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The Effects of Microalloying Elements and Temperaging Treatments Parameters on Nb-V Containing Cast Microalloyed Steels

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ABSTRACT

Electrically conductive composite material PANI- Zr(IV) molybdophosphate (PZMP) was synthesized, via treatment of Zr(IV) molybdophosphate with PANI (polyaniline) gel. The membrane of this material is fabricated for detection of mercury in waste samples. By using 4-in-line-probe the conducting behaviour of the material was determined, and it was found that conductivity of the nanocomposite lies in the range of semiconductors. The composite showed In this study, base composition without alloying elements and three microalloyed steels containing 0.08% wt V, 0.06% wt Nb and 0.06% wt Nb-0.1% wt V in induction furnace, in controlled condition, were casted. Temperaging were carried out on all of specimens for precipitation strengthening. For studying the influence of temperaging time and temperature, specimens with different chemical compositions were temperaged at 400,500,600 and 700 °C for 1,3 and 5 h. All of specimens in as-cast condition were studied using optical microscope and hardness tester. Results showed that as-cast specimens having ferrito-pearlitic microstructures. Nb-bearing specimens shows acicular microstructures. The heat treated samples were studied using Electron Microscope Analysis and hardness tester. Studying of mechanical properties of heat treated specimens, showed that because of precipitation strengthening, hardness of samples increased. By increasing of temperaging temperature in a constant time, hardness has an optimum value.

Material

To study the effects of microalloying additions and cooling rate on the microstructural and mechanical properties, three heats were produced in the form of 8Cm ×8Cm ×20Cm and 8Cm ×3Cm ×20Cm blocks. The chemical composition of these heats is shown in Table 1.

Samle	C	Mn	Si	P	S	V	Nb	N
Base	0.15	1.5	0.3	0.01	0.015	-	-	0.01
V	0.15	1.5	0.3	0.01	0.015	0.1	-	0.01
Nb	0.15	1.5	0.3	0.009	0.011		0.04	0.01
Nb-V	0.15	1.5	0.3	0.009	0.012	0.1	0.04	0.01

Table 1: Chemical compositions of alloys studied (weight %).

The alloy designations in Table 1 show the main alloying elements in the heats. The base composition for all heats is 0.15 wt% carbon and 1.5 wt% Mn. Ferroniobium was added to some heats to raise the Nb level to 0.04 wt%. Furthermore, sulfur plus phosphorus levels ranged from 0.02 to 0.035 for all heats.

Experimental results

To assess the effects of microalloying additions on the mechanical properties, tensile, hardness and Charpy impact tests were conducted for each composition. In order to avoid scattering, three samples were prepared for each test.

Optical microscopy and scanning electron microscopy were used for justifying the variation in the mechanical properties. Samples of each heat were optically examined at magnifications ranging from 100 to 1000 times in order to observe major phases and their distributions. Moreover, pearlite volume fraction was determined quantitatively using an image analyzer. Scanning electron microscopy was used for more detailed study of pearlite.

Optical microscopy

The optical microscopy micrographs of different alloys revealed that all microstructures consisted of pearlite and ferrite. Considerable microstructural changes were not observed after the addition of microalloying elements. Figures 1-6 are the 100×

optical micrographs depicting ferrite and pearlite constituent in different alloys. Table 1 shows variation of pearlite volume fraction in different alloys.

sample	Pearlie volume fraction (%)
Base	32.18 ± 1.48
V	38.23 ± 2.21
Nb	28.60 ± 2.52
Nb-V	34.27 ± 2.9

Table 2: Pearlite volume fraction in different alloys.

