

Destructive testing and production system integrity

^{1,2}Ishaya Z. D., ²Dauda Mohammed, ²Pam G. Y. and ²Kulla D. M.

¹Peugeot Automobile Nigeria Limited, Kaduna, Nigeria

²Mechanical Engineering Dept., Ahmadu Bello University, Zaria, Nigeria

ABSTRACT

Destructive testing of automobiles is performed to determine the tensile strength for static and dynamic stability of the welded vehicle body or part. The specific objectives of destructive testing are to detect and correct inactive welds and other production system weaknesses that may not show up under normal production conditions. This will ensure high system integrity and to determine service life of the products, processes and the production system. The testing was conducted using the Descriptive design. The sixteen (16) number destructive testing was evaluation using percentile and comparative method. The data collated were tabulated, analyzed and graphically presented using Micro-Soft Excel software. The major tools for the test include the Destructive Work Table, Hydraulic Spreader, Torque Wrench, Pneumatic Chisel and Personnel Protective Equipment. Hydraulic powered Spreader with the capacity of up to 700 Bars was used to split the welded metal sheets, while Chisel and Hammer are used to create maximum access for Spreader to enable good application. The tensile strength global targets are that failure should not exceed 0.5% and 1.0% for safety and non-safety welds respectively. The test frequency was one car for every 3months. The destructive tests result shows downward trends defined by $Y = 0.642 - 0.020X$ for safety spots and $Y = 0.986 - 0.013X$ for non-safety spots. The overall results show continuous improvement despite the incapability of some production means that questions the production system integrity.

Key words: Destructive Test, Inactive Spot, Spot Weld, Technical Audit, Tensile Strength.

INTRODUCTION

Destructive testing is most suitable form of validation of the quality of mass produced product, process and Welder certification. The testing is to leads to sustainability of the new technologies, production system and products. Destructive testing drives the need for improvements. This type of test is cost effective. It offers great benefits of negligible cost of destroying a small number of samples compared with the benefits derivable from the testing. Also, it will ensure the average of 1,26MWh used to produce a car [1], delivers the minimal acceptable automobile safety standard. Conventionally, the Test Sample is subjected to shock stress or prolonged endurance under the most severe operating conditions, until the sample actually fails, that is either broken or destroyed [2]. The purpose of destructive testing is to detect design weaknesses that may not show up under normal working conditions - which include Non-destructive testing. Also, Destructive testing ensures high product, process and system reliability and help reveals the service life of products and means.

The different forms of destructive testing are Crash, Stress, Hardness, Chemical analysis, Metallographic testing, among others. The common types of welds destructive testing are known as Free Bend, Guided Bend, Nick-Break, Impact, Fillet welded joint, Etching, and Tensile test [3]. In the automotive industry, this test may be referred to as Crash Test. Spot welds, Metal Inert Gas (MIG) welds, Metal Argon Gas (MIG) welds and Cataphoresis tests in a

physically destructive form are deliberately carried out on the car metallic body shell. The tests are carried out on the sample, until the sample practically fails, in order to understand the sample's structural performance or material behaviour under pre-determined failure load [4]. Destructive tests are generally much easier to carry out, yield more information, and are easier to interpret than nondestructive testing. For example, in the Housing industry, destructive tests are more frequently carried out for structures which are to be constructed in earthquake zones. Such tests are carried out to verify the designed seismic performance of a new building, or the actual performance of an existing building. The tests are, mostly, carried out on a platform called a shake-table which is designed to shake in the same manner as an earthquake. Simulation of the effect of severe accident on automobiles in a particular batch of production is revealed in the result of the sample tested. The need to secure the occupant in a car and the environment in the case of accident is the major objectives of this type of test. Also, it is to ensure quality assurance and correct technical auditing of car body; and the presentation of the destructive test results in standard forms for continuous improvement and global certification.

The specific objective of the destructive testing on car bodies or sub-assemblies when safely carried out is to determine the strength and appearance of spot-welds, MAG welds and MIG welds; and other joining operations in assuring the quality of a batch of vehicles produced. Also, the thickness and the penetrative rate of paint deposit, especially on difficult to access area of the car after the electrolytic process in (Cataphoresis) is sometimes included in the destructive testing process. The destructive test provides information to the Welding Experts in order to guarantee that the practical quality level of welds is within the globally acceptable limits. In automobile assembly, spot welds are classified as either Safety (Class "A") or Non-safety (Class "B") base on their technical functions. Normally, safety spot weld are majorly for structural rigidity and stability, while non-safety spot weld are for reinforced unitization and sealing. The ten types of spot weld defects are *Inactive* and *Weak* welds inspected by destructive means, while *Missing*, *At-edge*, *Beyond-edge*, *Wrong position*, *Perforation/Burnt*, *Deformation*, *Rags/Splash/Projection*, and *Indentation-mark* welds are detected by visual inspection. Globally, the tensile strength targets is that failure should not exceed 0.5% and 1.0% for safety and non-safety welds respectively [5, 6].

