ON FLEXURAL BEHAVIOR OF MICROWAVE PROCESSED NI-WC-CR$_3$C$_2$ BASED COMPOSITE CLAD

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Abstract: Current research emphasizes the utilization of microwave energy for developing composite clads on the austenitic stainless steel surface. Ni-WC8Co-Cr_3C_2 based composite clads were developed on SS-316 L steel surface using microwave energy at 2.45 GHz and 900 W. The characterization of so developed clads was carried out through SEM and measurement of Vicker's microhardness. Further, the flexural behavior of the developed clads was evaluated using three-point bend tester. It was observed that microwave processed clad exhibited the maximum flexural strength of 795±20 MPa.

***IndexTerms* – Microwave Clad, Composite Material, Surface Engineering, Flexural Behavior.**

I. INTRODUCTION

Today's industry era requires the material components with excellent corrosion and wear resistant properties to function in the severe working environment. However, it is not easy to find a suitable combination of material which could provide both corrosion and wear resistant at the same time. Austenitic stainless steel of SS-316L grade is commonly used in chemical, food processing industries and marine environment due to its excellent corrosion resistant properties. However, it often fails under severe wear environment and causes a huge economic loss to the concerned industries (Adachi and Ueda, 2013). Replacement of the failure component by the new component is not a good solution. An alternate solution for improving the wear resistant properties of such grade steel is the surface modification of the component vulnerable to wear environment. There are many techniques available for surface modification such as thermal spraying (HVOF, Plasma spraying, etc.), chemical vapor deposition, physical vapor deposition, and laser cladding. Laser cladding technique provides very good quality cladding on the material surface due to its good control over dilution (Birger et al., 2011). However, laser cladding is associated with high thermal and residual distortion and porosity. Cladding through microwave energy has been evolved as a relatively new surface modification technique in the past few years. Microwave cladding due to the volumetric nature of microwave heating provides excellent microstructure and less porosity in the clad surface. The composite clad of WC10CoNi based materials were successfully produced by Gupta et al., 2012. Later on Kaushal et al., 2017 produced various composite clads of Ni-SiC, Ni-WC based materials on various grades of steel. It was observed that microwave processed composite clad exhibited excellent wear resistance without compromising the corrosion resistance.

In the present investigation Ni-WC-Cr_3C_2 based composite clads were developed through microwave heating at 2.45 GHz frequency and 900 W power level. To assess the various features of the developed clads, characterization such as microstructure, Vickers microhardness was carried out. Further, the flexural strength of the developed clad was calculated to know the adhesion strength of developed clad.

II. MATERIALS AND METHODS

Nickel is associated with excellent corrosion resistance and higher toughness. On the other hand, WC and Cr_3C_2 particles due to their higher hardness provide wear resistance properties. By considering these factors in the present work Ni-based EWAC powder (matrix phase) was mixed with WC8Co and Cr_3C_2 based ceramic based powders to produce higher toughness and wear resistance clad layer. Figure 1 shows the morphology of raw powder materials which reveal the sharp edge morphology of WC and Cr_3 C_2 particles and round edge morphology of Ni particles. These powders particles were mixed in a mechanical mixture to produce a composite mixture of Ni +10%WC8Co + 10% Cr_3C_2 by weight %. SS-316 L grade austenitic stainless steel was used as the base material in the present investigation and machined to dimensions 50× 10×8 mm^3. To develop the composite clad on SS-316 L substrate microwave hybrid heating technique (MHH) was utilized. The complete description of microwave hybrid heating was given by Gupta and Sharma (2011). Before developing the clad on the substrate, the substrate was cleaned with acetone and the powder layer was placed on it manually by maintaining a uniform thickness of 1 mm. Then using the MHH principle clad layer was successfully developed on the substrate surface within 20 minutes of exposure time. The various process parameters for microwave processing are shown in Table 1.

