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Development and Microstructural Characterization of High Speed Tool Steel through Microwave Energy

K. Sachin Yadiyal[1], Ajit M. Hebbale[1], M. S. Srinath[2]*

[1]Department of Mechanical Engineering, NMAM Institute of Technology, Udupi - 574110, Karnataka, India.
[2]Department of Mechanical Engineering, MCE, Hassan - 573202, Karnataka, India.

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ABSTRACT

In the present work, surface alloying through microwave energy was explored as a processing method for enhancement of surface properties of high-speed tool steel. The experiments carried out using 900 W multimode microwave applicator. The average thickness of 20 µm WC-Ni clad was developed on M2 high-speed steel tool insert having good bonding between substrate and powder. Microwave cladding process is one of the potential cladding techniques to enhance surface properties of a target material. The experimental trials were conducted in a domestic microwave oven with the help of Al_2O_3 shield (specimen enclosures) to avoid direct exposure of metals to microwave with metals. The developed clads were characterized through scanning electron microscope, energy dispersive X-ray spectrometer, X-ray diffraction tests, to determine the microstructure, and elemental composition of the developed surface. Surface roughness is checked and is found that feed rate and surface roughness is proportional. The minimum surface roughness can be obtained with the combination of input parameters cutting speed (50 m/min), feed rate (0.08 mm/rev), and depth of cut (0.3 mm).

***Key words:** Microwave cladding, Microstructure, Chemical composition, Surface roughness.*

1. INTRODUCTION

Most of the engineering components in various industries fail due to the surface wear taking place especially in steel. Therefore to minimize the surface wear the most common solution is to modify the surface using various techniques. The most common techniques are a surface coating, high-velocity oxygen fuel spraying, thermal spraying, laser cladding, and microwave heating. The popular technique used is microwave heating technique. Microwave heating is a method in which microwaves couple to materials and absorb the electromagnetic energy and transform it into heat which helps in the formation of clads between the substrate and powder [1,3,5]. The properties of the surface formed are very high when compared to other technique. In the present work, cladding takes place between WC-Ni and M2 high-speed steel (HSS) tool insert. WC-Ni is a gray powder which can be used in industrial machinery, cutting tools when pressed into different shapes. M2 high-speed steel in tungsten-molybdenum series is widely used to produce different types of tools, drill bits. Wear resistance is high in M2 high-speed steel. Microwave heating is done using a microwave oven of 900 W power at 2.45 GHz frequency.

*Corresponding Author:
E-mail: sachin.yadiyal@gmail.com
Phone: +917760905561

2. EXPERIMENTAL PROCEDURE

2.1. Materials Used

In this present work, readily obtainable WC-Ni powder is used to develop clad on high-speed tool steel insert using microwave energy. Figure 1 represents the scanning electron microscope (SEM) image of the WC-Ni powder. Figure 2 represents the SEM image of the HSS tool insert. X-ray diffraction (XRD) pattern of WC-Ni powder is shown in Figure 3. It indicates the high existence of WC particles along with nickel. The WC provides hardness while Ni provides toughness thus improving the properties when combined. The M2 high-speed tool steel insert is of the size 12.90 mm * 12.70 mm * 4.76 mm. The chemical composition of WC-Ni powder and M2 HSS insert is checked using energy dispersive X-ray spectrometer (EDS) as shown in Table 1.

2.2. Development of Cladding

During the process of development of clads preparation of HSS insert as well as powder plays an important role. Hence before cladding process is started, substrates are polished using emery papers of grits 2000. The powder is then mixed with the resin for the proper bonding to take place between the substrate and the powder.

