Analysis of Distortion Behavior of TRB races during Heat Treatment

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Abstract - **Bearing is an important element of machine which bears the load and also reduces friction. Therefore, manufacturing process of bearing has to be precise for unhindered and smooth rotation. There are chances of faulty manufacturing of bearing. The present work focuses on the reduction of ovality in the cup of taper roller bearing. Ovality is a degree of deviation from perfect circularity of the cross section of core. The problem of ovality arises mainly during quenching process due to non-homogenous cooling of track and outer diameter of cup. As a consequence of ovality, the track will not trace the roller path and there will be more friction between the cup and rollers thereby leading to reduction in bearing life. This paper focuses on reduction of ovality in taper roller bearing cup which arise majorly during the heat treatment and subsequent quenching.**

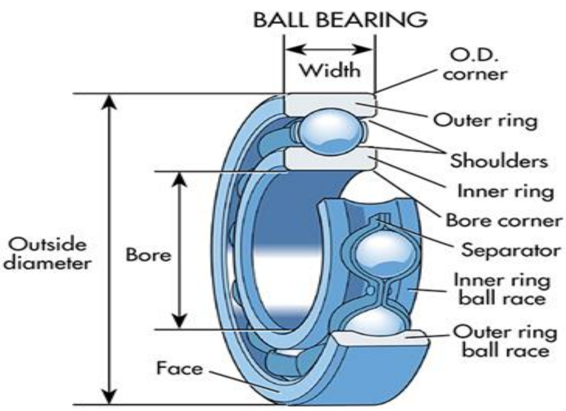
Keywords —Tapered Roller Bearings, Heat Treatment, Ovality, Quenching, Distortion

I. INTRODUCTION

Basically, Bearings are precision-made components that help machinery to move at high speeds and carry heavy loads with ease and efficiency. Generally, SAE52100/SUJ2 Grade steels are used for manufacturing of Tapered Roller and Ball Bearings. Bearings are classified in four categories with particular characteristics suited to specific applications. These categories are: Ball bearings, Taper Roller bearings, cylindrical and needle roller bearings, spherical bearings [1], [2], [3].

A ball bearing is ball type rolling-element bearing that uses balls to maintain the separation between the moving parts of the bearings - the inner and outer part of the bearings. The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. Ball bearings are of simple design, durable in operation and easy to maintain. They are available in single and double row designs and in open and sealed variants. Some other types of bearings available in market are Deep Groove Single Row Ball Bearing and Double Row Angular Contact Ball Bearing (DRAC). Due to their low frictional torque, they are suitable for high speeds.

A taper roller bearing is used to bear combined axial and radial loads, such as in wheel applications in cars. The tapered roller bearing as shown comprises of cup and cone, made from bearing steel 100Cr6(0.97% C) and the tapered rollers so that vertices of raceways and the roller axes, when projected, coincides at common point center line of the bearing, which is called Apex Point. Such geometry makes the motion of cones remain coaxial and ensures true rolling motion on track surfaces of cone and cup. The function of cage is to retain and guide the rollers. Fig.1 represents sectional view of the Tapered roller bearing and Ball bearing [4], [5], [7], [10]



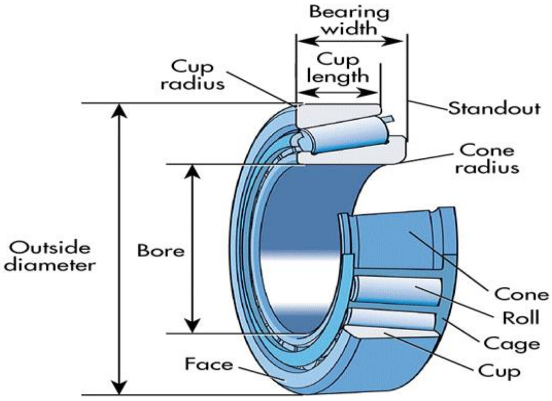


Figure 1.Design of Ball and Tapered Roller Bearings

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II. MATERIAL ANALYSIS

2.1. Process Flow

Manufacturing of bearing components are followed by general flow chart as shown in fig.2.

