Failure Analysis in Forgings after Heat Treatment -Case Studies

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Abstract— In this case study, metallurgical analysis of defects encountered during forging of input shaft and stub axle has been done in detail. Hence, in order to find the root cause of failure & to study the different defects during forging process. Study was carried out, aim of the case study was to find out reasons behind the cracks, to study the process of forging and the defects encountered during the forging process. A complete failure analysis was done on rejected input shaft & stub axle which had developed defects during forging. Different parameters were taken into consideration and various tests were performed to find the reason behind the failure. In the end some corrective actions and suggestions will be provided in order to improve the process and to counter the reasons that cause cracking of input shaft and stub axle during forging.

Key words: Forging Defect; Surface Hardness; MPI; SEM; EDX

I. INTRODUCTION

Input shaft and stub axle are very important part of automobile industry. The input shaft is connected to the engine via the clutch, such that when the clutch is engaged, power goes straight from the engine to the input shaft of the transmission, and the crankshaft and input shaft rotate at the same speed. A stub axle is one of the two front axles that carries a wheel in a rear in a rear wheel drive vehicle. The stub axle consists of wheel bearing which support the wheel hub.

Surface crack is found in the input shaft and stub axle. We have to identify the cause of cracking the components.

The aim of work is to investigate possible cause of cracks occurring in forging & mechanism by characterization techniques such as scanning electron microscopy (SEM) Energy Dispersive Spectroscopy (EDS) and optical microscope to detect element present at or near to crack. After investigate possible solution to eliminate cracks has been proposed.

II. MATERIAL

Input shaft of carbon steel (SAE8620) 0.19C-0.79Mn-0.23S-0.02S-0.44Ni-0.48Mo-0.018Al and the stub axle of carbon steel (EN8D) 0.45C-0.4Si-0.9Mn-0. 05P.input shaft has been forged and normalize. stub axle has been forged and hardened and tempered.

III. OBSERVATION

Surface crack is present in the surface of input shaft and stub axle that is found with the help of magnetic particle inspection (MPI).it is a non-destructive testing process for detecting surface discontinuities in ferromagnetic materials such as iron, nickel, cobalt and some of their alloys. The process puts a magnetic field into the part. The piece can be magnetized by direct or indirect magnetization.

The Magnetic Particle Inspection (MPI) method is applicable for detecting surface and subsurface defects, which are not visible to naked eye.

The magnetic particle method is based on the PRINCIPLE that ― Magnetic field lines when present in a ferromagnetic material will be distorted by a change in material continuity, such as a sharp dimensional change or a discontinuity. If the discontinuity is open to or close to the surface of a magnetized material, flux lines will be distorted at the surface, a condition termed as ―flux leakage. When fine magnetic particles are distributed over the area of the discontinuity while the flux leakage exists, they will be held in place and the accumulation of particles will be visible under the proper lighting conditions.

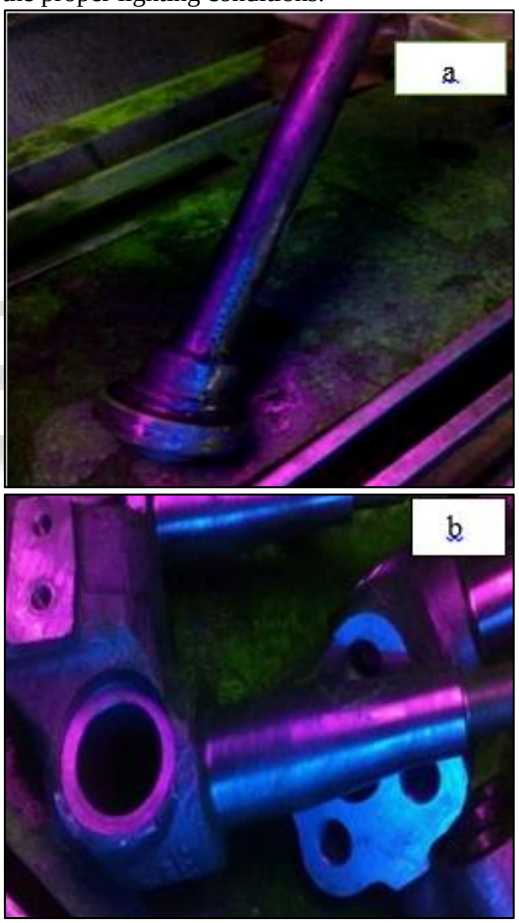


Fig. 1: Showing Surface Crack in the Surface of Input Shaft and Stub Axle (a and b)

