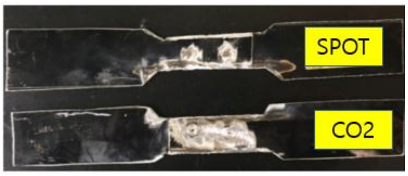

Figure 4. Trunk test material sample

Figure 5. Trunk tensile test

As for the strength degradation of rear trunk welding parts, the significant impact of an accident on the vehicle at a low speed may not cause much difference, but the significant impact may cause the welding part to be disconnected at a high speed, with the shock-absorbing ability decreasing significantly.

TABLE III. RESULT OF TENSILE TEST (NORMAL VEHICLE: REPAIR WELDING CO_2)

Unit	Thickness	Width	Distance	Max Test Force	Max Stress	Elastic Rate
	mm	mm	mm	KN	N/mm^2	N/mm^2
Spot	1.69	23.8	50	4.351	108.189	6.8
CO_2	1.99	25.1	50	4.69	93.75	6.8

D. *Interpretation-based Test Verification*

In reality, it is difficult to test a re-accident collision of a vehicle already repaired once in a former accident. Since conducting a test with an actual vehicle is fairly challenging, several objects and vehicles need to be selected in the reflection of specifically determining factors of trunk repair such as work scope and method, as well as on the assumption of the same vehicle spot and work area for a simulation test. To secure the reliability of finite element interpretation, the NCAP test data of an actual vehicle and the date of interpretation elements were compared so that the simulated test condition would be the same as the condition in an actual collision accident.

For interpretation, modelling and verification were conducted utilizing the KNCAP test method. Modeling sample is shown in Figure 6. The same test method was also used to verify if there was a deflection in the interpretation. In general, the results were of a similar form, and it was checked whether there was any deformation on the driver's seat steering column and A-pillar to secure the reliability after modelling. As a result, it turned out that the result was satisfactory and that there was little deflection between the collision test data and the interpretation collision. There was deflection in the interpretation on the deformation of the steering column because interior materials as in a normal vehicle were not considered in the CAE interpretation, but this deflection was regarded as insignificant. While the interpretation assumed a fixed wall, the fixed wall used in the test included a shock-absorbing layer to absorb the impact, which caused some difference but the extent was insignificant. The actual result of deformation after the frontal collision was compared with the result of the object vehicle test after modelling as shown in the Fig. 7. The deflection from the result of the actual vehicle was 6.1%, but this was probably because it was difficult to apply the barrier's material properties of the object vehicle in the collision section interpretation just as they were. RCAR collision test is shown in Fig. 8. Comparison of frontal impact is shown in Fig. 9.

