The importance of heat treatment in the high precision bearing application

The importance of heat treatment in the high precision bearing rings

Dortmund, Germany 10.10.2017
The importance of heat treatment in the high precision bearing application

Dr. Pietro PROSINO
Director of PROSINO S.r.l.

Our company helps (since 1946) the producers of super precision and custom made bearings by supplying them high quality rings (mostly black rings).

We are located in Italy and we employ 92 workers

Every year we machine roughly 1,000 Tons of 100Cr6 steel

In the last 25 years we have supplied >100,000,000 rings to some of the most important EU producers such as FAG-INA, SKF, GMN, NTN-SNR.

Dortmund, Germany 10.10.2017
The purpose of my speech today is to draw your attention on the importance of the correct heat treatment of the rings used later by our customer to produce HPBB.

I will show some real cases that happened during my career that made me understood the importance of this production step.

The cases that I will show are related to 100Cr6 steel (SAE 52100 – Din 1.3505)
The importance of heat treatment in the high precision bearing application

Topics that we will face today

1. HT: some highlights
2. The hardness level
3. The correct steel structure after HT
4. The issue of residual austenite
5. Residual stresses
6. A possible action line
What is the **heat treatment**?

By HT of steel we define a process that *alter* its physical characteristics.

Infact HT provides an efficient way to *manipulate* the properties of the metal by controlling the rate of diffusion and the rate of cooling within the microstructure.

Proper heat treating requires precise control over temperature, time held at a certain temperature and cooling rate (**TTT curves**).
The importance of heat treatment in the high precision bearing application

Dortmund, Germany 10.10.2017
What is the heat treament (2)

During HT, a particular steel structure which is soft and with coarse and irregular grain structure called **austenite** is transformed in **martensite**

Martensite is harder, resistant to wear and with a much more regular structure.

Unfortunately austenite won’t transform completely in martensite leaving always a **certain % in the heat treated part.** This is the root cause for **residual stresses** within the heat treated part.
1. The hardness level

The heat treatment has the main purpose to create a structure that resist to friction and to fatigue (which are minor loads that occur within a fixed frequency).

Every bearing producers has his own technical spec about the hardness level. We have 2 hardness level request from our customer: HRC 58-62 and HRC 60-64.

The hardness level is achieved by applying different temperature level during final anhealing.
What is fatigue?
The importance of heat treatment in the high precision bearing application

The HT is typically described in 3 phases:

1. **AUSTENITIZATION** 860°
2. **QUENCHING** 105°
3. **STRESS RELEASE** – **ANNHEALING** 180-240°

A typical HT cycle is described by the following curve (our process B-05)
The importance of heat treatment in the high precision bearing application
2. The **correct steel structure** after HT

The heat treated structure must show carbides with a **roundish shape** and **evenly distributed** (= no concentration).

When we see this structure we can be sure that the HT has been done **correctly**.

Dortmund, Germany 10.10.2017
During Austenization the main problems that could occur are:

1. *Decarburization*. It represent a lack of carbon content. It can be detrimental to surface properties (mechanical characteristics will not matching to the standard).

2. *Excessive growth of austenitic grain*, due to excessive permanence of the parts in this phase. It also weaken the mechanical characteristics
3. The issue of residual austenite

Retained austenite is a something that is unavoidable when there is a heat treatment of steel with a high level of alloy elements, that is typical for bearing rings for special application. There are two main problem related to the retained austenite that have the same origin.

1. Retained austenite is not stable at room temperature and, for this reason, if there are some kind of stresses (mechanical, thermal...), it can be transformed during work of the bearing. This transformation involves a volume variation that generates also a dimensional variation of the bearing itself and a internal stress that can be trigger the propagations of a crack and then drastically reduce the bearing fatigue resistance.
To reduce as much as possible the retained austenite there must be careful control of the hardening parameters. The first elements is the austenitization temperature, because a too high temperature increases the quantity and stability of the retained austenite during the quenching.

One other parameter is the time between quenching and stress release, because more time pass between the two operation, more the retained austenite tends to stabilize. Furthermore the stress release temperature is important, not only for the hardness of the steel, but also for the reduction of residual austenite. The higher is the temperature, more residual austenite is reduced.
Residual Stresses

Residual Stresses is that which remains in bearing ring after having completed the heat treatment. We can simply define it like steel portion with different physical & chemical characteristics. In particular with different volumes. They generate tensions that could get free during subsequent machining operation like grinding.

Certainly one of the goal of the HT is to produce a ring free of residual stresses that can influence its dimensional stability over time.
What we want to achieve?

A hard ring with the lowest possible level of residual stresses and maximum dimensional stability.

Lowest possible level of residual stresses and dimensional stability can be achieved with the adoption of a special heat treatment with double annealing and subfreezing (S0).
The importance of raw material purity and cleanliness requirements, for precision bearing rings

Dortmund, Germany 10.10.2017
The importance of raw material purity and cleanliness requirements, for precision bearing rings

As you can see we have introduced a cryogenic step after the first stress release.

The permanence of the rings at -80° is allowing the complete transformation of the residual austenite in martensite.
The importance of raw material purity and cleanliness requirements, for precision bearing rings

Dortmund, Germany 23.03.2016
The importance of raw material purity and cleanliness requirements, for precision bearing rings

Results of customer lab on the steel structure

4. Ergebnisse

<table>
<thead>
<tr>
<th></th>
<th>Soll S0</th>
<th>Ist AR 71912 gleit-geschliffen</th>
<th>Ist AR 71912 sandgestrahlt</th>
<th>Ist AR 7008 gleit-geschliffen</th>
<th>Ist AR 7008 sandgestrahlt</th>
<th>Ist AR 71913 gleit-geschliffen</th>
<th>Ist AR 71913 sandgestrahlt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restaustenit</td>
<td>max. 5 %</td>
<td>1 %</td>
<td>1 %</td>
<td>1 %</td>
<td>1 %</td>
<td>1 %</td>
<td>1 %</td>
</tr>
<tr>
<td>Gefüge</td>
<td>max. nadeliger Martensit</td>
<td>feinnadeliger Martensit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mischgefüge</td>
<td>Rand: ≤ 1 % bis 0,07 x DW Abstand in den Funktionsflächen Kern: ≤ 5 %</td>
<td>nicht festgestellt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Randanomalien</td>
<td>≤ 20 µm</td>
<td>5 µm</td>
<td>10 µm</td>
<td>5 µm</td>
<td>5 µm</td>
<td>5 µm</td>
<td>5 µm</td>
</tr>
</tbody>
</table>

Dortmund, Germany 10.10.2017
The importance of raw material purity and cleanliness requirements, for precision bearing rings

Thank you for your attention!

Who is interested in these topics can meet me at my booth in the hall

Dortmund, Germany 10.10.2017