After the development of clad the microstructural characterization of the clad was carried out using scanning electron microscopy (SEM) equipped with energy dispersive spectroscopy (EDS). Further Vicker's microhardness tester was used to measure the microhardness of the developed clad. Three-point bend tester was utilized to know the adhesion strength of developed clad through flexural behavior. The complete information about three-point bend tester is illustrated in Fig. 2. The flexural strength of the clad was evaluated using formula

$$\sigma = \frac{3W_mL}{2wt^2} \qquad (1)$$

Where $\boldsymbol{\sigma}$ is the flexural strength (MPa), W_m is maximum load (kN), w is wthe idth of the specimen (mm) and t is tthe hickness of the specimen (mm)

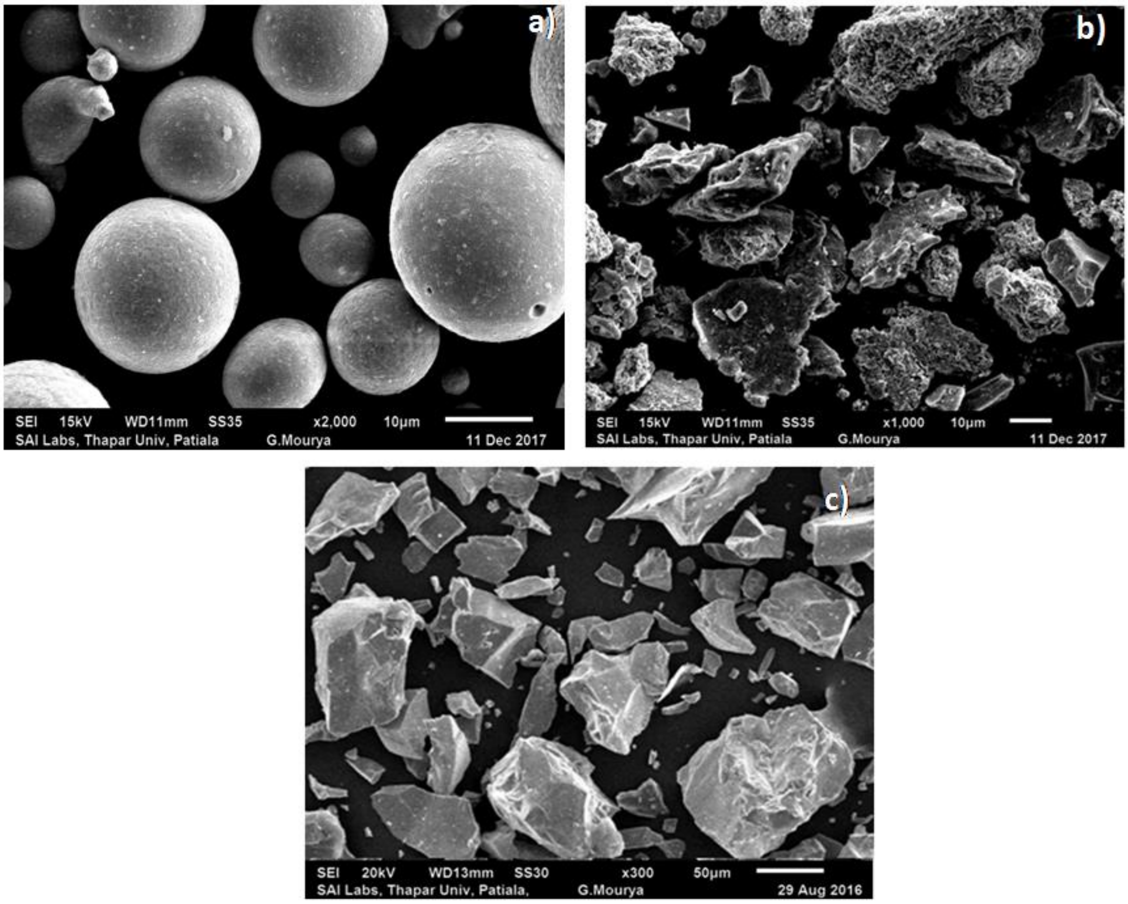

Fig. 1: SEM images showing the morphology of (a) Ni-based EWAC powder, (b) WC8Co based power, (c) SiC-based powder

Table 1. Various process parameters for microwave processing

Parameters	Description
Applicator used	Microwave charcoal type
Power level	900 W
Exposure time	15 min
Separator	Alumina sheet (~ 1mm thickness)
Susceptor	Charcoal powder
Powder used	Ni-based EWAC, WC8Co, Cr_3C_2 (~20-40 µm)

