MICROSTRUCTURAL CHARACTERISTICS OF MICROWAVE PROCESSED NI-10%CR_3C_2 COMPOSITE CLADDING

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***Abstract* :** In the current study microwave energy has been used to develop composite clad of Ni+10%Cr_3C_2(by wt%) on SS-316 substrate in a domestic microwave oven, generally used for low-temperature applications, having a frequency range of 2.45GHz and 900W power. The developed composite clad are characterized by various metallurgical and mechanical techniques such as SEM/EDS, XRD and Vickers microhardness. The developed composite clad of thickness 750µm show fine microstructure without any visible cracks and significantly less porosity. The microhardness of developed composite clad has evaluated 430±65 HV. The various hard carbide phases Cr_3Si, NiC, Cr_3Ni_2SiC, $CrSi_2$, SiC, $FeNi_3$ have been confirmed from XRD study.

***Index Terms-* Cr_3C_2, Composite Clad, Characterization, EWAC, Microwave Energy.**

I. INTRODUCTION

Hydropower operated industries face huge revenue loss due to cavitation erosion wear of engineering components. A lot of efforts has been done by researchers to reduce cavitation erosion wear in hydropower operated industries. Surface modification of engineering components is cost effective and efficient method to handle this problem. In this method surface of the substrate has been modified or coated/cladded with some wear resistant material. The surface of engineering components can be modified with many techniques like plasma spraying, welding, thermal spraying, laser cladding etc. **[1-4]**. Among all these techniques laser cladding is extensively used in industries due to its characteristic of good metallurgical bonding between clad and substrate. Although, the laser is an intense heat source and direct application of laser onto the substrate, and then transfers inwards through conventional heat mode, causes thermal distortion due to the large thermal gradient. Moreover, the initial set up cost of the laser is very high and the processing of large areas is not cost effective **[5-6]**. The problems of existing surface modification techniques motivate researchers to develop a new technique which can cover all the limitations of existing techniques. In recent years' microwave processing of materials has attracted researchers due to its versatile properties like low set up cost, high deposition rate, rapid heating, selective heating and volumetric heating which leads to uniform and fine grain structure. The processing time can be lowered down to a great extent by this technique **[7]**. Among all other grades of austenitic stainless steel grades, SS-316 is widely used in the food and hydraulic industries due to its excellent corrosion wear resistance. Austenitic stainless steels are generally less hard which limits their use in severe wear conditions. However, the surfaces which are more prone to degrade due to cavitation erosion wear of these grades of steels can be modified by coating/cladding with wear-resistant materials through microwave irradiation and the working life underwear conditions can be increased significantly. Many authors have reported successful development of wear-resistant claddings through this novel route **[8-10]**. Generally, the combination of hardness and toughness is required to absorb the impact energy produced during the cavitation phenomenon. Many metal matrix (Cobalt and Nickel based) has been used along with different reinforcement materials (Silicon carbide, Chromium carbide, Tungsten carbide) etc. for developing anti-wear composite clads. Chromium carbide is frequently used as reinforcement material due to its good corrosion resistance and Nickel is widely used as a soft matrix due to its good oxidation resistance at elevated temperatures. The purpose of the current study is to develop Ni+10%Cr_3C_2 (by wt%) composite clad through microwave irradiation in a domestic microwave oven, generally preferred for low-temperature applications, having frequency 2.45GHz and 900W. The developed composite clad are characterized by different mechanical and metallurgical techniques like XRD, SEM/EDS and Vickers microhardness.

II. EXPERIMENTATION

2.1 Details of Materials

In the present experimental study austenitic steel of grade, SS-316 is used. The rolled plate is machined to dimensions 10x10x6 mm. The Ni-based EWAC is used as soft metal matrix and Chromium Carbide (Cr_3C_2) is used as a reinforcing agent. The surface morphology of both the powders hasbeen shown in SEM images in Fig 1. The SEM images confirm the spherical surface morphology of EWAC powder and knife shaped surface morphology of Cr3C2 powder. Table 1 contains the details of the chemical composition of raw clad powders and substrate. The preheating of raw clad powders, at 180^0 C, has been done to remove the presence of any moisture content. The desired properties of composite powders (Ni+10% Cr_3C_2) has been obtained by mixing the preheated powders in a mechanical mixture.

