COATING OF ST37 STRUCTURAL STEEL SURFACE WITH WC-ST6-ST21 AND FERRO55 USING LASER CLADDING TECHNIQUE AND INVESTIGATION OF SURFACE HARDNESS

Beyza AVCI[1], Ibrahim Savas DALMIS[2], Serdar Osman YILMAZ[2]

[1] *DOMEKS Machinery Inc. Design Center, Türkiye*
[2] *Tekirdağ Namık Kemal University, Çorlu Engineering Faculty, Mechanical Engineering Department, Türkiye*

Abstract

Improving material properties such as surface hardness and wear resistance play a vital role in modern industrial applications. Surface coating techniques offer a practical approach to achieve these improvements. This study focuses on laser cladding as a method to coat ST37 structural steel material with WC, ST6, ST21 and Ferro55 powders and investigates the resulting surface hardness. ST37 structural steel with a base hardness of 120 HV was used as the starting material. Laser cladding was used to apply WC, ST6, ST21 and Ferro55 powders to the steel surfaces using various process parameters. Hardness measurements of the laser cladded samples were carried out using HV0.3 load for evaluation. The study examines the surface hardness differences between ST37 steel samples coated with different powders, highlighting the highest and lowest hardness values.

Keywords: Stellite6, Stellite21, Ferro55, WC, Laser, Laser cladding

INTRODUCTION

The development of technology and the widespread use of mechanical parts lead to the development of alloys containing various properties. However, in some cases, these alloys may be insufficient. For this reason, surfaces are subjected to various processes to increase the desired properties such as heat resistance, hardness and friction resistance. With these processes, the desired properties are obtained by forming a layer, alloy or a separate structure on the surface.

Such special conditions include high temperature environments (800°C-1000°C), metal forming, aviation, aerospace, automotive, energy sectors. In such cases, superalloys are often used.

Lazer cladding yöntemi, diğer metal kaplama yöntemlerine göre daha dayanıklıdır. Bu yöntem, daha pahalı süper alaşımlar yerine daha ekonomik süper alaşımların kullanılmasını sağlamaktadır. Ayrıca, bu yöntemle metal matris kompozitlerinin kaplanması da mümkün hale gelmiştir [1].

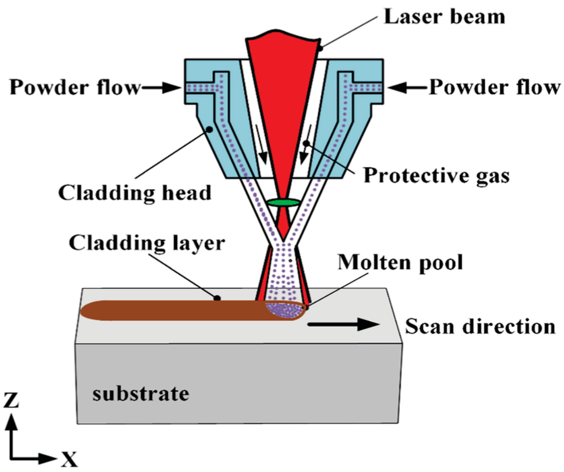

***Fig. 1.** Schematic representation of laser cladding [8]*

Today, laser cladding, one of the leading manufacturing technologies, is used in various industrial fields. The process is used to protect metallic surfaces or to improve their properties. As a result of this process, which is carried out by spraying the melted powder of high-power lasers onto the surface, the coated surface properties increase significantly and it becomes possible to produce high-performance materials. This method increases the resistance of components against factors such as wear, corrosion, fatigue and improves the thermal, mechanical and chemical properties of materials. It is widely used for especially prototype production, repair operations and manufacturing applications. In addition, it has a wide range of applications in many fields such as aviation, space, automotive, defence industry, medicine [2].

Various studies have been carried out on Laser cladding method, which is widely used in daily life.

In the study performed by Singh et al. (2023), Hogonos+50%WC coatings were applied by laser cladding method to alleviate the erosion problem in hydromechanisms. The effects of laser beam power, torch travelling speed and powder feed rate on the coating quality were investigated. Cross-sectional characterisation, XRD analysis, microhardness and slurry analysis of the coated samples were performed. Scanning speed contributed to a greater increase in hardness than other parameters such as laser beam power and powder feed rate. Hogonos+50%WC coated samples are more resistant to slurry erosion than uncoated SS304 steel. Mixed fracture mode (ductile and brittle) was observed in both coated and uncoated samples [3].