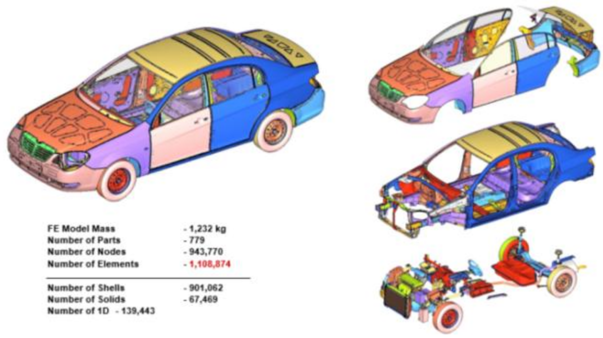

Figure 6. Modeling sample

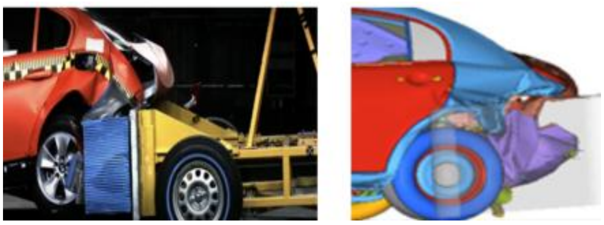

Figure 7. Comparison of the actual crash test

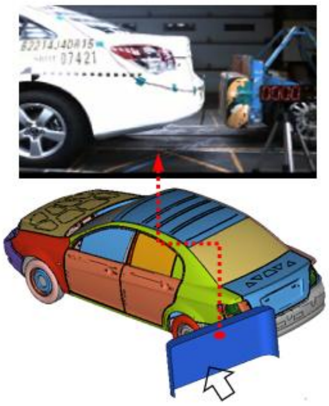

Figure 8. RCAR Collision Test

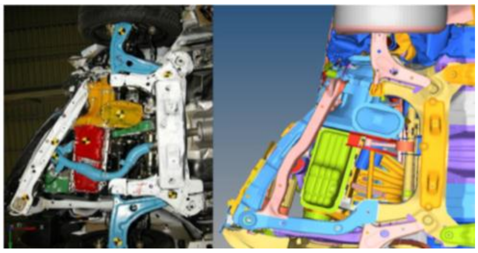

Figure 9. Comparison of frontal impact tests with analytical vehicular tests

TABLE IV. TEST RESULT (COMPARISON OF TEST AND ANALYTICAL VEHICLES)

Sortation	Before	After	Difference (%)
Steering Column	2494.9	2434.6	7.9%
Steering Column (CAE)	2496.8	2241.9	
A - Pillar	2814.2	2738.3	4.3%
A – Pillar (CAE)	2946.5	2856.2	

As shown in the table 4, there was a difference between the steering column part and the A-pillar because interior materials and plastic or rubber parts were disconnected from the steering section in the interpretation [15]. The deformation of the actual vehicle was measured utilizing a 3D distance measurer, and the probability of deflection was rather low.

E. Deformation and Force Difference Between a Normal Vehicle and a Repaired Vehicle Depending on the Driving Speed

For restoration after an accident, the spot welding section of the rear trunk was disconnected and then CO2 welding was performed to compare the energy of vehicles. Internal energy is the energy consumed by vehicle deformation upon a collision is shown in Figure 10. In this regard, there was no significant difference in the case of the rear trunk.

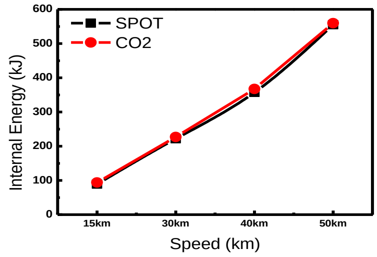

Figure 10. Internal energy of trunk replacement vehicle

1) Comparison of Force & Displacement

As the vehicle displacement was compared with displacement in the collision test with speed variations, the level of stability was highest when the shock was absorbed consistently upon a collision. The curved line indicates that the level was inconsistent, which implies that the deflection in the absorption ability was significant. Particularly in the section of 20 to 40 km/h, the displacement was quite significant.

2) Collision Interpretation with Speed Variations: F-D Curve (trunk)

