

# Control of Irregular Expansion of Bearing Races after Heat Treatment

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**Abstract:** Through hardenable bearing races are prone to distortion and size changes during heat treatment as a result of the complex interaction of stress induce by thermal gradient and phase transformation dimensional changes essentially depend on precipitation of fine carbide from martensite and decomposition of transformation of retained austenite. In the present work, an attempt has been made to provide the required dimensional stability to bearing races after heat treatment by optimization of the heat treatment process parameters through design of experiments. Results have been discussed in light of phase transformation, i.e., stabilization of retained austenite

**Keywords:** Heat Treatment, Stress, Martensite, Austenite, Optimization

## 1. Introduction

Heat treatment of bearing components involves heating and cooling under controlled atmosphere to impart the desired hardness, dimensional stability along with high fracture toughness, ductility, high tensile strength, good machinability, and reduce stress. Hardness is an influential heat-treatment-induced variable. For most rolling bearing applications it is required that the Rockwell C hardness at operating temperature is 58 degree or higher [1]. In general, the higher the hardness of the bearing steels at operating temperature, the longer the life. A relationship that approximates the effect of bearing material hardness on fatigue life has been developed [2].

$$LF = \exp \{m [(RC)_T - 60]\}$$

Where  $m$  is an exponent relating material hardness life (typically  $m = 0.1$ ) and  $(RC)_T$  is the Rockwell C hardness at operating temperature. It was further assumed that this equation can be extended to other bearing steels. A three point increase in hardness can result in a 35 percent increase in bearing life. With the exception of AISI 52100 and other low-tempering bearing steels, most bearing steels can be expected to maintain their room-temperature hardness after soaking at elevated temperatures [3].

The most common through-hardened bearing is made from SAE 52100 high carbon and high chromium steel. These steels are received from steel producer which are generally in a soft spheroidised annealed condition suitable for machining. The microstructure consists of spheroidal carbide particles in a ferritic matrix [4]. The microstructure transform to austenite during the heating cycle by altering the cooling rate form the austenitizing temperature the morphology and distribution of the phase can be modified thus giving a wide variation in the resultant material properties. Bearing races are prone to distortion and size changes during heat treatment as a result of complex

interaction of stresses induced by thermal gradients and phase transformation. Since it is virtually impossible to achieve complete transformation of the austenite to martensite in industrial quenching practice, varying amounts of austenite, depending upon severity of quench, are retained in the as quenched microstructure. Dimensional changes essentially depend on precipitation of fine carbide from martensite and decomposition or transformation of retained austenite during use. Change in dimension can also be induced in the bearing races during service due to temperature or stress environment. Consequently, selection of appropriate heat treatment is necessary to provide the required dimension stability. In the present study an attempt has been made to control the irregular expansion of bearing races after heat treatment by optimizing the heat treatment process parameters.

## 2. Experimental Details

Bearing races produced from high carbon, high chromium bearing steels conforming to SAE 52100 where used. The chemical composition of the material is given in Table 1. The schematic diagram of the bearing races chosen for this investigation is given in Fig. 1 and the dimension of the race for different symbols used in this study are summarized in Table 2.

**Table 1:** Chemical Composition of Steel in wt. %

C	1.04
Mn	0.35
P	0.01
Si	0.26
Al	0.04
Cr	1.44
Ti	0.008
Mo	0.001
Ni	0.026
Cu	0.024
S	0.009
O <sub>2</sub>	7 <sub>ppm</sub>

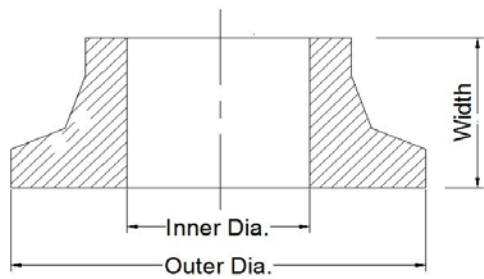


Figure 1: Schematic Sectional View of the Bearing Races Used in the Present Study.

