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Improvement of Microhardness Using Laser Cladding Technique

Anu Shrestha

Institute of Engineering, Purwanchal Campus, Dharan, Nepal

anushrestha@ioepc.edu.np

Abstract

In this paper, the laser cladding was used to improve the microhardness which was Al-based metal matrix composite in-situ. Especially, mechanical behavior, i.e. microhardness of metal has been tested to carry out to change a wide range of functional properties. For this work, the high-power laser beam was used which can be controlled by main control unit. The microhardness was tested using a LM-700 digital indentation tester. The hardness values of the substrate material show 48Hv0.05. The coating materials of average hardness values are approximately 15~20 times improved with respect to the base material. This method of improvement of microhardness showed significantly enhanced as compared to traditional coating methods in which sidewise shielding gas was supplied on the preplaced powder of the substrate material.

Keywords: *Microhardness; Laser Cladding Technique, Surface Engineering, .*

1. Introduction

We need extensive researches in surface engineering to enhance mechanical properties of the metal with high wear-resistant. The method of Laser cladding can be implemented in low cost. The laser cladding is a process of deposition of new layer of material on a substrate by fusing blown powder or preplaced powder material with the help of high power laser beam to achieve surface modification and for repair and manufacture of the required dimension and shape of the components. In this process metallurgical bonding can be achieved with minimum dilution of newly applied material and substrate material. Low heat affected zone , low crack, low porosity and low distortion etc. are advantages of the laser cladding process which are better than

Corresponding Author: Anu Shrestha
Author's affiliation: Instituet of Engineering (IoE), Purwanchal Campus, TU, Nepal
Email: anushrestha@ioepc.edu.np

traditional coating method [1-2].

2. Laser Cladding Technique

In laser cladding, the laser beam is focused on the substrate material with a selected spot size and scanned. The laser head is automatically moved across the substrate material to deposit single tracks, complete layers or even high-volume build-ups. The materials can be deposited on a substrate using 2-step cladding method and 1-step cladding method [3-4].

2.1. 2-step cladding method (preplaced powder method)

In this method, powder is preplaced on the substrate material and laser beam is scanned on the powder which melts powder as well as minimum portion of the substrate material and strong bond can be formed. The powder may be preplaced by conventional method by flam spraying, plasma spraying, electroplating and electro deposition etc. or directly applying powder onto the substrate. When using powder, they are prepared in the form of slurry by mixing sticking agents such as cellulose acetate acetone solution mixed with ethanol, dendrite, epoxy resin acetone, borax solution etc. and baked in the furnace in the required temperature. A laser beam is then scanned over the new layer to form strong metallurgical bond. Figure 1 shows the 2-step laser cladding method. [4].

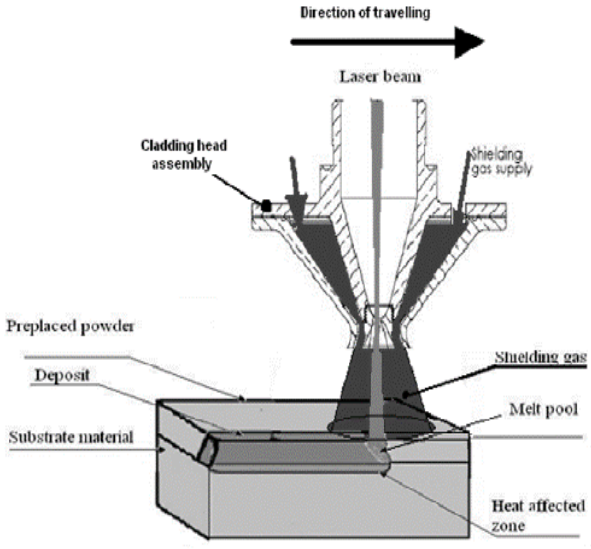


Figure 1. Preplaced powder cladding method

2.2. 1-step cladding method (powder feeding method/wire feeding method)

This is popular method in which powder or wire is dynamically fed on the molten pool made by laser beam. In this process laser beam preheats and melts feeding materials and bonds with the substrate material. 1-step cladding technique are also achieved by co-axial powder feeding method, off axial powder feeding method, and wire feeding method. Figure 2 and figure 3 show the axial and off-axial laser cladding method in which

the nozzle of both axial and off-axial show the higher amount of powder with decreasing the nozzle exit width [4-6].