Fig.1 (a) show the surface the surface crack in the surface of input shaft and the fig 1 (b) show the surface crack in the surface of stub axle that crack is found with the help of magnetic particle inspection (MPI).The Magnetic Particle Inspection (MPI) method (Nondestructive type) is applicable for detecting surface and subsurface defects, which are not visible to naked eye. The magnetic particle method is based on the PRINCIPLE that ― Magnetic field lines when present in a ferromagnetic material will be distorted by a change in material continuity, such as a sharp dimensional change or a

discontinuity [14]. If the discontinuity is open to or close to the surface of a magnetized material, flux lines will be distorted at the surface, a condition termed as ―flux leakage. When fine magnetic particles are distributed over the area of the discontinuity while the flux leakage exists, they will be held in place and the accumulation of particles will be visible under the proper lighting conditions.

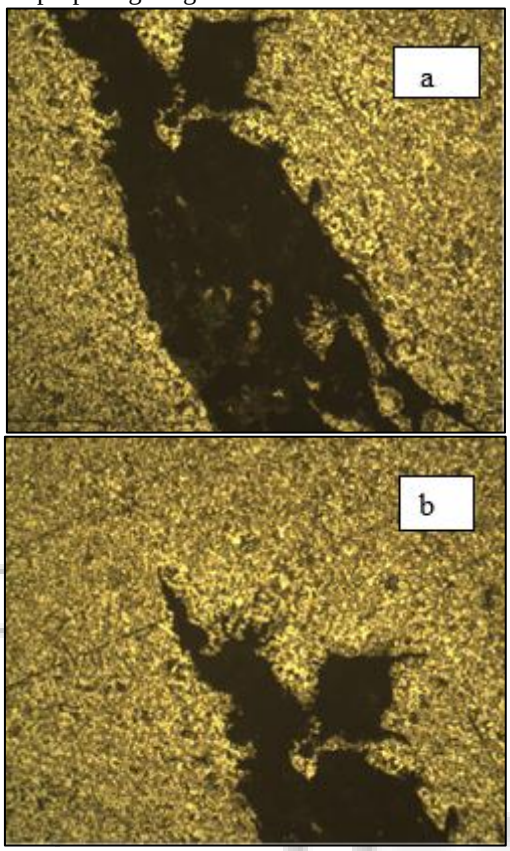


Fig. 2: Microstructure of surface crack in the input shaft (a and b) at 100X

Fig 2 (a & b) show the microstructure of input shaft at 100X.microstructure show the nature of crack present in the surface of input shaft. With the help of SEM/EDX testing we analysis the crack and tell the reason of crack in input shaft.

The Scanning Electron Microscope (SEM) is one of the most versatile instruments for investigating the microstructure of metallic materials. Compared to the optical microscope, it expands the resolution range by more than one order of magnitude to approximately 10 nm in routine instruments, with ultimate values below 3 nm. Useful magnification thus extends beyond 10,000× up to 100,000×, closing the gap between the optical and the transmission electron microscope.

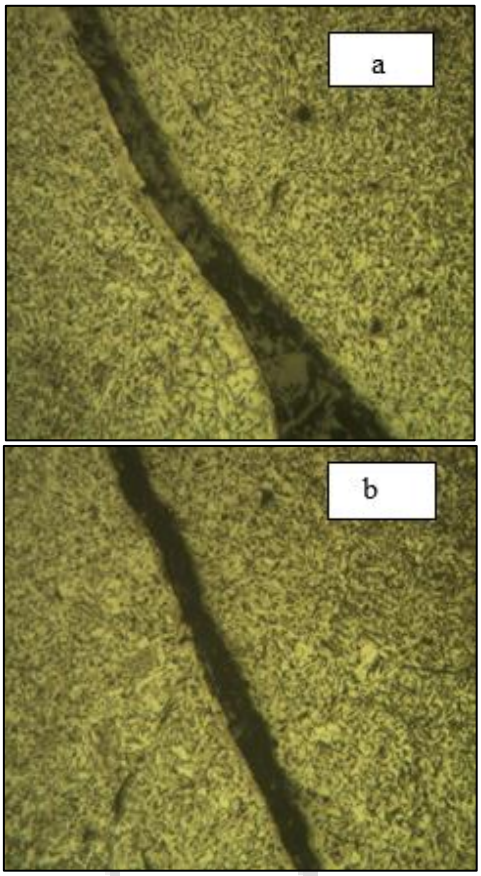
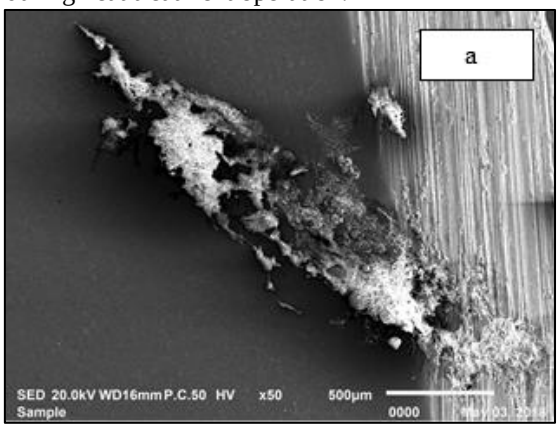


Fig. 3: Microstructure of Surface Crack in Stub Axle (a & b) at 100X.