MATERIALS AND METHODS

Most manufacturing factories employ systematic – repetitive operations in the production process for mass production using new technologies. Past production records help in fine-tuning the testing procedure for testing each unit in this industry. Thus, the descriptive instrument of design was used for the testing, data collection and evaluation of prospectively collected data covering a period of 4 years (that is sixteen-16 consecutive and periodic destructive testing) using percentile and comparative method. The data collated were tabulated, analyzed and graphically presented using Micro-Soft Excel software.

Materials

The major materials required are:

1. The Sample is the Body-In-White (BIW) – A complete car metallic body shell. It may be car body subassembly and some Jigs production (may have Cataphoresis coating).
2. Destructive Work Table,
3. Hydraulic Spreader (700Bars),
4. Pneumatic Chisel,
5. Torque Wrench,
6. Wire Brush and,
7. Personnel Protective Equipment /Safety Gears.

Method

The Audit Technician issue a job request for the performance of maintenance operations and certification of all equipment in the shop before the destructive test operation. The test sample is selected at random through an unbiased approach. The test is carried out immediately using Destructive Testing Process Sheets on the sub-assemblies or complete car bodies welded in the normal production process. The report on the welding guns parameters monitoring operation is to indicate Means capability. The test start from removing the roof panel, followed by the roof cross-members, then move from the rear-to-front end of the car left body side while maintaining structural rigidity, same approach is followed on the right body side, scuttle manifold, loading floor, front floor, front side-members. Where feasible, the testing starts on welds classified as safety welds.

The safety of the operators must be respected. Safety Rules requires no more than three (3) occupants during the testing and all the other personnel should be behind the Operator using the tool during the testing operation. The Operator must ensure all the safety cautions around the shop environment and within the shop are completely observed and respected by all. These 16 tests were conducted with respect to the safety rules and good application on the use of Hydraulic/Pneumatic or manually powered Chisel and Hammer according Destructive Test requirements as indicated in the spot welds monitoring plan.

Frequency and Duration of Destructive Test

Destructive test is conducted once in every Three (3) calendar months for production of less than or equal to 250 cars per day. Otherwise, it is once a month for high production rate cars greater than 250 cars per day. The duration for executing the Destructive Test is Twenty-Four (24) working hours broken into Eight (8) working hours per shift.

Destructive Test Procedure

The Destructive testing technician will sequentially check for defects visually then destructively using the welding assembly manual as standard reference book. First, the tucker studs, screws and nuts are checked visually for missing, wrongly positioned and not perpendicular defects. The base of the studs, screws and nuts are visually inspected for burnt, perforations, welding rags, deformations or indentations. On the thread, check for welding rags, scratches and burnt is done visually. Torque wrench of value that is greater than 12.0Nm is used destructively on the Tucker Studs, Screws. The Test starts from the engine compartment, then car interior and boot compartment. This is to test for the strength of the weld at the base of the Part.

Inspection of Spot Welds on BIW during the Destructive Test.

The audit technician will check visually for defects such as missing, wrong position, insufficient length and bad appearance of welded beads as per illustration in the Car body Assembly Manual. Example of bad appearance are rolled up, curved, concave, cracked, small cross section, unfinished bead or bead with a pierced on either sides. Similarly, this is followed by visual detection of spot weld defects such as missing, wrong position, burn's, perforations, welding rags and projections, indentations on the spot on the assembly as per BIW Assembly Manual. Subsequently, the physical destructive form of testing to reveal inactive and weak spot welds commence by the use the of hammer and chisel to create access for the spreader from the front left and right hand sides of the roof. Similar approach is used to create access for good spreader application on other car body parts as described on the Process Sheet for Destructive Test. This is executed as per Specification/Norme B13, 1226 [6] and B13, 1220 [7], and Destructive Test Visual Illustration. Similarly, inactiveness and insufficient weld or sealant bead fusion on either of the joined materials is evaluated. This is done using the BIW Assembly Manual. When required, the BIW is coated with Cataphoresis-Electrolysis deposit before the test. After the destructive test, measurements of Cataphoresis thickness on metal sheets, especially car body interior where three or more metals are welded together is taken to assess the penetrative power of the Paste into difficult to access zones of the assembly.

