FEM Based Crack Analysis of a Sensor Boss of Passenger Vehicles

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Abstract— **The existing part of sensor boss is facing a problem of occurrence of crack at compaction stage only. So further the part does not get processed and is been rejected at initial stage only. By every possible setting of tooling and trials the crack observed is not removed from the part. Initially the crack observed is slight but after sintering the crack gets opened and is not visible by naked eye. The aim is to identify the root cause of the crack. And also to eliminate it with help of FEA without changing the compaction pressure.**

***Index Terms*— sensor boss, crack, compaction, sintering, FEA**

I. Introduction

THE goal of this project is to determine the mechanism of the crack obtained and to identify the root cause of the crack obtained during compaction process. The crack is not visible by naked eye after compaction process, but when the part is passed through sintering furnace the inter-metallic particles gets bonded with each other due to high temperature. The inter-metallic particle gets bonded with each other and forms a crack at the radius.

The green part is just a form of the powder and can be broken easily without much application of load. The green part is more brittle which does not go any elongation and breaks quickly with smaller application of load. Many forces act on the component during compaction process from powder filling to ejection.

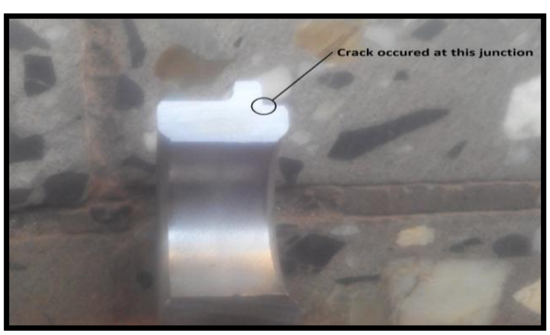

Fig.1. Cut section of Part for inspecting Crack.

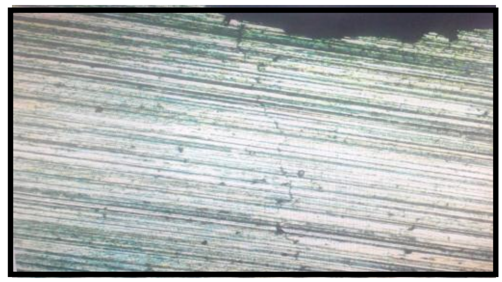

Fig.2. Crack viewed under Metallurgical Microscope with Magnification of 10X.

Literture Review

S.M. Tahir , A.K. Ariffin- investigated that a preliminary assessment and qualitative analysis on fracture criterion and crack growth in metal powder compact during the cold compaction process.

Sydney H. Luk, Frank Y. Chan, Alan B. Davala, Thomas F. Murphy Hoeganaes Corporation- investigated that Green strength enhanced material systems have been developed for iron and Low alloy as well as stainless powder metallurgy applications.

Thomos F. Murphy and Bruce Lindsley- investigated that preliminary assessment and qualitative analysis on fracture criterion and crack growth in metal powder compact during the cold compaction process.

J. A. Hernandez, J. Oliver, J. C. Cante and R. Weyler- investigated the modeling of crack formation during the ejection stage in powder metallurgy die compaction processes has fallen outside the scope of conventional finite element studies on this process.

II. Basic Tool Setup & Working Details

The powder compaction process plays an important role in Powder metallurgy industry. Compaction process has various phases: Die filling, Powder rearrangement, Compaction, Unloading and Ejection.

At first the die cavity is filled with powder which is to be compacted. The spherical powder particles can be packed more densely than irregular particles. Powder arrangement can be done by feed shoe and die orientation. The density distribution is important condition for compaction. To obtain uniform density and green strength of compacted part the fill density distribution is important.

During compaction the volume between die and the punches is reduced. Initially the pressure of the punches is low. As pressure of the punches increases the plastic deformation takes place in particles. At the end of compaction the small amount of fill is remaining in the die cavity. During deformation at the inter particle cold welding occurs which contributes to the strength of the component.

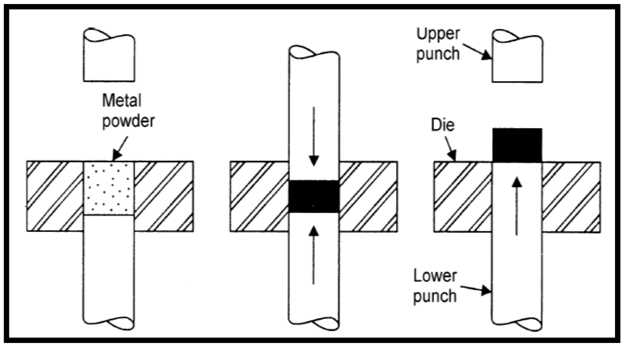

Fig.3. Steps in Powder Compaction Process.