Wu et al. (2023) prepared two different coatings on the surface of 60Si2Mn spring steel using laser cladding technology. The first coating consists of Fe/WC coating layer, while the second consists of Fe/WC coating layer and Ni60 transition coating. The study shows that the Ni60 transition coating reduces the risk of pore and crack formation in the Fe/WC composite coating, promotes the upward elongation tendency of columnar crystals, and does not significantly affect the solidification properties of the coating layer. The solidification properties of the two coatings consist of dendrites and inter-dendrite eutectics. Additionally, it was determined that the microstructure in the upper and middle zones of the single Fe/WC composite coating generally shows snowflake-like equiaxed crystal distribution, while columnar crystals dominate in the lower zone. With respect to mechanical properties, it was observed that the diffusion of Ni element decreased the microhardness of the coating layer, while Fe/WC composite coating increased the average friction coefficient and wear volume. However, these mechanical properties were considerably improved compared to the properties of the matrix [4].

In their study Yang et al. (2022), Stellite 6 coatings were produced by high-speed laser cladding technique and inward powder feeding method. The microstructure, hardness and wear resistance of the coatings were investigated. The results show that all Stellite 6 coatings are free of any visible defects. The coating thickness decreased inversely proportional to the coating speed and increased with increasing laser power and ranged from 429.35 to 842.19 micrometres. The coatings were generally composed of γ-Co and carbides, and the microstructure of γ-Co exhibited different crystal structures from the base to the coating surface. The second dendritic arm length (SDAS) of γ-Co shows a positive linear relationship with laser energy density (LED). The liquefaction rate of Stellite 6 coating increased with laser power and coating speed, while the microhardness showed an inverse variation. The highest hardness value of 610.26 HV was obtained when the laser power was 1600 W and the coating speed was 4000 mm/min. The wear resistance of the Stellite 6 coating was approximately 2-5 times higher than that of the 45# steel base and this was found to be largely due to the hardness of the coating. Micro-shearing and impacting caused by abrasive particles are the predominant damage mechanisms, but corrosion attack due to 3.5% NaCl solution was found to be negligible. Therefore, it was observed that the wear resistance of Stellite 6 laser coating can be further improved by increasing the hardness of the coating [5].

In their study, Zeng et al. (2021) investigated the surface quality, microscopic morphology, microstructure and mechanical properties of Fe50/TiC/WC ternary coatings on AISI 1045 carbon steel. The results of the research show that WC and TiC particles do not dissolve in the coating powder, but are rather retained in the coating. This leads to the formation of more particle reinforced microstructure. It was determined that the best performing coating was Fe50/TiC/WC coating with 10% WC. This coating has advantages over the substrate such as less porosity, microhardness of about 56.1HRC and wear volume of 1.5 [6].

Bartkowski et al. (2014) investigated the preparation method and results of metal matrix composite coatings (MMC coating) for Stellite-6 and tungsten carbides system. The research addressed microstructure, corrosion resistance, microhardness, changes in phases and chemical composition, and surface conditions. Stellite-6/WC MMC coatings were produced by laser cladding technology using a 1 kW continuous wave Yb:YAG disc laser. Powder mixtures with two different WC contents and three different laser beam power values were used. The increase in the amount of WC showed that the microhardness of the coating increased. Depending on the laser beam power, coatings containing 30% WC achieved a microhardness between 350 HV0.05 (700 W) and 680 HV0.05 (550 W). Doubling the amount of WC particles increased the microhardness from 700 HV0.05 (700 W) to 1500 HV0.05 (550 W) [7].

Based on the literature research, it has been observed that there are many studies using laser cladding method with various powders. In these studies, it was observed that material microstructure, microhardness and wear resistance of the material were examined by coating the material surfaces using different percentage ratios of the same powders. Unlike other studies, this study measured the microhardness of St37 structural steel surface coated with 4 different powders using laser cladding method and the obtained results were analysed.

MATERIAL AND METHOD

This study was carried out by coating St37 structural steel with Stellite6, Stellite21, WC and Ferro55 powders using laser cladding method.

Test Pieces

For the tests, 8 pieces of 118*64*15 mm St37 structural steel with a hardness of 120 HV, whose chemical composition is given in Table 1, were used as the main material.

