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THE EFFECT OF SINTERING TIME ON TENSILE STRENGTH OF NB-V MICROALLOYED POWDER METALLURGY STEELS

ABSTRACT

Microalloyed steels can be defined as low alloyed high strength steels which increase the strength of steel by mechanisms such as precipitation hardening, aggregation hardening, particle size reduction, dispersion hardening by adding microalloy elements such as aluminium, niobium, vanadium and titanium in the range of 0.05% and 0.20%. Powder metallurgy is one of the manufacturing methods in which small parts which are difficult to manufacture can be produced in series with some parts which are close to the final shape with minimum material loss and which cannot be produced by other production methods. In this work, effect of different sintering time (1h., 2h. and 3h.) on the tensile strength of powder metallurgy (PM) plain carbon steel and microalloyed steels with different amount of niobium and vanadium content (0-0.1-0.2 wt%) were investigated. As a result, it was determined that the added alloying elements increased the mechanical properties. 0.2 wt % Nb-V added and sintered 2 h. PM steel showed the highest values in yield strength (YS), ultimate tensile strength (UTS).

Keywords: Powder Metallurgy, Nb-V Microalloyed Steels, Microstructure, Tensile Test, Sintering Time

1. INTRODUCTION

Steels can be referred to as iron carbon alloy. Factors affecting the strength of steel can be listed as deformation processes such as carbon content, alloying element, heat treatment and rolling. The amount of carbon increases the strength to a certain extent in steel. Alloy elements, on the other hand, affect the strength of the steel generally by precipitation or by changing the phases of the microstructure [1, 2 and 3]. Microalloyed steels can be defined as low alloyed high strength steels with mechanisms such as precipitation hardening, grain size reduction by adding microalloy elements such as niobium, vanadium and titanium in the range of 0.05% and 0.20%. Microalloyed steels are the steel group which can have superior properties such as high strength, high toughness, excellent weldability and corrosion resistance by applying different hardening mechanisms and suitable thermomechanical processes. The main role of microalloy elements is to reduce grain size, prevent recrystallization and contribute to precipitation hardening. The effect of microalloy elements on grain boundary movement and recrystallization is a result of carbide, nitride and carbonitride deposits [4, 5 and 6]. Powder metallurgy is one of the independent production methods such as casting, which are close to the final shape with the minimum material loss of small parts which are difficult to manufacture. In recent years, especially in the automotive industry, the production technique of some parts is entirely based on powder metallurgy. Powder

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metallurgy production method is used as an independent production option in the manufacturing sector due to factors such as homogeneous quality distribution, controllable content and low unit cost [7, 8, 9 and 10]. Although most of the microalloyed steels produced today are produced as flat and tubular products, in recent years the production of microalloyed steels has also gained momentum. In addition, microalloyed steel is produced by powder metallurgy method, which is not sufficient today [8 and 12]. For example, Erden et al. [10] produced Ti microalloyed steel by TM method. They carried out sintering for 1 minutes at 1150℃ and found that there was an increase in yield and tensile strength as Ti ratio increased (0-0.1-0.15 and 0.2% by weight). They attributed this to the formation of precipitates such as TiC (N) during sintering and during cooling after sintering. The authors showed that precipitates such as TiC (N) prevent the grain growth during sintering and cause the formation of small austenite grains and as a result increase the strength of the materials. In this study, unalloyed and Nb-V microalloyed steel production by powder metallurgy was carried out at different sintering times. It has been investigated how sintering time to unalloyed and microalloy steel produced contributes to yield and tensile strength and percent elongation.

2. RESEARCH SIGNIFICANCE

Depending on the size, distribution, shape, dissolution temperatures and cooling rate of the carbo-nitrides formed by microalloy elements, the conditions of formation are very important. It is more difficult to control these properties in casting method than powder metallurgy method. The production of microalloy steel by powder metallurgy has been realized and it is aimed to contribute to the previous studies by adding a new one to the studies in this field. In this study, by using powder metallurgy method, 0.1- 0.2% by weight of sintered steel with different sintering times was added. This study aims to contribute to the increase of powder metal steel production.