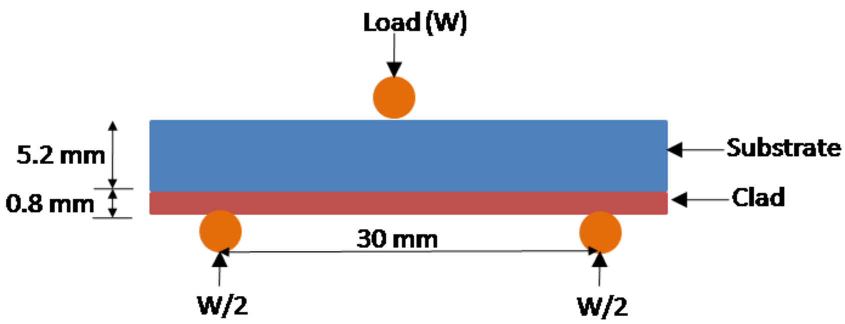

Fig. 2: Schematic of Flexural testing

III. Results and discussion

The microstructure of the Ni-WC-Cr_3C_2 based composite clad is shown in Fig. 3, which reveals the formation of clad of the approximate thickness of 0.8 mm. The clad is free from any type of porosity and visible cracks. It might due to the volumetric heating nature of microwave heating, which results in a uniform thermal gradient throughout the clad. Further reinforced ceramics particles in the form of dispersed particles can be clearly seen in the Ni-based matrix. The microhardness of the Composite clad region was observed to be 612±23 HV, which was approximately 3 times that of the substrate. The flexural strength was evaluated using three-point bend tester. The flexural profile of the composite clad sample is illustrated in Fig. 4. It was observed that up to point A, the microwave processed clad exhibited elastic behavior and the load was taken by the Ni matrix. Beyond point, A as the load increased the clad underwent plastic deformation up to point B and the microcrack initiation started in the clad surface. With further increase in load, the micro cracks on the hard carbide surface grew. With further increase in load at point C, the microcracks propagated to the clad interface surface. At this point, the clad gets failed and load is further transferred to the substrate surface.

Figure 5 shows the top and side view of the fractured clad surface which depicts the formation of microcracks in the clad surface. The flexural strength of the clad surface was evaluated using equation (1) and found to be 795±20 MPa.