Table 1. *St37 Chemical Components of Structural Steel (%)*

Elements	%
Mn	max 1,4
P	max 0,04
S	max 0,04
N	max 0,012
Cu	max 0,55
C	max 0,2
CEV	max 0,38

Powders Coated with Laser Cladding Method

WC, Stellite6, Stellite21 and Ferro55 powders were coated on the steel of the given dimensions by laser cladding method from 4 different powders on each sample. The chemical compositions of the coated powders and the process parameters of the powders coated by laser cladding method are given in Table 2 and Table 3, respectively.

Table 2. Chemical components of powders coated by laser cladding method (%)

Elements	Stellite 6	Stellite 21	WC	Ferro 55
Fe	1.5	2.0		rest
Si	1.0	0.8-1		0.3
B	-	-	40	-
Ni	1.5	1.8-3.3		-
Cr	28.5	26-29		7
C	1.1	0.2-0.3		0.35
W	4.4	-	-	-
Co	rest	rest	-	-
Mo	-	5-6	-	2.2
Mn	-	0.5-0.8	-	1.1
WC	-	-	60	-

Table 3. Process parameters of powders coated by laser cladding method

Powders Used	Preheating (°C)	Power (W)	Feed Rate (mm/sec)	Powder Rate
WC	150	1100	13	1.8 kg/h
Stellite6	200	1200	11	2 kg/h
Stellite21	-	1300	10	2 kg/h
Ferro55	100	1350	11	4 round/min

The method used in the coating process and the images of the coated samples are given in Figure 2 and Figure 3, respectively.

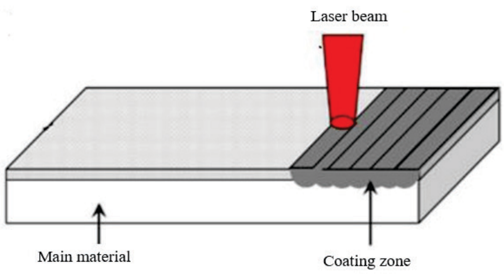

Fig. 2. Laser cladding coating method

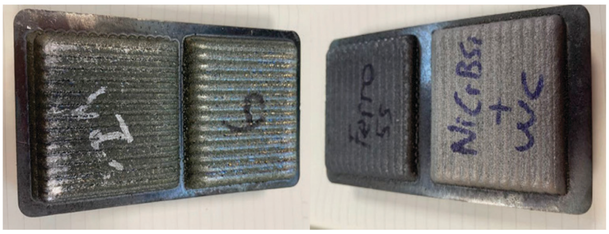

Fig. 3. Samples coated by laser cladding method

Surface Hardness Measurement Method

The hardness of St37 structural steel coated with laser cladding method was measured at 1 mm intervals from the coating surface to the base material surface. BMS Bulut Makine Micro Vickers Hardness Tester was used for hardness measurements. The schematic diagram of the hardness measurement path is given in Figure 4.

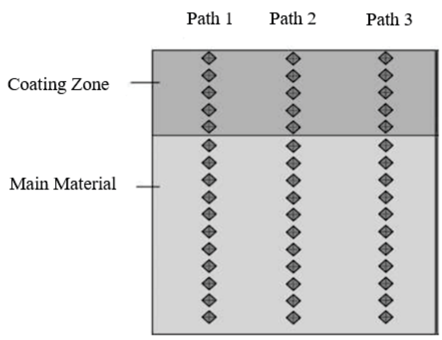

Fig. 4. Schematic diagram of the microhardness measurement path

RESULT AND DISCUSSION

Hardness measurements were carried out on the BMS Bulut Makine Micro Vickers Hardness Tester by making 5 measurements from each point at 1 mm intervals from the HV0.3 load coating zone towards the base material. The changes of microhardness values are shown in Figure 5.

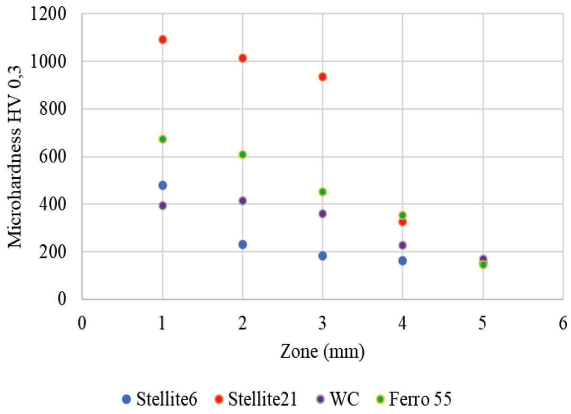

Fig. 5. *Microhardness results*

According to the measurements made:

• The hardness of the Stellite 6 coated sample in zone 1 was measured as 447,86 HV0.3, the hardness of the Stellite 6 coated sample in zone 2 as 231,12 HV0.3, the hardness of the Stellite 6 coated sample in zone 3 as 183,04 HV0.3, the hardness of the Stellite 6 coated sample in zone 4 as 162,54 HV0.3 and as 150,78 HV0.3 in zone 5.

