REVIEW ON- BEARING CUP FAILURE ANALYSIS USED IN AUTOMOBILES

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ABSTRACT

Drive shaft is used to transmit torque from transmission gear box to differential. In the study analysis of bearing cup failure in drive shaft assembly was carried out to identify and eliminate the causes of failure investigation of failed parts reveals that the failure was caused due to brittleness caused by through hardening during carburizing of bearing cup. Differentiate surface treatment like carbonitriding, nitriding, were suggested and comparative evaluation was made on the basis of wear test, chemical analysis, hardness test, push-out load test etc. The result reveals that specific wear rate was less for surface treated samples that for untreated sample. Push-out load was more for carbonitriding and nitriding sample as compare to carburizing sample. Carbonitriding and carburizing shows good fatigue strength than nitriding as case achieved in nitriding was less. After evaluating all the processes carbonitriding was selected as alternative surface treatment process.

Keyword: - *Drive Shaft, Carburizing, carbonitriding, Nitriding etc….*

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1. INTRODUCTION

The automobile is a typical industrial product that involves a variety of materials and technologies. The present societal needs necessitate that metallic materials are ideally suited for applications in heavily stressed components that require high durability. A propeller shaft or cordon shaft is a mechanical component for transmitting torque and rotation usually used to connect other components of a drive train that cannot be connected directly because of distance or the need to allow for relative movement between them. The universal joint is used to transfer drive (power) from one shaft to another when they are inclined (non collinear) to each other.

1.1 Elements of Power Transmission System

The movement of vehicles can be provided by transferring the torque produced by engines to wheels after some modification. The transfer and modification system of vehicles is called as power transmission system and has different constructive features according to the vehicle‘s driving type which can be front wheel drive, rear wheel drive or four wheel drive. Fig.1 gives elements of a front wheel and a rear wheel drive power transmission system. The elements of the system include clutch, transmission system, propeller shaft, joints, differential, drive shafts and wheels. Each element has many different designs and construction properties depending on the brands of vehicles. The carden shaft also called drive shaft is used to transmit motion from gear box to differential. The universal joint consists of two forged-steel yokes or forks joined to the two shafts being coupled and situated at an angle to each other. Friction due to rubbing between the journal and the yoke bores is minimized by incorporating needle-roller bearings between the hardened journals and hardened bearing caps pressed into the yoke bores.

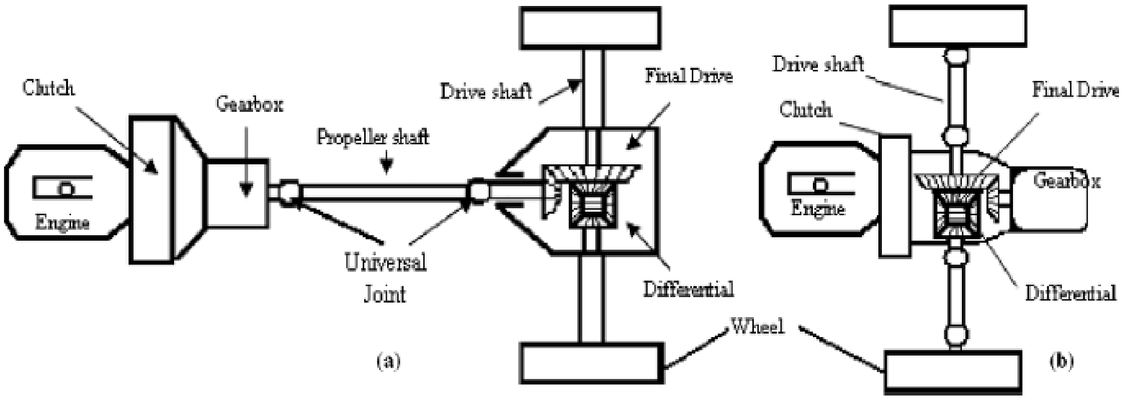

Fig. 1: Elements of Power Transmission System (a) Rear Wheel Drive (b) Front Wheel Drive

1.2 Factors Considered During Propeller Shaft Design

The propeller shaft in an application must perform certain basic functions.
Following are the main factors which should be considered during designing of propeller shaft.
1. Torque
The basic purpose of propeller shaft in an application is to transmit torque through an angle between the power source and the driven member.
2. Rotation
The propeller shaft should be capable of rotating through a speed range as required by given application.
3. Angles
The universal joints used in propeller shaft must be capable of operating at fixed or varying angles.
4 Length changes
The propeller shaft in an application should compensate length variation.

