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HARDNESS AND STRUCTURAL ASPECTS OF THE HEAT – TREATED HS 18-0-1 STEEL

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ABSTRACT: High speed machinning requires tools from special materials (rich alloyed steel, cermet materials etc.). In the category of high alloyed tool steels the important are high-speed steels. To obtain the corresponding operating characteristics they must be heat treated to show comparative features with ordinary steel. The paper presents the heat treatment and the structural characteristics and hardness analysis of HS 18-0-1 high-speed steel used to manufacture tools for cutting with high speed.
KEYWORDS: HS 18-0-1 steel, annealing, quenching, tempering, ferroxation, X-rays diffraction

❖ INTRODUCTION

It's known that for cutting with high speed tools from high-speed steel are used. Compared with other tool steels these allow increased cutting speed of 2-4 times and ensure an increase of 10-30 times tool durability owing to high heat stability up to 600 – 620 °C [1, 4].

Achieving these performance is possible only after secondary quenching heat treatment followed by tempering which shows some features of carbon tool steels.

Based on these considerations, in the paper, the features of heat treatment and structural characteristics and hardness analysis of HS 18-0-1 high-speed steel are shown.

❖ PREPARATION OF SAMPLES AND APPLIED HEAT TREATMENT

HS 18-0-1 steel (symbolization as EN ISO 4957) is a rich alloyed steel for tools, from high-speed steel category (symbolization as STAS with Rp3). Chemical composition of this steel is: C = 0.7 – 0.8 %; W = 17.5 – 18.5 %; Mo = max 0.6 %, V = 1 – 1.2 %; Cr = 3.8 – 4.5 %.

Φ 20 x 15 mm specimens were made from forged bars, and were subjected to heat treatment. The heat treatment cyclogram is shown in figure 1.

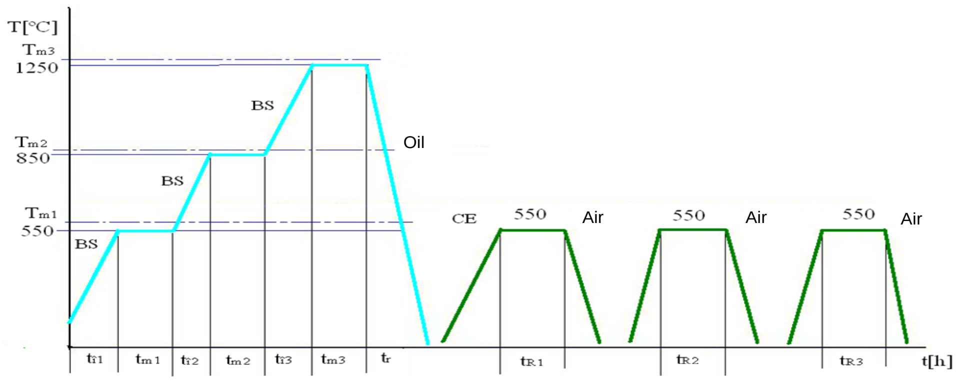

Figure 1. The cyclogram of the secondary heat treatment applied on the HS 18-0-1 steel

The transformations suffered by the material are as follows:

HEATING TRANSFORMATIONS

The heating for austenitization in order to quench high speed steels is made at high temperatures (1200-1300°C). This ensures that a large quantity of carbides are decomposed and dissolved in austenite enriching it, and after cooling enriching the martensite [2,4].

These temperatures are much higher than the euthectoid temperatures of carbon steel used for tools. The components of the alloy (which are α-gene) increase the temperatures of critical points A_{c1}

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and A_{c3} forming carbides and reducing the susceptibility of overheating the austenite, reflected by its granulation (the susceptibility of overheating the austenite increases with the increase of dissolved carbon).

QUENCHING TRANSFORMATIONS

Because of the high austeniting temperatures, carbon and alloy components that lower the martensitic transformation point M_s, the austenite becomes stable and exists for a longer time, preventing it from fully transforming into martensite, leading to residual austenite. Thus, quenched high speed steels contain residual austenite, un-dissolved carbides and a small quantity of martensite. The presence of residual austenite in the structure prevents the reaching of a maximum hardness after quenching.

TEMPERING TRANSFORMATIONS

During the tempering process the diffusion intensifies because of the heating, resulting in a loss of hardness at about 300°C after carbon separation. Continuing with the heating process the diffusion of the iron and alloy components is favored resulting in the precipitation of granular carbides that endow the structure with greater hardness. Thus, the austenite has a lower concentration of carbon and alloy elements, leading to an increase of temperature for martensitic transformation points, enabling the transformation of residual austenite in tempering martensite connected with an increase in hardness. The maximum hardness is obtained at 550°C and is called "secondary hardness" [1,2,3,4].