This resin mixed powder is then applied manually on the faces and edges of the tool and proper average thickness is maintained. The microwave cladding is done using a multimode microwave applicator. The various parameters used in microwave cladding are mentioned in Table 2. XRD of the WC-Ni powder is done to determine the phase analysis were we can find that WC is the main component in the WC-Ni powder shown in Figure 3. In Microwave cladding, the mixture of traditional heating and microwave heating helps in uniform heating of the material. In this present work coal powder is used as susceptor which increases the temperature of the resin mixed powder during the heat transfer process taking place. A thin layer of glass wool is used as a separator to stop the adulteration of resin mixed powder with coal powder. As the time increases during the heating process the temperature increases. Once the temperature increases above critical temperature, melting of the powder particles starts. At certain time and temperature small amount of melting also takes place on the surface of the HSS tool inserts. Due to the comprehensive melting of powder particles and partial melting of the tool inserts cladding takes place hence producing a clad of WC-Ni powder and M2 HSS tool inserts. Diagram of the experimental setup used in microwave cladding is shown in Figure 4 [4]. Stepwise microwave cladding process is explained in Figure 5. In the preheating phase, the microwave energy is absorbed by the coal powder to get heated up. Heated coal powder transfers heat to the resin mixed powder through traditional modes of heat transfer at 600 s after the process is started. At certain point temperature of the powder reaches the critical value. At that point powder starts absorbing microwaves. This phase is known as interaction-cum-heating phase. This phase takes place at 1200 s after the process is started. At certain time and temperature, small amount of melting also takes place on the surface of the HSS tool inserts. The next phase is known as melting-cum-dilution phase. At 1500 s after the process has started clad powder starts to melt forming melt pool. Due to complete melting of powder particles and partial melting of the surface of the tool inserts, clads are formed at the interface of the WC-Ni powder and surface of the M2 HSS tool inserts. Metallurgical bonding between the clad powder and the substrate takes place. The melting of the tool inserts starts after 1600 s which needs to be avoided [7].

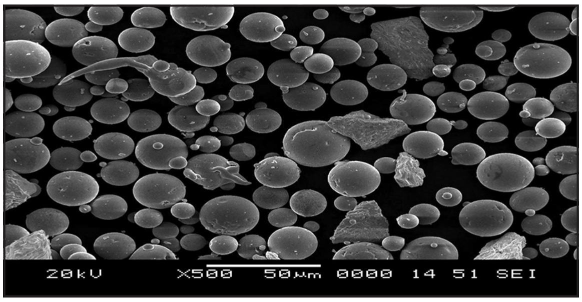

Figure 1: Scanning electron microscope of WC-Ni powder.

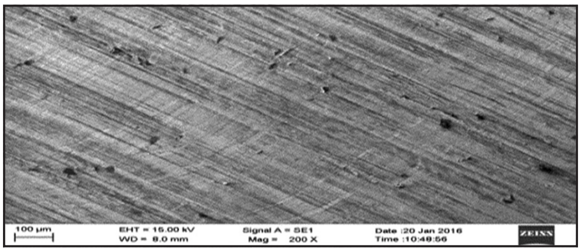

Figure 2: Scanning electron microscope image of M2 high speed steel insert.

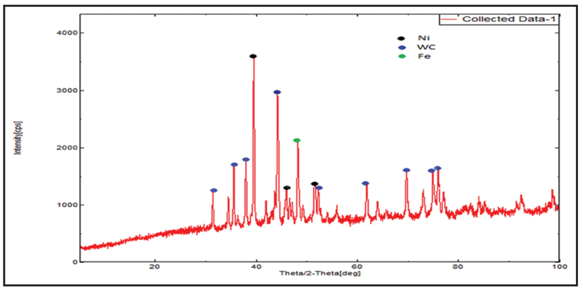

Figure 3: X-ray diffraction of WC-Ni powder.

2.3. Characterizations of the Clads

The developed clads samples are then polished using standard metallographic methods. The polished specimens are then cleaned with acetone and dried. SEM and EDS are used to obtain the microstructures and chemical composition of the developed clads [2]. XRD is used to determine the phase analysis of the

Table 1: Chemical composition of WC-Ni, high speed steel.

Material	Elements in weight percentage						
	Fe	Cr	Mo	WC	Ni	B	Others
M2 high speed steel tool inserts (substrate)	58.14	3.26	3.92	28.16	0.12	-	6.4
WC-Ni (clad powder)	10	10.5	-	20	45	12	2.5

Table 2: Microwave process equipment and parameters.

Parameters	Description
Microwave applicator	Multimode (make LG; solar Dom)
Frequency	2.45 GHZ
Exposure power	900 w
Exposure time	1500 s
Clad powder	WC
Substrate	M2 high speed steel tool insert
Size of substrate	12.90 mm * 12.70 mm * 4.76 mm

developed clads. The scan rate during the XRD was kept at 2° per min within the scan range of 10-80°. Machining is done in a CNC lathe using the WC-Ni coated M2 HSS inserts at speed of 50 m/min with the feed rate of 0.08 and 0.14 mm/rev, respectively, and at a depth of 0.3 and 0.4 mm, respectively. Surface roughness values were measured as shown in Table 3 [6].