2. LITERATURE REVIEW

The literature survey is carried out as a part of the project work. It has provided review of the past research about propeller shaft failures and other researches. Literature review is carried out for various heat treatments and its effect on wear and fatigue. The past research effort will properly guide to justify the scope and direction of the present effort.

2.1 Literature Review Related To Drive Shaft

There have been several studies on drive-shaft malfunctions. Heat treatment was responsible for a majority of the failures. Godec et. al. [2009] investigated a car‘s drive shaft that ruptured at a very early stage of its use (7000 km). Scanning electron microscopy revealed an inter-crystalline fracture in the carbo-nitrided region of the shaft. This suggests an incorrect heat treatment procedure, such as an inappropriate austenitisation temperature, and tempering time, which caused the embrittlement by promoting the appearance of a Fe_3C layer at the grain boundaries and additional phosphorous segregation [1].
Bayrakceken et.al. [2006] did failure analysis of an automobile differential pinion shaft which reveals that the fracture has taken place at a region having a high stress concentration by a fatigue procedure under a combined bending, torsion and axial stresses having highly reversible nature. The crack of the fracture is initiated probably at a material defect region at the critical location [2].
Makevet et.al.[2006] in their paper present a case study in failure analysis of a final drive transmission in an off-road vehicle. The failure involved a satellite gear mounting shaft that departed from the differential assembly as a result of fracturing of a retaining pin. An investigation of the mechanical condition of various transmission components, consisting primarily of visual (macroscopic) inspection, geometrical investigation and analysis of mechanical loads, led to the assignment of two principal causes of failure [3]. Asi [2006] studied the failure analysis of a rear axle shaft used in an automobile which had been involved in an accident. The axle shaft was found to break into two pieces. The investigation was carried out in order to establish whether the failure was the cause or a consequence of the accident. An evaluation of the failed axle shaft was undertaken to assess its integrity that included a visual examination, photo documentation, chemical analysis, micro-hardness measurement, tensile testing, and metallographic examination. The failure zones were examined with the help of a scanning electron microscope equipped with EDX facility. Results indicate that the axle shaft fractured in reversed bending fatigue as a result of improper welding [4].

2.2 Literature Review Related To Different Surface Treatments

Funatani et. al. [2004] presented various heat treatments and surface technology which satisfy customer needs and environmental norms. Heat treatment and surface modification are the key technologies available today to enhance the effective use of materials, to achieve the desired properties of the components used in the automotive industries, to save energy and conserve natural and surface modification technologies including future technological possibilities of relevance to the automotive industry are also reviewed [5].