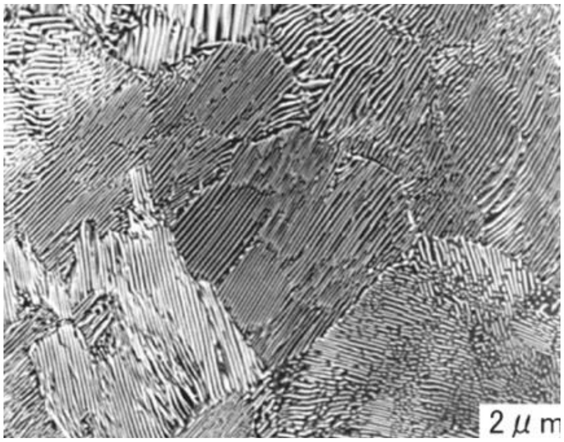

Figure 1: Ferritic-pearlitic microstructure on alloy Nb (SEM micrograph).

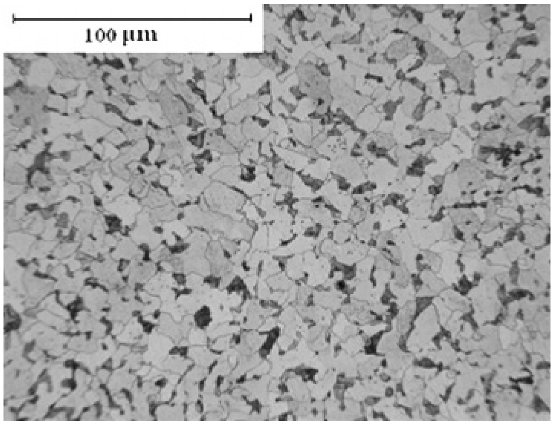

Figure 2: Optical micrograph of alloy Base.

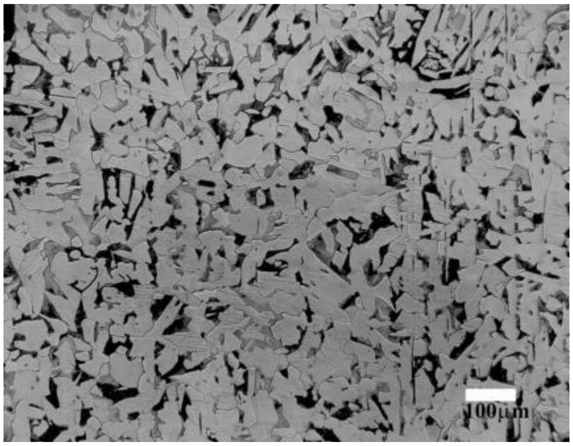

Figure 3: Optical micrograph of alloy Nb.

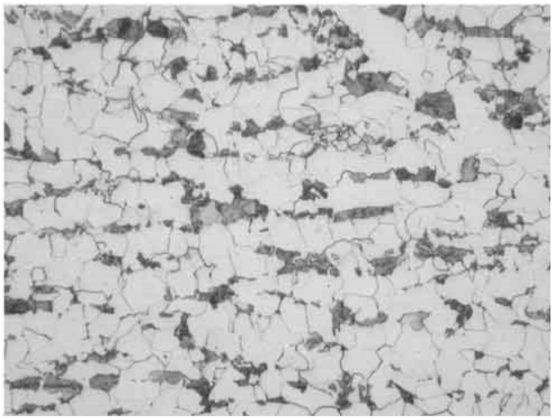

Figure 4: Optical micrograph of alloy V.

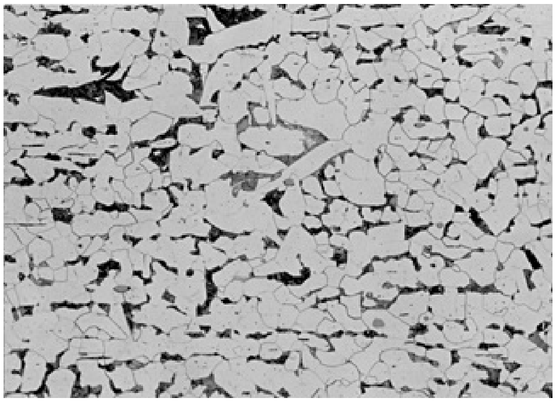

Figure 5: Optical micrograph of alloyNb-V.

