A review: Induction Hardening on Axle shaft

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Abstract — In this paper an axle shaft of a Bolero car has been taken into consideration. Data for CAD modeling is extracted from reverse engineering. In analysis results it is clear that the shaft will break at the joint location. So, an attempt is to be made to improve its strength by placing a bush at the region of failure and induction hardening on the place where bush is to be placed. This paper shows the study of different authors who have been worked in this area of research.

Keywords — Axle shaft, Finite Element Analysis, Induction Hardening.

I. INTRODUCTION

Hardening is a process that is used to improve wear resistance of parts without affecting core of the part. This combination of hard surface and resistance to wear is a very important property of a component. Most surface treatments result in compressive residual stresses at the surface that reduce the probability of crack initiation and help arrest crack propagation at the case-core interface.

Induction heating is an extremely versatile heating method that can perform uniform surface hardening, localized surface hardening, through hardening, and tempering of hardened pieces. Heating is accomplished by placing a steel ferrous part in the magnetic field generated by high-frequency alternating current passing through an inductor, usually a water-cooled copper coil. The depth of heating produced by induction is related to the frequency of the alternating current, power input, time, part coupling and quench delay. The higher the frequency, the thinner or more shallow the heating. Therefore, deeper case depths and even through hardening are produced by using lower frequencies. The electrical considerations involve the phenomena of hysteresis and eddy currents. Because secondary and radiant heat are eliminated, the process is suited for in-line production. Some of the benefits of induction hardening are faster process, energy efficiency, less distortion, and small footprints. Care must be exercised when holes, slots, or other special geometric features must be induction hardened, which can concentrate eddy currents and result in overheating and cracking without special coil and part designs.

II. PROBLEM STATEMENT

Failure of a rear axle on a vehicle can cause a rollover under certain conditions. These conditions usually occur in SUVs because of their higher center of gravity. This work aims at increasing the strength of the shaft.

III. LITERATURE REVIEW

Barsoum, F. Khan , Z. Barsoum [1] Author in this paper has presented finite element modelling of hardened splined shaft. Purpose of research is to determine the torsion strength by considering detailed spline and the material gradation due to the hardness profile. Six different spline geometries and seven different hardness profiles including non-hardened and through-hardened shafts have been considered. From result it is concluded that the torque causing yielding of induction hardened splined shafts is strongly dependent on the hardness depth and the geometry of spline teeth of the shaft. Also concluded that best results can be achieved if the shaft are hardened to half their radius. Some changes were made to geometry and tested for torsion failure. It was found that if dedendum is increased by keeping the addendum same torque is distributed over a larger number of spline teeth.

Robert Crydermana, Nima Shamsaeib, Ali Fatemim [2] this study investigates the influence of continuous cast section size on the mechanical performance of induction hardened parts produced from steel bars. SAE 1050 steel from commercially produced Jumbo Blooms, Blooms, Rotary Round, and Billet were hot rolled into round bars with diameters of 37–44mm. These bars were then normalized, machined into test specimens, the gauge sections were polished, and the specimens were case-hardened by induction hardening. Fatigue test were conducted to study the the effect of the initial continuous cast section size on deformation and fatigue behavior.

Souvik Das, Goutam Mukhopadhyay, Sandip Bhattacharyya[3] Authors have studied fractured axle shafts made of induction-hardened steel to determine the root cause of the failure. Several microstructure and hardness tests like optical microscopes, field emission gun scanning electron microscope (FEG-SEM), energy dispersive spectroscopy (EDS). Chemical analysis indicated that the shaft was made of 42CrMo4 steel grade as
per specification. Microstructural analysis and micro-hardness profile showed that the shaft was improperly heat treated resulting in a brittle case, where crack was found to initiate from the case in a brittle mode in contrast to ductile mode within the core. The analysis suggests that the fracture initiated from the martensitic case as brittle mode due to improper heat treatment process (high hardness).

Dr. Lynn Ferguson, Dr. Zhichao Li, Dr. Valentin Nemkov, Robert Goldstein, John Jackowski, Greg Fett[4] Authors have considered full float type of truck axle into study. The process includes a dwell heating of the flange and a scan hardening of the shaft and spline. Computer simulation of electromagnetic and thermal processes was made using Flux software. The power densities from Flux are then exported and mapped into the DANTE for thermal, metallurgical, stress and distortion simulation. From the results osf simulation it was found that The total length of the axle grows about 2.3 mm after induction hardening, and the shaft shrinks about 4 μm radially. Induction heating affects the residual stress distribution.