The green component is unloaded axially by the punches. The radial force is generated radially between component and the die wall. Thus the component gets stuck inside the die and is to be forcefully ejected. Punches exert the force on the component to eject from the die. If lubricants are present in the powder the ejection force can be reduced. Lubricants will reduce die wall friction and tool wear, but the pressure-density relation will be affected.

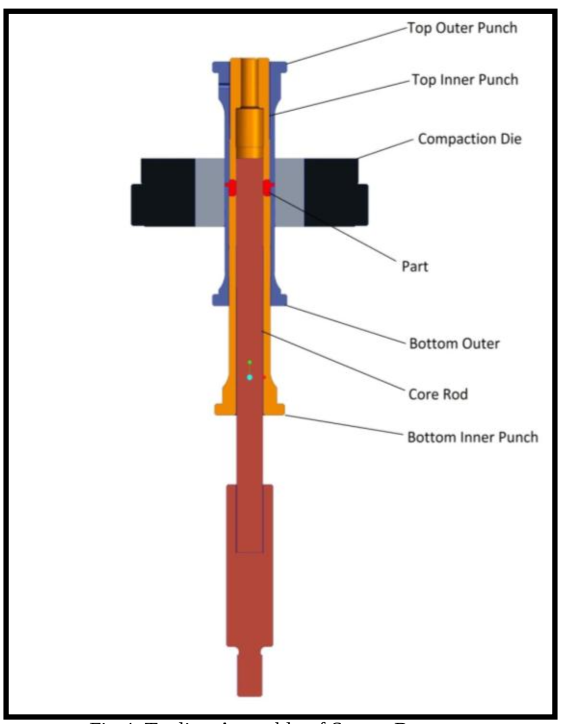

Fig.4. Tooling Assembly of Sensor Boss.

III. Causes of Cracks

The main causes of crack found in powder metallurgy compacts are divided into Five basic categories: improper material composition, inter-particle side shifting action, improper elastic strain release and high tensile/shear stresses.

A. Improper material composition

Sometimes the metal powder is used without additives for various reasons. This results for poor compressibility and higher ejection forces. The addition of lubricants will improve compressibility and reduce ejection forces. Sometimes it may have negative effect on bond formation due to presence of binders, impurities and air entrapment.

B. Inter-particle side shifting

Inter-particle side shifting is another mechanism for crack generation. The inter-particle bonds are formed by plastic deformation and bulk movement of the powders. In some ideal cases an inter particle side shifting does not take place when the densification is bilateral, symmetrical and simultaneous. This particle motion after densification can prevent the inter particle bonds from forming and generate a crack.

C. Improper elastic strain release

Another mechanism of crack formation is Improper elastic strain release. An unrecoverable plastic deformation of the particles occurs during compaction. When the tooling elements reach their final required positions, the related pressures are reduced and during ejection will eventually go to zero. At the moment of release from compaction pressures, the compressive stresses relax and the green compact will change abruptly from a plastic to a purely elastic stage. If the internal stresses are beyond the compact's strength limit, cracks will form.

D. High tensile/shear stress

The tensile/shear stress which can be generated by external or internal factors in a compact exceeds its green strength in green p/m state then crack would be formed.

E. Cracks due to Ejection

In P/M compaction process, when part is to be ejected from die the bottom punch exerts force on the part and the friction is generated between part surface and the die wall, this results in formation in crack at the junction points.

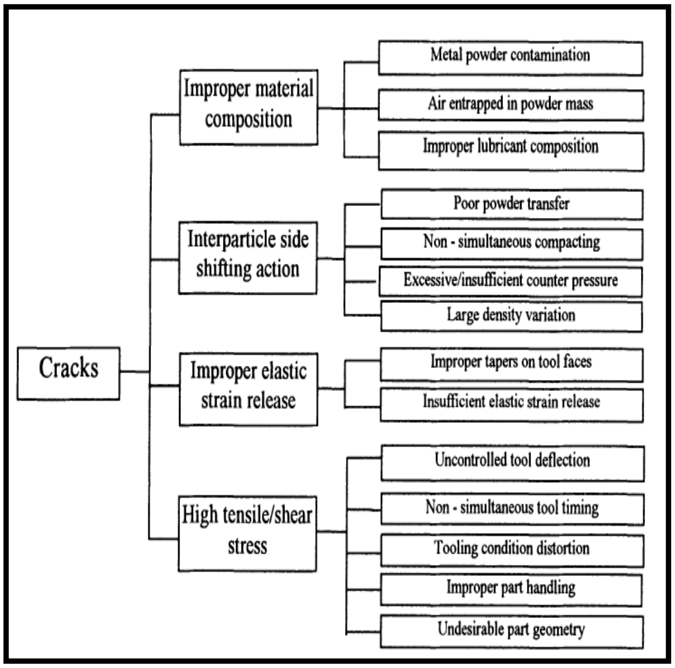

Fig.5.Causes of Cracks in P/M Compact.

