Experimental Analysis of Bearing Cup Used In Automobiles by Heat Treatment Processes

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ABSTRACT

In Automobile Propeller Shaft assembly, bearing cup assembly get cracked during operation in universal joint. This was highest rejection; hence it was decided to eliminate bearing cup failure in drive shaft assembly with effective solution. Investigation of failed part reveals that due to improper heat treatment like through hardening bearing cup get brittle. Differentiate surface treatment like carburizing, nitriding and hardening were suggested and comparative evaluation was made on the basis of chemical analysis, hardness test, microstructure study etc. After evaluating all the processes result reveals that carburizing process as heat treatment process for bearing cup assembly has given good results over earlier process of surface hardening.

INTRODUCTION

A propeller shaft or cardan 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. 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.

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. Further strength, toughness, fatigue strength and wear properties result largely from the microstructure and hardness results created by heat-treatment condition and methods applied.

Carburizing

In this method carburizing is done by immersing the steel components in a carbonaceous fused salt bath medium at a temperature in the austenitic region. The bath is composed of sodium cyanide, sodium carbonate and sodium chloride. Alkaline earth salts of barium,calcium or strontium are usually added to the bath to encourage the cyanamide shift.

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 structure, followed by quenching and tempering to form a martensitic microstructure. 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 [3].

Nitriding

Gas nitriding is a case-hardening process whereby nitrogen is introduced into the surface of a solid ferrous alloy by holding the metal at a suitable temperature (below Ac1, for ferritic steels) in contact with a nitrogenous gas, usually ammonia. Quenching is not required for the production of a hard case. The nitriding temperature for all steels is between 495 and 565 °C (925 and 1050 °F).

The term liquid nitriding has become a generic term for a number of different fused-salt processes, all of which are performed at subcritical temperature. Operating at these temperatures, the treatments are based on chemical diffusion and influence metallurgical structures primarily through absorption and reaction of nitrogen rather than through the minor amount of carbon that is assimilated. 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).

Induction Hardening

It is widely applied to automotive components that require locally hardened areas. Cam shafts, ball joint stud and miscellaneous components are induction hardened to yield high surface hardness by induction heating and quenching. Induction heating is also an energy efficient heat treatment process not only for hardening but also having the benefit of being able to soften selected areas for improvement of toughness in case hardened components. Recent technology enabled hardening of gear tooth profile via the precise control of heating cycle and optimum coil design. This profile hardening process can introduce extraordinary high compressive residual stress at the surface layer compared with traditional carburizing and hardening processes. The combination of technologies to optimize case depth with the high residual compressive stresses seems to expand their application into gearing of transmission and machines [3].

EXPERIMENTATION PLAN:

Following tests were planned for selected processes
1) Chemical Composition Analysis.
2) Heat treatment processes.
3) Hardness measurement of selected processes.
4) Microstructure Study of selected processes.

Tools and Testing Machines:

Following tools and test rigs were used during experimentations.
1. Rockwell Hardness Testing machine.
2. Microscope.
3. Spectrometer

Chemical and Metallurgical Analysis

Bearing cup subjected to different heat treatment procedures like carburizing, liquid nitriding and hardening. These cups were tested for chemical, metallurgical analysis and hardness test.

CARBURIZING PROCESS

Carburized Samples

Bearing cup samples were surface treated by carburizing at 920ºC and hardening at 850ºC and tempering at 180ºC in vertical retort furnace. Chemical analysis was performed by spectrometry. Chemical compositions are tabulated in Table 2.1, material composition confirms to SAE1117.

C	Si	Mn	P	S	Cr	Ni
0.419	0.160	0.500	0.0448	0.0484	0.038	0.020

Microstructure:

Microstructure of carburized sample has been examined and following conclusions have been drawn. Micrograph at 100 % magnification etched with 3% nital (3% conc. Nitric acid in methanol solution)

solution was taken with microscope as shown in Fig 2.1. It was observed that the microstructure near surface was fine tempered martensite with some amount of retained austenite.