Fengjie Yin, Ali Fatemi b, John Bonnen[5] This paper refers to a fatigue life prediction of case hardened steel specimen by considering variable loading conditions. In the study fatigue life predictions were made using a two-layer model based on case and core material fatigue properties and compared to the experimental results. The results concluded that or case-hardened specimens subjected to periodic overload or variable amplitude service load history, the linear damage rule (LDR) resulted in reasonably good life predictions.

Chongxue Zhang, NicolaBowler, ChesterLo[6] Author studied magnetic properties of two sets of carefully characterized 25-mm-diameter case-hardened steel rods were studied with the aim of developing new methods to evaluate the case depth nondestructively. Induction-hardened 4140 steel and carburized 8620 steel rods were studied. Surface-hardening of steel is commonly performed to increase resistance to wear.

C. Kendall Clarke, Don Halimunanda[7] In this paper, author has taken fracture mechanics approach to fing the when axle will fail. The axle can be reliably said to have failed prior to rollover if the estimated force for failure is equal to or less than forces imposed on the axle during events leading to the rollover.

Thomas Neumann, Kenneth Pickett[8] Axle shafts used in this study were made of hot-rolled AISI1050M steel bars having a manganese content of 0.8-1.1%. The axle shaft forging/extrusions are machined and formed to a near net shape condition and then induction hardened and quenched in water to 40 HRC with and effective case depth (ECD) of 0.120 to 0.250 in. (3 to 6.3 mm) in the barrel of the shaft. After hardening, the shafts typically are tempered at an ambient furnace temperature of 280 to 325°F (140 to 165°C) for a minimum of 75 minutes. A post tempered hardness of 60 HRC minimum must be maintained at the bearing journal surface. The results of this work show that effective tempering of induction hardened axle shafts is dependent on actual heat transfer rates and component temperature rather than on time at a specified ambient furnace temperature..

IV. REVERSE ENGINEERING AND ANALYSIS

Dimensions are required for calculating of boundary conditions. Hence its CAD model is necessary. The conventional model used in Bolero vehicles is used. Dimensions are taken through reverse engg i.e through hand calculations. CAD model then is made by the commands in CATIA of Pad, pocket, fillet, and geometrical selections in part design module.
Fig 2: CAD model and meshed model of an axle shaft

Type of element: tetra-hedral
No. Of nodes: 10039
No. Of elements: 52656

**Force Calculation:**
**Specifications of a car engine:**
- Displacement = 2523 cc
- Max power = 46.3 KW
- Max. torque = 195 Nm
- Transfer gear ration = 3.78

**Torque Calculation**

- Velocity, \( V = 120 \text{ Km/h} = 2000 \text{ m/min} \)
- Tire Diameter, \( D = 27.6 \text{ in} = 703 \text{ mm} = 0.703 \text{ m} \)
- Vehicle RPM = Speed of Vehicle / Circumference of tire
  \[
  N_v = \frac{V}{\pi D} = \frac{2000}{\pi \times 0.703} 
  \]
- Drive shaft rpm,
  \[
  N = N_v \times \text{gear Ratio} = 905.57 \times 3.78 
  \]
- Vehicle RPM = 3423.05 rpm
- Power, \( P = 2\pi N T / 60 \)
- \( 46.3 \times 10^3 = 2\pi N T / 60 \)
- \( T = 129.16 \text{ Nm} \)
- Abuse torque by considering FOS= 3.5
- \( T \text{ applied} = 129.16 \times 3.5 = 452.07 \text{ Nm} \)

Fig 3: Torque and constraint applied in Hypermesh

Following are the results displayed for stress and deformation (MS):

Fig: Von-mises stress for axle shaft

- Stress value for axle shaft is 166.945 N/mm\(^2\) which is well below the critical value. Hence, design is safe.
- The maximum displacement is coming out to be 2.5mm.

**V. CONCLUSION AND FUTURE WORK**

This paper gives the relevant information about existing drive axle. From results of finite element analysis it is observed that maximum stress which is maximum at joint location is coming out to be 166.945 N/mm\(^2\) which is within the safety limit. There is a great potential to optimize this safety limit which can be done by adding bush to increase its strength. The maximum displacement value is 2.5 mm which is also very less.

Future work will include induction hardening considering 2mm of case depth and studying its effect.
REFERENCES


