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Letter to the Editor

Effects of alloying elements with various heat treatment processes on the properties of high speed steels

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Abstract

In this study, effects of alloying elements and different heat treatment processes on the properties of DIN 1.3243, DIN 1.3343 and ASP 2052 were investigated. Austenitizing and tempering temperatures are critical parameters for the hardening of steels. Also, alloying elements have critical effect on microstructure and mechanical properties of steels. Various austenitizing temperatures with two tempering temperatures were implemented to samples. Effects of alloying elements, process parameters on the mechanical properties and tooling abilities of the specimens were investigated. Rockwell hardness tests were carried out on specimens, and their tooling abilities were characterized by the number of screws that were fabricated with specimens.

According to the results of experiments, higher hardness values were obtained for elevated austenitizing temperatures. Besides, higher hardness values were obtained due to presence of alloying elements and formation of secondary carbides during tempering process. Moreover, tooling ability of the specimens increased with higher hardness values and formation of alloy carbides. Hot work properties of specimens were evolved by Co.

Key words: high speed steels, hardness test, hardening, tempering

1. Introduction

High speed steel refers to any of a variety of steel alloys that engineers primarily use to construct machine tool bits and blades and drill bits for industrial power tools. Materials scientists can infuse this steel with differing percentages of elements to form a variety of high speed steel manufacturing alloy types. While all of these different types exhibit high speed steel's characteristic resistance to high temperature, the properties of each alloy vary depending on the percentage of other elements the alloy contains [1, 2].

Additionally, in the last few years, optimization of tool steel compositions and processing routes has been attempted by means of powder metallurgy [3–5]. The features of this manufacturing process make it suitable for alloy design due to fewer restrictions it imposes on alloy compositions compared with other processing technologies.

Cr, V, Mo, V and Co are the main alloying elements of the high speed steels. The main aims of the usage of alloying elements are to generate the alloy carbides and enhance the mechanical properties of the alloys such as hardness, wear resistance, mechanical strength and hot hardness [6–8].

The goal of this paper is to examine the effects of alloying elements and process parameters on the properties of DIN 1.3243, 1.3343 and ASP 2052 high speed steels.

2. Experimental

In experimental studies, DIN 1.3243, DIN 1.3207 and ASP 2052 high speed steels were used. ASP 2052 is a high speed steel that is fabricated by powder metallurgy with higher alloying elements content. Chemical compositions of the alloys are given in Table 1.

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Table 1. Chemical composition of alloys

Specimens	C (%)	Cr (%)	Mo (%)	W (%)	Co (%)	V (%)	Fe (%)
1.3243	0.93	4.2	5	6.4	4.8–5	1.8	Bal.
1.3207	1.27	4	3.5	9.5	9.5–10	3.1	Bal.
ASP 2052	1.6	4.8	2	10.5	8.5–9	5	Bal.

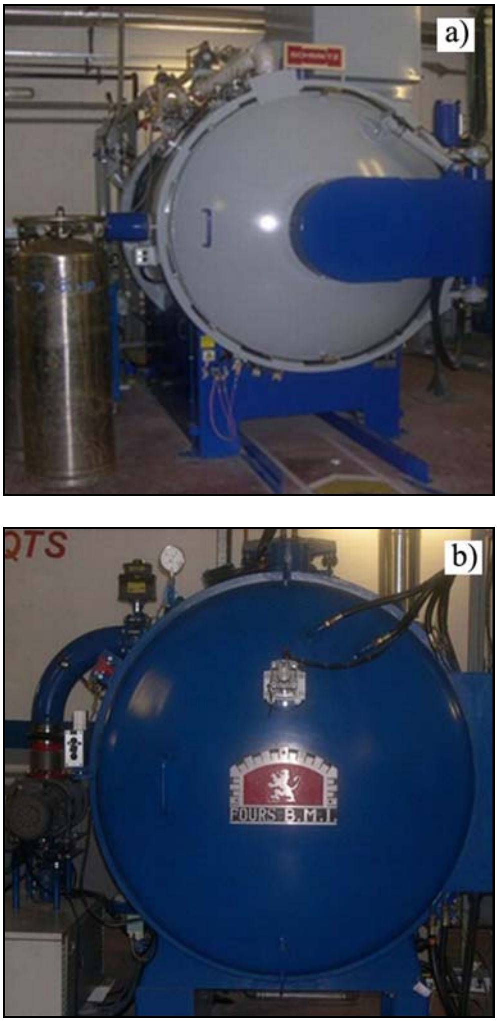

Fig. 1. Vacuum furnaces: a) Schmetz vacuum furnace, b) BMI vacuum furnace.