During compaction the main source of cracks are the tools. Large density variations can be caused by improper tool design. Large powder flow and non-simultaneous densification during compaction can be caused by unsuitable tool kinematics. During unloading the compact becomes slightly larger than the die and the expansion during ejection can cause failure in the green compact. Improper unloading of the punches in a multiple tooling system can cause tensile stress as portions in the compact are left unsupported. As the compact begins to emerge from the die improper die tapers can cause lamination cracks on the surfaces which are in contact with the die. Poor tool surface finish can cause tensile stress on the compact during ejection, e.g., when the compact is ejected upwardly, cracks might be formed on its upper surface.

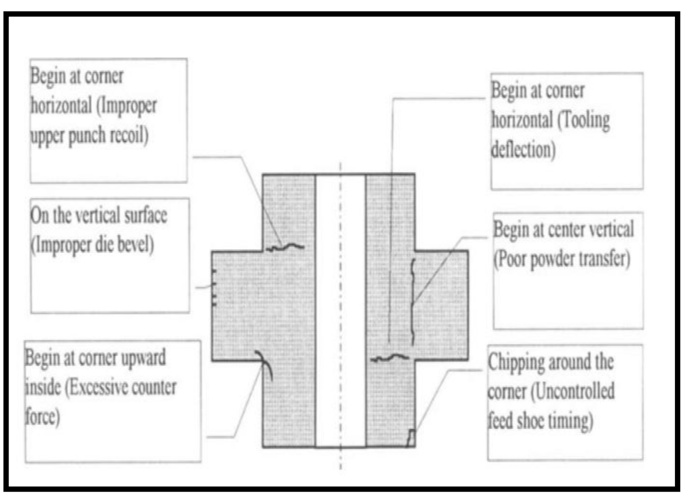

Fig.6.Common Cracks in Double Boss P/M Compact

IV. Engineering Analysis

The crack in green component is generated due to frictional force acting in downward direction. This frictional force is generated between the surface in contact with the die of component and the die wall.

Now the force required to compact the part is 520KN
F = 520KN = 520000N

Now the axial stress acting on the component for compacting is

$$\sigma_a = \frac{F}{A} = \frac{F}{\Pi r^2} = \frac{520000}{\Pi\left(31^2 - 16.56^2\right)} = \frac{520000}{8630.16}$$

$$\sigma_a = 241.0196 \text{ N/mm}^2$$

Now the radial stress is exerted by component on the die wall is

$$\sigma_r = \frac{\sigma_a \nu}{(1-\nu)} = \frac{241.0196 \times 0.35}{(1-0.35)} = \frac{84.3568}{0.65}$$

$$\sigma_r = 129.77 \text{ N/mm}^2$$

Ejection force required for ejecting the component from the die

$K = \mu 2\Pi r h \sigma_a$

= 0.25x2xΠx(25-16.56)x2.06x129.77

K = 3544.08 N

Pressure exerted by punch on the bottom of compact for ejection is

$$P = \frac{K}{\Pi r^2} = \frac{3544.08}{\Pi(25-16.56)^2} = \frac{3544.08}{223.786}$$

$P = 15.836 \text{ N/mm}^2$

Now the frictional force acting on the component during ejection in opposite direction of ejection force is

F = μP = 0.25x15.836

F = 3.959 N

V. Finite Element Analysis

The FEA method is very accurate method to determine induced stress in the component. FEM enables to find critical locations and quantitative analysis of the stress distribution and deformed shapes under loads.

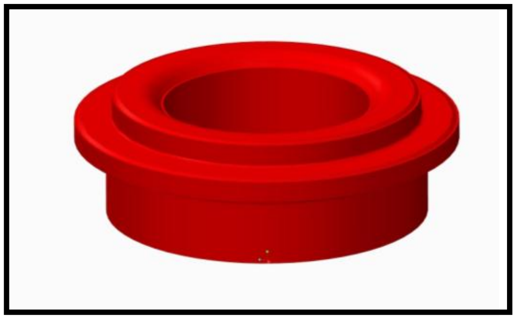

Fig.7. 3D model of sensor Boss.