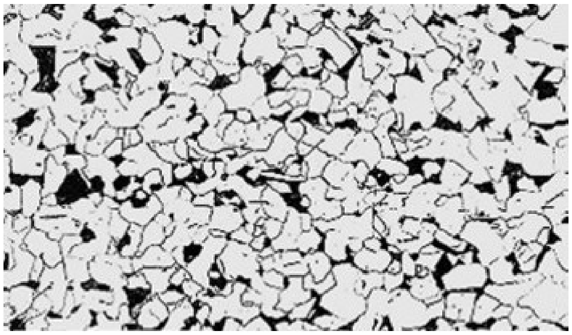

Figure 6: Optical micrograph of alloy Nb-V (thick).

Mechanical Properties

To evaluate mechanical properties of the plane and microalloyed steels in as-cast condition. Tensile, hardness and charpy impact tests were conducted. The results of these tests, which are shown in Table 2, are the average of three samples.

The results shown in Table 2, indicate that the presence of microalloying elements cause considerable changes in the mechanical properties. Comparison of the mechanical properties of microalloyed heats with base composition show that although yield strength. UTS and hardness of microalloyed heats have been enhanced, elongation and impact toughness have been reduced, this effect is more pronounce in impact toughness, since impact energy in microalloyed heats drastically has decreased [1]. However, since adverse effect of microalloying additions on mechanical properties in some heats are more than their positive effects [2].

sample	Yield (MPA)	UTS(MPA)	Elongation (%)
Base	274	470	30
V	379	578	23
Nb	374	536	18
Nb-V	435	596	17

Table 3: The results of mechanical tests.

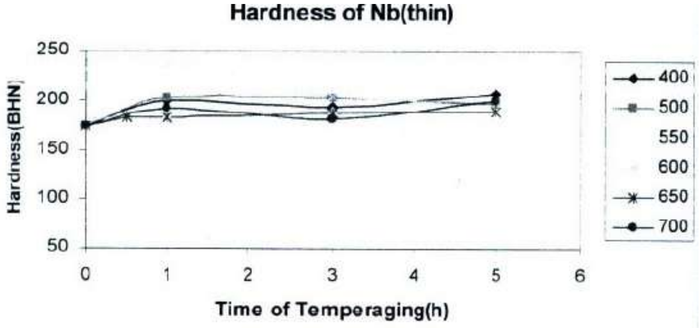

Figure 7: Results of harnesses of alloy Nb.

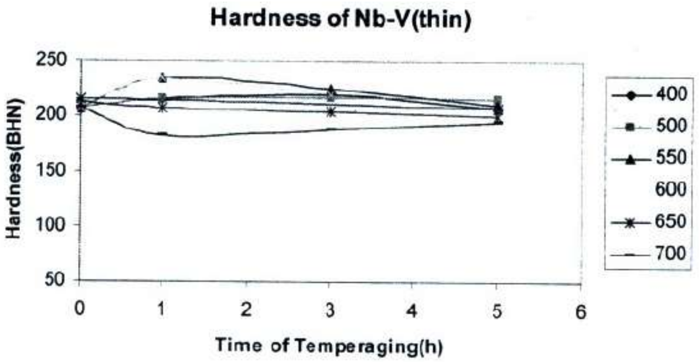

Figure 8: Results of hardnesses of alloy Nb-V.

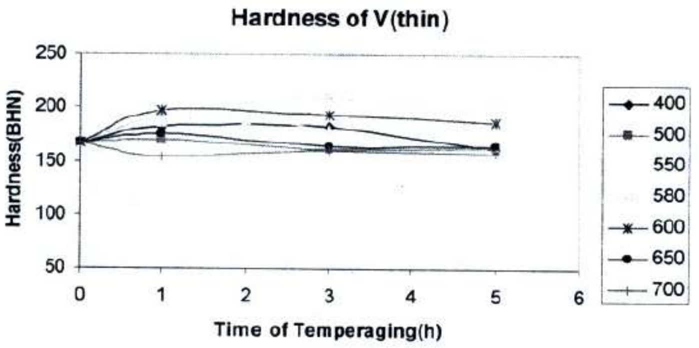

Figure 9: Results of hardnesses of alloy V.