Ulutan et. al [2010] studied effect of different surface treatment methods on the friction and wear behaviour of AISI 4140 steel in this study sample surfaces of AISI 4140 steel were treated by quenching, carburising, carborizing and plasma transferred arc (PTA) modification. The microstructural characteristics of surface treated steel samples were examined by optical microscopy and scanning electron microscopy (SEM). The mechanical properties of the samples including the surface roughness, micro hardness, and abrasive and adhesive wear characteristics were also evaluated. Wear tests were applied by using a block-on-disc configuration under dry sliding conditions. The wear behavior and friction characteristics of the samples were determined as a function of sliding distance. Each sample group was compared with the other sample groups. It was observed that the carburized samples demonstrated the lowest weight losses; however, PTA-treated samples demonstrated the lowest coefficient of friction in comparison to the other sample groups at the same sliding distance [6]. Rodzinak et al. [2010] studied effect of nitridation on contact fatigue and wear damage of Astaloy crL and crM steels they studied using pin on disc technique that wear testing did not yield unambiguous results. They were not in direct accordance with contact fatigue results. The two damage mechanisms are based on different principles. Behavior of PM materials is not sufficiently explored at present. It appears that the wear is more related to microhardness type of resulting carbides and their exclusion, evenly in the grain or grain boundaries. It is necessary to verify this supplementary observation by targeted laboratory procedures. It is found that the nitridation improves the wear resistance of the experimental materials the differences between the material variants were insignificant [11]. Fillari et.al. studied effect of case carburizing on mechanical properties and fatigue endurance limits of p/m steels study describes resistance and of PM steel components. The key to the successful improvement in carburizing however is understanding and interpreting the microstructure of the carburized case. The main area for growth in the PM industry is in the high performance gearing applications. The success of penetrating this area depends upon the ability to understand the key components that affect the fatigue endurance limits of PM. The carburized samples resulted in fatigue endurance limits equivalent to or greater than samples that were machined from AISI 8620 wrought [12]. Shaw et. al. studied surface treatment and residual stress effects on the fatigue strength of carburized gears they presented results from an investigation into the effects of different surface peening and blasting processes on the bending fatigue strength of pulsator tested case carburized gears. The main conclusions were large increases in fatigue strength can be produced, through the careful control of the condition of the surface layers of material in a carburized gear. Controlled peening has been shown to be effective in suppressing the detrimental effects of internal surface oxidation and it has been found that in the absence of surface oxidation and oxide inclusions, larger MnS inclusions will act as initiation sites for fatigue [13].

2.3 Critical Discussion On Literature Review.

Several researchers studied the failures of elements of power transmission system as there are many cases of failures. Bayrakceken studied failure of pinion shaft which reveals that fracture has taken place at high stress concentration. Godec studied failure of car‘s drive shaft which was due to incorrect heat treatment procedure. Makevet analysed failure of final drive transmission in off road vehicles which was due to fracture of retaining pin.

Asi studied failure of rear axle shaft which was due to reverse bending fatigue. Some studies for alternative design and production of propeller shaft which was the biggest element of the system of rear wheel drive vehicles are carried out. Lee et al. proposed an aluminum matrix composite shaft. They carried out some stress analysis of proposed shaft by finite element technique. By using this single part shaft instead of the conventional two part shaft has given a 75% weight reduction and 160% increase of torque transmission capacity.

After review of several research papers related to wear, following important information related to selected problem was gathered which could lead to decide the methodology and solution.

Carburized samples demonstrated the lowest weight losses as compared to quenched and carbonized sample when tested for wear for AISI 4140 steel [6].Samples having greater case depth and surface hardness are more wear resistant than that with low case depth and low surface hardness [7]. Induction hardening improves wear resistance of steel [8]. Nitriding improves wear and friction properties of steel [9]. Fatigue and wear of case hardened steel is maximum when the concentration of carbon in the surface layer is 1-1.2% [16]. Nitriding improves fatigue resistance of steel [10]. Carburized samples improve fatigue limit of steel

[12]. Carbonitriding improves fatigue limit of steel [14]. Microstructure plays important role in promoting fracture and fatigue [15]. Fatigue performance of the high temperature gas carburized specimens was relatively poor compared to the conventionally gas carburized specimens [17].

3. PROBLEM DEFINITION

After all this literature review we conclude that in most of cases in drive shaft failure stress concentration and improper heat treatment were the prime cause for failures. From study related to surface treatment, it is concluded that we will able to achieve case hardness and hence wear resistance by various processes like induction hardening, carbonitriding, nitriding, carburizing which can probably eliminate the through hardening of steel hence we decided to study this process on various parameters and do experimentation to achieve wear resistance and fatigue strengths with cost effective solution.

3.1 Heat Treatment

Selection of steel types and grades and appropriate heat treatment methods are very important to produce components of reliable quality. The control of a given alloy‘s chemical composition and the inclusion content of steel have an impact upon and can create variance in an alloy‘s properties. Other contributing factors impacting the quality and reliability of final components include refining, casting, rolling and cooling methods. Further strength, toughness, fatigue strength and wear properties result largely from the microstructure and hardness results created by heat-treatment condition and methods applied. As a result it is quite important to be cognizant of these factors and to ensure that appropriate methods are applied. As per Kiyoshi Funatani [5].

