THE INFLUENCE OF VACUUM HEAT TREATMENT ON HIGH SPEED STEEL CHARACTERISTICS

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Abstract. This paper intends to highlight the advantages of technical and economic vacuum heat treatment compared with classical methods. Thus were subjected to final heat treatment of high speed steel samples both by heating in molten salts bath and quenching in oil, and also vacuum heating and cooling in nitrogen recycled. On samples so treated were made measurements of hardness, resilience and metallographic studies. Samples treated in vacuum have revealed near uniform and finer structure and better mechanical features 10 ... 15%. Also, an advantage that can not be neglected is the better quality of surfaces, which require further processing insignificant.

Keywords: vacuum, high pressure quenching, optimization, vacuum quenching

1. Introduction

High speed steels have a high content of alloying materials, tungsten, for example, reaching 20%, resulting in their high thermostability, between 600 °C and 650 °C and can work at cutting speeds up to three times greater than tools made of carbon steel tools (50 ÷ 60 m/min). This steel category is represented by high speed steel (Rp 1 ... Rp 10). Alloying with a high degree elements such as Cr, V, Mo and W in particular, make that after heat treatment tools to provide a high hardness, very high resistance to especially wear and thermal stability [5].

This particularly favourable set of properties is the result of alloying and is emphasized only when the heat treatment is correct. Proper application of quenching and tempering treatment can be done only if these high speed steel features are known regarding phase transformations taking place on heating (austenitisation) on cooling (quenching) and tempering. The structure of high speed steel in annealed state consists of fine globular sorbite, in which are included primary and secondary carbides. By heating in austenite domain occurs the pearlitic transformation in austenite.

This transformation takes place at temperatures slightly higher because alloying elements being alfa iron higher Ac_1 point position. The austenitisation it is done at temperatures much higher compared to Ac_1 because it aims to decay and dissolution of carbides in austenite, respectively obtaining rich alloy austenite. Thus, it comes that austenisation to be done at 1200 ... 1300 °C, when this could reduce the amount of undissolved carbides. Depending on the conditions in which the cooling is made from the austenisation temperature, it can get the same types of structures as carbon steels, respectively perlite, sorbite, troostite, bainite and martensite.

Due to austenitisation high temperature and high carbon content and alloying elements in austenite, the martensitic transformation point position is shifted towards lower temperatures, so that by hardening the ambient temperature in structure is still a large amount of residual austenite, with some martensite and undissolved carbides. Due to the large amount of residual austenite, the hardness after tempering fails to reach the maximum offered by these steels. In the process of tempering, by heating, diffusion is increasing, so that at 300 °C, following the separation of carbon, there is a slight reduction of hardness. Further heating promote and the diffusion of iron and alloying elements, which results in precipitation of fine carbides of globular shape, and consequently increasing the hardness and wear resistance [3].

However, the austenite became leaner in carbon and alloying elements, in new conditions, the martensitic transformation points increase to higher temperatures, facilitating the massive transformation of residual austenite to tempering martensite, processing also accompanied by an increase of hardness. Maximum hardening occurs around 550 °C and is known as "secondary hardening".

At tools of medium and high alloyed steels self-hardened, the hardening critical speeds can be achieved using inert gas, recycled using vacuum furnace fan. It hardened so cold forming tools in classes with 5% Cr and 12% Cr, the elements forming the plastic mold and die casting, high speed steel tools [4].

The pressure inside the heating and maintenance will be kept within the limits of 1 ÷ 15 Pa, to avoid vaporization of elements such as Fe and Cr. and at temperatures above 950 °C for Cr alloy is flooding the chamber with inert gas to prevent its evaporation.

For Rp5 high speed steel tooling at preheating is 10^{-1} Pa vacuum, and heating final 10 to 30 Pa. Pressure grows for the vaporization of alloying elements should be avoided.

The hardening of parts and tools can only be done in cold wall vacuum furnace equipped with tank and oil promoter, or promoter with the cooling gas ventilated (H_2, He, N_2) [1, 2]. The tempering in vacuum cleaner is made to keep the surface from hardening. For tempering temperature (below 700 °C) heat exchange by radiation is very weak, after flooding the vacuum chamber is an inert gas, at pressures of 104 Pa, which is recirculated, transferring heat by convection.

The vacuum heat treatment of tools lower the deformation and increase ductibility by 10-50%.

2. Experimental attempts

Tests were made in the laboratories in the Transilvania University of Brasov. Here have been made measurements of tensile strength and resilience on the equipment of the department.

From Rp5 high speed steel with chemical composition indicated in table 1 were made samples for experimental testing of final heat treatment and for determination of some mechanical characteristics.

Table 1.Chemical composition

Mark Steel	Chemical composition [%]									
	C	Si	Cr	V	W	P	Mo	Co	Mg	Fe
Rp 5	0.80	0.288	4.81	1.63	5.94	0.024	4.56	0.056	0.020	81.0

To highlight the influence of vacuum were performed heat treatments in parallel, both in normal conditions and also in vacuum. In table 2 there are presented the working conditions for the classic technique and in table 3 there are presented the working conditions for vacuum heat treatment.