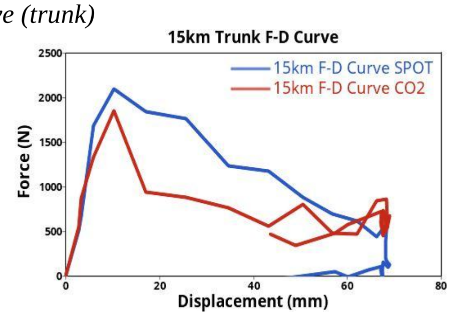

Figure 11. Trunk 15 km/h F-D Curve

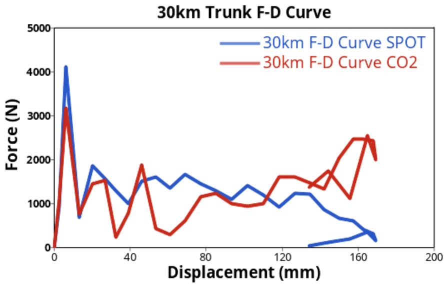

Figure 12. Trunk 30 km/h F-D Curve

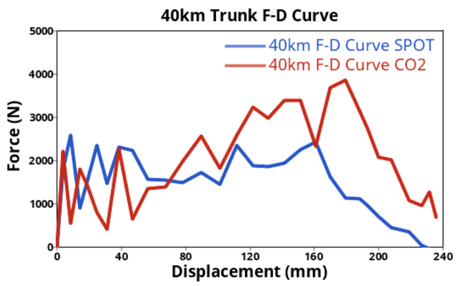

Figure 13. Trunk 40 km/h F-D Curve

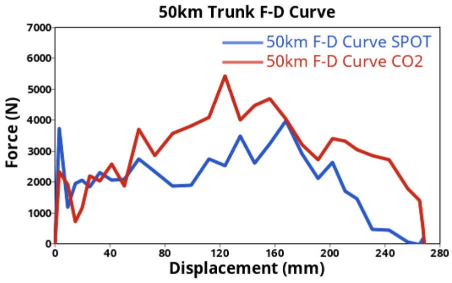

Figure 14. Trunk 50 km/h F-D Curve

In contrast with the low-speed case, body deformation was significant and it was unable to bear the force at the speed of 40 to 50 km/h is depicted in Figure 11, Figure 12, Figure 13 & Figure 14. As a result, the welding section was separated. Shock absorption was inferior both at low and high-speed sections. In a high-speed collision, deformation increased drastically to the point that the sheet irons were overlapped and deformed. This indicates that in the case of the vehicle whose trunk was replaced and welded with CO2, the energy absorption rate was low. It is thought that an accident of a vehicle running at high speed would affect passengers' safety significantly.

3) Collision interpretation with Speed Variations: Effective Plastic Strain

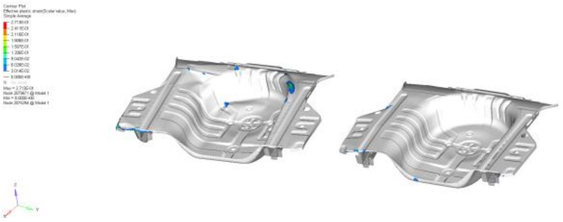

Figure 15. Trunk 15 km/h Deformation SPOT-CO_2

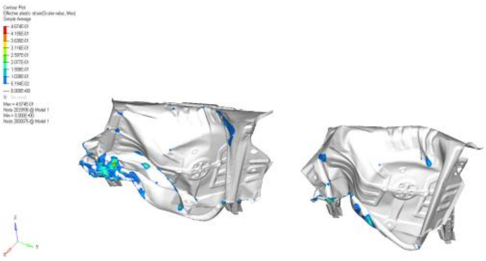

Figure 16. Trunk 30 km/h Deformation SPOT-CO_2

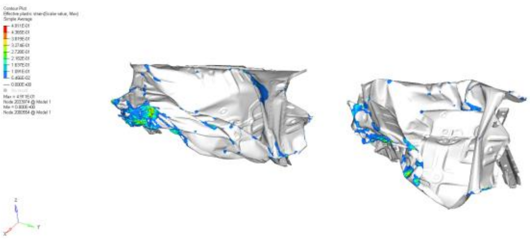

Figure 17. Trunk 40 km/h Deformation SPOT-CO_2

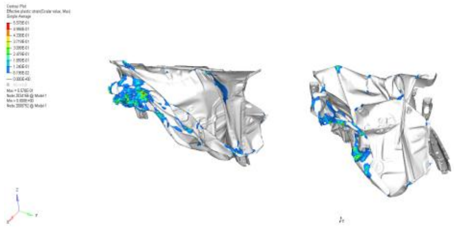

Figure 18. Trunk 50 km/h Deformation SPOT-CO_2

Fig. 15-18 shows the valid plastic deformation indicating the extent of uniaxial tension plastic deformation to indicate the state of multiaxial stress.

Based on the results of collision testing on a normal vehicle and a vehicle repaired after an accident whose trunk was welded with CO_2, the state changes were examined. As a result, the extent of deformation increased in proportion to the speed of the vehicle in a collision and the deformation spot was not uniform. Particularly in the range of 40 to 50 km/h, the trunk welding section was disconnected and rolled up and some parts were shock-distributing locally.

4) Collision Interpretation with Speed Variations: Force Depending on the Speed

The force changes were examined based on the results of the collision test on a normal vehicle and a vehicle repaired after an accident whose trunk was welded with CO_2. In the case of the vehicle repaired after an accident and whose trunk was welded with CO_2, the resistance in the initial stage of the vehicle collision was significantly low compared to that of a normal vehicle except in the speed range of 40km/h as shown in Figure 19, Figure 20, Figure 21 & Figure 22.