3. EXPERIMENTAL STUDY

In this study, TM steel production was realized by applying different sintering times. Unalloyed steel and microalloyed steel were produced by mixing the chemical compositions given in Table 1. Tensile test and microstructure examination were performed for the samples. The results were compared with each other. Prior to mixing, the powders were carried out in a digital precision tailor with a sensitivity of 0.0001 in the proportions given in Table 1 in the chemical composition. Weighed powders were mixed with Turbula brand triaxial mixer for one hour without ball.

Table 1. Chemical composition of microalloyed powder metal steels

Composition	Graphite (% ağ.)	Nb (% ağ.)	Al(% ağ.)	Fe (% ağ.)
Alloy 1	0.4	-	-	Rest
Alloy 2	0.4	0.05	0.05	Rest
Alloy 3	0.4	0.1	0.1	Rest

Pressing of the prepared mixture powders was made unidirectionally in the mold prepared according to ASTM 8M powder metal standard at a pressing pressure of 750MPa using a hydraulic press with a capacity of 100 tons pressing. In this study, the sintering process was carried out at a sintering temperature of 1300℃ started with rapid heating. After the temperature has reached the sintering temperature, the samples are kept at this temperature for 1-

2 and 3 hours and then at room temperature 5°C/min cooled rapidly. TM samples which were sintered at 1300°C. Microstructure pictures were taken by etching with 2% nital etch. tensile tests of unalloyed and microalloyed TM steel samples was performed 1mm/min speed.

4. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 1 and Table 2 show the tensile results of microalloy steel with unalloyed steel and Nb-V added.

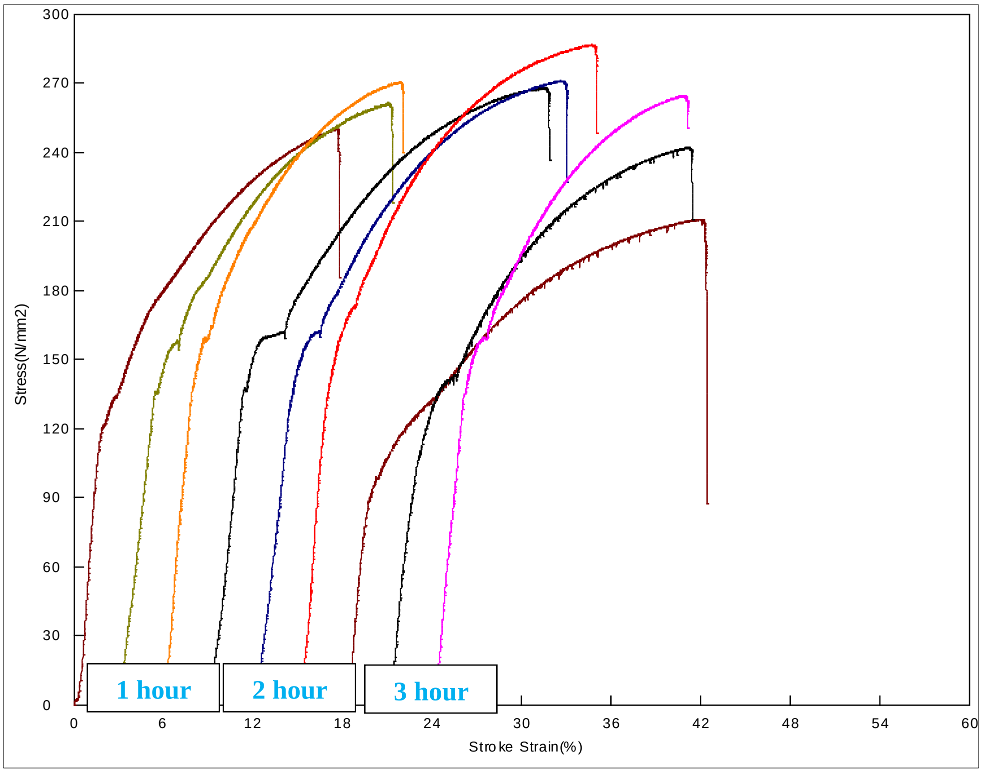


Figure 1. Stress-elongation diagrams of samples produced by TM method (Alloy 1, Alloy 2 and Alloy 3 in sequence)