3.1.1 Carburizing

Carburizing is a case-hardening process in which carbon is dissolved in the surface layers of a low-carbon steel part at a temperature sufficient to render the steel austenitic stucture, followed by quenching and tempering to form a martensitic microstructure [5]. Carburizing is a remarkable method of enhancing the surface properties of shafts, gears, bearings, and other highly stressed machine parts. Low-carbon steel bars are fabricated by forging and machining into finished shapes and then are converted by carburizing into a composite material consisting of a high-carbon steel case and low-carbon steel core. When this steel composite is quenched to martensite and tempered, the high hardness and strength of the case microstructure, combined with the favorable case compressive residual stress developed by interactions between the case and core during quenching produce very high resistance to wear, bending fatigue and rolling-contact fatigue.
At first glance, the microstructures of carburized steels appear to be quite straightforward. High-carbon martensite is gradually replaced by martensite of lower carbon content with increasing distance from the carburized surface. This view of the microstructures of carburized steel is essentially correct. Lightly tempered martensite is the dominant microstructural constituent of properly carburized steel.

3.1.2 Carbonitriding

Carbonitriding is a modified form of gas carburizing, rather than a form of nitriding. The modification consists of introducing ammonia into the gas carburizing atmosphere to add nitrogen to the carburized case as it is being produced. Nascent nitrogen forms at the work surface by the dissociation of ammonia in the furnace atmosphere; the nitrogen diffuses into the steel simultaneously with carbon. typically, carbonitriding is carried out at a lower temperature and for a shorter time than is gas carburizing, producing a shallower case than is usual in production carburizing. In its effects on steel, carbonitriding is similar to liquid cyaniding. Because of problems in disposing of cyanide-bearing wastes, carbonitriding is often preferred over liquid cyaniding. In terms of case characteristics, carbonitriding differs from carburizing and nitriding in that carburized cases normally do not contain nitrogen, and nitrided cases contain nitrogen primarily, whereas carbonitrided cases contain both.

3.1.3 Nitriding

A typical commercial bath for liquid nitriding is composed of a mixture of sodium and potassium salts. The sodium salts, which comprise 60 to 70% (by weight) of the total mixture, consist of 96.5% NaCN, 2.5% Na_2CO_3, and 0.5% NaCNO. The potassium salts, 30 to 40% (by weight) of the mixture, consist of 96% KCN, 0.6% K_2CO_3, 0.75% KCNO, and 0.5% KCl. The operating temperature of this salt bath is 565 °C (1050 °F). With aging the cyanide content of the bath decreases and the cyanate and carbonate contents increase (the cyanate content in all nitriding baths is responsible for the nitriding action, and the ratio of cyanide to cyanate is critical). This bath is widely used for nitriding tool steels, including high-speed steels, and a variety of low alloy steels, including the aluminium-containing nitriding steels.

3.2 Methodology

Following steps are involved for analysis

Step 1: Select the Theme.
Step 2: Justify the choice.
Step 3: Understand the current situation. .
Step 4: Analysis.
Step 5: Implement corrective measures.
Step 6: Confirm the Effects.
Step 7: Standardize.
Step 8: Summarize & Plan future actions.

Experimental study of selected processes was planned as per following tests.

1) Microstructure study of selected processes.
2) Hardness gradient study of selected processes.
3) Wear test of selected processes.
4) Push out force of selected processes.

4. CONCLUSIONS

After experimental study conclusions were drawn and best cost effective solution was selected for implementation and result monitoring after implementation of solution. Change in surface treatment with induction hardening scored low on high capital investment and delivery time. Other proposals of changing surface treatment to carbonitriding and nitriding scored almost same and hence considered for experimentation. After evaluating all the processes results carbonitriding surface treatment process selected as a probable cost effective solution.

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