Reporting Destructive Testing

Defects found by the Technician must be immediately shown to the Operator, Team Leader and other production related Managers using the Defect Alert Form. The Quality Assurance personnel should stop the production at the affected Workstation and consequently perform the Serial Non-Conformity Follow-up check according to the defined procedure. Internal Alarms are raise when safety and/or regulation defects are detected during the normal production activities.

At the end, a comprehensive Destructive Test Report is dispatched. The report on each defect including the spot weld identification n^o, class of weld, type of defect, equipment n^o, reference chapter from the production manual, post of operation, part name, and entries on the corrective actions taken, test after correction for validation and remarks are made to the complete entries. Consequently, the result are presented to the authorities in tabular and graphic forms.

The present work surveyed the destructive test results patterns and reasons for variation from each progressive testing period. From information gathered using the above methodology and computations made, targets for the future results are agreed and recommendation for implementation shall be made to assure improvement without compromising production process and product quality.

RESULTS AND DISCUSSION

Peugeot Automobile Nigeria factory assembles at present in CKD, a mid-range economy vehicle. The production rate is 36 Sedan-vehicles per shift. Welding spots are executed through 37 welding guns equipped with two programs and network controls parameters, that is using a monitor that cuts automatically the circuit of power supply to the welding system as soon as that the pressure of the air falls under a threshold of 5.5 bars, or temperature of the cooling water exceeds 37 °C at the entrance of water circuit, or that the tension of current is under the 385V for a nominal voltage of between 400 and 420V. For spot weld, electrodes are dressed by cleaning and re-shaping to deliver 6mm diameter electrodes-to-materials contact surface or working area during welding with better thermal resistance to meet safety and economic needs. These operating conditions is are to ensure at least 4mm spot weld slug diameter or nucleus or core is maintained after welding and the subsequent pull-out of uncoated or zinc coated steel sheets using a tensile test machine. Thus, the spot weld is declared “Active” weld.

Total number of spot welds put on the vehicle is 3066, constituting of 724 safety and 2342 non-safety spot welds. Also, welded are 30 Tucker studs, 22 Nuts, 55 MIG/MAG and 25 Mastic application point. This excludes the welds produced by a supplier of Parts or Sub-assemblies. The Tensile Strength Quality target of not exceeding 0.5% and 1.0% for safety and non-safety welds respectively [6] implies that, more than 3 safety spots weld failure and or more than 23 non-safety spot welds failure respectively will result to production batch and process failure. The Tensile Strength welds failure includes inactive, weak, missing; burnt/perforated welds and spot weld beyond-the-edge. Excluding the other appearance defects will indicate Positional welds failure. Table 1 shows the destructive test results of 16 sequential samples.

Table 1: Sixteen (16) Destructive Test Results Covering Four Years

Destructive Test (DT) Results			Destr. Test 01	Destr. Test 02	Destr. Test 03	Destr. Test 04	Destr. Test 05	Destr. Test 06	Destr. Test 07	Destr. Test 08	Dispersion (nominal)
Tensile Strength Quality Indicator	Safety Spot "A"	(%)	1.25	0.15	0.78	0.60	0.13	0.80	0.00	0.50	
	Non-safety Spot "B"	(%)	0.57	0.80	1.19	1.28	0.41	0.87	0.91	1.20	
Destructive Test (DT) Results			Destr. Test 09	Destr. Test 10	Destr. Test 11	Destr. Test 12	Destr. Test 13	Destr. Test 14	Destr. Test 15	Destr. Test 16	
Tensile Strength Quality Indicator	Safety Spot "A"	(%)	0.50	0.40	0.30	0.40	0.69	0.28	0.41	0.41	0.48
	Non-safety Spot "B"	(%)	1.20	0.90	1.00	1.10	1.07	0.68	0.30	0.56	0.91

Again, each defect gives rise to correction on the products and production processes. This is executed after analysis, verification, processing of the work-in-progress and implanting the review of the processes on approvals.