❖ METALOGRAPHIC, OPTICAL, ELECTRON, WITH X-RAY DIFFRACTION ANALYSIS AND HARDNESS MEASUREMENTS

After secondary heat treatment (as figure 1), the specimens were metalographic prepared and analysed by optical, electron microscopy and with X-ray, using equipment existing in the Chair of Materials Science and Welding - Timisoara (UPT – Mechanical Faculty).

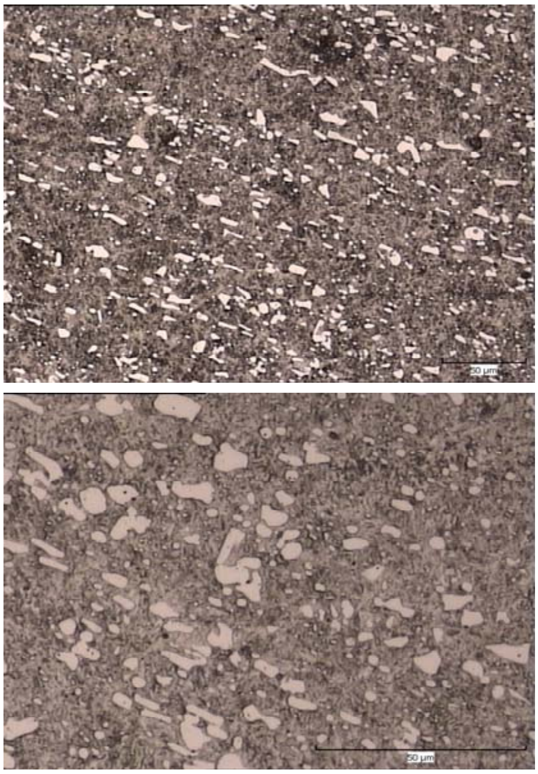

Figure 2. HS 18 – 0 – 1 steel – forged + annealed (Sorbite and, primary and secundary carbides)

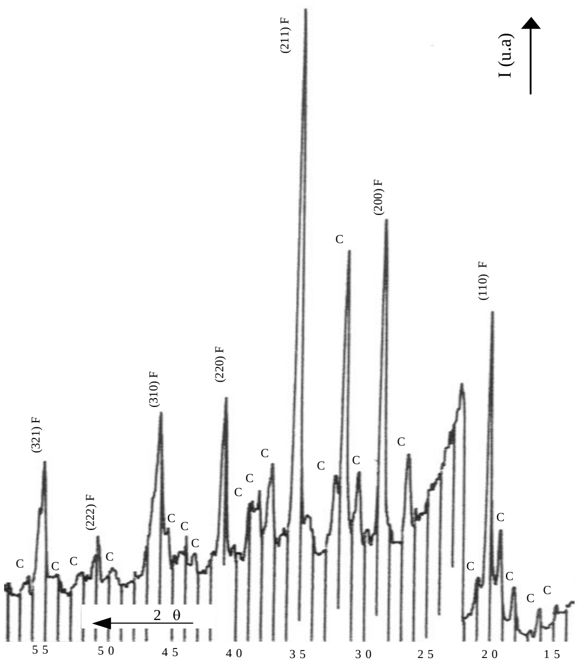

Figure 3: The diffractogram of the annealed status. (F-ferrite, C -Fe_3W_3C carbides)

In figure 1 is shown the microstructure (optical microscopy) of the specimen, which is in forged and annealed state, and in figure 3 is the corresponding X-ray diffraction spectrum.

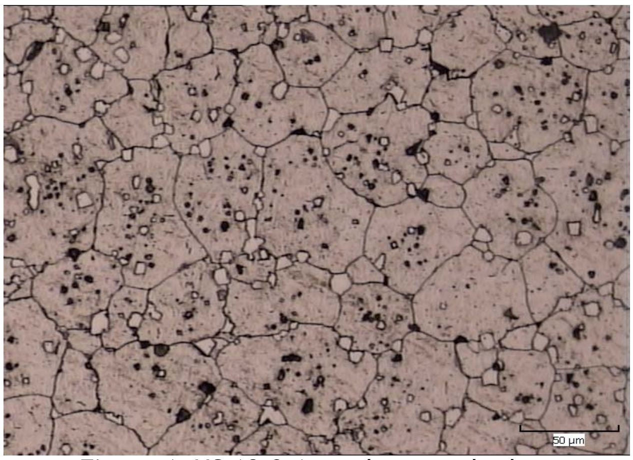

Figure 4. HS 18-0-1 steel – quenched

It is noted that the structure in annealed state is formed by fine sorbite that includes primary and secondary carbides. The arrangement of carbides in strings is due to the forging.