3. RESULT AND DISCUSSION

3.1. Microstructure Study

Microstructure study is used to determine the microstructure, the different phases formed, grain boundaries, morphology, etc. Figure 6 represents SEM image of the WC-Ni microwave clad, which shows that 20 µm thickness of the developed clad is formed. SEM image of the clad formed during microwave heating is shown in Figure 7. The volumetric heating in microwave heating technique helps in the formation of homogenous microstructure. Tungsten carbide particles are uniformly distributed over the M2 HSS insert which provides toughness to the clad.

3.2. Elemental Study

EDS study is carried out at different locations to determine various elements present in the microstructure of the microwave clad formed. Figure 8 represents the microstructural area of the clad at which EDS study was conducted. Figure 9 shows the presence of Fe (62.7%), W (14.4%), Cr (15.6%), and Mo (5.6%) in microstructural area of the clad. EDS study is carried out at 2 other areas as well. It was found that well-distributed carbide particles provide high wear resistance to WC-Ni clads.

3.3. Phase Analysis

XRD analysis is done to determine the different phases in WC-Ni clad developed. XRD spectrum is shown in Figure 10. The spectrum indicates the presence of FeNi3 corresponding to 2θ at 35.717°. The spectrum also shows the presence of Fe2W corresponding to 2θ at 44.115°. The presence of W2B corresponding to 2θ at 44.484°. The presence of complex carbide FeW3C corresponding to 2θ value 51.242° can be said that was the development of local currents in melt pool of the melted powder layer and the layer of the substrate that origins for the mingling of the particles in clad. The presence of σ phase of σCrFe corresponding to 2θ at 57.040°. FeB49 is present at 2θ=62.767°. The presence of V5B6 corresponds to 2θ at 30.477°.

3.4. Surface Roughness

Machining is done in a CNC lathe using the WC-Ni coated M2 HSS tool inserts at speed of 50 m/min with the feed rate of 0.08 and 0.14 mm/rev, respectively, and at a depth of 0.3 and 0.4 mm, respectively. The average surface roughness was found out. The surface roughness values for different combinations of speed, feed rate, and depth of cut are mentioned in Table 3. Feed rate and surface roughness are directly proportional to each other. Increase in the feed rate raises the surface roughness. The minimum surface roughness can be obtained with the combination of

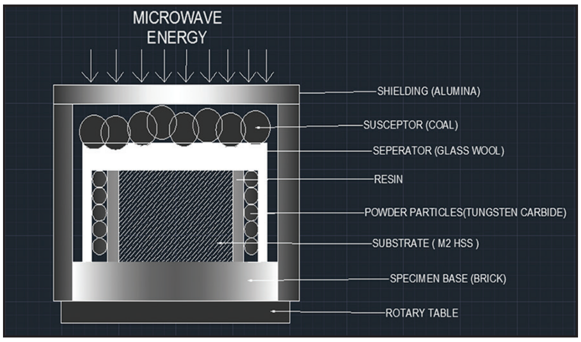

Figure 4: Experimental setup in microwave heating.

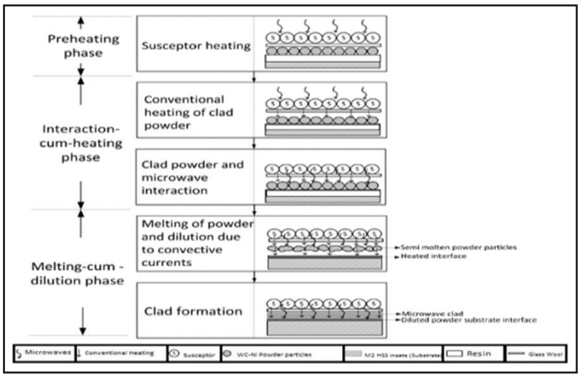

Figure 5: Microwave cladding process.

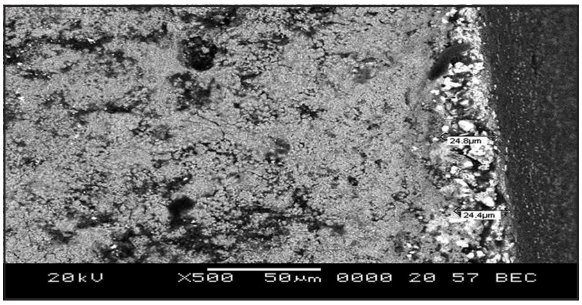

Figure 6: Scanning electron microscope of the WC-Ni microwave clad.