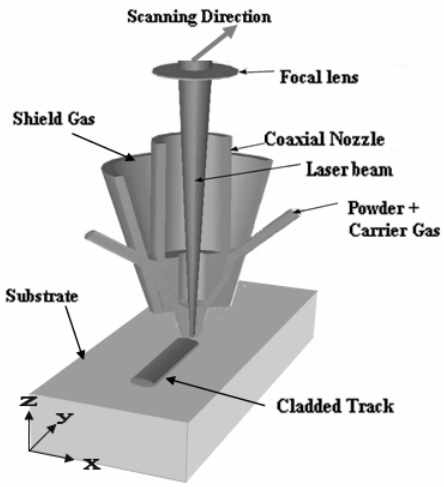


Figure 2. Coaxial laser cladding method

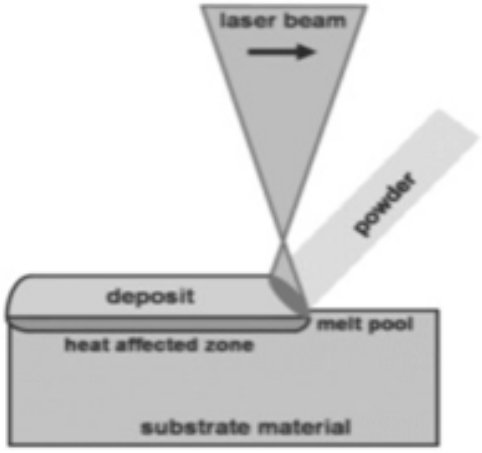


Figure 3. off-axial laser cladding method

However, there are some drawbacks of powder laser cladding methods. These can be as follows: a) It cannot be used for complex geometry component due to flat surface, b) powder may be blown due to high pressure of gas, c) It requires high energy for desired depth, and d) It cannot be easily controlled the molten zone between clad layer and substrate.

3. In-situ and Ex-situ Process for Metal Matrix Composite

In-situ composites are multiphase materials where reinforcing phases are synthesized by chemical reactions between elements within the matrix during composite fabrication. This contrasts with ex-situ composites where the reinforcing phase is synthesized separately and then inserted into the matrix during the secondary process such as sintering and powder metallurgical processing. In-situ process can create a variety of morphologies of composites ,ranging from continuous to discontinuous and the reinforcement may be either ductile or ceramics phases [7].Compared to the conventional MMCs produced by ex- situ methods such as different casting processes, injection molding, liquid metal infiltration processes, diffusion bonding, spray deposition, powder metallurgical processes, solid state hot pressing etc., the in-situ MMCs exhibit the following advantages: (a) the in-situ formed reinforcements are thermodynamically stable at the matrix, leading to less degradation in elevated-temperature services; (b) the reinforcement matrix interfaces are clean, resulting in a strong interfacial bonding; (c) the in-situ formed reinforcing particles are finer in size and their distribution in the matrix is more uniform, yielding better mechanical properties[8]. Ex-situ composites show the presence of gaps and porosity suggesting poor adhesion between matrix and particulate interfaces and crack may propagate from the interface, Tjong et al. [8]. showed the agglomeration of ceramic particulates during processing of ex-situ composites, leading to the formation of composites with poor mechanical strength and toughness.

4. Experiment

2 KW fiber laser based on Ytterbium operating at 1085nm wave length is used in this work. This beam quality is 10 times better than a standard Nd-YAG laser. This laser is being used for the experiments. The laser head can be controlled by main control unit. The laser machine setup is shown in the Figure 4. The specifications of the main control unit and technical parameters are given in Table 1.