Fractigraphy

Fractigraghy of impact specimens was carried out in scanning electron microscopy to study the type of fracture surfaces. The fracture surfaces of microalloyed samples were dominated by cleavage facets, while the fracture surface of alloy base was dominated by microvoid coalescence. Presence of cleavage facets confirmed the drastic decrease in impact energy of microalloyed samples. Even this phenomenon can be seen in alloy V that has the best impact energy among microalloyed samples. Figure 10-13 depict the scanning electron fractographs of different alloys [3,1].

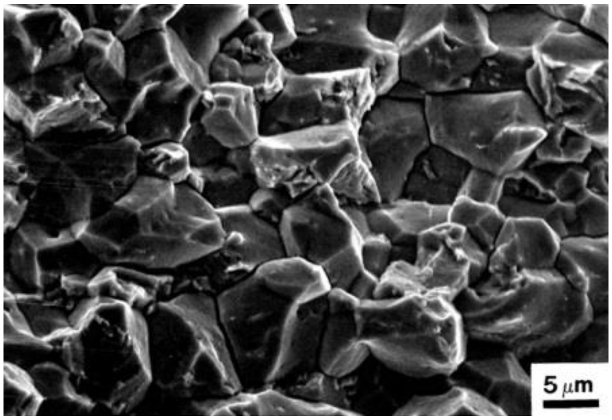

Figure 10: Scanning electron fractograph of alloy base.

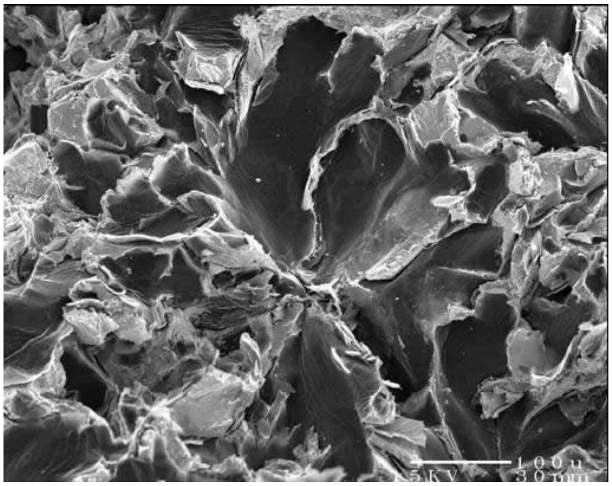

Figure 11: Scanning electron fractograph of alloy Nb.

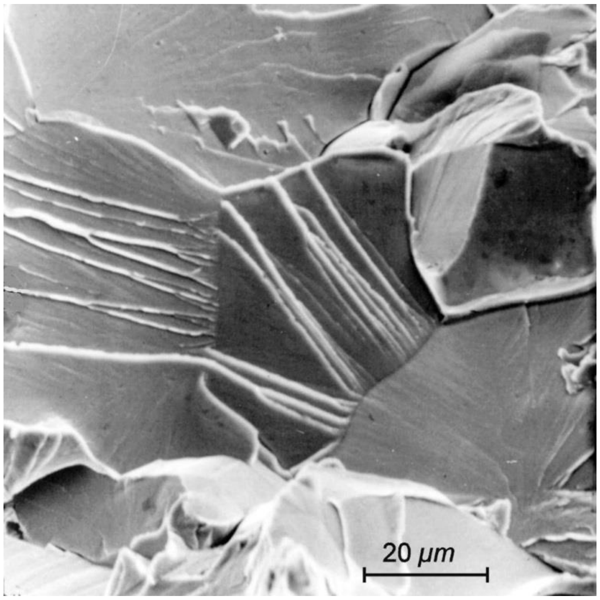

Figure 12: Scanning electron fractograph of alloy V.