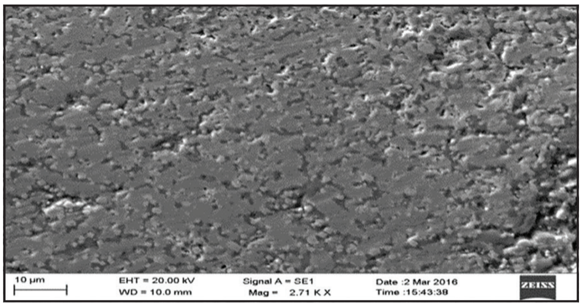

Figure 7: Scanning electron microscope of the clad formed.

Table 3: Average surface roughness corresponding to speed, feed and depth of cut.

Cutting speed V (m/min)	Feed rate f (mm/rev)	Depth of cut d (mm)	Average surface roughness Ra (µm)
50	0.08	0.3	0.8979
50	0.08	0.4	0.9185
50	0.14	0.3	1.0835
50	0.14	0.4	1.1553

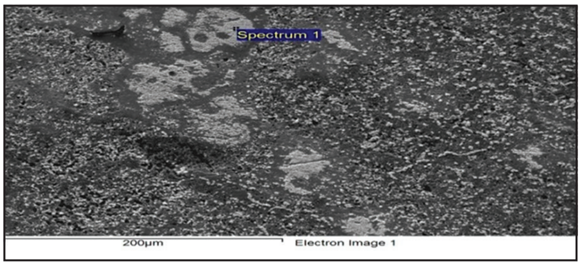

Figure 8: Microstructural area of the clad energy dispersive X-ray spectrometer is done.

input parameters - cutting speed (50 m/min), feed rate (0.08 mm/rev), and depth of cut (0.3 mm) (Figure 11).

4. CONCLUSION

In the present work, the possibility of using microwave energy to develop WC-Ni clad on M2 HSS tool insert is found out. The major results found are as follows:

i. The average thickness of 20 µm WC-Ni clad was developed on M2 HSS tool insert using microwave heating technique at 2.45 GHz frequency and 900 W power.

ii. The characterization of the microwave clads is done by fractional diffusion of the substrate, i.e., HSS tool inset due to the localized currents in the melt-pool. Clads are formed due to the metallurgical bonding between the powder particles with the fractional melting of the high-speed tool steel interface layer.

iii. The formed WC-Ni clads are crack free due to unvarying heating with microwave heating technique.

iv. The average surface roughness was found out. Feed rate and surface roughness are directly

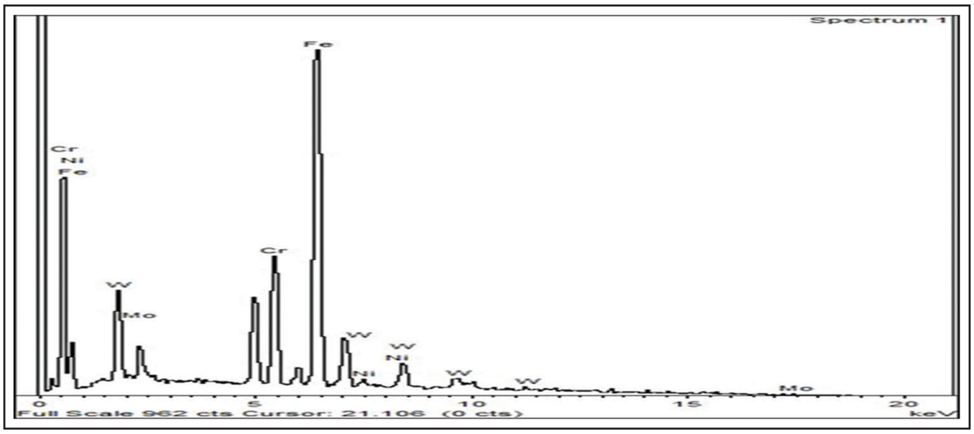

Figure 9: Energy dispersive X-ray spectrometer spectrum of clad.

