Initial microstructure influence on rapid austenitization in hypereutectoid steels

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1. Context

The present study was conducted in collaboration with the company Les Usines Métallurgiques de Vaillorbe (UMV), one of the world leading file manufacturer. The study is focused on one of their major product in terms of production volume, namely Ronde A Chaînes (RAC) files for sharpening saw chains. The files are made from a relatively low cost tool steel close to the 120Cr3 grade. The as received steel rods have a microstructure of ferrite and spheroidized cementite of hardness low enough (around 200 HV) to allow easy tooth carving. After rapid quenching the files microstructure consists of undissolved cementite in a martensitic matrix (carbon content around 0.8%-wt) having a relatively high hardness (900 HV). The property of interest is the file’s grip, previous collaboration between UMV and EPFL ([1]–[2]) showed the importance of carbon content inside martensite at the teeth’s tip. To improve productivitiy, austenitization is done by heating with Joule effect: the temperature reaches 1000°C in less than one second. After quenching, most files have a satisfying grip but the discard rate is important, especially for a steel coming from one particular supplier (J), although all suppliers fulfill the same requirements. The goal of this study is on the one hand to find a macroscopic property (resistivity) to discriminate steels that will lead to process instability and on the other hand to relate this property with observations of the microstructure.

2. Requirements are similar for the different steel suppliers

<table>
<thead>
<tr>
<th>Element</th>
<th>Fe</th>
<th>C</th>
<th>Cr</th>
<th>Mn</th>
<th>Si</th>
<th>P</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier J</td>
<td>balance 1.20-1.35</td>
<td>0.5-0.8</td>
<td>&lt;0.4</td>
<td>&lt;0.3</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td></td>
</tr>
<tr>
<td>Supplier T</td>
<td>balance 1.20-1.30</td>
<td>0.6-0.8</td>
<td>&lt;0.4</td>
<td>&lt;0.3</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td></td>
</tr>
</tbody>
</table>

- Composition of each shipment is controlled by an independent company.
- Each supplier delivers steels within this range of composition.
- Within this composition range, J steel has a lower content of allowing elements.
- Elements not specified in the requirements are not found in J but can present in steel from other suppliers (e.g. Ni, Cu, V).

3. Experimental procedure

**RAC process**

After carving, files with as received microstructure (spheroidized carbides + ferrite) are heated by Joule effect with a fixed input current. To reach the desired maximum temperature, the time is controlled down to the millisecond. Then files are released into a water bath. Steels from two suppliers are studied: J steel has a high discard rate when going through RAC process and T steel is satisfying.

**Characterization methods**

Resistivity was measured using a four-point setup and a 0.500 A current, as described by Weber [3]. Thermoelectric power was measured at UMV by a machine developed at EPFL. Microhardness was measured with a Q50A micro-hardness tester.

**Microstructure observation**

Optical micrographs were taken with a Leica CTR 6000, image analysis was done with ImageJ. A XLF30 field emission gun SEM from FEI was used to perform EDS and EBSD analyses.

4. TEP vs. file’s grip

5. Resistivity vs. TEP

6. Carbides

- This steel is a two-phase composite of resistive carbides embedded in more conductive ferrite.
- The presence of carbide alignments are consistent with the difference of resistivity.
- Moreover, carbides in J being less finely dispense, the short austenitization time of RAC process probably leads to less homogeneous austenite.
- This might explain the difficulty to control J file temperature during RAC process because it is inhomogeneous along the file.

7. Conclusion

- Although the two steels are relatively similar, it was possible to discriminate the problematic one with resistivity measurements.
- The difference in resistivity is caused by two contributions: (i) alloying elements in solid solution and (ii) carbides alignments.
- Thermoelectric power was also measured: it is, as a first approximation, proportional to conductivity.

8. References