U.S. QUENCHING AND DIMENSIONAL STABILITY IN TIME 
OF 100Cr6 STEEL

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Abstract: Due to the relatively high susceptibility to deformation and cracking, the bearing steel 
creates major problems to quenching, especially in the case of complex geometric configurations. On the 
other hand, the dimensional stability of bearing elements influences significantly bearing durability. In 
this paper, the authors present a series of experimental results on the dimensional time behavior of 
100Cr6 steel for several martensitic volume quenching.

Keywords: quenching, bearing steel, dimension stability.

1. General consideration

Sustainability of precision bearings largely 
depends on the dimensional time stability provided 
by the structure elements obtained from the final 
heat treatment. In this case the notion of structure 
defines the nature, form, size, distribution of 
phases and structural constituents also the size and 
and sign of residual stresses induced in product 
following due to the heat treatment applied.

Martensitic quenching is a heat treatment of the 
technologies that induces stress and strain in 
dimensional stability with implications for long 
periods of time. The transformation of austenite 
into martensite in quenching induces large amounts 
of residual material stress, due to the difference in 
specific volume of the constituents (martensite has 
higher specific volume than austenite from which 
it came). Finally, on the quenching product surface 
tensile stress is formed which is summed 
algebraically with the tensions caused by thermal 
shock. Parts of the residual stresses are "downloaded" during its return through specific 
mechanisms. On the other hand in the structure of 
quenching steel the residual austenite and 
martensite phases are out of balance and so 
unstable over time. These phases tend to evolve 
over time, even at ambient temperature, the phase 
constituents close to balance or causing 
dimensional changes in some operational situations 
affecting the product behavior in exploitation.

Collective concerns of the thermal treatments 
laboratory FIMMM Suceava on optimization of 
heat treatment of bearing steel dates back to 1985. 
In the article are presented results of research 
regarding the influence of quenching regime for 
dimensional stability in time of 100Cr6 steel 
(symbolizing the ancient RUL1).

2. Research methodology

Typically, dimensional stability in time is 
expressed as relative linear strain variation over 
time; the measurements are made until the full 
stabilization of the dimensions. To study the 
dimensional stability in time was designed and 
implemented a device like in figure 1. With five 
workstations, the device allows embedding of 
cylindrical specimens with Ø10 x 150 mm, 
between a high rigidity wall and an elastic wall on 
that are bonded strain gauge.

Figure 1. Device for testing dimensional stability
To limit thermal deformation caused by changes of ambient temperature environment after mounting the samples device are placed in a thermostatic chamber in which temperature is maintained at 20°C with an accuracy of ±0.2°C. Strain gauges in full bridge are connected to five bridges N2305, selected in advance as stability while balancing adjustment. In order to ensure stable mechanical properties over time after implementation, the device was subjected to thermal stress relief treatment of 100 hours at 200°C. Immediately after heat treatment, samples were mounted in the device, gathering performing with torque indicator handle wrench to maintain the same measurement conditions. After placing the device in the thermostat room and after temperature stabilization was done to balance each strain gauge bridge. Calibration of each station was done with an orthotest. We worked with lots of five specimens for each group thermal treatments are presented in Table 1. Austenitizarea for quenching was performed in a CARBOLYTE electric furnace heated to 850°C, keeping time was 40 minutes. As cooling environment mineral oil Lubrifin MET I R type II was used, recommended for quenching bearing elements.