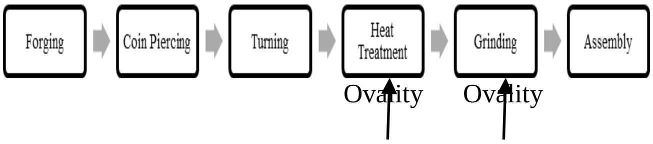

Figure 2.General flow chart for manufacturing of bearing races

2.2. Heat Treatment of Bearing Steels

Heat-treatment of SAE52100 steel is done to achieve various mechanical properties such as desired hardness of about 60 to 62 HRC, excellent wear resistance and high load carrying capacity. Microstructure with uniformly distributed Carbides in Martensite will give improved ductility and high impact strength along with high hardness value. Heat-treatment cycle for bearing steels is given below [2], [5], [11].

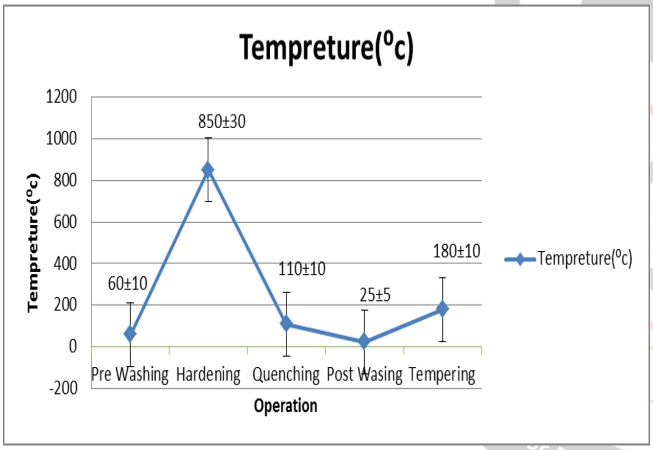

Figure 3.Heat-treatment cycle for manufacturing of bearing races

2.3. Chemical Composition of Bearing Steels

Standard required amount of alloying elements compared with actual amount present in SAE52100 bearing steel in raw as well as heat treated condition is mentioned in the tables given below.

Table 1&2.Spectroscopic Analysis and Comparison of Chemical Composition of Bearing Steels

Parameters	Material Type	Raw Material / Turned Races			
		Elements	Std. Value		Actual Value
			Min	Max	
Chemical Composition	SAE52100/SUJ2	%C	0.93	1.05	0.99
		%Mn	0.25	0.45	0.34
		%Si	0.15	0.35	0.23
		%S	-	0.015	0.008
		%P	-	0.025	0.009
		%Cr	1.35	1.6	1.51
		%Ni	-	0.25	0.015
		%Mo	-	0.1	0
		%Cu	-	0.25	0.12
		%V	-	0.05	0.001
		%Al	0.01	0.05	0.018
		%Ti	-	30 ppm	12 ppm

Parameters	Material Type	Heat Treated Material			
		Elements	Std. Value		Actual Value
			Min	Max	
Chemical Composition	SAE52100/ SUJ2	%C	0.93	1.05	0.97
		%Mn	0.25	0.45	0.33
		%Si	0.15	0.35	0.27
		%Cr	1.35	1.6	1.47
		%S	-	0.015	0.005
		%P	-	0.025	0.011
		%Ni	-	0.25	0.022
		%Cu	-	0.25	0.015
		%O	-	0.05	0.002

Amount of Carbon is a very important parameter in terms of applicability of the final product. The higher amount of carbon will result in the presence of carbides in the microstructure of heat treated part that will generate internal stresses in the same and will lead to higher hardness and higher ovality. Higher amount of carbon will also increase brittleness of part. Presence of Cr and Mn will impart wear resistance, toughness and machinability while Si will help in getting desirable ductility in bearing races.

2.4. Description of the problem of ovality

Ovality in bearing may occur during turning and heat treatment. There is a risk of ovality as a consequence of residual internal stresses left after turning. They also arise during phase changes as the material is subjected to quenching. They occur in different severity depending on the heating and quenching cycle. The processing factors affecting ovality include feeding mechanism, hardening time, temperature, cooling rate, quenching media, agitation during quenching, quench oil temperature and tempering temperature. The quenching parameter heat transfer coefficient is critical to process and depends on agitation, temperature and stacking condition. The preferable quenching media are oil and salt bath as compared to normal water quenching. The agitation during quenching leads to rapid heat transfers and thus affects the quenching severity [13], [15], [16], [17].