Hardness Measurements:
Hardness measurement of carburized bearing cup samples was done on Rockwell hardness tester with 60 kg load and diamond indenter following readings was taken for sample.
Surface hardness – Observed value – 78-83 HRA.
Case Depth Measurement: 0.2 – 0.35 mm.

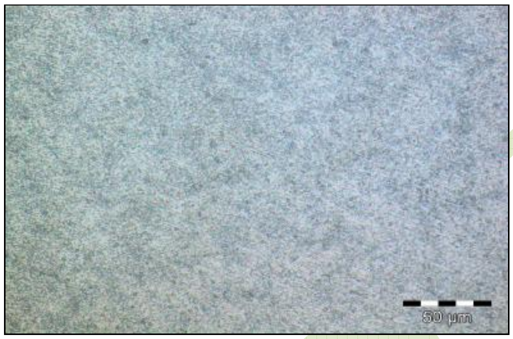

Fig.2.1 Case Microstructure of SAE 1117 Carburized Specimen Nital 3% 100X

Table shows the experimental results after Carburizing Process on bearing cup.

Table 1.1: Shows Experimental results after completion of Carburizing Process.

A)CARBURIZING				
	FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
	TEMP(°C)	900	910	920
	TIME(Hrs)	1	1.25	1.5
EXPT. NO.	**TEMP**	**TIME**	**CASE DEPTH**	**HARDNESS**
1	900	1	0.2 mm	78 HRA
2	900	1.25	0.25 mm	79 HRA
3	900	1.5	0.3 mm	80 HRA
4	910	1	0.21 mm	79 HRA
5	910	1.25	0.27 mm	80 HRA
6	910	1.5	0.32 mm	82 HRA
7	920	1	0.23 mm	79 HRA
8	920	1.25	0.29 mm	80 HRA
9	920	1.5	0.35 mm	83 HRA

NITRIDING PROCESS

Nitrided samples

Bearing cup was liquid nitrided, chemical analysis was performed by spectrometry. Chemical compositions were tabulated in Table 2.2, material confirms to SAE117 steel.

Table 2.2: Chemical composition in (wt%) SAE 1117

C	Si	Mn	P	S	Cr	Ni
0.419	0.160	0.500	0.0448	0.0484	0.038	0.020

Microstructure:
Microstructure of nitrided sample has been examined and following conclusions have been drawn. Micrograph at 100 % magnification etched with 3% nital solution was taken with optical microscope as shown in Fig.2.2. It was observed that the microstructure near surface was fine tempered martensite with some amount of retained austenite.
Hardness Measurement:
Hardness measured on Rockwell hardness tester at load 150 kg with diamond indenter

Following reading were taken
Surface Hardness – Observed value – 788 Hv1.
Case Depth Measurement: 12 – 17 microns.
From these readings it was observed that for nitrided sample case depth is less as compared to carburized samples.

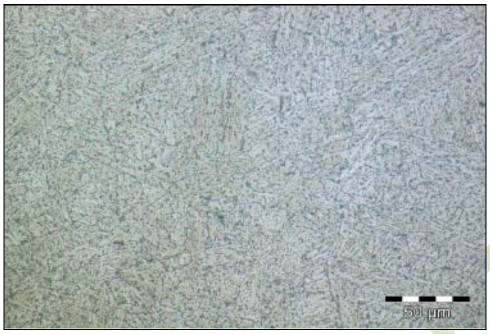

Fig.2.2 Case Microstructure of Nitrided Specimen Nital 3 % 100 X

Table shows the experimental results after Nitriding Process on bearing cup.

Table 1.2: Shows Experimental results after completion of Nitriding Process.

