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Root Cause Analysis for Failure of Door Lock Case Assembly during Caulking Process

S.P. Sundar Singh Sivam[a,b], K. Saravanan[c], Ganesh Babu Loganathan[d], D. Kumaran[a,e] and S. Rajendrakumar[a,f]

[a]*Dept. of Mech. Engg., SRM Institute of Sci. and Tech., Kancheepuram, India*
[b]*Email: sundar.sp@ktr.srmuniv.ac.in*
[c]*Dept. of Mechatronics Engg., SRM Institute of Sci. and Tech., Kancheepuram, India*
Corresponding Author, Email: saravanan.kn@ktr.srmuniv.ac.in
[d]*Dept. of Mechatronics Engg., ISHIK University, ERBIL, KRG, Iraq*
Email: ganesh.babu@ishik.edu.iq
[e]*Email: kumaran.d@ktr.srmuniv.ac.in*
[f]*Email: rajendrakumar.s@ktr.srmuniv.ac.in*

ABSTRACT:

This paper details the failure analysis of deformed passenger car door lock case and presents a solution to avoid the part deformation during caulking process. This failure was observed during the assembly of case and its cover by caulking process. Mechanical properties and chemical composition of case (Zn Al_4 material) has been checked by universal testing machine and spectra material analyser. The material composition having less aluminium content leads to the casting strength and cast ability losses. In order to get the exact load requirement for caulking process, analysis has been carried out by using finite element method. In finite element method, the case and its cover model has created by AUTODESK INVENTOR & stress analysis was carried using same software. The induced stress and deflection are obtained for various load conditions. The experimental measurement was taken from the machine by using load cells. By comparing the experimental data with FEM data we found that the problem happened due to the overload. From this result data the machine design was optimized by changing booster and cylinder which is used to generate the load. The hydro pneumatic circuit of the caulking machine has been optimized and redesigned to avoid future problems.

KEYWORDS:

Caulking process; Failure analysis; Finite element method; Stress analysis

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1. Introduction

In the present manufacturing process, there are many types of failure occurs during the operation. The failure can happen due to fatigue, creep, wear and tear, corrosion, chemical composition issues and over load during the pressing. Passenger door lock assembly process contains several stages [1-3]. In that caulking is one of the stages to assemble the case and its cover parts. Caulking is one of the press fit process which is used to assembly the two parts permanently. Here the high force is applied at any one part to deform the material to get the required shape to make both the parts in as assembled condition. Another part should not get any deformation or shape change due to the high force [4-7]. In our case both the parts got deformation during the caulking process. Reason for the failure can be material, machine, method, and man. If the problem is happening frequently, it is difficult to achieve the product quality and functional requirement [8]. So finding the root cause for the failure is important to avoid defective product and in process rejections. This article considered the root cause analysis for material and machine problems. Failure analysis has been conducted to find the root cause and optimize the hydro pneumatic circuit.

2. Materials and Methods

The product failure in terms of part deformation during the pressing operation is shown Fig. 1. Fig. 2 shows two parts using in this assembly process, case and its case cover. Case is made by ZnAl4 material, Case cover is made by SUS430 material of 0.15mm sheet thickness. During process, the case cover is inserted into the rotor case as shown in Fig. 3. Manually after insertion, the case cover is fixed with rotor case rigidly by applying the compressive load at the top of the case cove and side punches comes towards the centre to complete the caulking process is shown in the Fig. 3. While pressing the side punches, only the case cover should deform and achieves the required shape, but here the case also getting deformation some times. So the part is getting damages. This problem is happening during manufacturing once in 1000 pieces.