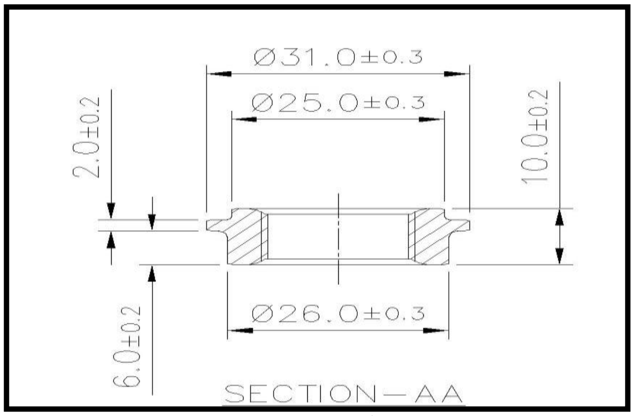

Fig.8. Dimensional view of sensor Boss.

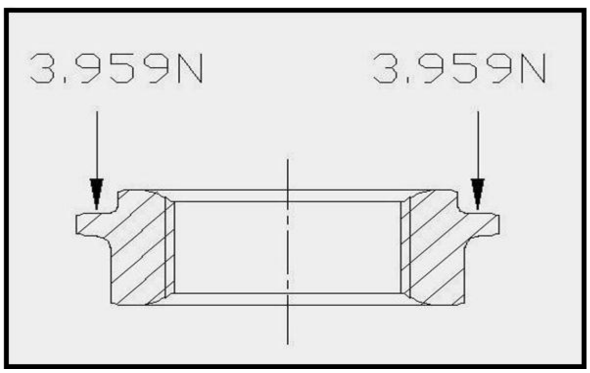

Fig.9. Loading diagram of Sensor Boss

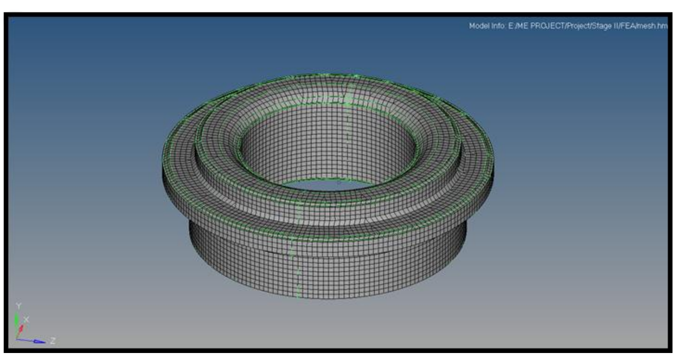

Fig.10. Meshing diagram of sensor Boss.

The basic model of the component is prepared in Creo. The figure no shows the component drawn in Creo software. Hypermesh software is used for meshing and preprocessing. Optistruct is used for post processing.

Material properties	Parameters
Young's modulus, E	10 MPa
Poisson ratio	0.35
Coulomb's friction coefficient	0.25
Initial green density	6.8 g/cc

Table 1 Material properties of SS 434L powder

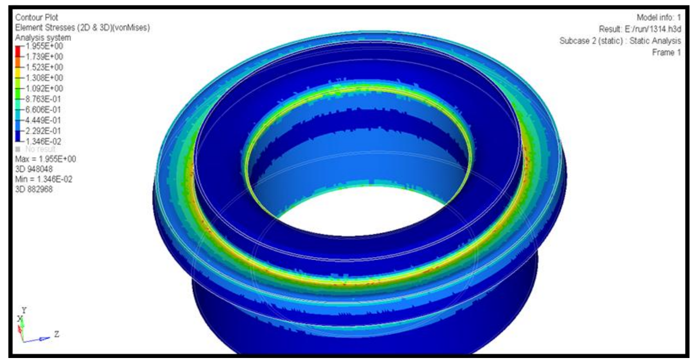

Fig.11.Stress analysis of component with radius 0.25mm.

The stress generated at the junction is due to frictional force acting in downward direction opposite to the ejection force. The amount of force generated is 1.955 N/mm2.

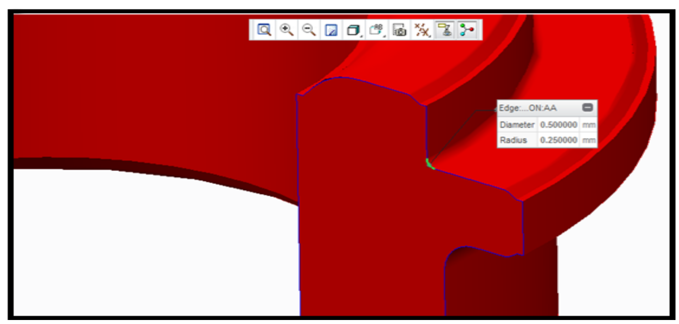

Fig.12.3D Model of Sensor Boss with radius 0.25mm.

