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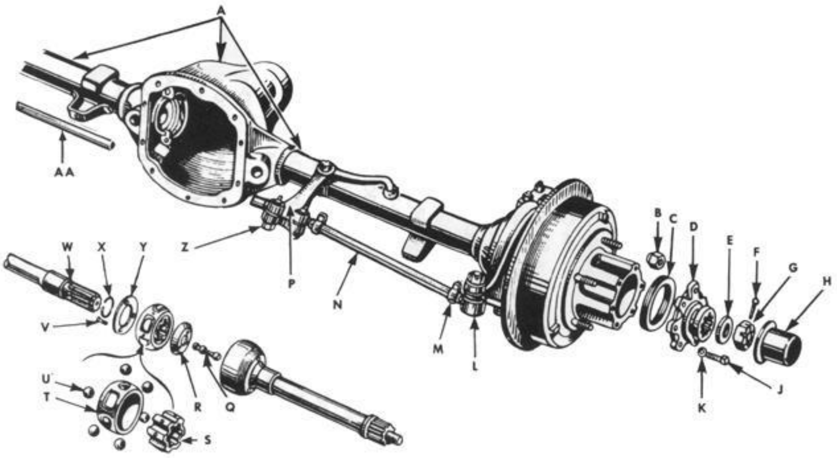
Failure Analysis Case Study

Failure Analysis of a Truck Axle due to Fatigue



Key words: Truck Axle, Fatigue

Material: Carbon Steel

Introduction

A broken truck axle was submitted for failure analysis. The axle had broken at two locations resulting in three parts. The broken axle is one of the several similar axles that have broken in the recent batches. Two intact axles, one used and one unused, were also sent for reference. Bearings were not available for analysis. Visual examination, Chemical, mechanical and metallographic analyses was performed on the submitted sections to look for root cause of the failure.

Visual Examination

The outside diameter in the middle of the axle was found to be less than 2 inches, as specified in the drawing. No machining marks were observed on the outside surface of the shaft where the two fractures had occurred.

Scoring on the surface at the flange end fracture was observed, Figure 1. No scoring on the outside surface of the other fracture zone was observed. Both the fractures surfaces were roughly in a helical plane. The location of fractures may have a relationship to the anchoring points on the axis. Though much of the fracture features had been obliterated by rubbing of the mating surfaces, well defined markings could be seen in certain areas, in Figure 2.

Figure 1: Scoring on the surface the flange end

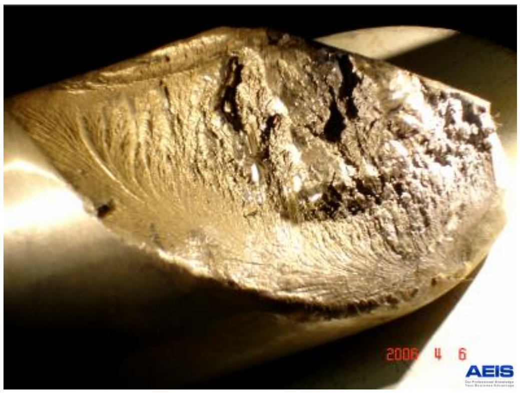


Figure 2: Markings on the fracture surface on spline end

Chemical Analysis

Axle materials were analyzed for chemical composition. Following results were obtained.

Element Percent	Axle1-Unused	Axle 2-Failed	Axle 3 – Used	UNS G 15410
C	0.41	0.41	0.41	0.36 / 0.44
Mn	1.54	1.6	1.56	1.35 / 1.65
P	0.021	0.13	0.22	0.04
S	0.032	0.024	0.032	0.05
Si	0.17	0.29	0.25	-
Cr	0.15	0.11	0.14	-
Ni	0.09	0.05	0.08	-
Mo	0.02	0.01	0.03	-
Cu	0.17	0.11	0.16	-

Mechanical Test

Hardness survey on the cross section close to the spline end fracture i.e. about 5 inches from the spline end, was compared to cross section at the similar location of the two intact axles. The hardness was measured in superficial scale to have a better relationship with Rockwell C values as well as to average out a larger area for each indentation. Two readings in each cell of the table below correspond to opposite points from the centerline. The center point shows a single reading, for obvious reasons.

ID/L	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Axle 1	83/ 87	85/ 87	85/ 86	82/ 84	79/ 78	76/ 79	75/ 73	75/ 73	73/ 73	73
Axle 2	87/ 88	88/ 88	85/ 84	79/ 78	75/ 77	67/ 68	67/ 68	67/ 68	65/ 68	67
Axle 3	88 /89	88/ 89	88/ 87	86/ 83	80/ 77	70/ 70	71/ 70	69/ 70	70/ 70	70

Microscopic Examination

A specimen was prepared across the region of origin of spline end failure down to the core for microscopic examination. The examination did not show any non-metallic inclusion or discontinuity in the case and substrate. A sample taken from the middle of the failed axle was prepared for microscopic examination. The core had equi-axed grains while the zone between the hard case and the core showed Ferrite–Pearlite banding that had not been effectively homogenized in the blank.