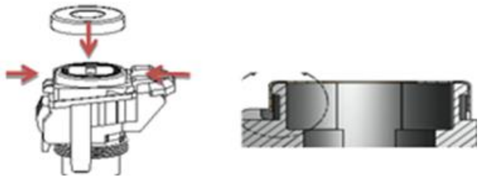

Fig. 1: Assembly direction and after assembly of case and its cover

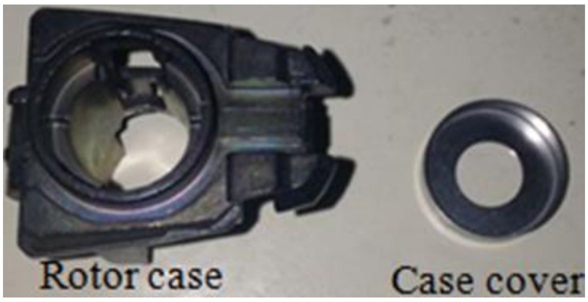

Fig. 2: case and its cover parts

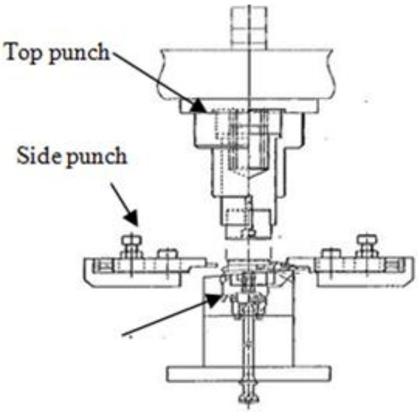

Fig. 3: Concept of pressing operation

3. Analysis

The analysis contains the three stages; first two stages are the material analysis such material composition analysis and mechanical properties confirmation with UTM. The third stage analysis contains machine redesign such as the experimental analysis with caulking machine and stress analysis for case model by FEM software in AUTODESK Inventor.

3.1. Material composition analyser

A material of ZnAl4 has prepared with compact size to check the material composition. The metal analysers is optical emission spectroscopy (arc spark OES or spark OES). The required block has been placed into the locator and clamped rigidly. While switch on the spectra analyser the locator block moved towards inside of the machine to the desired position. Test material is vaporized with the testing by an arc spark discharge. The molecules, particles and ions contained in the atomic vapour are energized into emission of radiation. The radiation transmitted is passed to the spectrometer (arc spark OES) optics specifically or by means of an optical fibre, where it is scattered into its unearthly segments. From the scope of wavelengths transmitted by every component, the most reasonable line for the application is measured by methods for a CCD or PMT. The radiation intensity, which is corresponding to the convergence of the component in the specimen, is recalculated inside from a put away arrangement of calibration curves and can be demonstrated straight forwardly as percent focus.

3.2. Tensile strength check for mechanical properties

The mechanical property of the material has been checked through the tensile testing with UTM machine (AUTOGRAPH AGX - 50KN) as per the ASTM Standard. The specimens of 4.03mm diameter at necking and 65mm of the gauge length were prepared as per ASTM Standard. The specimen was loaded to the universal testing machine (UTM) in Fig. 4 and conducted the test by applying the tensile load. From the results the ultimate strength of the material & % of elongation has been calculated.

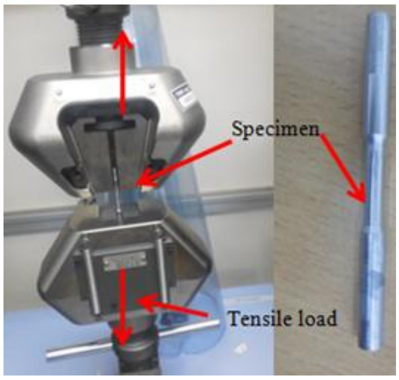

Fig. 4: Tensile test in UTM

3.3. Machine side analysis

This testing method contains an experimental work as well as theoretical calculation. The schematic diagram of the press fit caulking machine has shown Fig. 5. The machine containing the hydro pneumatic cylinder with 16Mpa capacity, 11times pressure increasing booster, and linear actuators. From this machine we have measured the actual load developed by the cylinder while press fit process. The process was conducted as below steps.

- Step 1: Pressure input kept to 0.15Mpa, and the load cell (5 tonne capacity) kept at part the location (instead of the part, load cell placed). While switch on the machine the hydro pneumatic cylinder presses the load cell and the generated load displayed in digital display.
- Step 2: The above step has repeatedly conducted with different pressure input conditions and the results are plotted as graph.

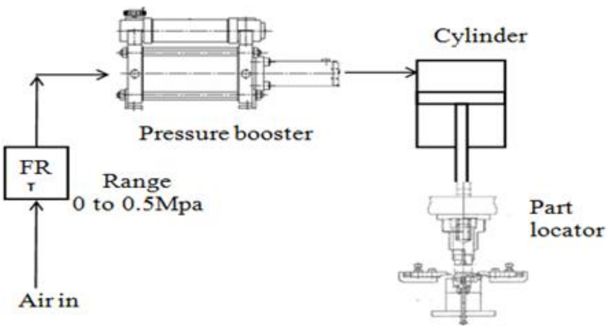

Fig. 5: Schematic diagram, of the machine structure

Fig. 6 shows the machine data - Pressure vs. Load as two lines. First one is actual measurement taken from machine and second one is theoretically calculated value based on the booster capacity and cylinder capacity. If the input pressure is 0.35MPa booster will generate 0.35 X 11 = 3.85MPa. Based on the cylinder catalogue, cylinder area is 2127mm^2, F = P X A. Load for 0.35 MPa is 3.85 × 2127 = 8188N. But actual measurement for 0.35 MPa is 29319.6. So the machine is in abnormal.