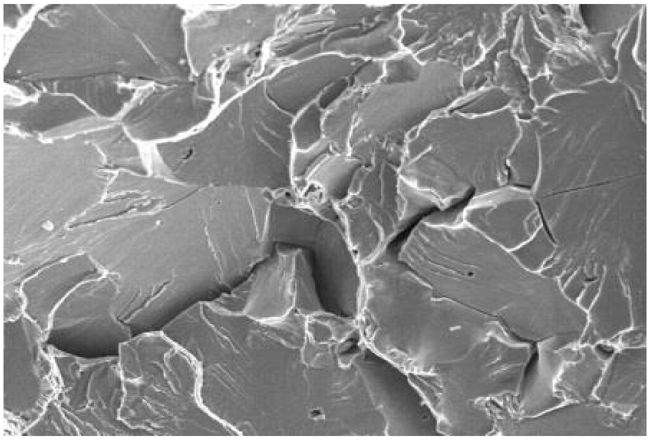

Figure 13: Scanning electron fractograph of alloy Nb-V.

Discussion

As mentioned in section 2-2, the addition of microalloying elements increase yield strength, UTS and hardness. This effect can be attributed to several factors such as variation in volume fraction and interlamellar spacing of pearlite and formation of carbonitride precipitates. However, optical microscopy and SEM studies indicate that the first and second assumptions do not play a major role in increasing the strength of the microalloyed heats [4,5]. The results in table 1 show that there is not a direct relationship between strength and pearlite content due to the fact that the yield strength of Nb-V with the least pearlite content, even less than alloy B, is more than V which has the highest pearlite content. Furthermore, while detailed SEM investigation has not been carried out on the microstructures of as-cast samples, primary studies did not show considerable changes in the pearlite interlamellar spacing in different alloys. Moreover, it was almost difficult to determine a reliable number for the pearlite content and interlamellar spacing in as-cast microstructures, because of the irregular distribution of pearlite constituent due to the varying cooling rate and microsegregation in different parts of the blocks to avoid considerable errors in determining the pearlite content and interlamellar spacing. As a result, the variations in yield strength, UTS and hardness can be correlated with the carbonitrides formation in the microalloyed heats [6,8].

Carbonitrides precipitation has been the subject of many investigation having studied different aspects of the precipitates and their effects on mechanical properties. Although most of these investigations have been restricted to wrought alloys, their findings can be applied to the present research. Based on these studies, carbonitrides precipitate in three different ways:

- Precipitation in the matrix or in the vicinity of austenite grain boundaries
- Precipitation on the advancing interface (interphase precipitation)
- Precipitation from supersaturated ferritic matrix (random precipitation)

Microalloying elements such as Nb which can precipitate at elevated temperatures generally from the first type precipitate. Nevertheless, if being sufficient in chemical composition. They can from the second and third type carbonitrides. On the other hand, vanadium carbonitride, precipitating at lower temperatures, generally appear in the second and third types. It is noteworthy that determining the exact temperature for carbonitrides formation depend on the several factors such as microalloying elements, carbon, and nitrogen contents which the first and the latter play an important role. Many studies, however, have shown that TiN is the most stable microalloyed precipitate remaining undissolved up to the melting point.The result in Table 2 show that vanadium and niodium increase the strength whenever added to the heats either separately or simultaneously.

Although it has been tried to interpret the variations in yield strength, UTS and hardness by citing from previous related studies on microalloyed steels. It is necessary to conduct detailed TEM studies in order to depict variation in shape, density and distribution of microalloyed carbonitrides in the microstructure of mentioned alloys. On the other hand, since few researches have concentrated on the microalloyed carbonitrides in as-cast condition, it can be valuable to focus on these microstructural features.

The results in Table 2 show that elongation and charpy impact energy values have been decreased due to the presence of microalloying elements. While the decrease in elongation values can be attributed to the increase in strength levels, the rationalization of the decrease in charpy impact energy values is more complicated and needs more detailed microstructural studies.

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