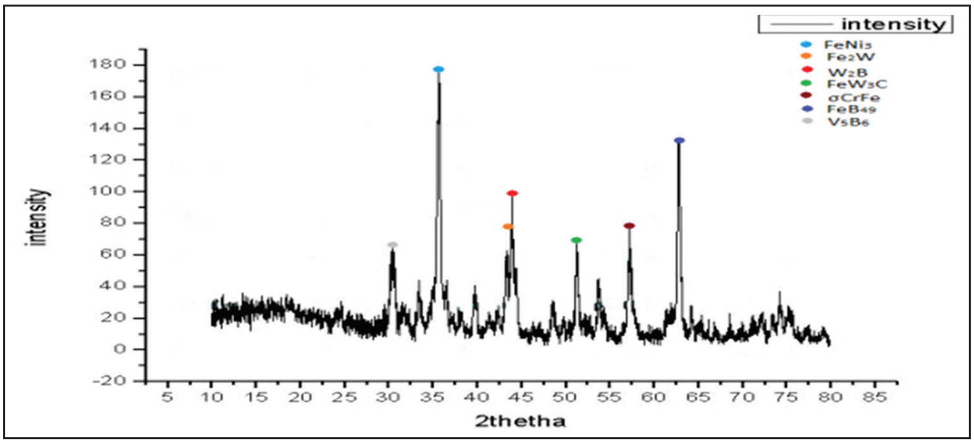

Figure 10: X-ray diffraction spectrum of WC-Ni clad.

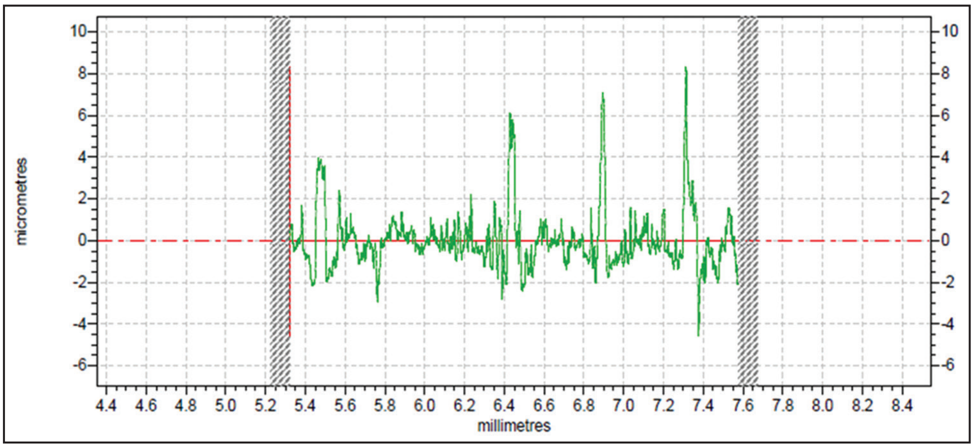

Figure 11: Average surface roughness (Ra) spectrum.

proportional to each other. Increase in the feed rate raises the surface roughness. The minimum surface roughness can be obtained with the combination of input parameters - cutting speed (50 m/min), feed rate (0.08 mm/rev) and depth of cut (0.3 mm).

v. WC-Ni clads developed can be successfully used in wear resistant applications.

5. REFERENCES

1. S. Zafar, A. K. Sharma, (2014) Development and characterizations of WC–12Co microwave clad, ***Materials Characterization,*** **96:** 241-248.
2. G. K. Dosbaeva, M. A. El Hakim, M. A. Shalaby, J. E. Krzanowski, S. C. Veldhuis, (2015) A Cutting temperature effect on PCBN and CVD coated carbide tools in hard turning of D2 tool steel, ***International Journal of Refractory Metals and Hard Materials,*** **50:** 1-8.
3. M. Narasimha, M. Patel, R. Rejikumar, (2014) Application of coating on carbide insert, ***The International Journal of Engineering and Science (IJES)***, **3(4):** 1-7.
4. D. Gupta, A. K. Sharma, (2011) Development and microstructural characterization of microwave cladding on austenitic stainless steel, ***Surface & Coatings Technology,*** **205:** 5147-5155.
5. A. A. Arshi, A. Dighewar, (2013) Study and analysis of effect of coating on HSS cutting tool, ***International Journal of Science, Engineering and Technology Research (IJSETR)***, **2(4):** 814-817.
6. G. O. Hasan, K. M. Nalbant, (2006) The effects of cutting tool coating on the surface roughness of AISI 1015 steel depending on cutting parameters, **Turkish Journal of Engineering and Environmental Sciences, 30:** 307-316.
7. A. Prasad, D. Gupta, (2013) Microwave cladding: Emerging innovative cladding process. Proceeding of International Conference on Emerging Trends in Engineering and Technology, 03. AETS.2013.3.272.

***Bibliographical Sketch**

Sachin Yadiyal K. Received his B.E. degree in Mechanical Engineering from MITE, Moodabidri (VTU, Belgaum) in 2014. He is currently pursuing M.Tech degree in Machine Design (Mechanical Engineering) from NMAMIT, Nitte (VTU, Belgaum).