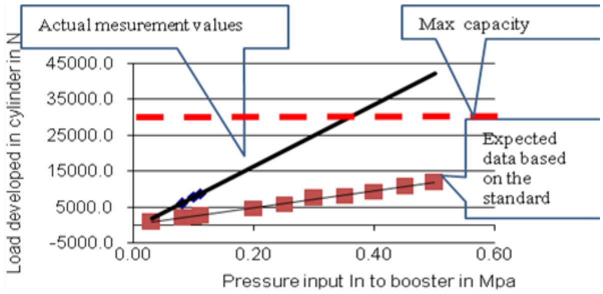

Fig. 6: Machine data - Pressure vs. Load

For FEM analysis of the case commercial software AUTODESK Inventor was used. A 3D model was generated with AUTODESK inventor 2016 version by assigning the ZnAl4 grade material to the model in Table 1. The model was meshed and constrain made in outer surface which is constrained during the assembly process in actual machine. By applying the compressive load on the sides of the parts the developed stress and deflection was recorded. The various results has generated with various load conditions. The material specifications are used for FEM (for case). By applying the compressive load on the sides of the parts the developed stress and deflection was recorded. The various results have generated with various load conditions and shown in the Fig. 7, Fig. 8. Fig. 9. When the case is applied with 1200N condition the ultimate strength reaches and material get started deformation. More than this load requirement part can get permanent deformation, our requirement case cover should get deform not case. Fig. 10 and 11 shows the stress analysis for case covers at 200N and 2000 N.

Table 1: Material property of case and its cover

Properties	Case	Cover
Material	ZnAl4	SUS430
Young’s modulus	21000 N/mm^2	20000 N/mm^2
Poisson’s ratio	0.2	0.275
Yield strength	208 N/mm^2	205N/mm^2
Ultimate tensile strength	268 N/mm^2	480 N/mm^2