Table 2. The heat treatment after the classic working conditions

Mark Steel	Hardening				
	Preheating I	Preheating II	Final heating	Cooling	Tempering
Rp 5	650 °C furnace gas	850 °C salt bath furnace	1190 °C salt bath furnace	Oil tank 80 °C	560 °C (3×1h)

Table 3. Parameters used after vacuum heat treatment

Mark Steel	Type of heat treatment	Parameters used for heating			Cooling
		Pressure [torr]	Temperature [°C]	Time	
Rp 5	Hardening	10^{-1}	850	40 min	Purified nitrogen
		0.2 ... 0.3	1190	9 min	Purified nitrogen
	Tempered	400	570	3×1h	Purified nitrogen

In the sequence of vacuum heat treatment technology is following:

- degreasing perchlorethylene settlement in the remote device to avoid sticking;
- filling in the oven disposal of high vacuum oven at 0.01 ... 0.02 torr;
- Heat to 850 0C with a duration of 40 min heating to 1190 °C made with progressively increasing pressure 0.2 ... 0.3 torr and maintenance between 8 ... 10 min;
- Cooling is done in the presence of nitrogen purified recycled to 540 °C and final cooling to 65 °C in approx. 30 min;
- Heating in the tempering is made by the initial discharge oven, followed by flooding with inert gas (nitrogen) at a pressure less lower atmospheric pressure, then resorting to forced recirculation gas with the fan to achieve heat transfer through convection.

The results obtained after applying these methods of heat treatment are shown in table 4.

Table 4. Results obtained after these methods of heat treatment

Nr. Crt.	Mark Steel	Type of heat treatment	hardness [HRC]		Tensile strength [N/m^2]	Resilience [J/cm^2]
			Hardness after quenching	Hardness after tempering		
1	Rp 5	Classic heat treatment	60.5	63	1106.87	3.98
2	Rp 5	Vacuum heat treatment	61	63.5	1196.57	4.25

Metallographic analysis revealed the structures obtained from various heat treatment operations. The figures below shows the micrographs of the high speed steel samples Rp5 magnifications corresponding optical microscope.

The hardening structures highlight the grain size and they are made of hardening martensite, residual austenite and undissolved carbides during heating and stabilizing.

The tempering occurs of martensite hardening transformation in martensite tempering, conversion of the largest part of the residual austenite into martensite and secondary carbides precipitate in the matrix. They admit as much finer than those already existing structure.

Figure 1. Rp5 high speed steel hardened (with heating in salt baths) Nital attack; 500:1

Figure 2. Rp5 high speed steel hardened (with heating in salt baths) Nital attack; 1000:1

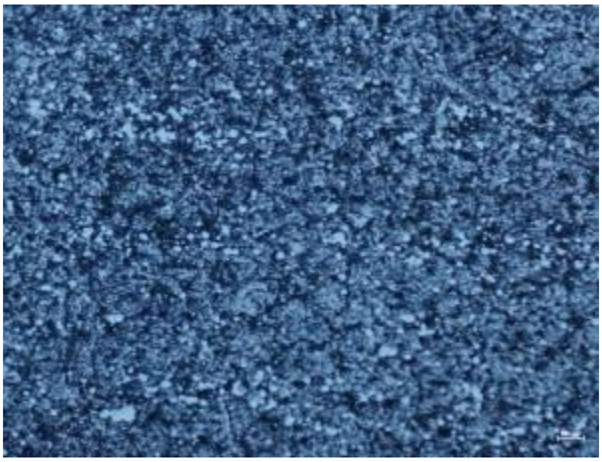

Figure 3. Rp5 high speed steel hardened (with heating in salt baths) tempered at atmospheric pressure Nital attack; 500:1

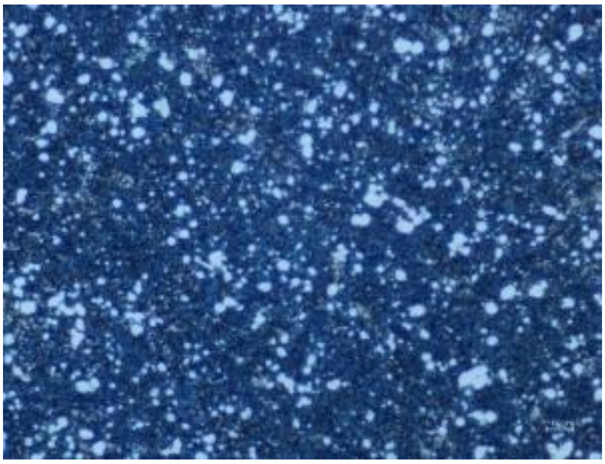

Figure 4. Rp5 high speed steel hardened (with heating in salt baths) tempered at atmospheric pressure Nital attack; 1000:1