The result on Figure 1 shows a downward Zig-Zag pattern. The audit result attained for the process after destructive test-2 was used to calibrate the process, system and the fabrication factory as “**capable**” at the Launch phase of the destructive testing project. This was the first Destructive testing on cars in Africa. The trend is defined by $Y = 0.642 - 0.020X$, with the worst and best safety spots result at test-1 (1.25%) and test-7 (0.00%) respectively. Similarly for non-safety spots, the trend is defined by $Y = 0.986 - 0.013X$, having the worst and best result is test-4 (1.28%) and test-15 (0.30%) respectively. From the action plan report and as displayed in Figure 2, significant failures were recorded at test-3, test-4 and test-13 principally from wrong Operators posture during welding and the best production system certification was at test-5 and test-7. Subsequently, the same defective spot welds were not found over 5 consecutive audits after destructive test-11 to validate the global system capability. These are from known and announced “**In-capable**” welding guns that were replaced due to economic realities.

Also, the test result was used on the current production, for setting the thresholds for engaging reactivity actions over the method, surveillance plan, product and the rectification process. Thus, the result of test-13 is from poor reactivity evident from the trend from test-11 results. Generally, it is acceptable for factory management to set performance targets for safety welds using monthly averages, even yearly averages within welding quality management. When necessary, it is acceptable for derogation approval to be made on the doubtful section having safety defect when correction is not possible in the immediate for certain batch of production. The derogation is considered, when there is no defective weld on the first two spots at one or other end of the line of spot welds. The failure limits of 0, 1, and 3 safety spots for 2 to 9, 10 to 19 and more than 19 spot welds per line or group of spots respectively is globally acceptable in the industry.