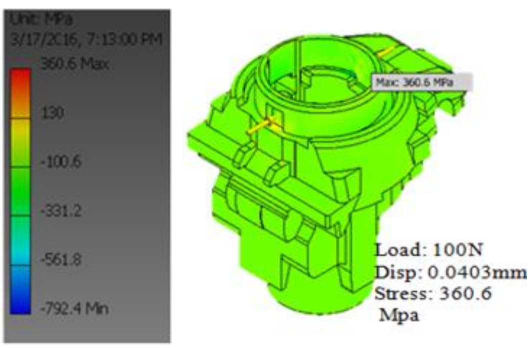

Fig. 7: Stress analysis for case at 100N

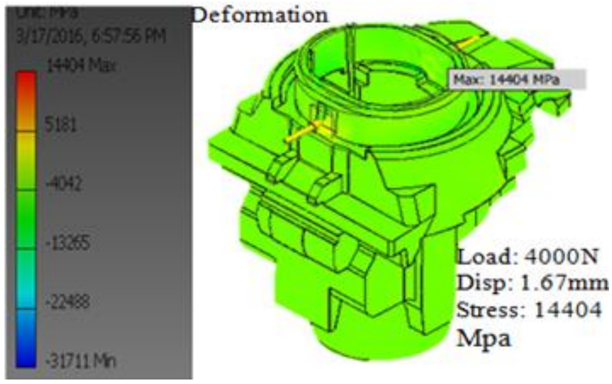

Fig. 8: Stress analysis for case at 4000N

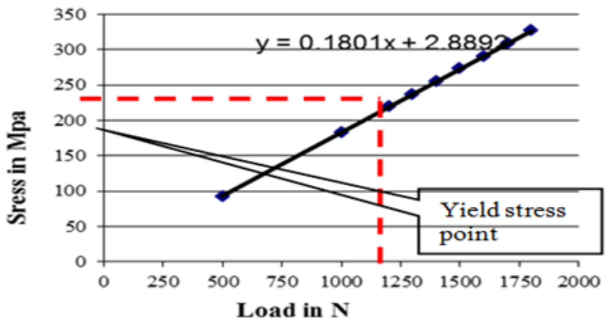

Fig. 9: FEM data for case cover- Load vs. Stress

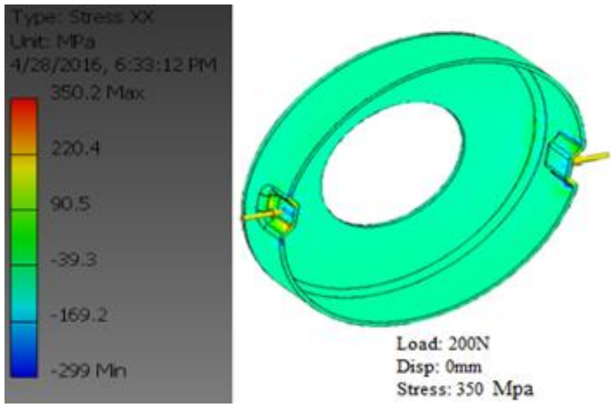

Fig. 10: Stress analysis for case cover at 200N

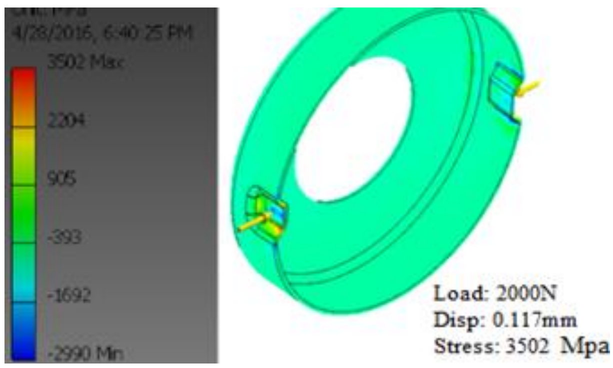

Fig. 11: Stress analysis for case cover at 2000N

From Fig. 12, load requirement for case cover is more than 580N to deform the material. At the time the load should not exceed the 1100N. Because, based on the yield stress of the case material it can get deformation [9].

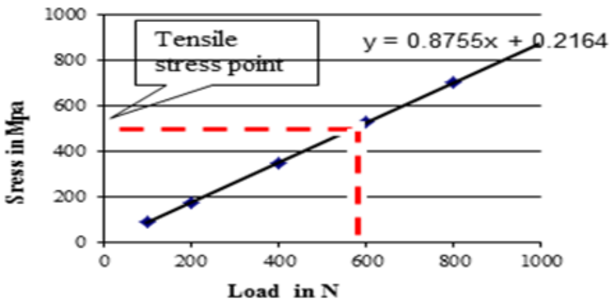

Fig. 12: FEM Data for case cover – Load vs. Stress

4. Results and discussion

4.1. Chemical composition results

The chemical composition results of the material has tabulated and compared with the standard specification. From the above results the aluminium content has less than the requirement .There is some loss of cast ability and properties when the aluminium content is decreased below to the specified range.

4.2. Machine analysis result

As per the machine analysis result, the measured load values are more than the theoretical design value. Based on FEM Result, The case is getting deformation at 580 N. So the cylinder capacity, we can choose 1000N capacity (present condition is 10000N). If cylinder capacity more than 1200N capacity case can get deformation. So need to choose 1000N cylinder because our requirement is only deforming the case cover.

4.3. Current problem in machine

The actual load requirement to do the caulking process is 1200N (FEM analysis report). But the cylinder is activating 25000N. The overall cylinder stroke is controlled by valve actuation timer in PLC. So, the cylinder will move to press the part with in desired time only. Once the time is reached cylinder will come back to origin. When the cylinder is controlled by the stroke, the part will not get damage even 25000N force. So, before getting the part deformation the cylinder will come back to origin. The standard operating pressure is 0.3 Mpa for machine .When the cylinder pressure is reaching to 0.4Mpa the cylinder movement will become little faster, so the cylinder will move over stroke with desired time. During this condition the part will get small deformation. So, the pressure regulator & pressure relief valve needs to add in-between the booster and cylinder to standardize the cylinder motion.

5. Conclusions

This case study performs the failure analysis of deformed passenger car door lock case and gives the solution to avoid the part deformation during caulking process the following suggestions were made. Material aluminium composition level needs to increase till 3.5%. Machine hydraulic circuit redesign: addition of précised flow control valve and pressure relief valve in current machine. Machine cylinder capacity optimized to 1000N from 10000N capacity & booster can eliminate in future design. Standardization of the machine input pressure based on new cylinder requirement.

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