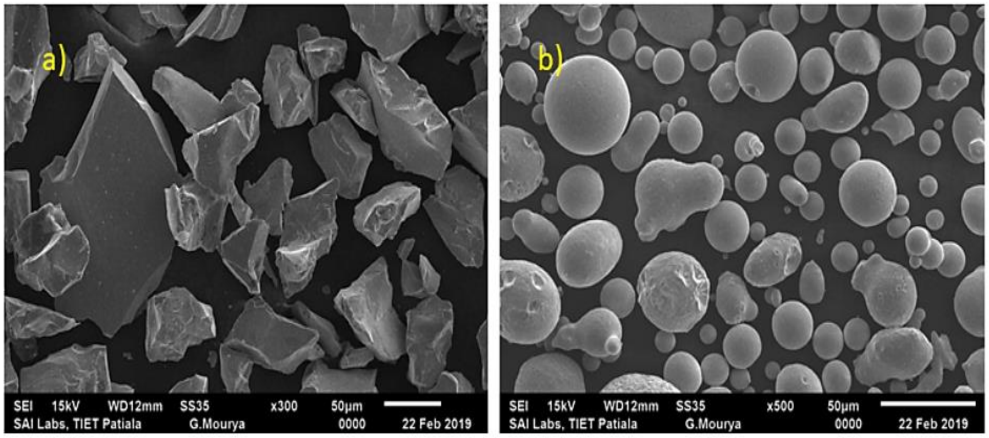

Fig: 1 SEM images a) Cr_3C_2Powder b) EWAC Powder

Table: 1 Chemical Composition of Raw Materials by Weight Percentage

Materials	Chemical Elements								
	P	C	Si	S	Mn	Mo	Ni	Cr	Fe
SS-316	0.041	0.024	0.281	0.069	1.22	1.99	9.83	17.0	Bal.
Cr_3C_2	-	31.8	-	-	-	-	-	68.2	-
EWAC	-	-	3.88	-	-	-	Bal.	2.07	-

III. CLAD DEVELOPMENT AND CHARACTERIZATION

Prior to the formation of clad the substrate is cleaned and polished to remove any dirt and oxide layer. The preheated powder is placed over SS-316 substrate. The thickness of clad powder is tried to maintain a uniform. The substrate is then placed on a refractory brick. The mechanism of Microwave Hybrid Heating (MHH) has been used to developed composite clad. The details of MHH has been reported by many authors **[11-15]**. The Fig 2(a) and 2(b) shows the schematic and actual set up of clad formation through MHH route respectively. The parameters used for clad formation are tabulated in Table 2.

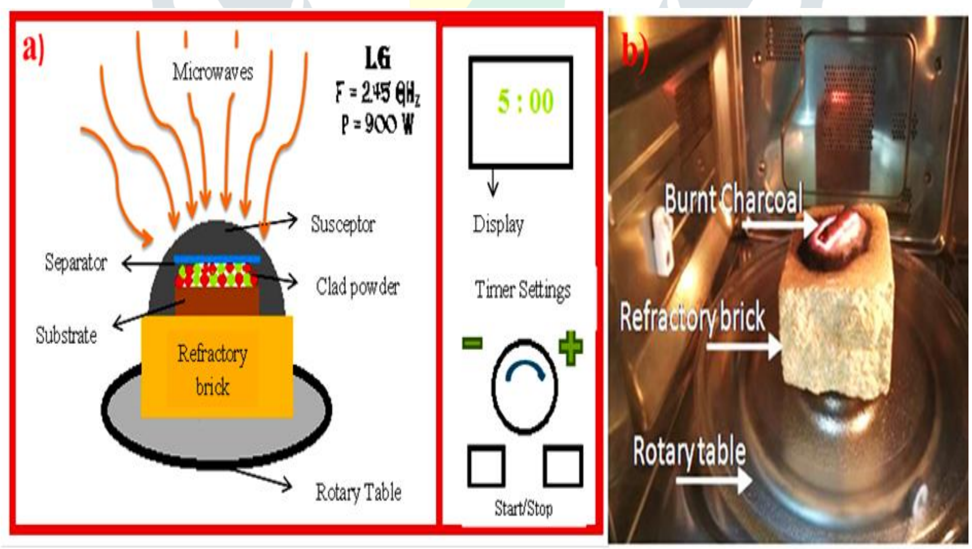

Fig: 2 Clad Formations Through MHH a) Schematic Principal b) Actual Setup

Table: 2 Parameters Used for Developing Composite Clad

Parameters	Applicator	Exposure Time	Exposure Power	Frequency	Cladding Powder	Susceptor	Separator	Preheating Temp.
Description	Multimode	420 secs	900W	2.45GHz	Ni+ 10%Cr_3C_2	Charcoal	Alumina	180^0C

The composite clad of Ni+10%Cr_3C_2 were developed in 420 secs exposure of microwave irradiation. The developed composite clad were sectioned along with thickness with the low-speed diamond cutter for characterization. Further, the developed composite clads were polished with emery papers of different grits and finally polished with diamond paste to get mirror polish. The Vickers microhardness tester was used for evaluation of microhardness of developed composite clad. The different phases of developed composite clad were analyzed using XRD technique. The scan rate and scan range were used 1^0 per min and 30^0 to 100^0 respectively. Prior to microstructural investigation the developed composite clad were etched using Nital. The backscattered microscopy (BSE) technique was used for microstructural investigation. Further, for confirmation of different elements, EDS (energy dispersive spectroscopy) technique was used.