Fig 3 (a & b) show the microstructure of stub axle at 100X.microstructure show the nature of crack present in the surface of stub axle. With the help of SEM/EDX testing we analysis the crack and tell the reason of crack in stub axle. Fig 2 and Fig 3 show the microstructure of input shaft and stub axle at 100X.input shaft has been forged and normalize hence in the microstructure of input shaft pearlite structure has shown. Surface crack is shown clearly in the microstructure of input shaft (Fig2).

Stub axle has been forged and hardened and tempered microstructure of stub axle shown the crack in the surface of stub axle. (Fig3). Residual stresses is present in the material these stresses could have been introduced in stub axle during heat treatment operation.



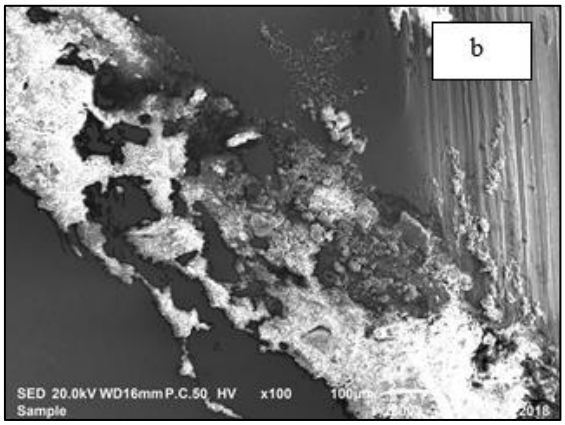


Fig. 4: SEM Images of Input Shaft (a & b)

SEM images of input shaft show the scaling present in the surface of input shaft. Scaling is entrapped during rolling process. This is seen as irregular deputation on the surface. This is primarily caused because of improper cleaning of the stock used in forging. The oxide and scale get embedded into the finish forging surface. When the forging is cleaned by pickling, these are seen as deputation on the forging surface.

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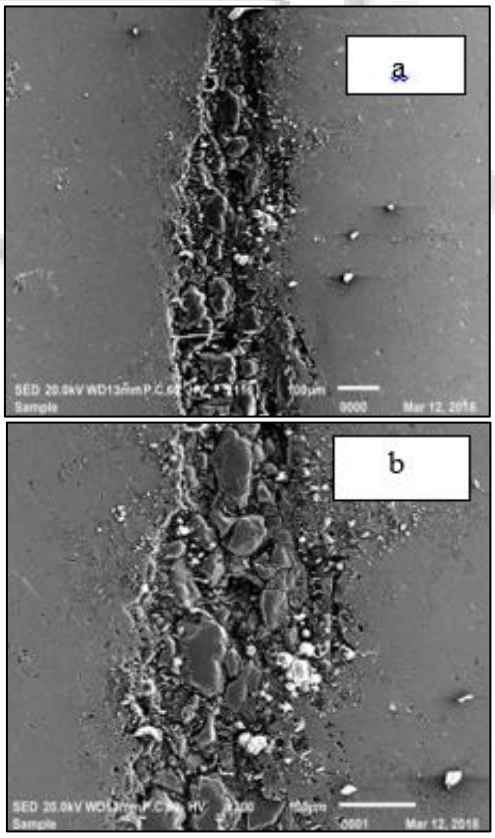

Fig. 5: SEM Images of Stub Axle (a & b)

Fig 4 and Fig 5 show the SEM images of input shaft and stub axle respectively. SEM image of input shaft show the scaling entrapped in the surface of input shaft. SEM image SEM images of input shaft show the scaling present in the surface of input shaft. Scaling is entrapped during rolling process. This is seen as irregular deputation on the surface. This is primarily caused because of improper cleaning of the stock used in forging. The oxide and scale get embedded into the finish forging surface. When the forging is cleaned by pickling, these are seen as deputation on the forging surface.

SEM image of stub axle revealed the initiation of crack in the stub axle appear to be due to high residual stresses and presence of segregation particle in the material. These stresses could have been introduced in the stub axle during the heat treatment operation.