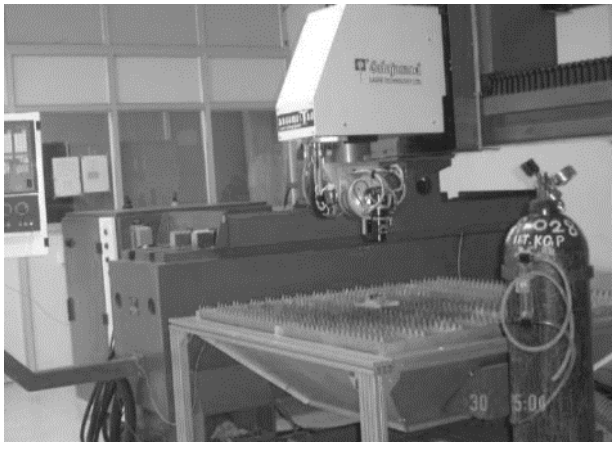


Figure 4. Laser machine setup

In the present work, vicker's microhardness was tested for the samples by using a LM-700 digital indentation tester, LECO with a vicker's indenter. After preparation of the cladded samples Vickers microhardness was examined on the transverse cross section of the coating. Initially, 50g working load and dwell time 15seconds were used in the microhardness tests. Hardness indentations were made on the transverse cross sections of the samples from the top surface of the clad layer to the surface of the substrate materials. At least five indentations were made on different zones of each cladded samples. The cleaned and poised traverse surfaces are examined for vicker's hardness testing. The different hardness values were tested on the traverse plane of the coating and listed in the table 2 and 3. The hardness values of the substrate material show 48Hv0.05. The coating average hardness values are approximately 15~20 times improved with respect to the base material. The laser power, preplaced powder layer and powder composition vs microhardness values are listed accordingly in the table 2 and 3.The table 2 shows that as the laser power increases the microhardness also increases .The reason behind this might be the higher the laser power input there is a temperature gradient created which leads to higher cooling rate results in finer grain growth. So due to higher cooling rate hardness also increases. The table 3 shows that layer thickness of preplaced powder has nominal effect of clad layer.

Table 1. Fiber laser specification

Parameters	Value (Max.)	Value (Min.)	Resolution
Power	200W	50W	50W
Scan speed along X	100m/min		0.001mm/min
Scan speed along Y	100m/min		0.001mm/min

Scan speed along Z	10m/min		0.001mm/min
Scan speed along C	100rpm(360/min)		0.001deg/min
Scan speed along A	100rpm(360/min)		0.001deg/min
Gas pressure	10 bar	1 bar	0.1 bar
Frequency	1000Hz	50Hz	50Hz
Duty cycle	100%	0.001mm	5%
Movement along X	100mm	0.001mm	0.001mm
Movement along Y	100mm	0.001mm	0.001mm
Movement along Z	400mm		0.001mm
Movement along C	-135^0+45^0		0.001deg.
Movement along A	$+/--90^0$		0.001deg.

Table 2. Effect of different process parameters on hardness of coating

Power Composition	**Spec. No.**	**Layer Thickness (μm)**	**Laser Thickness (W)**	**Scan Speed (mm/s)**	**Hatching Distance (mm)**	**Micro-hardness**	**Average**
CuO 10% SiO_2 20% Al 70%	A13	250	700	1500	0.7	793	765
	A38					765	
	A28		1200	1700	1.1	735	1042
	A7					1058	
	A26					1086	
	A33					982	
CuO 10% SiO_2 20% Al 70%	A25	400	800	2000	0.7	892	890
	A29		1000			980	
	A31		700			794	
CuO 10% SiO_2 20% Al 70%	A4	500	800	1500	1.0	829	811
	A5					809	
	A15					794	
	B3		1000		0.8	903	919
	B4					920	
	B7					936	

Table 3. Effect of laser power and layer thickness on average micro-hardness values.

Laser power (W) vs. Microhardness ($HV_{0.05}$)		**Layer thickness vs. Microhardness ($HV_{0.05}$)**		**Power composition vs. Microhardness ($HV_{0.05}$)**	
700	765	250	903	Al 70^0	793
800	811	400	890	CoO 10^0	765
1000	919	500	865	Al 60^0	920
1200	1042	-	-	CuO 20%	936

5. Conclusion

In this work, Al-based metal matrix composite was formed in-situ for improve hardness and wear-resistance by preplaced laser cladding process. Different mechanical behavioral tests like microhardness, wear-

resistance tests have been carried out to change a wide range of functional properties. This laser is being used for the experiments. The laser head can be controlled by main control unit. The microhardness was tested using a LM-700 digital indentation tester. The hardness values of the substrate material show 48Hv0.05. The coating average hardness values are approximately 15~20 times improved with respect to the base material.

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