IV. RESULTS AND DISCUSSION

4.1 Microhardness Study

The hardness of clad region, generally, enhanced by the presence of hard carbide phases in the clad region. To establish this fact Vickers microhardness testing (Fig 3) of developed composite clad has been evaluated. The indentations have been taken at 80μm appx. distance starting from the top of the clad surface. The graph shows non-uniformity which could be due to the indentations have been taken on the hard carbide phase as well as on soft matrix. The observed microhardness value exhibited 430±65 HV. The higher value of microhardness reveals that these cladding can be used in anti-wear applications.

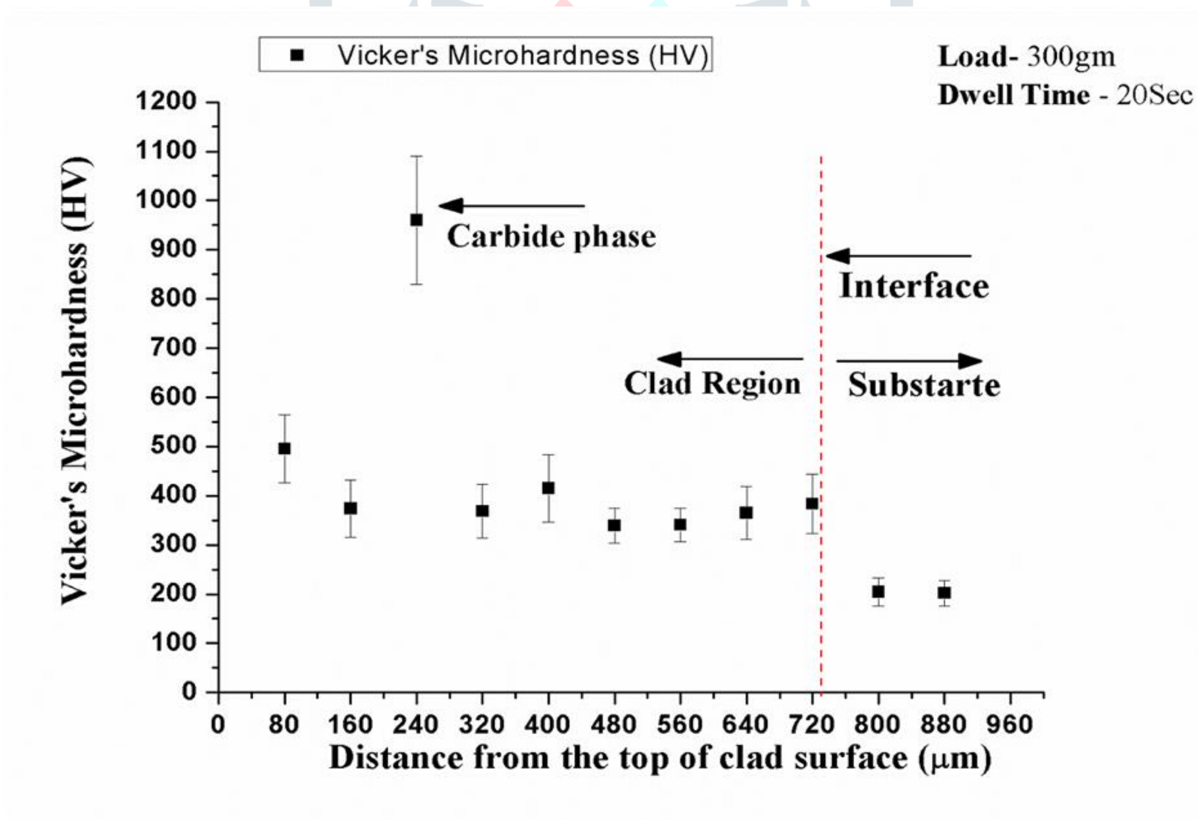

Fig: 3 Vickers Microhardness Values of Developed Composite Clad

4.2 XRD Study

The XRD spectra of developed composite clad has been shown in Fig 4. The phases Cr_3Si, NiC, Cr_3Ni_2SiC, $CrSi_2$, SiC, $FeNi_3$ were confirmed from XRD spectra. Due to high temperature involved in microwave heating the decomposition of Cr_2C_3 into Cr and free C took place. Further, the reaction of this free carbon with Si and Ni formed phases SiC and NiC. Some complex carbide Cr_3Ni_2SiC has also been formed. The formation of $FeNi_3$ confirms the dilution of clad material with the base material. Moreover, the presence of phases Cr_3Si, $CrSi_2$ confirm this statement of metallurgical bonding with minimum dilution as Si present in base material reacts with Cr present in the clad powder. The presence of hard phases also confirmed from microhardness study.