Table 2. yield-tensile strength of steel samples produced by TM method, % elongation values

Bileşen	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (%)
Alloy 1 (1 hours)	131	251	18
Alloy 2 (1 hours)	155	262	18
Alloy 3 (1 hours)	161	270	16
Alloy 1 (2 hours)	161	268	22
Alloy 2 (2 hours)	164	272	21
Alloy 3 (2 hours)	174	288	20
Alloy 1 (3 hours)	105	212	24
Alloy 2 (3 hours)	145	242	20
Alloy 3 (3 hours)	162	265	18

As shown in Figure 1 and Table 2, when the Nb-V ratio in weight increases to 1%, yield and tensile strength increases. It can be said that there is a decrease in % elongation values. The carbide, nitride and carbonitride precipitates formed by the elements Nb and V prevent austenite grain size and austenite recrystallization, thus allowing the material to be small grained. Smaller grain structure has more grain boundaries and these grain boundaries prevent dislocation movement increases strength. The reduction in grain size also contributed to the% elongation of the material. In addition, the precipitates formed contributed to the increase of yield and tensile strength by different strength increasing mechanisms such as precipitation hardening, dispersion hardening and clustering hardening [5]. The increase in sintering time improves the% elongation values representing the formability. This is expected. Increased sintering time is expected to increase grain size. On the other hand, it was observed that the grain size increased and the% elongation value increased because it decreased the grain boundary. However, it is thought that with increasing sintering time to two hours, the amount of precipitation formation increases, and strength increase occurs as the precipitates prevent further dislocation movements. It is thought that the sintering time increases to 3 hours and precipitates grow and their effectiveness in inhibiting the displacement movement decreases. As a matter of fact, there are studies supporting this result in the literature. For example, Erden [5] investigated the effect of sintering temperature on Nb-V microalloyed steel. In this study, the increase in sintering temperature contributes to the resistance up to a certain temperature, while the temperature decreases to 1400°C. The reason for this is due to the decrease in the efficiency of grain growth and sediments as mentioned above.