The stress is generated at this region is due to small radius is 0.25 mm present at the junction. The stress is concentrated at this region due to small radius.

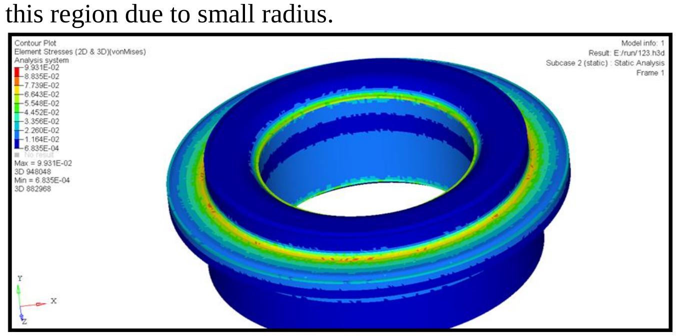

Fig.12. Stress analysis of component with radius 0.4mm.

In this diagram the stress is generated at very small amount as the stress concentration is decreased due to increased radius is 0.4mm. The amount of force generated is 0.0993 N/mm2

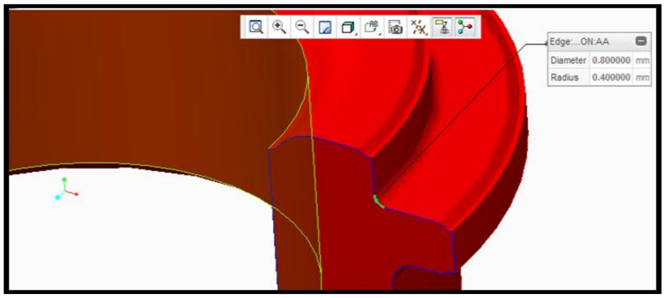

Fig.13. 3D Model of Sensor Boss with radius 0.4mm.

To reduce the stress concentration the radius at the junction is to be increased up to 0.4mm. The design of the component gets changed while increasing the radius. Now necessary changes in design are to be done in tooling also. The Top outer punch is to be reworked for increasing radius.

VI. Experimental Validation

New production trial for 500 parts was done after modifying the tooling on the same press as was before Dorst 70 Tones Press. Now the radius at the junction was increased on the part after compaction. And the overall dimensional report is also within specified limit.

Fig.14. Dorst 70 tones Press.

After sintering the green parts at regular temperature condition part is been cut for checking under metallurgical microscope.

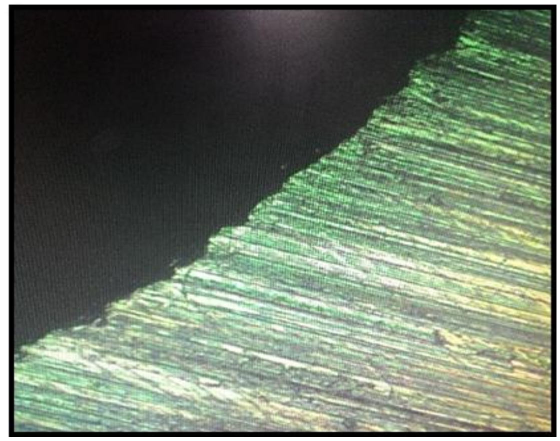

Fig.15. Part viewed under Metallurgical Microscope for crack with Magnification of 10X.

After checking the crack was absent from the part. The structure of the component was not changed. Dimensional, FEA and Metallurgical reports have sent to customer for Finalization of revised Drawing. And quantity of 100 parts is also been sent to customer for further Validation of parts at their end.

VII. Conclusion

Static analysis of the Sensor boss has done using commercial software hyper mesh and its inbuilt solver Optistruct. Analysis is to find out the total amount of stresses generated in structural components.

- The material of the component cannot be changed as it is required by the customer.
- Frictional forces between the die and the compact acts in downward direction to pull the main body.
- So as per our analysis report the stress is generated at the junction of the sensor boss due to high stress concentration at that region.
- As per discussion with customer we have decided to increase cross section of the part where maximum stress is induced.
- Before the radius of top outer punch was 0.25mm and now after modification is 0.4mm.
- So as per new modification in tooling the parts were produced and the crack was removed from part.
- After the validation gets completed at customer end the actual production will start and the organization will meet the defined target for production.

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