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Investigation of Manufacturability of WC Particle Reinforced Steels by Powder Metallurgy Method

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Abstract – Stainless steels are the development of low-alloyed or unalloyed steels. Stainless steels are widely used in industry and biomaterial fields due to their advanced properties such as superior mechanical properties, resistance to corrosion, and use as a biomaterial. Graphite, iron, titanium, vanadium and tungsten carbide were used in this study. By PM method, 0.05 wt% and 0.1% WC were added into graphite, iron and titanium powders. The powders were subjected to mechanical alloying process with a mechanical alloying device at 400 rpm for 60 minutes. Samples of each composition were formed by cold pressing the mixed powders with a one-way press device under 600 MPa pressure in the mold produced. After pressing, it was sintered for two hours at 1300°C in an argon atmosphere gas environment. Production process, microstructure analyzes were done.

Keywords – Powder metallurgy, WC Particles, Mechanical Properties, Alloy Element, Steel

I. INTRODUCTION

The materials produced by the PM method are better in terms of mechanical properties due to their more homogeneous structure [1,2]. Although the quality of the materials produced with PM is very good, it is also very good in terms of surface roughness, secondary processing is generally not needed. The production of complex shaped parts with the PM method has features that other production methods do not have due to its advantages such as low material loss or no material loss during production, mass production and low production cost [3-4]. In addition, the parts produced by the PM method are used in many areas in the automotive industry, electrical industry, military equipment parts, and health sector. PM production generally consists of powder production, powder mixing, pressing and sintering, respectively. Unalloyed steels cannot provide the desired properties in terms of formability, corrosion resistance and mechanical properties. For this reason, stainless steels containing alloying elements such as nickel, chromium and molybdenum are used instead of unalloyed steels. The mechanical properties, corrosion resistance, aesthetic appearance and ease of shaping of stainless steels have led to an increase in the usage areas day by day. The resistance of stainless steels against corrosion is provided by the chromium alloy. The chromium alloy forms an oxide layer by clinging to the surface of the stainless steel, and thanks to this layer, it gains resistance to environments such as chloride and acid [5]. Apart from chromium, other alloying elements are added to improve the properties of stainless steels. Alloys such as nickel, molybdenum, vanadium are some of the alloying elements added [6]. Steels contain carbon, silicon phosphorus and small amounts of aluminum elements[7-9]. While these elements impart hardness to steels, elements such as nickel, vanadium, titanium and manganese give stainless steels the ability to be shaped. Stainless steels are widely used in industry and health fields due to their high corrosion resistance, resistance at variable temperatures, long life, being usable in terms of health and many advanced features [10]. In this study, the effect of adding WC to steel at different weight % ratios on the microstructure was investigated.

II. MATERIALS AND METHOD

In this study, the production of WC reinforced samples, which were added at certain ratios, was carried out using the PM method. The microstructural properties of the produced samples were examined by tensile testing.

The mixed powders were subjected to unidirectional cold pressing under 600 MPa pressure in a mold. The pressed samples were sintered at 1300°C for 1 hours in an argon atmosphere gas environment, and the production of the samples was completed. XRD analyzes of the produced samples were made. For all samples, SEM images were taken at different magnifications from various areas and care was taken to ensure that these images were representative of the entire microstructure.

III. RESULTS AND DISCUSSION

Scanning electron microscopy analyzes of the samples produced by powder metallurgy method by supplementing WC at different rates were performed (Figure 1). According to the results of this analysis, evaluations were made from the data obtained.

