Studies Concerning the Microstructure and Hardness Obtained After the Heat Treatment Applied to Steels Used for Components of Rolling Stock

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Abstract. This paper proposes a study on the influence of the hardening and annealing thermal treatments applied on two types of steels used for rolling stock. There is a type of analysis in two ways, according to the thermal furnace used for the applied treatments. The results obtained demonstrate the low wear of the rolling stock components.

1. Introduction
During the circulation rolling stock is subject to both static and dynamic strains; freight wagons are strained when are charging, also. All these result in the production of wear, cracks or deformation to the components of the rolling stock.

With the increase in tonnage hauled and increasing speeds are necessary measures to improve road safety. An important factor for ensuring the movement of trains is removing the derailmentes and the causes that produce them.

The most common cases to derailment are due of wear of components of the rolling stock. Because most of these wear may not be detected when conducting technical revisions to trains or brakeing, them are considered to be the most dangerous for traffic safety.

2. The main components of rolling stock that are subject to wear

2.1. Wheelset
Traffic safety depends largely on the condition of the wheelsets (figure 1).

Fig. 1. Wheelset
As a result of the variable stresses and vibrations to which the wheelset in service are subjected, frequently appears defects on bearings, suspensions and even wheel bandages (figure 2).

![Fig. 2. Defects of the wheelsets](image)

From the calculations made by specialists, confirmed of exploitation calculations, wheelsets have some dangerous sections where can fracture:
- the places where are connected wheelsets parties with different diameters, when these sections presents defects obtained by processing (ridges resulting from turning processes or too small radius of racordation);
- the places where the coxswain brake bars rubbed wheelset, producing ridges.

2.2. Axle box (figure 3)
During the rolling of rolling stock are produced wear on the components of the wheelset: seizing of bearings, bearing premature wear, flaking of rollers, fissures or cracks, corrosion and oxidized stains, corrosion by friction.

2.3. Arches of suspension
Arches of suspension are solicited in stationary, when the wagon is loading (especially when the loading is mechanized), and in the rolling while the vehicle rail track. The most common defects of the arches can be grouped into:
- wear and cracks in the parts of the suspension, such as arch supports, spring bolts, plates, rings, etc.;
- cracks and fractures in the sheets and connection arches;
- allowing the deformation of the arches or spaces between the sheets, moving of sheets, weakening of the arches connection.

2.4. Chassis (figure 4)
Wear the chassis results, primarily due to metal corrosion, corrosion action is manifested in the painted portions inappropriate, or where the damage was produced in the paint. In addition, as a result of careless or violent use of vehicles, it causes wear, cracking, breaking or deforming the main frame, especially at loading the wagon with heavy parts or in their handling to composition the train.
2.5. Coupling device (figure 5)
Coupling device is extensively applied in service of railway vehicles, which increases with increasing tonnages and towing trains with multiple traction.

![Fig. 5. Coupling device](image)

The failure of the coupling device occurs due to jerks or reactions occurring in the train during the movement and, in particular, due to starting, inadequate repairs, lack of lubrication etc. Also, unregulated brakes cause reactions in the train's body, which leads to increased wear of the component parts of the coupling device or even to the breaking of one or the other of them.

2.6. Traction device (figure 6)
As with coupling devices, traction devices are required due to the use of high capacity wagons and a long trains. The failure of the components of the traction device are explained similar to the coupling device: improper execution, inadequate heat treatment, the material of lower quality, improper repair, violent starting etc.

![Fig. 6. Traction device](image)

3. Materials and equipment’s

3.1. Used materials and samples
For experimental tests we chose two grades of steel, OLC55X and 42CrMo4, frequently used in manufactured in components subject to wear of the rolling stock.

In table 1 and table 2 are presented the chemical composition and the mechanical properties of steels.

**Table 1. Chemical composition of studied steels**

| No. | Steel       | Chemical composition [%] |
|-----|-------------|--------------------------|
|     | Numerical symbol | Alphanumeric symbol | C  | Si  | Mn  | Cr | Mo | S   | P   |
| 1   | 1.1203      | OLC55X                   | 0.57 | 0.40 | 0.72 | -  | -  | 0.02 | 0.025 |
| 2   | 1.7227      | 42CrMo4                 | 0.40 | 0.40 | 0.60 | 1.15 | 0.25 | 0.04 | 0.04  |
Table 2. Mechanical properties of studied steels

| No. | Steel     | Tensile stress [MPa] | Yield stress [MPa] | Hardness [HB] | Elongation min. [%] |
|-----|-----------|-----------------------|-------------------|--------------|-------------------|
| 1   | OLC55X    | 710-860               | 430               | 210-260      | ≥15               |
| 2   | 42CrMo4   | 800-950               | 550               | 135-305      | ≥14               |

The studied steels are in accordance with European Norme, EN 10083-2+A1:2002 for 1.1203 steel and EN 10083-1+A1:2002 for 1.7227 steel.