Table 2. Hardening and tempering processes of the specimens

Alloy	Austenitizing temperatures (°C)	Tempering temperatures (°C)
1.3243	1080–1140 1180–1200	525–560
1.3207	1080–1140 1180–1200	525–560
ASP 2052	1080–1140 1180–1200	525–560

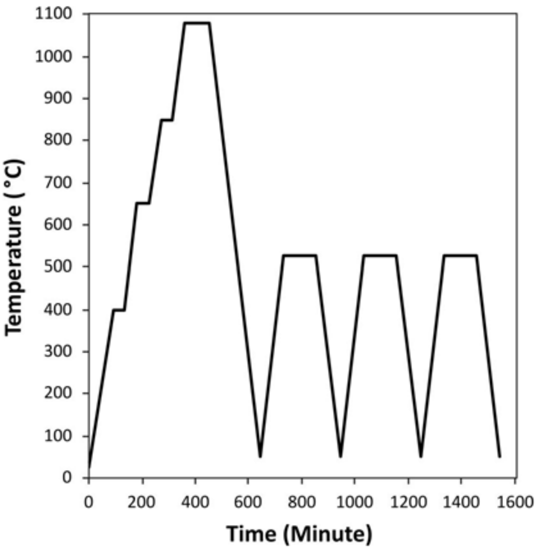

Fig. 2. Heating steps of the alloys that were austenitized at 1080 °C and tempered at 525 °C.

Hardening and tempering processes were applied in vacuum furnace with various austenitizing and tempering temperatures. Hardening processes were applied in Schmetz vacuum furnace at nitrogenous atmosphere, and tempering processes were applied in BMI vacuum furnace. Schmetz and BMI vacuum furnaces can be seen in Fig. 1.

Hardening and tempering processes of the specimens are given in Table 2. Austenitizing processes were carried out with different austenitizing temperatures by DIN 1.3243, DIN 1.3207 and ASP 2052. Three consecutive preheating steps were applied to each specimen during the hardening process at 400 °C, 650 °C and 850 °C, respectively. Preheating steps were applied with 45 min holding time. Specimens were quenched at 50 °C by 3 bar pressure and each specimen was soaked at 50 °C by 60 min before the tempering processes. Afterwards, hardened specimens were tempered at two different temperatures 525 °C or 560 °C by 3 consecutive tempering steps with 120 min holding time. Heating steps can be seen in Fig. 2.

Effects of heat treatments on the properties of

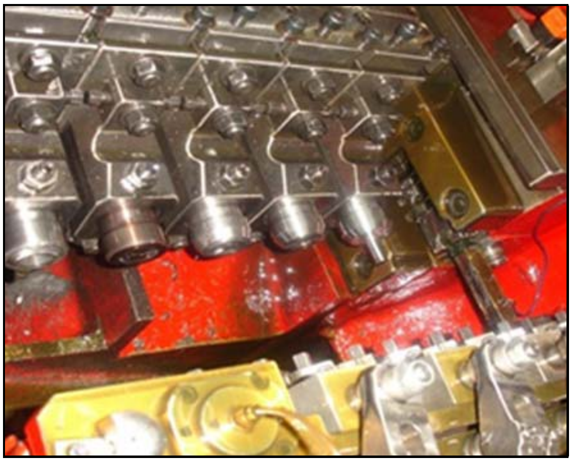

Fig. 3. Screw fabrication machinery and high speed steels.

specimens were investigated with Rockwell hardness tests. Moreover, tooling abilities of the DIN 1.3243, DIN 1.3207 and ASP 2052 were determined by examining the number of fabricated screws with these specimens. Fabrication machinery of screws can be seen in Fig. 3.

3. Results and discussion

Hardness tests were carried out to investigate the effects of heat treatments on the properties of alloys, and tooling ability of the specimens was investigated by examining the fabrication of screws. Hardness values for the specimens of alloys after hardening processes can be seen in Table 3.

The hardness values of the alloys are increasing after hardening processes with increasing austenitizing temperature. Higher dissolved carbon fractions were obtained in the austenite structure at elevated temperatures. Also, rapid cooling conditions hindered the diffusion of C from austenite structure, and precipitations of alloy carbides were prevented. In this manner, martensite structure has higher C content, and the hardness values of the specimens are increasing with elevated process temperature. After the hardening process, ASP 2052 has higher hardness values than 1.3243 and 1.3207 because of higher C content. Moreover, 1.3207 has higher hardness values than 1.3243 with C, W and V contents. W and C are comprised of MC type alloy carbides. This type of carbides protects their structure at elevated temperatures. Thus, alloys that have MC type carbides in their microstructures have higher hardness values than 1.3207.