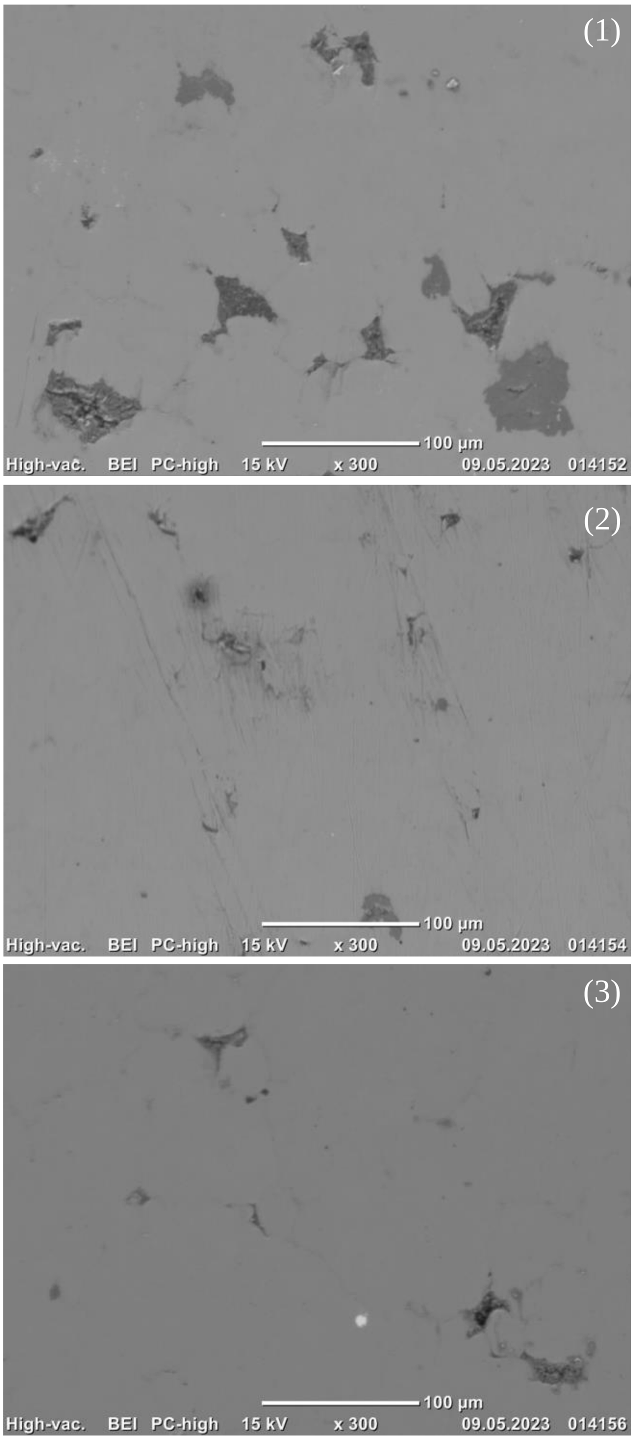

Fig. 1 SEM images of the produced samples.

The main structure of the compound is clearly seen in the SEM images given in Figure 1. It is clearly observed that WC, which is added as reinforcement particles at different rates into this main structure, is homogeneously dispersed. When the SEM images given above were examined, partial cracks and pores were detected in the samples produced [11]. In addition, when the given SEM images were examined, it was determined that the amount of pores decreased and changed depending on the WC addition rate. It has been determined that the homogeneous spreading of the Vanadium material in the main structure depends on the mixing of the powders during the production phase and the correct sintering process. This determined situation is supported by existing studies in the literature [12].

The XRD graphics of the samples produced by the powder metallurgy method are given in Figure 2. When the given XRD graphs were examined, it was determined that the phases appeared. However, there has been the presence of compounds as the dominant phases. The phases we detected in this study were also determined in current literature studies.

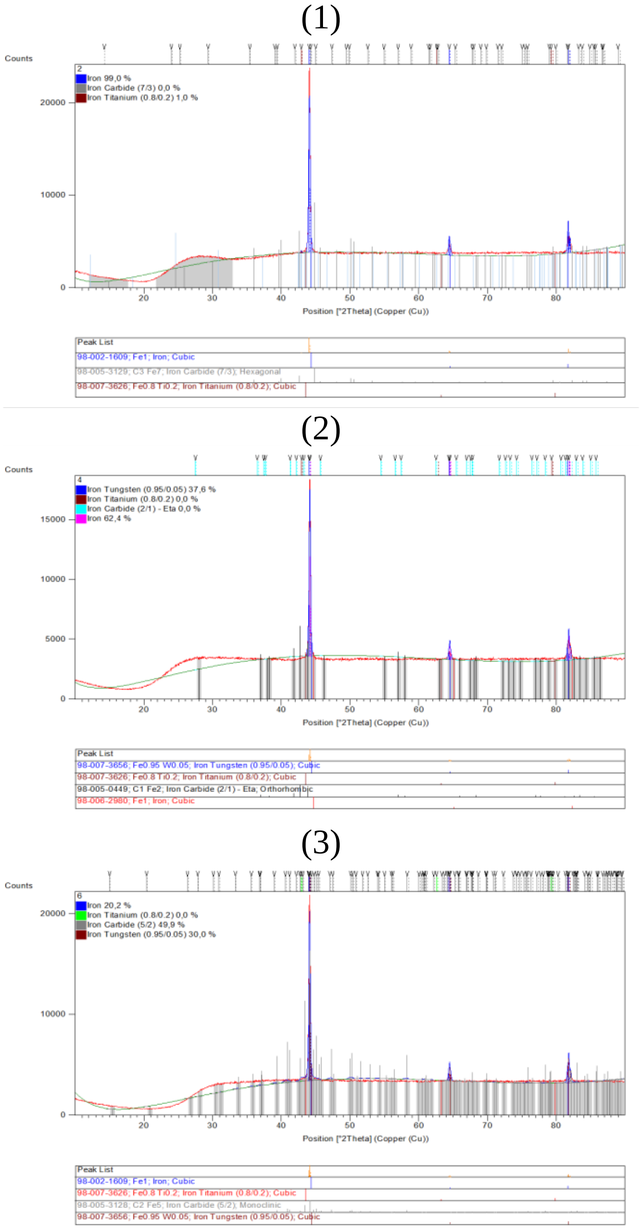

Fig. 2 XRD graphics of the produced samples.