With the help of EDX we analysis we find out the scale material present in the surface of input shaft & the inclusion that is present in the stub axle.

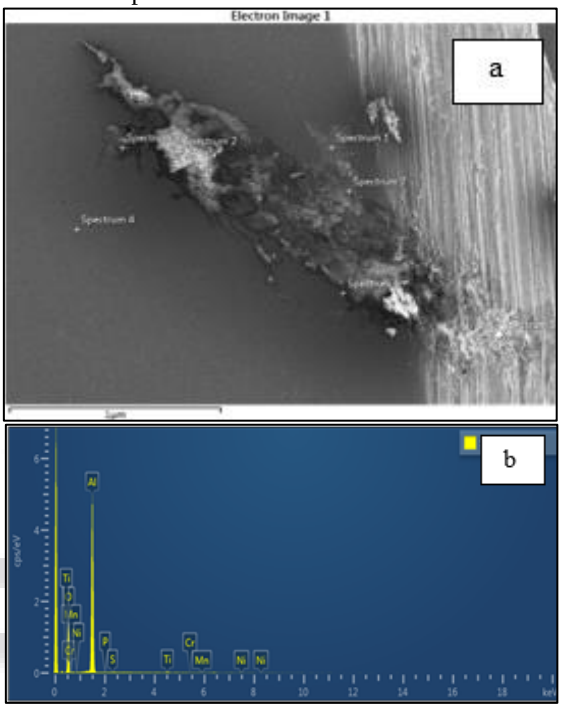

Fig. 6: EDX Analysis of Input Shaft (a & b)

Element	Weight %
O	47.00
Al	45.40
Ti	0.41
P	0.00
S	0.00
C	6.42
Mn	0.00
Cr	0.00
Fe	0.52
Ni	0.25
Mo	0.00

Table 1: EDX Analysis of Input Shaft

EDX Analysis of input shaft revealed scaling is present in the material.

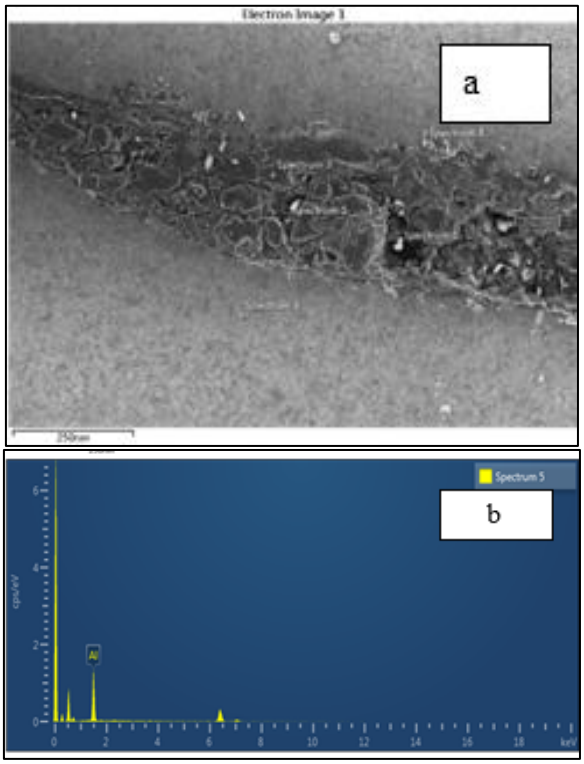

Fig. 7: EDX Analysis of Stub Axle Shaft (a & b)

Element	Weight %
Al	27.73
Fe	29.08
C	43.19

Table 2: EDX Analysis of Stub Axle

EDX analysis of stub axle revealed that the segregation is present in the material

IV. Discussion

SEM/EDX images of input shaft show the scaling present in the surface of input shaft. Scaling is entrapped during rolling process. This is seen as irregular deputation on the surface. This is primarily caused because of improper cleaning of the stock used in forging. The oxide and scale get embedded into the finish forging surface. When the forging is cleaned by pickling, these are seen as deputation on the forging surface.

SEM/EDX image of stub axle revealed the initiation of crack in the stub axle appear to be due to high residual stresses and presence of segregation particle in the material. These stresses could have been introduced in the stub axle during the heat treatment operation.

V. Conclusion

- SEM/EDX analysis of input shaft revealed scaling is entrapped during rolling process.
  Remedy-proper cleaning of stock prior to forging.
- SEM/EDX analysis of stub axle revealed the initiation of crack in the stub axle appears to be due to high residual stresses and presence of segregation particle in the material. These stresses could have been introduced in the stub axle during the heat treatment operation.
  Remedy-slow cooling of the forging in a furnace or under ash cover a period of time.

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