**Table 1. Quench cooling variants of the samples group**

<table>
<thead>
<tr>
<th>Group code</th>
<th>Getting austenite</th>
<th>Mineral oil cooling (40°C)</th>
<th>Draw back</th>
<th>Running maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI</td>
<td>850°C/40 minutes</td>
<td>Mechanical agitation</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CI+R</td>
<td>850°C/40 minutes</td>
<td>Mechanical agitation</td>
<td>150°C</td>
<td>2 h</td>
</tr>
<tr>
<td>Mg</td>
<td>850°C/40 minutes</td>
<td>Continuous magnetic field 300 G</td>
<td>-</td>
<td>-</td>
</tr>
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<td>Mg+R</td>
<td>850°C/40 minutes</td>
<td>Continuous magnetic field 300 G</td>
<td>150°C</td>
<td>2 h</td>
</tr>
<tr>
<td>US</td>
<td>850°C/40 minutes</td>
<td>Ultrasonic field 40.4 kHz and 4W/dm²</td>
<td>-</td>
<td>-</td>
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<tr>
<td>US+R</td>
<td>850°C/40 minutes</td>
<td>Ultrasonic field 40.4 kHz and 4W/dm²</td>
<td>150°C</td>
<td>2 h</td>
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</tbody>
</table>

For magnetic field quenching was used an oil tank with 40 dm³ capacity, fiberglass located in the center of a DC powered coils. In the center of the basin is done a magnetic field strength of 300 Gauss, [1].

Ultrasonic field quenching was made in a tank with a capacity of 40 dm³, stainless steel sheet, in which at the bottom was placed a piezoelectric transducer with U.S. power of 200 W and the resonant frequency of 40.4 kHz. Power transducer was made from an electronic generator, developed in the laboratory, capable of ensuring a U.S. field strength of 4 W/dm², [1].

Quality assessment was done by measuring the heat treatment hardness.

**3. Experimental results**

Figures 2.a. and 2.b. are the results of hardness measurements and their statistics. From their analysis results the superiority of U.S. quench field over other hardening technologies experienced.

Measurement of dimensional stability in time was made in a period of 204 hours. After this time installation was found to stabilize the specimens dimensional. Measurement results are presented in Table 2 and chart in Figure 3.
### Table 2. Dimensional stability over time for different variants of heat treatment [µm]

<table>
<thead>
<tr>
<th>Time[h]</th>
<th>CI</th>
<th>CI+R.</th>
<th>US</th>
<th>US+R.</th>
<th>Mg</th>
<th>Mg+R</th>
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</tr>
</tbody>
</table>

![Figure 3. Variation of dimensional changes in time of the specimens heat treated [µm].](image)

### 4. Conclusions

1. Quenching technologies significantly influence the structure and properties of bearing steel. The amount of residual austenite in the structure, characteristics and size of residual stress of martensite is directly influenced by the parameters of the cooling operation. Metallographic structural analysis for various quenching regimes tested (Figure 4) is clearly observed differences between the quantity and distribution phases.
2. Activating U.S. cooling environmental drastically reduce calefaction on cooling and uniform heat exchange intensity in the first part of cooling, as confirmed by less dispersion of hardness values, as apparent from Figure 2.b. Furthermore, the U.S. vibration frequency of the fluid cooling determines the cooling capacity growth, and hence the cooling rate directly affects the amount of residual austenite in the structure. Compared with other types of heat treatment, U.S. quench ensure sensitive reduce of the residual austenite amount. (Figure 4.c.).

3. Mineral oil used as a cooling environment can be considered incompressible and ensure transfer of mechanical energy from the transducer to the product. Additional energy intake determines the transformation of additional austenite quantities into martensite at quench with direct implications on the content of residual austenite, [2, 3].

4. Following the additional energy intake, even during the quench, product stress relief is realized, phenomenon confirmed by experimental research, [1].

5. Dimensional stability over time is directly influenced by the proportion of phases and constituents in the metallographic structure. In bearing steel case is mainly on the amount of residual austenite in the structure, [1]. Among variants examined by heat treatment, the U.S. quenching ensures the most dimensional stability in time by dramatically reducing the amount of residual austenite in the structure in the first place.

6. As an alternative technology at industrial scale, the U.S. quenching has the advantage that it not requires major investment or significant changes in heat treatment lines or excessive energy consumption.

7. U.S. heat treatment oil activation reduces the negative effect of waste water and increases its use.

References