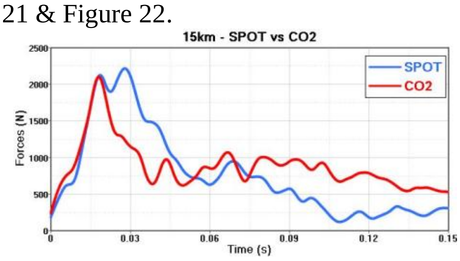

Figure 19. Trunk 15 km/h Force SPOT-CO_2

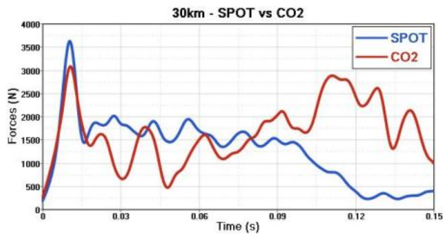

Figure 20. Trunk 30 km/h Force SPOT-CO_2

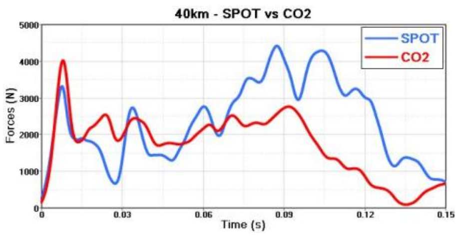

Figure 21. Trunk 40 km/h Force SPOT-CO_2

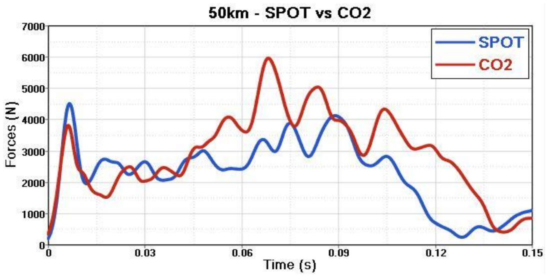

Figure 22. Trunk 50 km/h Force SPOT-CO_2

V. CONCLUSION

This study examines deformation the trunk of a semi-mid-sized monocoque body vehicle after an accident. In general, when a vehicle is repaired, the deformed trunk undergoes corrective treatment and the welded part is processed by using a drill. Holes are made with a drill and the trunk is disconnected. A new replacement is then installed in a way of CO2 welding, which is followed by coating and finishing work.

While a normal vehicle was completed with spot welding, a vehicle after an accident was repaired in a way of CO2 welding after trunk replacement. The collision stiffness of the normal vehicle was compared with that of the object vehicle repaired after an accident depending on the speed, specifically regarding the F-D diagram, effective plastic strain, and force. To verify the impact of repairing on the vehicle, tensile testing and finite element interpretation were conducted. The results are summarized as follows:

1) In the test of the welding part tensile strength, it turned out that the material strength 20% decreased compared to that of a normal vehicle.
2) When changes in the f-d diagram of the trunk of the repaired vehicle were analyzed, the spot welding part of a normal vehicle was stiffer than that of the vehicle repaired with co_2. The body deformation of the repaired vehicle was significant and it was unable to bear the force at the speed of 40 to 50 km/h. As a result, the welding section was separated.
3) The effective plastic strain indicates the extent of plastic strain in a state of multiaxial stress. According to the strain data, the extent of deformation increased in proportion to the speed of the vehicle in a collision and the deformation spot was not uniform. In the range of 40 to 50 km/h in particular, the trunk welding section was disconnected and rolled up and some parts were shock-distributing locally.
4) Based on the results of collision testing on a normal vehicle and a vehicle repaired after an accident whose trunk was welded with co_2, the force changes were examined. In the case of the vehicle repaired after an accident whose trunk was welded with co2, the resistance in the initial stage of the vehicle collision was significantly low compared to that of a normal vehicle except in the speed range of 40km/h.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] S. H. Shin, “The depreciation of a partially destroyed automobile after repairs and the measurement of damages,” *Legal Practice Study*, pp. 236-266, 2004.

[2] D. K. Yun and H. T. Lee, “Study on value appraisal after the repair of cars,” *Transactions of the Korean Society of Automotive Engineers*, vol. 22, pp. 19-24, 2014.