Ovality problem arises during heat treatment of bearing cup. It is measured as the difference in diameters measured in a plane in two perpendicular directions. The shape of bearing cup has to be perfectly circular. The primary focus of the research is to reduce this Ovality to as lesser as possible. Ovality can be measured by the relation as shown below [9], [10].

Ovality (%) = (Max OD-Min OD) / (Nominal OD) ×100

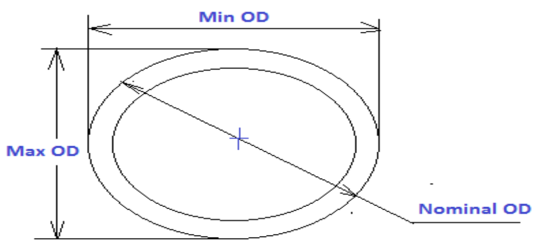

Figure 4.Ovality in Bearing Races

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III. EXPERIMENTAL SOLUTION OF OVALITY PROBLEM IN BEARINGS

Ovality occurs due to uneven heating and quenching during heat treatment. There are four zones of heating in heat treatment furnace and there has to be a gradual increase in temperature from period to period where the total heating time will equally be divided into a number of periods within the furnace. Therefore, the table below suggests specifications for hardening and tempering of bearing races to eliminate the problem of ovality. In general, hardening of SAE52100 is done at around 850 ºC where the stability of Liquid Austenite will be quite higher. So, infinitesimal amount of austenite will not convert into martensite during quenching. High stability of Austenite will result in presence of retained austenite in microstructure of end product after tempering. Presence of retained austenite will results in formation of internal stresses in microstructure that results in lower hardness and higher distortion in final product [12], [14], [15], [16].

Table 3.Process parameters for Heat-treatment

Parameters	Hardening	Tempering
Furnace	Hardening Furnace	Tempering Furnace
Periodic Temperature (℃)	830 ± 20 ºC for 10± 2 min	170 ± 20 ºC
	830 ± 10 ºC for 10± 2 min	170 ± 5 ºC
	830 ± 10 ºC for 10± 2 min	170 ± 5 ºC
	830 ± 5 ºC for 10± 2 min	NA
Quenching Media Temperature (℃)	115 ± 10 ºC	NA
Feeding Mechanism	Direct feeding on furnace surface/Single layer	Direct feeding
Quenching Severity	Low	NA
Heating Time	35-45 min	110 min

The specifications mentioned in Table 3 results in lower ovality in bearing races having size in the range of 40-60 mm Bore diameter [14], [15], [16].

3.1. Metallurgical Specifications

Required metallurgical specifications for raw and heat-treated material are mentioned below. All metallurgical specifications are found within the specifications [8],[9], [13].

Table 4.Metallurgical analysis of turned material

Parameters	Specified	Observed
Hardness	207 BHN max.	187 BHN
Microstructure	Spherodized Structure of evenly dispersed small globular carbides	Spherodized Structure of evenly dispersed small globular carbides
Decarburization	Nil	Nil
Perlite amount	3.0 max	3.0
Carbide Network	CN 4.2 or CN 5.2 max	5.1
Carbide Bending	CZ 6.2 max.	6.1

Figure 5.Microstructure of turned races at 1000x magnification

From above microstructure we can say that globular carbides are uniformly distributed in pearlite microstructure. Since pearlite is available in microstructure as a major content, hardness of races in soft condition will be quite less. Through hardening followed by quenching and tempering is required in order to get desired mechanical properties.

Carburizing prior to hardening may also be required in cases where we are using having very low carbon content other than SAE52100 steel.[5], [14]

Table 5.Metallurgical Analysis of SAE52100 (after Heat-treatment)

Parameters	Specified	Observed
Etachant used	10% Nital	
Hardness (HRc at 150kgf)	63 to 67	65
Microstructure	Uniformly distributed carbide in tempered Martensite matrix	Uniformly distributed carbide in tempered Martensite matrix
Decarburization	Nil	Nil