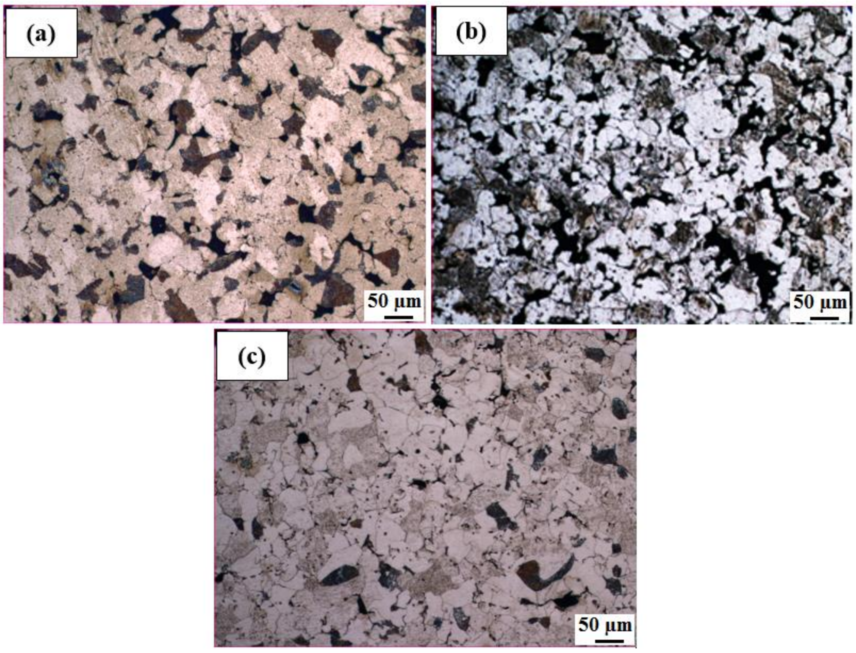
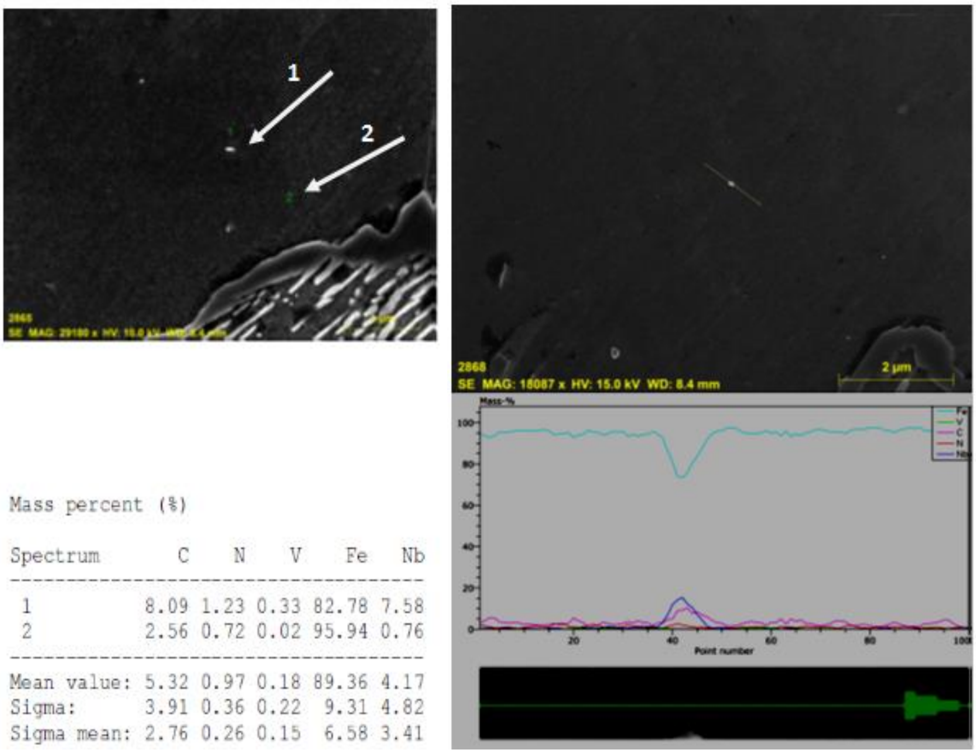


Figure 2. Microstructure drawings of unalloyed and Nb-V TM steel samples sintered for 2 hours at a sintering temperature of 1300°C (a-Alloy 1, b-Alloy 2 and c-Alloy 3 (200x)) µm

When the microstructure pictures were examined, it was observed that it consisted of ferrite and perlite phases. Microstructure drawings of unalloyed and Nb-V microalloyed steel samples which are sintered at 1300°C and V is added in different ratios are given in Figure 2. When the microstructure pictures are examined, it is seen that the structures consist of ferrite and perlite phases with different grain size in all samples. From microstructure pictures, it is seen that sintered unalloyed steel at 1300°C is larger grained than NbV microalloy steels with different ratios of Nb and V added. The reason for this is that microalloys during sintering form a precipitate that limits the growth of austenite grains. Microalloy elements are added to the steels separately or they are added as double or triple. The different mechanical properties required from microalloy steels require this [5, 12 and 13].

