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Investigation on mechanical properties and characterization of microwave cladded stainless steel

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This work reports on the investigation on microwave cladded stainless steel. Microwave cladding is a novel processing technique. Microwaves have electronic and magnetic properties which can be operated in the specific frequency range under the specific time to create metallurgical bonds. Microwave cladding is gaining more importance because the process helps in equal heating throughout the material from the molecular level. The main advantage of the microwave cladding is reducing the cost of the production and production time. Cladding denotes the bonding together of dissimilar metals. In the present work, metal matrix composite clads of WC10Co2Ni, a powder based material have been cladded on stainless steel substrate of grade SS-304 using microwave heating at 2.45GHz frequency. A concept of hybrid heating is used to process metal matrix composite clads at exposure power level of 900 W. The exposure time for developing metal matrix composite clads varies for different clad composites. The microwave claddings were characterized through field emission scanning electron microscope (FESEM) and measurement of Rockwell hardness. Clads were formed with partial dilution of a thin layer of the substrate. The microstructural analysis of microwave processed clads reveals the uniform distribution of WC10Co2Ni powder particles in the substrate material stainless steel of grade 304 and also an increase in the hardness value of the substrate.

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1. Introduction

Materials nowadays need more than one property for producing more efficient applications. Different properties however are often required in different areas of the products. Some products require wear and corrosion resistant surface, while other products require other properties depending upon their application and environment. Materials with enhanced properties can be produced with the help of microwave cladding. Studies report that cladding a hard material on a soft substrate can avert disintegrating on the rubbing surface thereby reducing wear [1-5]. Cladding is the coating of one material over another to enhance its property. Cladding doesn't alter the microstructure of base material instead it forms a new layer of different composition that will be harder than base materials. Cladding is widely used because of its capability to provide high hardness, better corrosion & erosion resistance, good bonding and suitable microstructure [6,7]. The benefit of cladding is that the materials and also the process can be preferred according to the necessities of the application and the requirement of bond strength [8,9]. Cladding is of various

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types that can be implemented based on the applications. One of the widely practised methods is laser cladding. Laser cladding has a few limitations and industries demand the best alternative process having the potential to overcome these limitations. One such processing technique is by using microwave energy [10] SS-304 is generally utilized in various manufacturing applications because of its corrosion resistance property. Still, these metals undergo metallic wear because of the production of adhesive interactions between the surfaces of contact. This steel has friction characteristics and low hardness, so these metals are not suggested for high wear applications. modification of surfaces with appropriate coating material through cladding is the solution for improving the hardness of the material. Nowadays, the microwave cladding process has been developed as a practical answer for wear and corrosion resistive applications because of its superior processing capability and its uniformity in the coating. Microwave processing has a remarkable property of volumetric heating, that bestows precise highlights in clad like low thermal distortion, pores and crack free structure. Microwaves are a part of Electro Magnetic spectrum with a frequency range of 300MHz to 300 GHz and wavelengths of 1m and 1mm respectively [11]. Recently, microwave processing has arisen to be a novel technique that has proved to be useful in various applications with many advantages over conventional processing techniques. The magnetic property and dielectric property of the metals assumes a significant part because the microwave components are symmetric to one another in microwave processing. Therefore, the handling of microwaves can be sorted in an alternate manner relying upon the microwave interaction with the focused material. Gupta et. al carried out an investigation on sliding wear performance of austenitic stainless steel (SS-316) substrate cladded with WC10Co2Ni and concludes that the clads show good metallurgical bonding and are crack free which also evince dense and uniform structure that possess significantly high micro hardness [12]. Kaushal et al. developed clads of Ni-Sic on SS-304 substrate and presents that Sic particles were uniformly dispersed inside Ni matrix exhibiting high micro hardness and are free from cracks and porosity as a result of volumetric heating with microwave [13]. Akshay et al. studied wear characteristics of mild steel cladded with EWAC + 20% WC10Co2Ni and concludes that the skeleton like structure of hard carbides of tungsten was uniformly distributed in soft Ni matrix show a higher micro hardness and wear resistance [14]. Hebbale et al. stated that Cobalt based clads on martensitic stainless steel (AISI-420) shows a higher micro hardness which increases the wear resistance [15]. In our work WC10Co2Ni is utilized as reinforcement for improving the hardness and a high percentage of Ni is used for corrosion resistance by coating over the substrate. After the process was completed, the hardness level of the substrate was tested and the SEM images were taken. In the current manufacturing scenario, there is a continuous necessity for the latest technologies for production, also to be cost-effective with superior strength and minimum manufacturing time.