Table 2: Dimension of the Bearing Race for Different Symbols Used in the Present Study

Dimensions are in mm				
Symbol	Outer Diameter	Inner Diameter	Thickness	Width
6203	24.74	16.75	7.99	12.24
6205	34.15	24.7	9.45	15.24
6207	47.03	34.7	12.33	17.24
6302	23.84	14.75	9.09	13.24
6307	49.63	34.7	14.93	21.24
6308	55.15	39.65	15.5	23.28
SP-28	50.48	27.7	22.78	18.24

2. Introduction

2.1 Standardisation of Austenitising Condition

The bearing races made of SAE 52100 were held at different austenitizing temperatures. Salt bath furnaces were used for austenitizing. The bearing races were immersed in a salt bath (KCl+NaCl+BACl<sub>2</sub>) held in the temperature range of 850<sup>0</sup>C to 870<sup>0</sup>C; the melting temperature of the salt being 650<sup>0</sup>C. When cold bearing races are introduced in salt bath a crust of salt forms on the surface which retards decarburization and ensured gentle heating resulting in a reduced thermal distortion.

2.2 Quenching

In the present work, quenching was done through marquenching route, because in the majority of instances the resulting distortion is significantly lower [5] compared with that in uninterrupted quenching (conventional) Apart from marquenching some specimen were also treated with intermediate quenching in oil (-40<sup>0</sup>C) followed by water cooling at 10<sup>0</sup>C to study the effect of high initial martensite content prior to tempering on the expansion behavior of races.

2.3 Tempering

Low temperature tempering up to 170<sup>0</sup>C was carried out in a low melting salt bath (KNO<sub>3</sub>+NaNO<sub>2</sub>+NaNO<sub>3</sub>). Time and temperature were varied depending upon the properties to be studied

2.4 Measurement of Retained Austenite

Quantitative phase estimation was done by means of X-ray diffraction using the principle of direct comparison as

outlined here. It is based on comparing the integrated intensities of selected (hkl) reflections of the martensite (M) and austenite (γ) phase. Let I<sub>M</sub> and I<sub>γ</sub> be the integrated intensity of martensite and austenite diffraction line respectively. Then

$$I_M = R_M V_M \tag{1}$$

$$I_\gamma = R_\gamma V_\gamma \tag{2}$$

Dividing (1) by (2) and rearranging yields

$$\frac{I_M}{I_\gamma} = \left(\frac{R_M}{R_\gamma}\right) \left(\frac{V_M}{V_\gamma}\right) \tag{3}$$

Where V<sub>M</sub> and V<sub>γ</sub> represent respective volume fraction of martensite and austenite phase R<sub>M</sub> and R<sub>γ</sub> are the factors contributing to the integrated intensity of the austenite and martensite lines, respectively. Once the value of  $\frac{I_\gamma}{I_M}$  is found

V<sub>γ</sub> can be estimated assuming V<sub>γ</sub> + V<sub>M</sub> = 1 which implies that the volume fraction of carbide is negligible.

In the present work, retained austenite measurement was carried out with M<sub>o</sub> K<sub>α</sub> radiation using the 211 and 200 martensite lines and the 311 and 220 austenite lines [6].

3. Results

The size variation, ovality, expansion and retained austenite content in the specimen after tempering are shown in Fig. 2. It is observed that extended tempering time and intermediate quenching gives the best results in the term of minimizing the expansion and ovality. The amount of retained austenite is reduced below the normal detection limit, by x- ray analysis though the extend tempering time gives better result in the smaller diameter symbols the result do not hold good for larger symbol like SP28 or 6308 on the other hand intermediate quenching gives the best result in terms of expansion and it is quite well below.

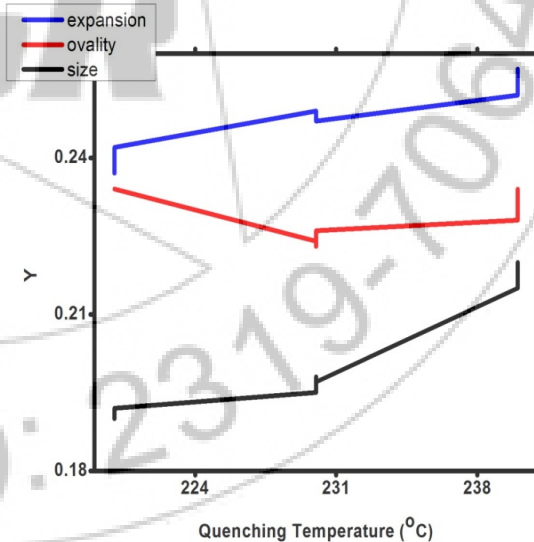
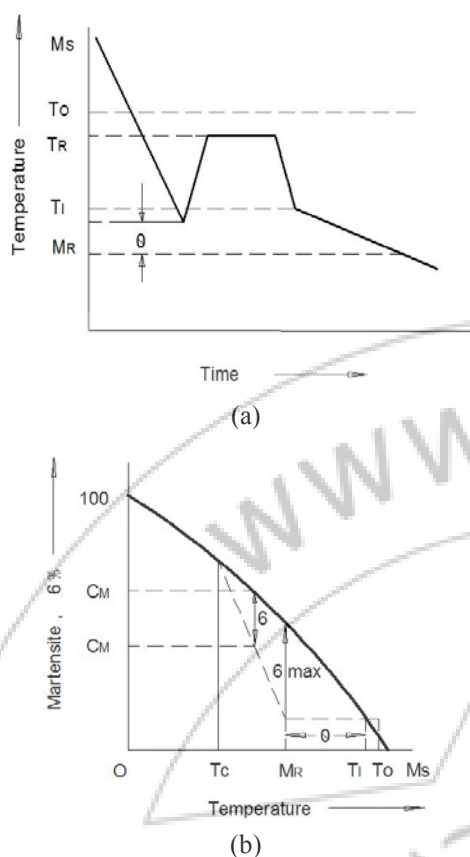