[3] I. S. Park and S. J. Heo, “Damageability, repairability and safety of vehicles at low speed 40% offset crash test,” *Transactions of the Korean Society of Automotive Engineers*, vol. 7, pp 1-9, 1999.

[4] I. H. Han, "Automobile collision reconstruction using post-impact velocities and crush profile,” *Journal of Korean Society of Transportation*, vol. 18, 2000.

[5] D. Anselm, “The passenger car body: Design, deformation characteristics, accident repair,” *Vogel*, pp. 93-96, 2000.

[6] J. H. Lim, I. S. Park, and S. J. Heo, “A study on characteristics of damageability and repairability with similar platform type at low speed 40% offset crash test,” *Transactions of the KSAE*, vol. 13, pp. 108-113, 2005.

[7] J. H. Lim, I. S. Park, and S. J. Heo, “A study on human injury characteristics and vehicle body deformation with car to car crash test for crash compatibility,” *Transactions of the KSAE*, vol. 13, pp. 135-141. 2005.

[8] A. Mohamed, A. Abdel-Aty, “Modeling traffic accident occurrence and involvement,” *Accident Analysis & Prevention*, vol. 32, pp. 633-642, 2000.

[9] V. Agaram, L. Xu, J. Wu, G. Kostyniuk, G. Nusholtz, “Comparison of frontal crashes in terms of average acceleration,” *Society of Automotive Engineers*, pp. 217-237, 2008.

[10] C. Jae-Ung and M. Byoung-Sang, “Simulation analysis on impact of automotive body,” *The Korean Society of Manufacturing Technology Engineers*, vol. 18, pp. 477-482, 2009.

[11] Y. Zhu, L. Li, and J. K. Yang, “Frontal structure improvement on car based on rcar impact test,” in *Proc. 2012 Third International Conference on Digital Manufacturing & Automation*, pp. 434-438, 2012.

[12] S. J. Kang, “*Bumper Stay Design for RCAR Front Low Speed Impact Test*” Transactions of KSAE, Vol. 24, pp 191-197, 2016

[13] Y. Yun Sik, K. Y. Shin, J. E. Sik, “Behavior analysis of active and proactive headrest during low-velocity rear-end collisions,” *Appl. Sci.*, vol. 10, pp. 1-11, 2020.

[14] L. M. Sik, P. J, Kang, C. Gil, “Drop-test simulations to investigate collision characteristics of automobile center-pillar structures according to partial quenching area,” *Key Engineering Materials*, vol. 794, pp 151- 159, 2019.

[15] C. M. Kiran, M. P. Girish, A. B. Akash, “Design and analysis of side door intrusion beam for automotive safety,” *Thin-Walled Structures*, vol. 153, pp. 1-10, 2020.

[16] Z. D. Sun, H. T. Zhu, W. Q. Peng, “Assessment of Car to Car Crash Compatibility Based on MPDB,” in *Proc. 2020 12th International Conference on Measuring Technology and Mechatronics Automation (ICMTMA)*, 2020, pp. 1-7.

Sung-ho kim has a master's degree from Hanyang University, Graduate School of Engineering in Korea. He has been working as an automobile engineer for 30 years at Korea. He's been awarded the President's Award twice for his excellent suggestions of crank train and steering. He's professional engineer and Contributions to the Development of Science and Technology in Korea. He also won the Minister's Award. He is currently pursuing his Ph.D. degree in mechanical engineering at Department of mechanical engineering, Kongju National University. His field of interest is change in rigidity and safety in the event of a recurrence after repairing a car accident.

HaengMuk Cho He is a renowned professor in South Korea. He is working as professor at Kongju National University in South Korea. He did Post Doctorate Fellowship from Department of Automotive Engineering of Loughborough University in UK and North Texas University in USA. He earned his PhD from Hanyang University, South Korea in 1997 and completed his M.D. in Environment Engineering from Yonsei University in S Korea. He is working on national and international projects in the field of Bio-fuels for IC engines and renewable energy. Professor HaengMuk Cho is working in the field of Renewable Energy and Biofuels. He is also a member of many societies, like Korea Society of Automotive Engineers, Korean Society of Energy (Korea), Korea Society of Marine Engineering (Korea) & Korea Society of Environment Engineer (Korea). He has published many national and internal research papers. Most of his papers are indexed in Scopus and SCI**.**