In figure 4 is shown the microstructure (optical microscopy) of the specimen which is in quenched state. It is noted that the structure in quenched state is formed by austenite (polyhedral shape), undissolved carbides with a quantity of martensite. The diffractogram of this specimen (figure 5) confirms the microscopic analysis.

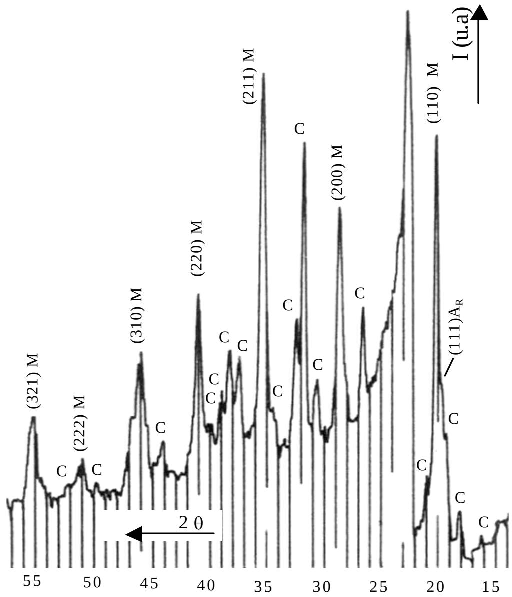

Figure 5: The diffractogram of the quenched status (M-quenching martensite, A_R- residue austenite, C-Fe_3W_3C carbides)

If the aim is to reduce the quantity of residual austenite before the high tempering treatment, the application of treatment at negative temperatures is required. [1],[4].

To draw attention of transformations from tempering process at 550ºC, especially the precipitations of fine carbides with globular shape, the quenching and tempering specimen at 550ºC was examined by electron microscopy (X 4000).

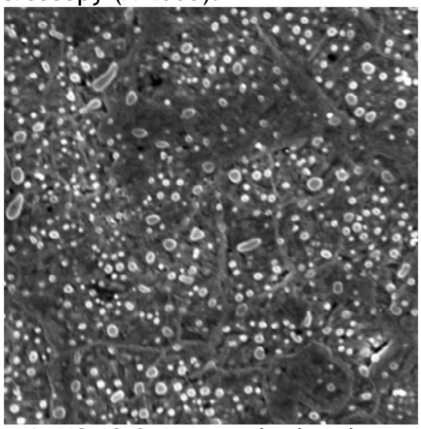

Figure 6. HS 18-0-1 quenched and tempered at 550 ºC (x4000)

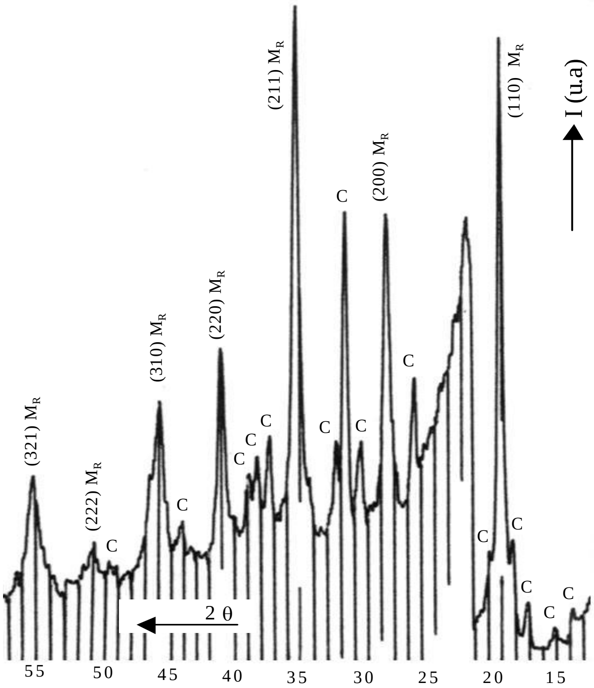

Figure 7: The diffractogram of the status, after tempering3 (M_R tempering martensite, C - Fe_3W_3C carbides)