2. Experimental procedure

In the present work, cladding has been developed on metallic substrate using microwave irradiation as the heating source. . The present work mainly focuses on development of surface engineering techniques in the form of microwave cladding . Microwave clads were developed by exposing the preplaced, preheated powder for a duration of 45 minutes to microwave radiation at 2.45 GHz frequency and 900 W power in a microwave system.

2.1. Material details

WC10Co2Ni system has been chosen as the clad material for the present study. In order to develop cladding on austenitic stainless steel, WC10Co2Ni powder having average grain size of 40 µm was used. Austenitic steel (SS-304) plates machined to dimensions 35 mm × 12 mm × 6 mm were used as substrate material. This is usually purchased in an annealed state. As SS 304 contains 18% chromium and 8% nickel, it is also known as 18/8 stainless steel.

2.2. Process

Microwave hybrid heating is used with susceptor which absorbs microwave radiation at normal temperature and get heated very fast manner so temperature reached at critical temperature and graphite plate was used as a separator to separate the charcoal and metal powder. Heat transfer takes place with the help convection and radiation mode initially temperature of upper layer of powder is higher than the layer which is lies below but after some time temperature of all layer becomes equal and metal powder starts defaced to each other finally temperature reaches the melding point of subtract and metal powder defused to subtract at this stage. Refractory brick was used to avoid direct contact to the incident radiation of microwave. Before cladding powder was dried on furnace at 200° C to remove moisture and volatile element. The powder was preplaced manually on SS-304 substrate. Two millimetre metal powder thickness layer will be maintained through all the experiment on the substrate then thin graphite plate was put on the powder than charcoal was put on the graphite plate. The Cladding setup is shown in Fig 1.

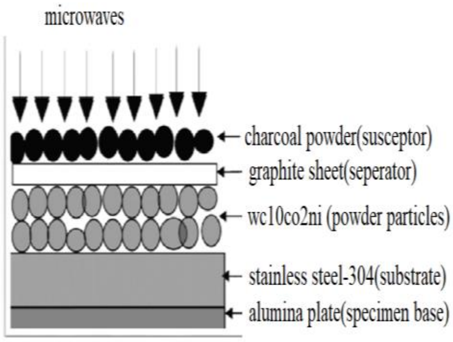

Fig.1. Schematic of the microwave cladding setup.

2.3. Clad characterization

The microwave processed composite clads were thoroughly washed with acetone ahead of characterization. The specimens were polished with emery papers. Etching of the polished samples was carried out using etchant solution of such as hydrochloric acid or acetic acid. The microstructure of etched samples was analysed using scanning electron microscope.

3. Result and discussion

3.1. Hardness test

Generally, increasing the hardness of components can enhance the wear resistance ability. Hardness is the measure of the resistance to the localized plastic deformation induced by either mechanical indentation or abrasion. Some materials are harder than others macroscopic hardness is generally characterized by strong inter molecular bonds, but the behaviour of solid materials under for is complex therefore, there are different measurement of hardness. Hardness is dependent on ductility, elastic stiffness, plasticity, strain, strength, toughness, viscoelasticity and viscosity.

The rock well's hardness of clad layer has been evaluated. An average of three measurements at each distance was considered .The readings are 95 HRB, 94 HRB and 95 HRB these readings are comparatively greater than before cladding process which is ranging from 89 HRB to 92 HRB.

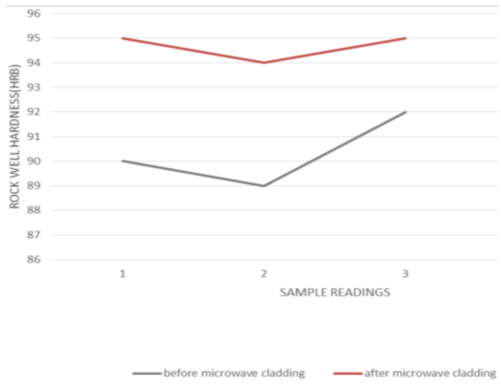

Fig.2. Hardness Graph.

The distribution of hardness is evaluated and the hardness of the clad section is 95HRB in most of the readings. The above graph represents the comparison of the hardness values of substrate before and after cladding. The distribution of hardness in the clad section is not observed to be uniform. An increasing tendency in hardness away from the substrate is seen. The observed higher hardness in the clad could be attributed to the presence of hard WC phase.

