HEAT TREATMENT OF AISI 52100 FOR BEARING APPLICATIONS

Manufacturing a component is oftentimes extremely complex, even when that component seems as simple as a bearing.

BEARINGS ARE CRUCIAL TO OUR INDUSTRIAL LIFE. THEY ARE found in virtually all industrial applications from wind bearings to aircraft engines. They are found in toys such as figits and bicycles, as well as automotive applications in engines and transmissions. Bearings allow parts to rotate in contact with another part with very low friction. Bearings are absolutely necessary to reduce energy consumption from friction loss.

Bearings consist of four components: the outer race, inner race, the rolling element (balls, cylinders or barrels), and a cage to separate the rolling elements. The inner and outer races contain the rolling elements, while the cage separates the rolling elements from touching each other and reduces contact friction.

There are essentially four types of roller bearings: ball bearings, cylindrical bearings (including needle bearings), spherical bearings, and tapered roller bearings. These are illustrated in Figure 1. In ball bearings, spherical balls are enclosed within two concentric rings. The balls allow the two rings to rotate relative to each other and support a radial load. For greater load capacity, cylindrical rolling elements are used. The greater load capacity is due to the larger contact surface area between the inner and outer rings and the cylindrical roller element. Needle bearings are a special case of the cylindrical bearing where the rolling element is long and thin. These bearings are designed to save space. Spherical roller bearings use two rows of barrel-shaped roller elements. This allows the bearing to permit a misaligned load. Tapered roller bearings have tapered rolling elements and rings. This increases the surface contact area between the inner and outer rings, allowing for large radial and thrust loads compared to ball or cylindrical bearings.

Figure 1. Types of bearings: (From left) ball bearing, cylindrical bearing, spherical bearings, and tapered roller bearings. (Photo courtesy of Timken Corporation, North Canton, Ohio)

While there are many steels used for the production of bearings, the most commonly used bearing material is AISI 52100. This is also known as 100Cr6 or other designations. The primary alloying element is approximately 1.3 to 1.6 percent Cr, with a carbon content of approximately 1.0 percent. The typical chemical composition of AISI 52100 is shown in Table 1.

In general, raw material for AISI 52100 is supplied as either hot rolled or spheroidized. The hot-rolled structure is predominantly pearlitic with proeutectoid cementite at the grain boundaries. The spheroidized microstructure is carbide within a ferrite matrix (Figure 2). As is typical for through-hardening steels, the normal sequence for hardening is austenitization, quenching, and tempering.

During austenitization, it is necessary to dissolve the carbides to obtain a fully austenitic microstructure. Under equilibrium conditions, AISI 52100 becomes fully austenitic in excess of 900°C; however, in practice, it is usually found that temperatures of 1,040°C for 20 minutes are necessary to dissolve the cementite1. The kinetics of carbide dissolution is shown in Figure 3. Residual carbides help improve the resistance of the steel to wear. Some chromium is absorbed by the carbides, so there is reduced chromium in the austenite matrix. Further, carbon is also absorbed by the carbides, so the matrix of the austenite is depleted in carbon. This results in a higher Martensite start temperature. As higher austenitization temperatures are used, more carbides go into solution with a decrease in the Martensite start temperature (Figure 4). This reduces the hardenability of the steel.

Quenching from the austenitizing temperature results in a microstructure that is predominantly Martensite, retained austenite and cementite that failed to dissolve during austenitization. The retained austenite depends on the austenitizing temperature and the final temperature. Martempering increases the percent of retained austenite. AISI 52100 is a medium hardenability alloy. Fast quenching is necessary to achieve a martensitic structure without non-Martensitic

<table>
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<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>Cu</th>
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<td>0.95 - 1.10</td>
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<td>≤ 0.35</td>
<td>1.30 - 1.60</td>
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<td>≤ 0.025</td>
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Table 1. Chemical specification of AISI 52100.
transformations of pearlite and bainite. The time-temperature-transformation curve of AISI 52100 is shown in Figure 5.

Distortion control is critical for bearings. Martempering is often used to control distortion, with temperatures of the quench oil exceeding 120°C.5 With low distortion, reduced grinding stock is necessary. Proper control of agitation is absolutely necessary to reduce distortion6.

The retained austenite present in the steel after quenching can be reduced by cryogenic treatments to convert to Martensite. However, this can lead to micro-cracking, with a decrease in toughness and fatigue7-8. To minimize the occurrence of micro-cracking, the parts are washed and rinsed in cold water at approximately 15-20°C. This colder rinse reduces the amount of retained austenite.

Tempering is normally conducted at low temperatures, typically at about 160°C. This leads to the decomposition of the retained austenite, and the precipitation of transitional carbides from the Martensite, and the formation of tempered Martensite. The hardness after tempering is shown in Figure 6. During tempering and the reduction of retained austenite and the precipitation of transitional carbides, dimensional changes will occur. These changes are illustrated in Figure 7. These changes in dimension affect clearances, as well as the resulting shape after tempering. These dimensional changes also limit the maximum temperatures of the bearings.

CONCLUSION

This short article on the heat treatment of AISI 52100 is by no means comprehensive, but illustrates the complexity of the manufacture of a component that is often taken for granted.

REFERENCES


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