Studies [11] have shown that the presence of several microalloy elements in the alloy leads to the formation of carbides and nitrides in different compositions. These precipitates play a much more effective role in increasing the strength. Since the amount of carbon and nitrogen in the solid melt is reduced with the formation of precipitates, the effect of solid melt hardening on the strength increase decreases. Therefore, it can be said that NbC, VC and NbVC (N) precipitates formed in steel are the reasons for the increase of resistance in (Nb-V) microalloyed TM steel. As seen in Table 3, in general, as the ratio (Nb-V) increased, yield and tensile strength increased. This change in strength values occurs as a result of the formation of precipitates such as NbC (N) and VC (N) and their distribution in different sizes in the matrix [5, 10 and 12].In the literature, the results of microstructure, SEM and EDS analysis showed that vanadium and niobium were present in solution and in the form of precipitated particles [5 and 12]. In the study of Erden, SEM microstructure pictures and EDS analysis results of samples with sintered (Nb-V) composition at 1400°C are shown in Figures 3.



Mass percent (%)

Spectrum	C	N	V	Fe	Nb
1	8.09	1.23	0.33	82.78	7.58
2	2.56	0.72	0.02	95.94	0.76
Mean value:	5.32	0.97	0.18	89.36	4.17
Sigma:	3.91	0.36	0.22	9.31	4.82
Sigma mean:	2.76	0.26	0.15	6.58	3.41

Figure 3. Point and line EDS results from steel sample containing Nb-V alloying element [5 and 12]

The point EDS analysis results in Figure 3 show that NbC (N) and VC (N) precipitates are formed because these precipitates contain niobium, vanadium and carbon elements and Fe_3C precipitates occur because of iron and carbon content. In addition, when the line EDS analysis results of the microalloyed TM steel are examined, it is seen that there is a difference in the type and amount of elements along the line intersecting the matrix and precipitate. Iron is rich in the matrix phase but niobium is rich in the round sediment. There was also a sharp increase in the amount of vanadium when the analysis line from the matrix crossed the precipitate. It is stated that these precipitates inhibit austenite grain growth and recrystallization and also increase the strength of the material by precipitation hardening [5, 11 and 12]. Siwecki et al. [13] studied the sedimentation behaviour of low carbon microalloyed steels containing titanium and vanadium. They found that TiN and VN co-precipitated in the austenite phase with the addition of titanium to steel to form Ti, V (N) precipitates. They found that the internal part of the precipitate formed as a result of chemical analysis is rich in titanium element and the outer part is rich in vanadium element. This shows that Ti, V (N) is formed by precipitation of vanadium on TiN. As shown in Figure 3, both vanadium and niobium were found in the point EDS taken from the sediment and the amount of carbon was significantly higher compared to the point EDS taken from the matrix. This precipitate is thought to form Nb, V (C). The point and line EDS analysis results obtained in this study show that deposits such as VC (N) and NbC (N) are formed in microalloyed TM steels when compared with the studies in the literature. As a result, the addition of Nb-V alloying element improved yield and tensile strength. The reason for this is thought to be provided by one or more of the strengthening mechanisms such as precipitation hardening, aggregation hardening and grain size reduction mechanisms formed by precipitates formed such as NbC (N), VC (N) and NbVC (N).

5. CONCLUSIONS

Unalloyed steel and Microalloyed TM steels with 0.1-0.2% Nb-V added (Nb-V) were produced by cold pressing followed by sintering in argon atmosphere at 1300°C for 1-2-3 hours. The results listed below were obtained from this study.

- (Nb-V) microalloyed steels exhibited smaller grain structure than unalloyed steels. This is due to the inhibition of grain growth of carbides and nitrides formed by alloying elements.
- (Nb-V) microalloy steels can be produced by powder metallurgy method. Solid melt hardening and precipitation hardening during or after sintering increase the strength of the steel.
- Non alloyed steels and (Nb-V) microalloyed steels sintered at 1300°C for 2 hours have been observed to have superior mechanical properties.

NOTICE

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