Figure 2: Heat treatment Details and Quality Parameters of Different Bearing Races Used in the Present Study.



**Figure 3: (a) & (b):** Systematic Illustration of the process of Thermal Stabilisation.

#### 4. Discussion

Amongst the many causes of both changes in part size and the occurrence of distortion [4], the results have been discussed in the light of phase transformation, particularly on the stabilization of retained austenite. Dimensional change during tempering of the martensite is primarily related to the precipitation of the carbides and transformation of retained austenite. Thus the extent of retained austenite would be one important parameter to control. It may be noted that the shrinkage expected during tempering of non-prestressed components containing little retained austenite, although this is directly related to the relaxation of martensite accompanying the precipitation of carbides, the degree of relaxation at a given tempering temperature is also dependent on how much carbon is initially in solution in the martensite. The austenitizing temperature, time and the corresponding solution of the carbides would influence the extent of distortion.

Stabilization of austenite in the context of austenite-martensite reaction refers to a process of reluctance on the part of retained austenite to form martensite upon lowering of temperature. There are various ways in which this sluggishness can be induced in austenite [7]. Amongst the many means of austenite stabilization. In the present case, stabilization is due to only thermal means, i.e., "thermal stabilization". Fig. 3 depicts schematically the process of thermal stabilization. The difference ( $\theta$ ) between the temperature of interruption ( $T_i$ ) of quenching and the temperature of reappearance of martensite ( $M_R$ ) is generally

preferred to serve as the major of the degree of stabilization of austenite than the difference ( $\delta$ ) in martensite content between the stabilized and unstabilized specimen, because  $\delta$  is strongly dependent on the reference temperature.

In the present study thermal stabilizations deals with stabilization through isothermal holding below  $M_s$  and associated with a thermal or dynamically stabilized martensite transformation. The underlying mechanism can vary stabilization caused by hindrance to nucleation of martensite phase and hindrance to the growth of the martensite nuclei through pinning down of the austenite – martensite interfaces and strengthening of the residual austenite matrix.

During tempering, carbon atoms migrate to the austenite-martensite or to the dislocations inside austenite. A strong interaction between dislocations and carbon atoms leads to retardation in the precipitation of  $\epsilon$ -carbide. In view of the presence of a large number of dislocations in austenite and as carbon atoms are known to be attracted towards these defects and possibly because of this any precipitation inside austenite is not observed [4-5]. Higher tempering helps in elimination of quenching stresses and also accelerates the diffusion of carbon and thereby helps decomposition of metastable martensite to stable products. With longer tempering time, a type of over ageing takes place during which concentration of carbon atoms would be reduced at the interface consequently, carbide precipitation once again is facilitated. In case of intermediate quenching, since the initial amount of retained austenite is less prior to tempering, the stabilization retained austenite is much more effective resulting in a better control of expansion after heat treatment. It has also been shown by several authors [8-9] that a higher initial martensite content leads to an increase in the degree of stabilization under similar condition. However, the exact mechanism needs to be elaborated further.

#### 5. Conclusions

Extended tempering time or intermediate quenching can result in a better control of distortion of bearing races following heat treatment. However, the effect of intermediate quenching is most significant in controlling the irregular expansion of bearing races after heat treatment, and such irregular expansions in the rings could be reduced from  $150\mu\text{m}$  to  $60\mu\text{m}$  through proper choice of heat treatment.

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