4. FESEM test

A scanning electron microscope is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample. The electron beam is scanned in a raster scan pattern, and the position of the beam is combined with the intensity of the detected signal to produce an image. In the most common SEM mode, secondary electrons emitted by atoms excited by the electron beam are detected using a secondary electron detector.

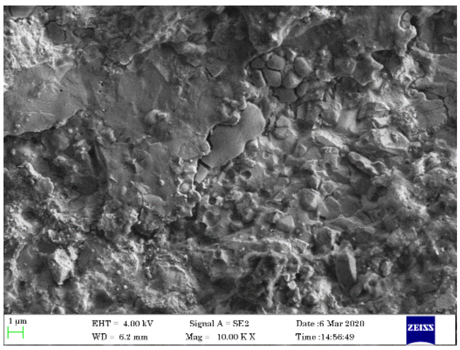

Fig. 3 Microstructure 1.

The Fig.3 represents the microstructure of the clad deposited in the substrate. This also indicates the presence of the tungsten carbide particles.

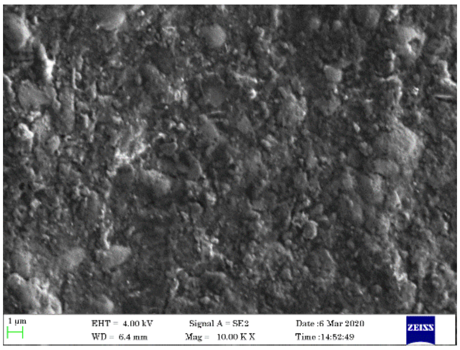

Fig. 4. Microstructure 2.

The Fig.4 represents the microstructure of the substrate that stainless steel after microwave cladding. From this Fig.4 it is clearly seen that the clad is partially diluted into the substrate thus forming a metallurgical bond.

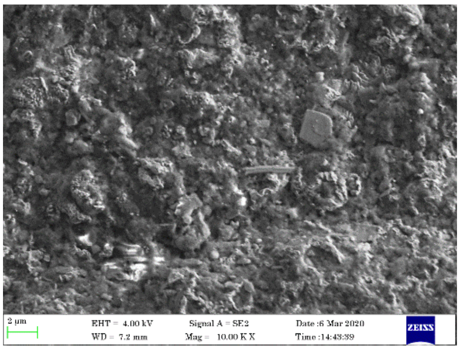

Fig. 5. Microstructure 3.

The Fig. 5 represents the microstructure of the substrate that is stainless steel, after microwave claddin*g*. This figure represents that there is no crack formation in the substrate.

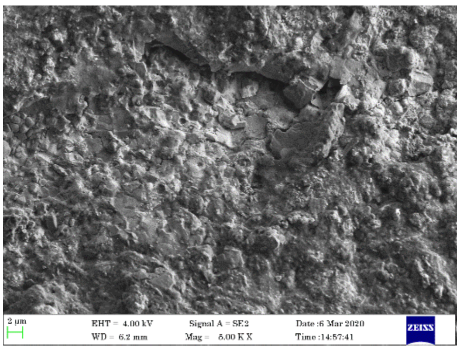

Fig. 6. Microstructure 4.

The Fig. 6 represent the microstructure of the microwave processed clad which is analysed through Scanning Electron Microscope. The SEM images revealed that the clad of 0.6 mm thickness was well bonded with the substrate without any interfacial cracks. The clad layer and interface can be clearly seen from the SEM images.

5. Conclusion

A new surface engineering technique for developing cladding on metallic substrate has been reported. The microwave cladding process uses electromagnetic that is microwave energy as the source of heat. Initial results of microwave cladding of WC10Co2Ni powder on stainless steel of grade 304 have been presented. Some important findings of the presented work are an irradiation time of 45 minutes was found to be sufficient for interaction of microwave with the WC10Co2Ni powder for melting and subsequent formation of cladding. Microwave cladding shows good metallurgical bonding with the substrate with varying degree of dilution. Tungsten particles get diluted well into the substrate and are uniformly distributed in the clad region upto certain clad depth. Presence of metallic carbides and tungsten particles in both clad and substrate due to dilution increases hardness of the clad. The process has the potential to grow as a new surface engineering technique and provides a viable option for developing cladding.

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