B) NITRIDING				
	FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
	TEMP(°C)	550	560	570
	TIME(Min)	50	55	60
EXPT. NO.	**TEMP**	**TIME**	**CASE DEPTH**	**HARDNESS**
1	550	50	0.012 mm	701 Hv
2	550	55	0.013 mm	713 Hv
3	550	60	0.014 mm	746 Hv
4	560	50	0.013 mm	733 Hv
5	560	55	0.014 mm	746 Hv
6	560	60	0.015 mm	753 Hv
7	570	50	0.015 mm	766 Hv
8	570	55	0.016 mm	773 Hv
9	570	60	0.017 mm	788 Hv

HARDENING PROCESS

Hardened Samples

Bearing cup samples hardening at 850ºC Tempering at 180ºC in vertical retort furnace. Chemical analysis was performed by spectrometry. Chemical compositions are tabulated in Table 2.3, material compositions confirms to SAE1117.

Table 2.3: Chemical composition in (wt%) SAE 1117

C	Si	Mn	P	S	Cr	Ni
0.419	0.160	0.500	0.0448	0.0484	0.038	0.020

Microstructure:

Microstructure of hardened sample has been examined and following conclusions have been drawn. Micrograph at 100 % magnification etched with 3% nital solution was taken with optical microscope as shown in Fig 2.3. It was observed that the microstructure near surface was fine tempered martensite with some amount of retained austenite.

Hardness Measurements:

Hardness measurement of hardened bearing cup samples was done on Rockwell hardness tester. With 150 kg load and with diamond indenter following readings were taken for sample.

Surface hardness – Observed value – 48-52 HRC.

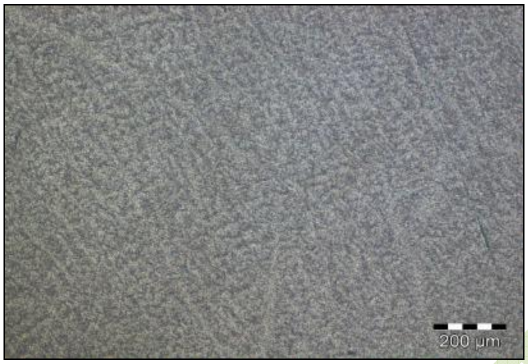

Fig.2.3 Case Microstructure of Hardened Specimen Nital 3 % 100 X

Table shows the experimental results after Hardening Process on bearing cup.

Table 1.3: Shows Experimental results after completion of Hardening Process.

C) HARDENING				
	FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
	TEMP(°C)	850	860	870
	TIME(Min)	10	15	20
EXPT. NO.	**TEMP**	**TIME**	**Case Depth**	**Hardness**
1	850	10	0.011	48 HRC
2	850	15	0.012	48 HRC
3	850	20	0.013	50 HRC
4	860	10	0.011	50 HRC
5	860	15	0.013	50 HRC
6	860	20	0.013	51 HRC
7	870	10	0.011	52 HRC
8	870	15	0.012	52 HRC
9	870	20	0.013	52 HRC

SUMMARY OF RESULTS

After reviewing all results following conclusions can be drawn

In this study failure analysis of bearing cup was carried out. Bearing cup assembly was produced from SAE1117 low carbon carburizing steel and was surface treated by hardening and tempering processes.

1. Carburizing process achieve good results to achieve martensite structures which gives good wear resistance.

Hardness achieved at surface was within range of 78-83 HRA case depth achieved was high around 0.35 mm.

2. Hardening process shows good results to achieve martensite structures which give good wear resistance, hardness achieved at surface was within range of 48-52 HRC. Case depth achieved was less as compared to Carburizing and Nitriding around.

3. Nitriding process achieve good surface hardness @ 788 Hv1, however case depth achieved was less within 17 microns ,case microstructure was fine tempered martensite.

4. Carburizing can replace over Carbonitriding, nitriding, tempering process in bearing cup assembly surface treatment process hence it implemented as solution.

5. Carburizing process as heat treatment process for bearing cup assembly has given good results over earlier process of surface hardening

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