When the graphs given in Figure 2 are examined, it has been determined as a result of XRD analysis that the phases we have determined as a result of a chemical interaction with Fe, graphite, Ti and WC elements during the sintering process [13]. It was determined that the peak intensities of the phases of the compounds interacting with Fe and WC increased with the increase in the WC ratios of the samples produced by adding WC at different rates. The peaks of the phases we detected in this study were also found in current literature studies and were supported by the literature [14].

IV. CONCLUSION

When the SEM images given above were examined, partial cracks and pores were detected in the samples produced. In addition, when the given SEM images were examined, it was determined that the amount of pores decreased and changed depending on the Vanadium addition rate. When the given XRD graphs were examined, it was determined that the phases appeared. However, there has been the presence of compounds as the dominant phases. The phases we detected in this study were also determined in current literature studies.

REFERENCES

[1] Liu, J., Chen, J., Liu, B., Lu, Y., Wu, S., Deng, X., ... & Qu, Z. (2020). Microstructure evolution of WC-20Co cemented carbide during direct selective laser melting. Powder Metallurgy, 63(5), 359-366.

[2] Stalin, B., Sudha, G. T., & Ravichandran, M. (2018). Investigations on characterization and properties of Al-MoO3 composites synthesized using powder metallurgy technique. Silicon, 10(6), 2663-2670.

[3] Lores, A., Azurmendi, N., Agote, I., & Zuza, E. (2019). A review on recent developments in binder jetting metal additive manufacturing: materials and process characteristics. Powder Metallurgy, 62(5), 267-296.

[4] Chen, H., Gu, D., Zhang, H., Xi, L., Lu, T., Deng, L., ... & Kosiba, K. (2021). Novel WC-reinforced iron-based composites with excellent mechanical properties synthesized by laser additive manufacturing: Underlying role of reinforcement weight fraction. Journal of Materials Processing Technology, 289, 116959.

[5] Shi, J., & Wang, Y. (2020). Development of metal matrix composites by laser-assisted additive manufacturing technologies: a review. Journal of Materials Science, 55(23), 9883-9917.

[6] Wang, J., Li, L., & Tao, W. (2016). Crack initiation and propagation behavior of WC particles reinforced Fe-based metal matrix composite produced by laser melting deposition. Optics & Laser Technology, 82, 170-182.
[7] Govindarajan, V., Sivakumar, R., Patil, P. P., Kaliappan, S., Ch Anil Kumar, T., Kannan, M., & Ramesh, B. (2022). Effect of tungsten carbide addition on the microstructure and mechanical behavior of titanium matrix developed by powder metallurgy route. Advances in Materials Science and Engineering, 2022.
[8] Chen, H., Gu, D., Kosiba, K., Lu, T., Deng, L., Xi, L., & Kühn, U. (2020). Achieving high strength and high ductility in WC-reinforced iron-based composites by laser additive manufacturing. Additive manufacturing, 35, 101195.
[9] Moreira, A. B., Ribeiro, L. M., Lacerda, P., Pinto, A. M., & Vieira, M. F. (2021). Production and characterization of austenitic stainless steel cast parts reinforced with wc particles fabricated by ex situ technique. Materials, 14(24), 7855.
[10] Yan, X., Huang, C., Chen, C., Bolot, R., Dembinski, L., Huang, R., ... & Liu, M. (2019). Additive manufacturing of WC reinforced maraging steel 300 composites by cold spraying and selective laser melting. Surface and Coatings Technology, 371, 161-171.
[11] Yu, R., Bai, X., Yu, X., & Zhang, H. (2023). WC-reinforced iron matrix composites fabricated by wire arc additive manufacturing combined with gravity-driven powder feeding: particle transportation and size effects. Rapid Prototyping Journal, 29(5), 1014-1028.
[12] Su, S., & Lu, Y. (2020). Densified WCu composite fabricated via laser additive manufacturing. International Journal of Refractory Metals and Hard Materials, 87, 105122.
[13] Lou, D., Hellman, J., Luhulima, D., Liimatainen, J., & Lindroos, V. K. (2003). Interactions between tungsten carbide (WC) particulates and metal matrix in WC-reinforced composites. Materials Science and Engineering: A, 340(1-2), 155-162.
[14] Wan, S., Li, H., Tieu, K., Xue, Q., & Zhu, H. (2019). Mechanical and tribological assessments of high-vanadium high-speed steel by the conventional powder metallurgy process. The International Journal of Advanced Manufacturing Technology, 103, 943-955.