Figure 5. Rp5 high speed steel, superheated quench (1250 °C) Nital attack; 500:1

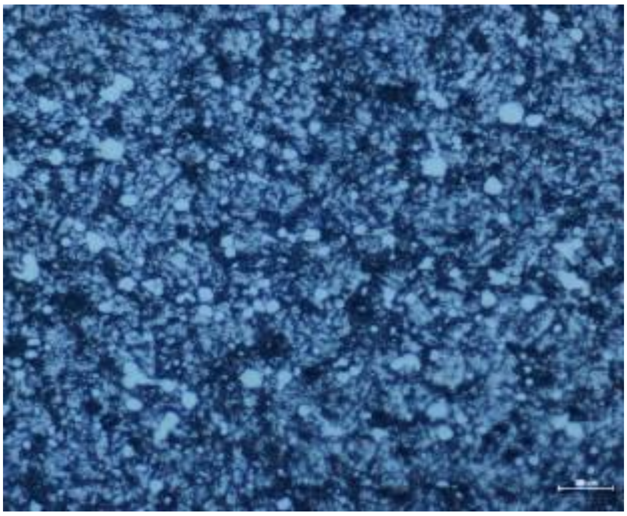

Figure 6. Rp5 high speed steel superheated quench (1250 °C) Nital attack; 1000:1

Figure 7. Rp5 high speed steel hardened in vacuum Nital attack; 500:1

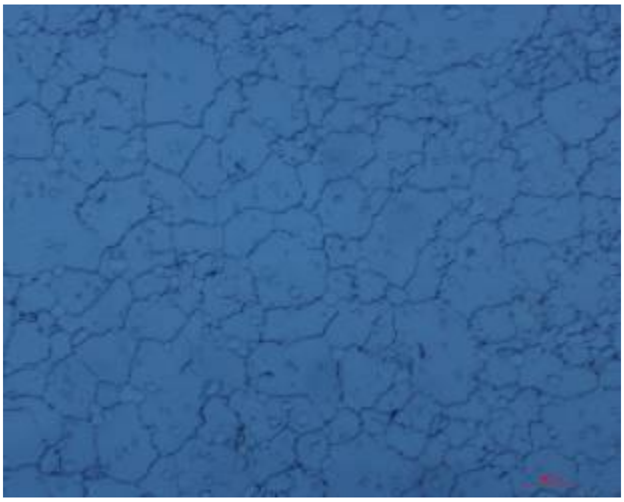

Figure 8. Rp5 high speed steel hardened in vacuum Nital attack; 1000:1

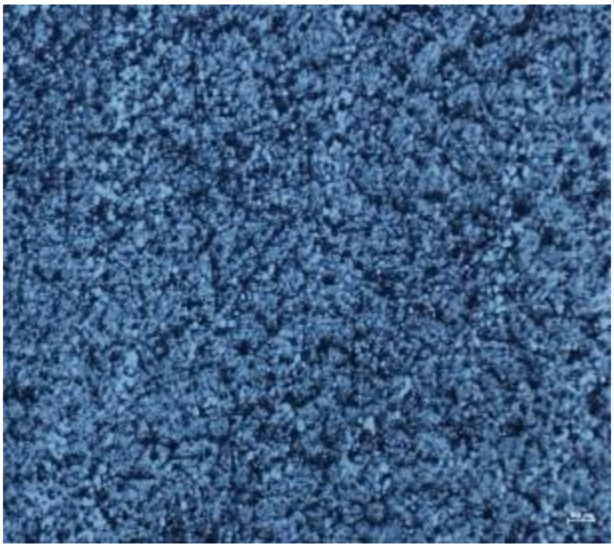

Figure 9. Rp5 high speed steel hardened and tempered in vacuum Nital attack; 500:1

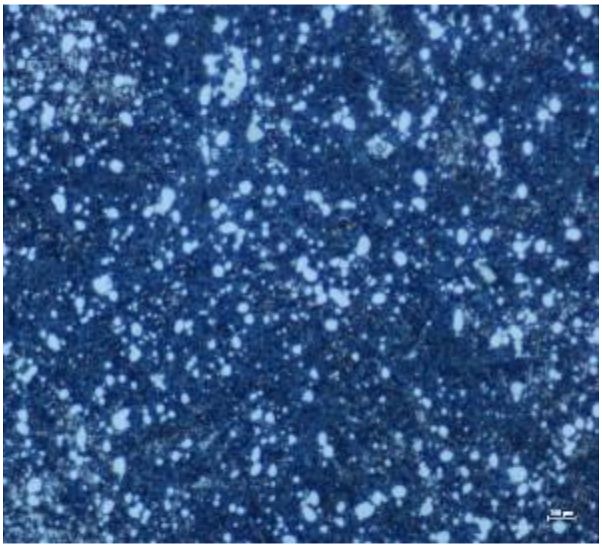

Figure 10. Rp5 high speed steel hardened and tempered in vacuum Nital attack; 1000:1

3. Conclusions

Vacuum heat treatment applied to tool steel and steel generally faster speed Rp5 especially wearing a number of advantages over the classic, highlighted in the results presented above, namely

- more hygienic working conditions and without the noxious emanations;
- finer structure, more compact and uniform higher density units Rockwell 1...2;
- higher resistance to shock 12...14%;
- higher tensile strength 7 ... 9%;
- surface quality tools smoother and cleaner results.

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