Figure 6.Microstructure of heat treated races at 1000x magnification

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Here, in the microstructure of final product, carbide spots are uniformly distributed in tempered martensite metrix. Generally carbides are present on the boundary martensite. Martensite formed after heat treatment will have very high hardness that will result in brittleness of part. In order to reduce hardness and residual stresses tempering below 180°c with sufficient time is required.[7], [11]

IV. Conclusion

The ovality mainly arises due to uneven temperature distribution in different heating zones of hardening furnace and uneven cooling during the quenching process. Major factors affecting the distortion behavior of bearing races are heating temperature and quenching severity. Lowering the Temperature from 850°c to slightly below 835°c along with low quenching severity will result in desirable hardness as well as quite less distortion. Tempering temperatures and time will also effect ovality at some extent. Also, the different temperatures in hardening furnace are to be controlled and minimum variation is to be maintained across different hardening and tempering regions. Thus, a 9 point temperature uniformity survey is suggested to be done for the furnace. Higher tempering time will reduce internal stresses of hard bearing races and will help in reducing ovality issue. Therefore, the standard hardening and tempering parameters have been suggested to reduce ovality to minimum level.

References

[1] B. Beekhuis, D. Stöbener, E. Brinks meier, G. Goch, Compensation of part distortion in soft-turning of bearing rings, IDE 2011, Bremen, Germany, September 14th – 16th 2011, pp 53 to 61.).

[2] Clausen, B.; Frerichs, F.; Klein, D.; Kohlhoff, T.; Lübben, Th.; Prinz, C.; Rentsch, R.;tofication of process parameters affecting distortion of disks for gear manufacture - Part I: casting, forming and machining. Proc. 2nd Int. Conf. on Distortion Engineering IDE 2008, September 17-19 2008, Bremen, Germany, p. 29- 39.

[3] Walton, H.: Dimensional changes during hardening and tempering of through--hardened bearing steels. Quenching and Distortion control (Conference Proceedings), ASM International, 1992, S. 265--273.

[4] Löser, K.; Heuer, V.; Faron D.R.: Distortion control by Innovative Heat Treating Technologies in the Automotive Industry. In: HTM 61 (2006) -- 6, page 326--329.

[5] Minarski, P., F. Preisser and R. Zenker. "Quenching Steel Parts in 20-Bar." Advanced Materials & Processes, April, 2000, pp. 23–26.

[6] R.W. Shin and G.H. Walter, in Proceedings of Residual Stresses for Engineers and Metallurgists, J. Vande Walle, Ed., American Society for Metals, 1981, p 1-20.

[7] B.R. Wilding, Heat Treatment of Engineering Components, Iron and Steel Institute, 1970, p 20-25.

[8] G.F. Melloy, Hardening of Steel, lesson 5, in Heat Treatment of Steels, Metals Engineering Institute, American Society for Metals, 1979, p 1-28J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[9] Mechanical Metallurgy by George E. Dieter.

[10] D. Scott MacKenzie, Andrew L. Banka, Evaluation of flow fields and orientation effects around simple geometries during quenching. IDE 2011, Bremen, Germany, September 14th– 16th 2011, pp 91 to 100.

[11] (1983), Thermal Processing of Steels, 384p, SNTL, Praha.

[12] ZVL auto spol, s.r.o. Presov (2008), Internal Documentation for tapered roller bearing production, Preshov.

[13] Kobasko, N.I. ; Liscic, B., Tensi, H.M. Luty, W.(Eds.) (1992). Intensive steel Quenching methods. Theory and Technology of Quenching. Berlin: springer-vertag, New York, Tokyo, 367-389.

[14] Kalpakjian, S., Manufacturing process for engineering materials, 3rd ed., 1997, Addison -Wesley, Menlo Park, California.

[15] Marinescu I.D., Hitchiner M., Uhlmann E. Rowe, W.B.,and Inasaki, 2007 Handbook of Machining with Grinding Wheels, CRC Press NY.

[16] Surm, H., and F. Hoffmann. "Influence of clamping conditions on distortion during heating of bearing rings." Materialwissenscharft und Werkstofftechnik40.5-6(2009):396-401-Books.

[17] Anton Panda, Jozef Jurko and Iveta Pandova., "Deformation Reduction of Bearing Rings by Modification of Heat Treating" Heat Treatment - Conventional and Novel Applications" 2012.

 DOI : 10.18231/2454-9150.2019.0398