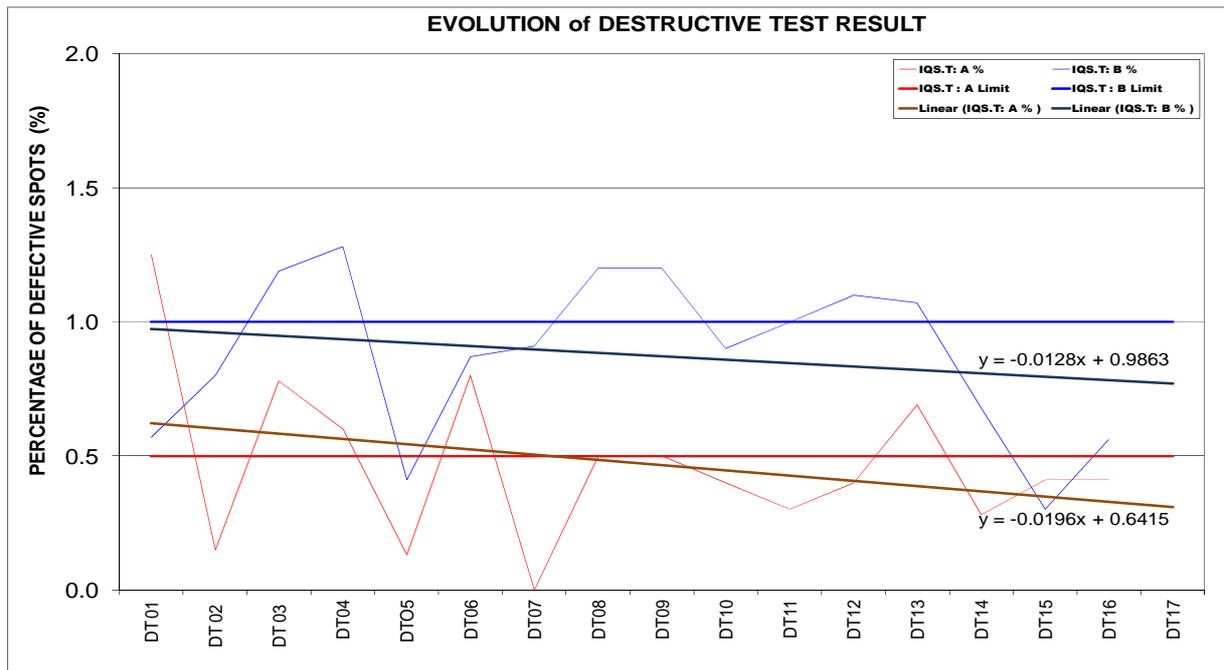


Figure 1: The pattern of the Destructive Test results showing improvement

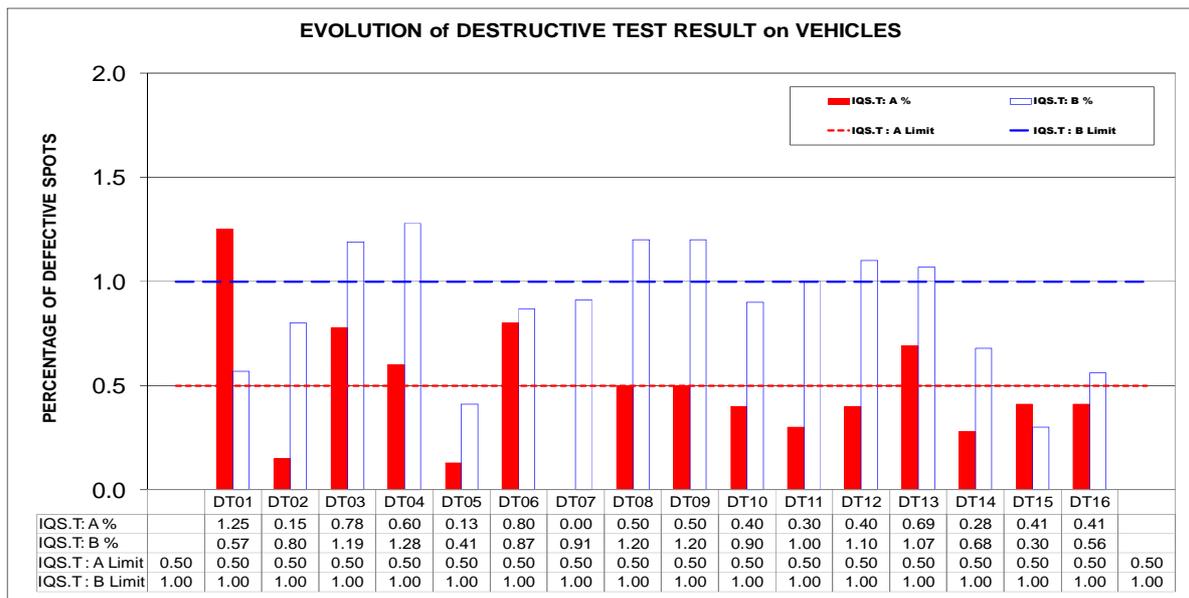


Figure 2: Histogram of the sixteen (16) Destructive Test results

CONCLUSION

The result of these tests conducted indicates consistent system improvement averaging 0.48%. But there is high risk - a delicate potent to approach the unacceptable constant of 0.64% safety spots weld tensile strength failure with the slightest process deviation. Also, the non-safety spot weld tensile strength failure rate of the system averages at 0.91% and can easily tend to 0.98% which is close to the 1.00% limit. Slack commitment to the respect of surveillance plans and implementation of dedicated action plans will drift the production to systemic failure as experienced during the period of test-13. Thus, this questions the integrity of the production system. Therefore trend

analysis should be monitored and the slightest deviation should be controlled rigorously to achieve production system stability. The destructive testing result delivers evidence-based surety for products, processes and machines certification. Thus, with system integrity in place, the consistent application of the destructive test serve as the platform for the development of new technologies for increased productivity and economic growth in automobile industry in a sustainable way.

Acknowledgements

The authors would like to thank Peugeot Automobile Nigeria Limited, Kaduna, and the Department of Mechanical Engineering, Ahmadu Bello University, Zaria, both in Nigeria, which made this study possible.

REFERENCES

- [1] Ishaya, Z. D., Bala, E. J., Folayan, C. O., Pam, G. Y. *Advances in Applied Science Research*, **2013**, 4(2), 176-180.
- [2] In destructive testing: Retrieved from <http://www.answers.com/>, <http://www.businessdictionary.com/> on 16 April, **2013**.
- [3] Fundamentals of Professional Welding, Retrieved from <http://www.sweethaven.com> on 16 May, **2013**.
- [4] Althouse, A.D., Turnquist, C.H., Bowditch, W.A. *Modern Welding*, Goodheart-Willcox Co., Inc. U.S.A., **1976**. Ch22-pp 10 &11.
- [5] Ishaya, Dauda, Z.D., M., Kulla, D.M., Bashar, D., Jumare, A.I., "Car Body-In-White Manufacturing Technical Audit for Sustainable Technological and Production Development". Book of Abstracts of Technical Papers, **2012**, pp12. (National Conference and Annual General Meeting of the Automotive Engineers Institute - A division of the Nigerian Society of Engineers-NSE), 27– 28 Sep, Kaduna- Nigeria).
- [6] *Resistance Spot Welding of Steel Sheets - Quality of Assemblies* B13 1226, 20th June **2002**, PSA, Normes Vehicules (Book of Specification) Pg 2-13.
- [7] *Resistance Spot Welding of Steel Sheets - Assembly Definition* B13 1220, 15th May **2003**, PSA, Normes Vehicules (Book of Specification) Pg 1-11.