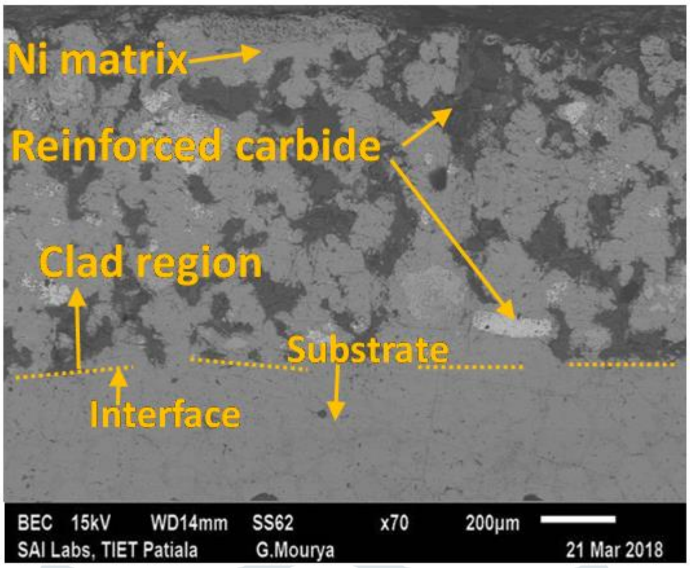

Fig. 3: SEM image showing the microstructure of composite clad

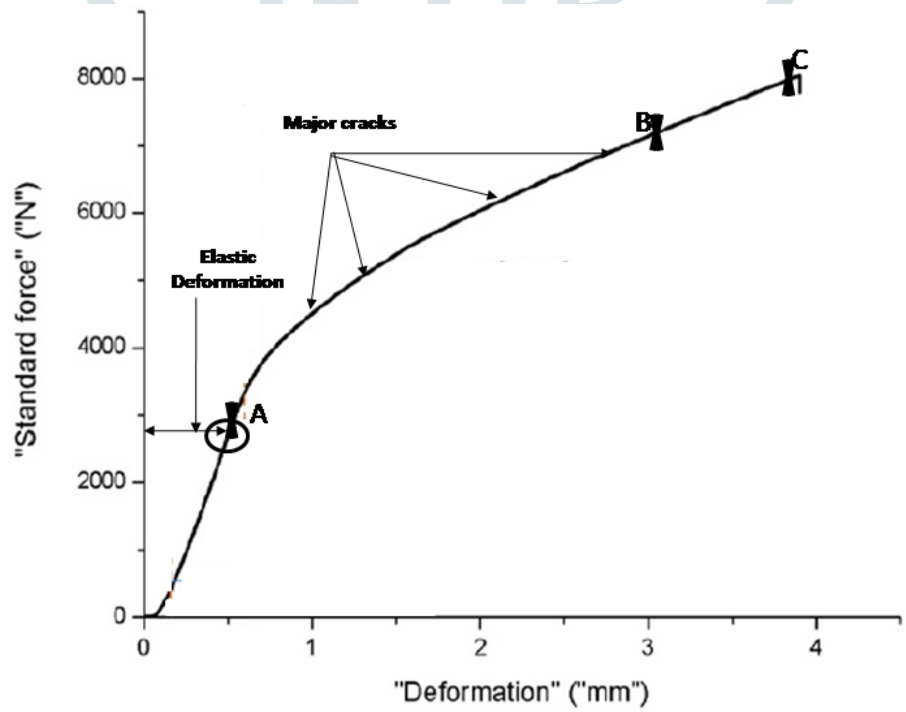

Fig. 4: Typical flexural characteristics of microwave based Ni-WC-Cr_3C_2 based composite clad

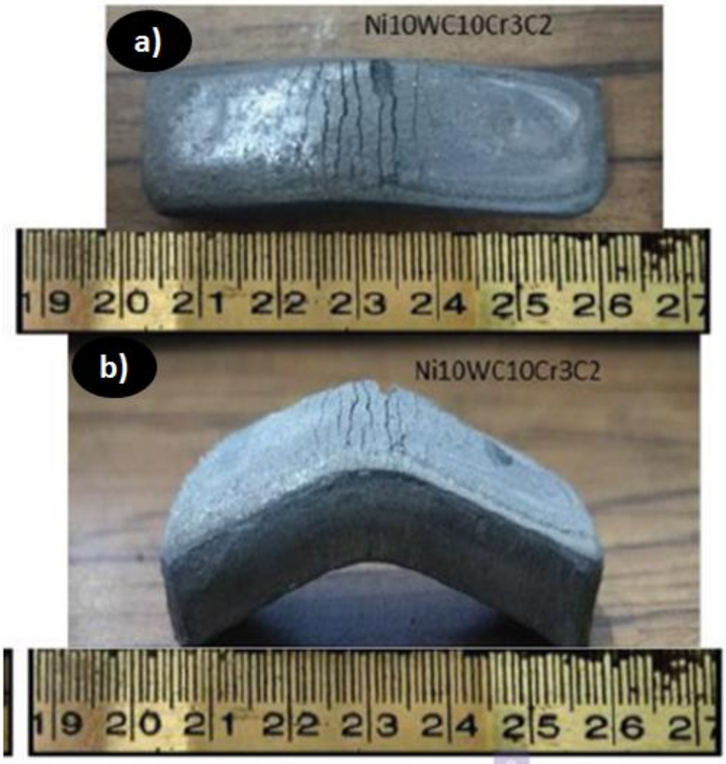

Fig. 5: Typical photographs of the fractured specimen after flexural testing (a) top view, (b) side view

IV. CONCLUSIONS

In the present research Ni + 10%WC8Co +10%Cr_3C_2 based composite clad was successfully produced using MHH technique at 2.45 GHz and 900 W. The following conclusions were drawn from the current work.

(a) Clad of 0.8 mm thickness was free from any type of visible crack and porosity.
(b) The reinforced carbide particles are randomly dispersed in the Ni matrix.
(c) The microhardness of the composite clad was observed as 612±23 HV, which was 3 times higher than that of the substrate.
(d) The flexural strength was observed as 795±20 MPa.

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