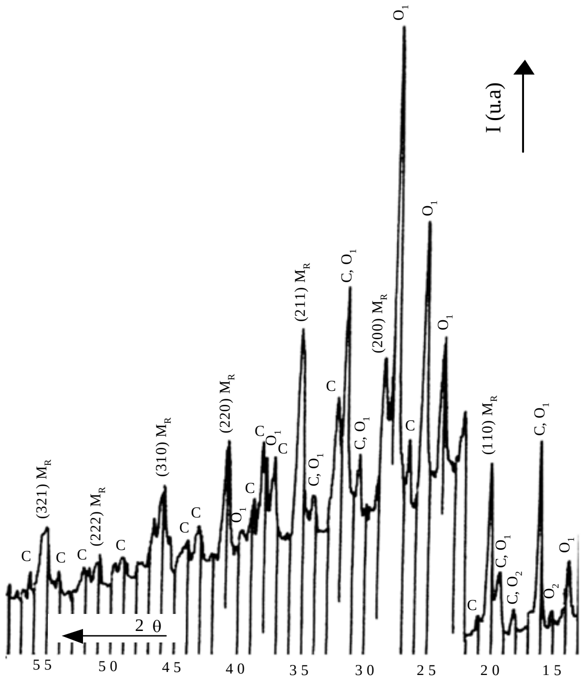

Figure 8: The diffractogram of the ferroxated state (M_R tempering martensite, C - Fe_3W_3C carbides, O_1- Fe_3O_4 oxide, O_2- Fe_2O_3 oxide)

In figure 6 is shown the microstructure (electron microscopy) of the quenching and tempering specimen in three rounds of one hour at 550ºC, and in figure 7 shows the resulting diffractogram.

It is noted that the structure is formed by fine martensite (Hardenită tempering martensite) and fine carbides. Thus, the residual austenite that exists in a very low percentage even in annealed status grows in quenched status and totally transforms after tempering 2. In order to ensure corrosion protection recommended application of termochemical ferroxated treatment.

Ferroxation was performed after the second tempering by introducing the specimen into a retort at a temperature of 350˚C for 20 minutes. Steam was then introduced at a pressure of 1,2 atm continuing up to 550˚C and one hour in the presence of steam. The opening of the retort follows and the cooling of the specimen at 100˚C and after this, the final cooling in oil at 50˚C.

Figure 8 presents the diffractogram of the ferroxated state. Structure is formed out of tempering martensite, Fe_3W_3C carbides and iron oxides Fe_3O_4 majoritary and Fe_2O_3 minoritary.

Table 1. Hardness measurements

No.	Material	Status of thermal treatment	HRC hardness in 3 points	HRC hardness, average
1	HS 18-0-1	Forged + annealed	32, 35, 31	32,66
2	HS 18-0-1	Quenched	61, 62, 61.5	61,66
3	HS 18-0-1	Quenched and tempered at 550 °C	62.5, 64, 63	63,16
4	HS 18-0-1	Quenched + tempered at 550 °C and ferroxated	65, 63, 62.7	63,56

For all specimens hardness measurements was performed (Rockwell Method HRC) and the obtained values were presented in Table 1. It is noted that the hardness values are in close correlation with microscopic analysis and certifies the previously presented phenomena. Hardness after multiple tempering is higher than the quenching, phenomenon known as secondary hardness and this must be exploited when using high-speed steel to manufacture cutting tools.

❖ CONCLUSION

- ❖ HS 18-0-1 heat-treated steel by step-quenching (salts bath), with oil cooling and tempering in three rounds of one hour at 550 °C, ensure an uniform, hard and very thermally stable structure formed by fine tempering martensite and carbides of alloys elements.
- ❖ For aggressive environments, cutting tools executed from HS 18-0-1high-speed steel, a final corrosion protection treatment is recommended.
- ❖ In special situations, when the active elements of the high-speed steel tool are strongly requested, for prolonging their service life up to three times, a coating with titanium nitride may be used.

❖ REFERENCES

[1.] Budău, V., Crăciunescu, C.M.: Studiul Materialelor. Ghid individual pentru lucrări de laborator. Editura Mirton, Timişoara, 1998
[2.] Duma, S., Popescu, M.: The influence of thermic and thermochemical treatment on the structural characteristics and hardness on drills fabricated from HS 18-0-1 steel, Procedings, Annual Session of Scientific Papers, "IMT Oradea – 2010", pp. 3.37, ISBN: 978-606-10-0128-6
[3.] Liţă, M.: Metode de investigaţie în ştiinţa materialelor, Editura Politehnica, 2009, ISBN 978-606-554-023-1
[4.] Mitelea, I., Budau, V.: Studiul metalelor, Indreptar tehnic, Editura Facla, Timişoara 1987
[5.] *** Metals Handbook, Ninth Edition, Vol. 9., Metallography and Microstructures, 1985

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