Alloys that were austenitized at 1200 ℃ have any alteration after both tempering processes at 525 ℃ and 560 ℃ (Table 4). Also, solubility of C in the austenite structure is higher at elevated process temperatures. In this manner, a large amount of C dissolves in the austenite structure during the austenitizing process at 1200 ℃. Moreover, diffusion of C from lattice structure and precipitating of alloy carbides

Table 3. Hardness values for the specimens of alloys after hardening processes

Alloy	Austenitizing temperature (℃)			
	1080	1140	1180	1200
1.3243	59 HRC	61 HRC	64 HRC	64 HRC
1.3207	60 HRC	62 HRC	65 HRC	65 HRC
ASP 2052	63 HRC	65 HRC	66 HRC	67 HRC

Table 4. Hardness values of the alloys after tempering processes

Austenitizing temperature (℃)	Tempering temperature (℃)	Alloy		
		1.3243	1.3207	ASP 2052
1080	525	59 HRC	60 HRC	63 HRC
	560	58 HRC	59 HRC	63 HRC
1140	525	61 HRC	62 HRC	65 HRC
	560	60 HRC	62 HRC	64 HRC
1180	525	64 HRC	65 HRC	66 HRC
	560	64 HRC	64 HRC	66 HRC
1200	525	64 HRC	65 HRC	67 HRC
	560	64 HRC	65 HRC	67 HRC

Table 5. Tooling ability of the specimens

Austenitizing temperature (℃)	Tempering temperature (℃)	Alloy		
		1.3243	1.3207	ASP 2052
1080	525	67000	69000	95250
	560	65000	68000	95500
1140	525	67500	69100	100000
	560	67000	69000	98750
1180	525	80000	82150	143000
	560	79500	81000	143000
1200	525	82250	86900	167000
	560	82250	87000	167300

have higher kinetics. For 1.3207 and 1.3243 alloys, decreased hardness values after the austenitizing process at 1080 ℃ and tempering process at 560 ℃ differ from those of ASP 2052. ASP 2052 alloy has no hardness decrease because of higher C content. Amounts of alloy carbides and precipitated secondary carbides are higher than in 1.3207 and 1.3243. Also, 1.3207 alloy has higher hardness values than 1.3243 alloy due to higher C content.

Determination of tooling abilities of the alloys was achieved by examining the number of tooled screws as seen in Table 5. ASP 2052 alloy that was austenitized at 1200 ℃ and tempered at 560 ℃ has the best tooling performances. Martensite structure that occurred during the hardening of ASP 2052 alloy has higher hardness values than 1.3207 and 1.3243 alloys due to higher C content. Moreover, ASP 2052 alloy has MC type carbides due to existence of W and V in the chemical composition. Tooling ability of ASP 2052 alloy increases with increasing austenitizing and tempering temperatures due to increasing solubility of C in austenite structure at elevated temperatures and increasing amount of secondary carbides formation at elevated tempering temperatures. Moreover, Co has strengthening effect on the hot work properties and tooling ability of ASP 2052. Tooling ability of the 1.3207 alloy is better than that of 1.3243 alloy. Martensite structure that occurred during the hardening of 1.3207 alloy has higher hardness value than that of 1.3243 alloy due to higher C content. Moreover, 1.3207 alloy has MC type carbides due to higher content of W and V in the chemical composition. Additionally, 1.3207 alloy has higher Co content than 1.3243 alloy. Thus, 1.3207 alloy has better hardness values and hot work properties than 1.3243 alloy.

4. Conclusion

In experimental processes, DIN 1.3243, 1.3343 and ASP 2052 alloys were used as specimens. Different austenitizing and tempering temperatures were implemented using three different alloys, and effects of alloying elements such as C, Co, V, W, austenitizing and tempering temperatures on the properties of the specimens were investigated. Four different austenitizing temperatures with two different tempering temperatures were selected. By the way, effects of alloying elements were determined with different austenitizing and tempering temperatures.

Higher hardness values were obtained for ASP 2052 alloy due to higher C, V and W content, with formation of MC type carbides and secondary carbides in the microstructure. Besides, ASP 2052 has the best tooling ability because of higher hardness values and higher Co content. Moreover, 1.3207 alloy has higher hardness values and tool life than 1.3243 alloy because of the C, V and W content, with formation of MC type carbides and secondary carbides in the microstructure as mentioned earlier.

In conclusion, martensite structure has higher hardness values with higher austenitizing temperature due to increasing solubility of C at elevated temperatures. Moreover, ASP 2052 alloy has MC type carbides, and formation of secondary carbides after the tempering process is more effective due to high alloying elements content. As a result, ASP 2052 alloy that was austenitized at 1200 ℃ and tempered at 560 ℃, has the highest tool life.

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