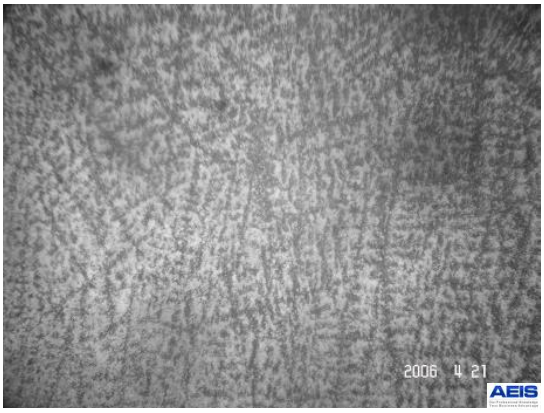


Figure 3: Microscopic structure below the hardened Zone. Dendritic pattern 37.5X

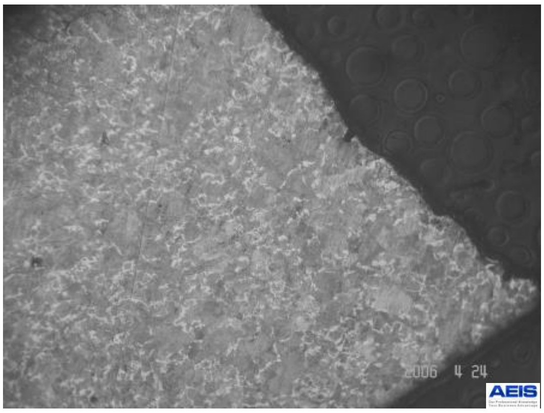


Figure 4: `Microscopic structure at the core 200X

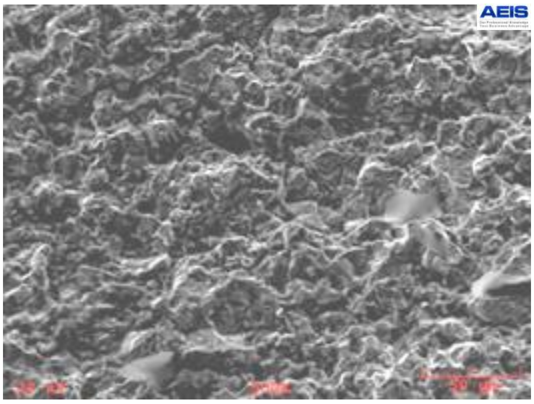


Figure 5: Fracture surface in the thumb nail zone SEM 500X

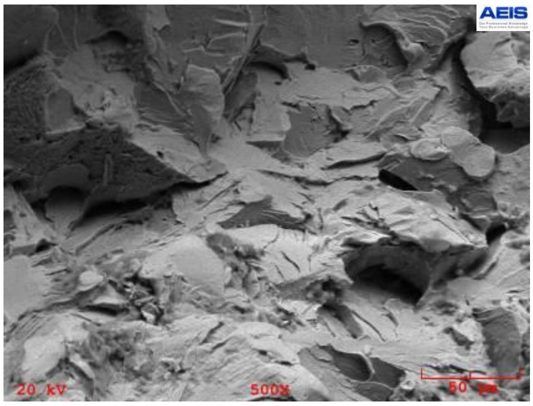


Figure 6: Fracture surface below the hardened edge SEM 500X

Discussion

Fracture markings indicate that the both the fractures took place under torsional loads beyond the capacity of the subject axle. Since the two fractures could not have taken place simultaneously and the flange end has score marks on the surface it is derived that that this fracture took place after the spline end fracture. The spline end fracture caused misalignment that resulted in jamming in the scored region. Chevron marks on the fracture surfaces indicate that the fractures originated from the surface or near the surface and propagated in the hardened case.

SEM analysis ruled out the possibility of fatigue cracking that could have been induced by cyclic loading. Ferrite- pearlite banding was observed below the hardened zone. The banding is attributed to higher manganese content and is not considered to have any marked effect on the mechanical properties to have caused the failure.

Macroscopic examination and hardness survey indicates differing case hardening patterns on cross section. Considering the similar total cross section area as well as the material of construction, there appears to be inconsistency in heat treatment. As the failures have been noted in several axles and only in recent batches the failure appears to be related to the axle quality rather than being induced by service conditions. Considering absence of any weakness in the parent material, the location of origin of crack, path of crack propagation and incongruence of hardened zone, a lapse in heat treatment practice is considered the most probable and primary cause of failure.

Conclusion

From the above observations and discussion following conclusions may be arrived at both the fractures took place under torsional load. Spline end fracture preceded the flange end fracture.

The flange end fracture was due to imbalance created by the preceding failure. The fracture of the spline end was by torsional load beyond the capacity of the subject axle. Considering absence of any weakness in the parent material, the location of origin of crack, path of crack propagation and incongruence of hardened zone, a lapse in heat treatment practice is considered the most probable and primary cause of failure.