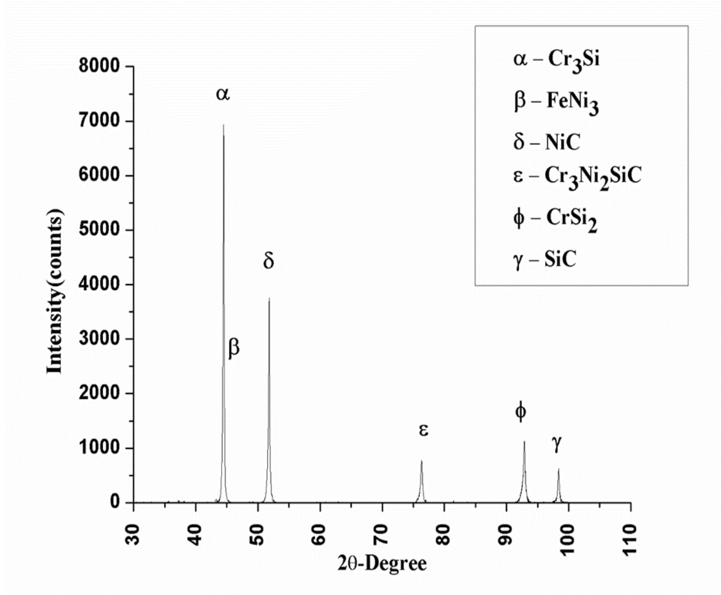

Fig: 4 XRD Study of Developed Composite Clad

4.3 Microstructure Study

The quality of clad highly depend upon microstructure. A good clad must be free from any defects and voids. The metallurgical bonding of clad must be good with the substrate. The cross-section of developed composite clad has been shown in Fig 5. The developed composite clad of appx. thickness 750µm is free from any visible cracks and voids (Fig 5a). The zoomed view of the clad region in Fig 5(b) shows the random dispersion of carbide particles in a soft Ni matrix. The grey and black region of developed composite clad represents the soft Ni matrix and reinforced carbide particles respectively. To confirm the elemental composition in different regions EDS at different points of developed clad has been done. The results clearly reveal the presence of Chromium carbide particles (point X) in the black region (Fig5c) and soft Ni matrix (point Y) in the grey region (Fig 5d). The combination of hardness and toughness in the developed composite clad has been confirmed by the presence of hard carbide as well as the soft metal matrix.

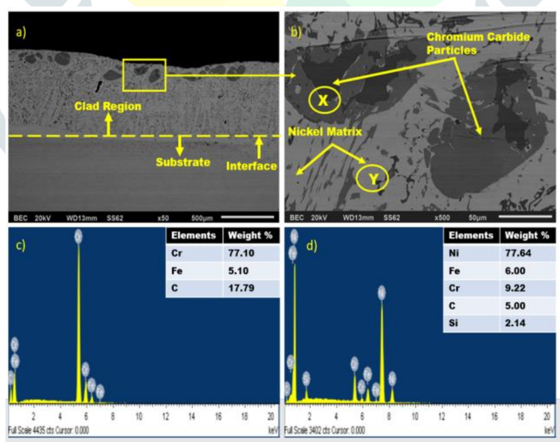

Fig: 5 BSE (Backscattered electron) images of a) Clad region b) Zoomed view of the clad region
EDS (Energy dispersive spectroscopy) of a) Carbide Phase b) Nickel Matrix Phase

V. CONCLUSION

1. In the current investigation composite clad of Ni+10% Cr_3C_2 were developed successfully by microwave irradiation on austenitic stainless steel grade (SS-316). The concluded points from the present investigation are:
2. The developed composite clad of appx 750µm, with microwave exposure of frequency 2.45 GHz and 900w power, were free from any defects and visible cracks.
3. The Vickers microhardness test exhibited that the average microhardness value of developed composite clad (Ni+10% Cr_3C_2) was 430±65 HV.
4. The presence of phases Cr_3Si, NiC, Cr_3Ni_2SiC, $CrSi_2$, SiC, $FeNi_3$ in developed composite confirmed from the XRD study.
5. The microstructure study exhibits that the reinforced carbide particles dispersed randomly in soft Ni matrix.

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