• The hardness of the Stellite 21 coated sample in zone 1 was measured as 1090,32 HV0.3, the hardness of the Stellite 21 coated sample in the zone 2 as 1014,86 HV0.3, the hardness of the Stellite 21 coated sample in zone 3 as 934,72 HV0.3, the hardness of the Stellite 21 coated sample in zone 4 as 327,76 HV0.3 and as 151,24 HV0.3 in zone 5.

• The hardness of the WC coated sample in zone 1 was measured as 394.2 HV0.3, the hardness of WC coated sample in zone 2 as 415.26 HV0.3, the hardness of WC coated sample in zone 3 as 358.6 HV0.3, the hardness of WC coated sample in zone 4 as 229.06 HV0.3 and as 170.02 HV0.3 in zone 5.

• The hardness of the Ferro 55 coated sample in zone 1 was measured as 672.1 HV0.3, the hardness of the Ferro 55 coated sample in zone 2 as 609.38 HV0.3, the hardness of the Ferro 55 coated sample in zone 3 as 450.5 HV0.3, the hardness of the Ferro 55 coated sample in zone 4 as 351.95 HV0.3 and as 147.28 HV0.3 in zone 5.

CONCLUSION

This study investigated the microhardness measurements of St37 structural steel coated with four different powders from the coating zone towards the main material. As a result of the measurements, it was observed that the Stellite 21 coated sample had the highest surface hardness in zone 1 and the WC coated sample had the lowest surface hardness. In zone 5, hardness results were measured very close to each other. In zone 2 and 3 the highest surface hardness belongs to Stellite 21 coated sample and the lowest surface hardness belongs to Stellite 6 coated sample.

ACKNOWLEDGMENT

This study was supported by DOMEKS Makine A. S. Design Center.

REFERENCE

[1] Öner, A., Yalçınkaya, S. (2020). "Çelik Yüzeylerine Lazer Kaplama (Lc) Yöntemi İle Süper Alaşımlar Kaplanması Ve Aşınma/ Korozyon Dirençlerinin İncelenmesi". Marmara Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul / Türkiye.

[2] Dindar, Ç., Altay, M., Aydın, H. (2021). Lazer kaplama prosesi ve proses parametreleri: derleme çalışması. Uludağ Üniversitesi Mühendislik Fakültesi Dergisi, Cilt 26, Sayı 2, 2021.]

[3] Singh, S., Bansal, A., Kumar, P., Goyal, D. P., (2023). Slurry erosion behavior of Hogonas+50%WC cladded SS304 steel prepared using variable laser cladding parameters, International Journal of Refractory Metals and Hard Materials (2023), https://doi.org/10.1016/j.ijrmhm.2023.106326

[4] Wu, T., Shi, W., Xie, L., Gong, M., Huang, J., Xie, Y., He, K. (2023). Study on the effect of Ni60 transition coating on microstructure and mechanical properties of Fe/WC composite coating by laser cladding. Optics & Laser Technology Volume 163, August 2023, 109387.

[5] Yang, Z., Jian, Y., Chen, Z., Qi, H., Huang, Z., Huang, G., Xing, J., (2022). Microstructure, hardness and slurry erosion-

wear behaviors of high-speed laser cladding Stellite 6 coatings prepared by the inside-beam powder feeding method. Journal of Materials Research and Technology Volume 19, July–August 2022, Pages 2596-2610.

[6] Zeng, X., Wang, Q., Chen, C., Lian, G., Huang, X. (2021). "Effects of WC addition on the morphology, microstructure and mechanical properties of Fe50/TiC/WC laser claddings on AISI 1045 steel". Surface & Coatings Technology, 427, (2021) 127781.

[7] Bartkowski, D., Mlynarczak, A., Piasecki, A., Dudziak, B., Goscianski, M., Bartkowska, A. (2014). "Microstructure, microhardness and corrosion resistance of Stellite-6 coatings reinforced with WC particles using laser cladding". Optics & Laser Technology, 68, (2015) 191-201.