From the mentioned steels, samples of different shapes and sizes were made, depending on the subsequent determinations that were considered, namely:
- samples for hardness tests;
- optical and electronic microscopy samples.

In figure 7 is presented some image of samples used on tests.

3.2 Equipments

3.2.1. Heat treatment

For heat treatment were used equipments for laboratory and industrial equipments, as follows:
- medium temperature laboratory oven with automatic temperature control (figure 8)
Characteristics:
- dimensions of the work room: 300x150x120 mm
- maximum temperature: 950 °C
- temperature precision: ± 3 °C
- power of installation: 5 kW
- supply voltage: 380 V
- low temperature laboratory oven (figure 9)

Fig. 9. Low temperature laboratory oven

Characteristics:
- dimensions of the work room: 200x200x180 mm
- maximum temperature: 700 °C
- temperature precision: ± 3 °C
- power of installation: 4 kW
- supply voltage: 380 V

3.2.2. Microscopy
The samples for metallographic analysis were prepared in accordance with specific standards. For structural analysis were used optical and electronic microscopes (figures 10).

Fig. 10. Optical microscope

4. Results and conclusions
Experimental samples was subject of different heat treatments, with different conditions, as following presents.
4.1. Hardening and annealing treatments in air atmosphere oven

In table 3 are presented the treatment conditions. Treatments were applied in laboratory oven with compartment.

| Table 3. Conditions of heat treatments |
|---------------------------------------|
| No. | Steel     | Hardening treatment | Annealing treatment | Hardness, HRC |
|-----|-----------|---------------------|---------------------|---------------|
|     |           | Temperature [°C]    | Time [min]          | Cooling medium | Temperature [°C] | Time [min]          | Cooling medium | After hardening | After annealing |
| 1   | OLC55X    | 830                 | 30                  | water          | 600             | 90                  | water          | 63.5           | 32.2           |
|     |           |                     |                     |                | 400             |                     |                |                | 42.7           |
| 2   | 42CrMo4   | 840                 | 30                  | oil            | 600             | 90                  | oil            | 53             | 34.6           |
|     |           |                     |                     |                | 400             |                     |                |                | 39.5           |

Heating temperature for hardening treatment was chosen within the range indicated by the standards. The holding time was chosen so as to ensure temperature uniformity throughout the sample section. Cooling was done in water or in oil at temperatures equal to the environment. Annealing treatments were made in two variants, namely at 600°C (high annealing) and 400°C (average annealing) respectively.

For metallographic analysis we used optical microscope and obtained the microstures presented in figures 11-18.
The microscopic analysis evidence the following structural components:
- at OLC55X steel samples:
  - as delivered: lamellar sorbite
  - after hardening: fine acicular martensite
  - after hardening and high annealing: globular sorbite
  - after hardening and average annealing: troostite + sorbite
- at 42CrMo4 steel samples:
  - as delivered: sorbite + carbures
  - after hardening: martensite + carbures + residual austenite
  - after hardening and high annealing: globular sorbite + carbures
  - after hardening and average annealing: troostite + sorbite + carbures

This structures correspond to the chemical compositions of steels and applied heat treatments. Also, obtained structures were confirmed by the Rockwell hardness values presented in table 3.

4.2. Hardening and annealing treatments in controlled atmosphere oven
These heat treatments were carried out in broadly the same parameters as in the previous case. The difference lies in the fact that the heating and the maintenance was carried out in a controlled atmosphere to a $\pi_c = 0.5$ carbon potential, which has led to the protection of the surface from oxidation and decarburization. In this way in industrial regime lower losses of material and labor are recorded. In table 4 are presented the heat thermal conditions and obtained values for hardness.
Table 4. Conditions for controlled atmosphere heat treatments

| No. | Steel   | Hardening treatment | Annealing treatment | Hardness, HRC |
|-----|---------|---------------------|---------------------|---------------|
|     |         | Temperature [°C]    | Time [min]          | Cooling medium | Temperature [°C] | Time [min] | Cooling medium | After hardening | After annealing |
| 1   | OLC55X  | 840                 | 40                  | water          | 600            | 90         | air            | 64.2           | 33.9           |
| 2   | 42CrMo4 | 840                 | 40                  | oil            | 600            | 90         | air            | 53.5           | 35.4           |

Obtained hardness are a little higher compared with hardness obtained after applied heat treatments in compartment laboratory oven. The difference is explain by the lack of light decarburization, inherent to thermal treatment in air.

Figures 19 and 20 show the microstructures obtained on samples subjected to thermal treatments with controlled atmosphere.

And for this batch of samples, the structures obtained are appropriate in terms of both the chemical composition and the thermal treatment applied. However, there is a more uniform structure than in previous cases.

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