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Microwave Cladding and Characterization of WC-12Co on Nickel Based Super Alloy

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***Abstract*— In the current work microwave cladding technique has been administered for reinforcement of surface properties of Nickel-based Super Alloy (Grade IN738). This is an expensive high performance alloy which is extensively used in gas turbine blades in marine and aerospace applications. Clads of WC-12Co have been developed on the substrate by using Microwave Hybrid Heating Technique (MHH).Clads of thickness approximately 500□m are developed by microwave exposure at frequency of 2.45 GHz. The developed clad have been characterized using SEM, EDS and the clad samples are also inspected under microscope to determine accurate structure.**

***Keywords*— Microwave cladding,SEM,EDS,XRD,Inconal738**

I. INTRODUCTION

Mobile ad hoc network is an infrastructure less, self maintained and self-configured network of mobile many engineering components primarily fail due to wear, errosion and corrosion in aggressive interacting environments. Turbo logical components in gas turbine plant and hydro power plant are usually subjected to such severe working conditions and consequently fail more frequently and also in industries like heavy mechanical industry (gas power plant & hydro power plant) automobile industries, defence industries, aviation industries are very much suffering by failure of components. designing such for longer life, first, bulk material design with high wear and corrosion resistance and second, modifying the surfaces to work satisfactorily in the aggressive working environment. in our present work is on cladding on nickel based superalloy in738 substrate, which is used in gas turbine blades in marine and aerospace applications. where corrosion, low oxidation, erosion, hot corrosion, which takes place due to high temperature, environmental attack such as in aggressive environment. it is operated in wide range of fuels including heavy fuels and this fuel contains corrosive elements like sulphur, sodium, potassium, led etc. as contaminants. It is also operated at elevated temperature, so hot corrosion takes place. Fuel contaminants, which salt water is common when fuel transported by barges. Salt can enter the gas turbine engine by means of air. This can make problems in gas turbine engine blades specially in marine application. Turbine blades also suffer from high temperature, high corrosion, and low temperature low corrosion apart from erosion. Hot corrosion reduces thickness of the blade, thus blades gets weak and fatigue takes place. Therefore, replacement of the bulk component by newly designed materials is often not permanent solution. Hence suitable modification on the surface of the blade could be done through different techniques, like; [1]Carburizing,Cyaniding,Nitriding,Coating or cladding etc. In this present work cladding is done to improve the surface property of Ni-based super alloy. Accordingly , cladding is defined as metallurgical bonding of same material or different material on its base material. It is widely used surface engineering technique to develop an overlay of suitable materials on substrates of designed properties by partial melting of substrate along with complete melting of the clad material. There are various methods for cladding they include Shielded Metal Arc (SMA) Metal Inert Gas (MIG) Submerged Arc (SA), Tungsten Inert Gas (TIG), High Velocity Oxy Fuel (HVOF) and laser cladding. Laser cladding is one of the most popular surfacing technique and widely practiced and competitive method to produce surface of desired properties. There are a few limitations of laser cladding including high set-upping cost, high operating cost, maintenance cost and low deposition efficiency [2].In spite of these, laser cladding has some limitations. That includes development of high thermal stress that causes clad cracking during processing and thermal distortion. And also cost effective for cladding in small areas. Thus it is

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important to investigate new processing techniques having potential to overcome the limitations of laser cladding, while producing improved microstructures and properties at low cost of high speed of processing.In order to reduce the problem, we have to increase the surface property of the substrate (Gas Turbine Blades). Cladding is to be done to increase surface properties. So on IN738 substrate clad of WC-12Co is to be developed. In order to increase hardness, toughness, wear resistance, high structural strength and high corrosion resistance this all is to be increased by cladding by using microwave hybrid heating. Usually WC-12Co based materials are widely used to provide wear resistance, corrosion resistance, increase in hardness to various industrial components. In general hardness and wear resistance of WC-12Co based cermets increase with the decrease of carbide particle size and increased volume fraction of the carbide. Reduced carbide particle size reduces the mean free part of the binder phase, resulting in greater constraints and higher hardness [3]. Various variants of thermal spraying have been a popular choice to deposit WC-12Co based coating. Several tribological investigations have been done on WC-12Co based coating. In the recent years, microwave processing of materials has emerged as one of the fastest material processing techniques. Microwave processing of materials is different from the conventional thermal processing methods. Microwave energy heats the material at the molecular level, which lead to uniform bulk heating, while in the conventional heating systems the material gets heated from the surface to the interior with higher thermal gradient which may result in poor microstructure. Microwave heating is well characterized by the volumetric heating which reduces the possibility of developing cracks, porosity, residual stresses and thermal distortion on the target material which compared to other thermal processes. Application of microwave energy in metallic material processing however, is challenging at the 2.45 GHz frequency which is commonly used for material processing. In the present work, WC-12Co clads will be deposited on nickel based superalloy grade IN8738 substrate using WC-12Co powders by microwave hybrid heating (MHH) technique. Microstructure of the microwave include clads will be studied using scanning electron microscopy SEM.To the most of the Author's knowledge, no literature is available on the cladding of Ni-based superalloy through microwave heating. This provide good opportunity to focus on the development of composite cladding of WC-12Co on Ni-based superalloy Grade IN738 substrate by using domestic microwave applicator. After successful cladding different characterization will be done. And later results will be checked for obtaining well fit for defining a new energy method of cladding.

II. EXPERIMENTAL PROCESS

A. Material Details:

Materials used for this microwave cladding as a substrate is Ni-based superalloy inconel 738. In order to develop WC-12Co cladding on nickel based super alloy, wc-12co powder having average particle size of 35 μm was used. The particles were irregular in shape. Typical morphology of the nickel based superalloy used as substrate is shown.the substrate nickel based super alloy cplates having dimensions 12mm×10mm×4mm. A typical secondary electron image of the substrate material before microwave processing is shown . The average grain size as observed from figure of IN738substrate.The chemical composition of both substrate and clad powder is shown in Table No1.and Table No2

Table 1: Chemical Composition of Grade In738

%	Cr%	Mo%	Fe%	Co%	Ni%	C%	Al%	Si%
Composition	16.1	1.9	0.05	8.29	61.1	0.17	3.34	0.21

It is a very hard material, which is used in gas turbine blades. Its melting range is 12300C – 13150C. Inconel 738 offers a combination of outstanding high-heat creep-rupture strength better than other superalloy. And the clad powder used is WC-12Co.

Table 2: Characteristics of the Clad Powder Used

Clad Powder	Morphology	Composition	Average Particle Size
WC-12Co	Irregular	77.33 W, 12.45 Co, 10.22 C	35–40 μm

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B. Methods of Characterization

The developed clad was first cleaned with acetone . specimen size is 12mm×10mm×4mm.the specimen used is inconal 738 . The developed clads were sectioned in a diamond cutter and polished using diamond paste.the cut samples where cold mounted for polishing using resins . The polished samples were cleaned thoroughly with acetone in an ultrasonic cleaner prior to proceeding for characterizations. The XRD patterns were obtained at room temperature. The scan rate used was 1°min−1 and the scan range was from 20° to 100°.The analysis of clad microstructures and chemical composition of the clads were carried out using a scanning electron microscope and also inspected under microscope.EDS was used for analysing the chemical composition

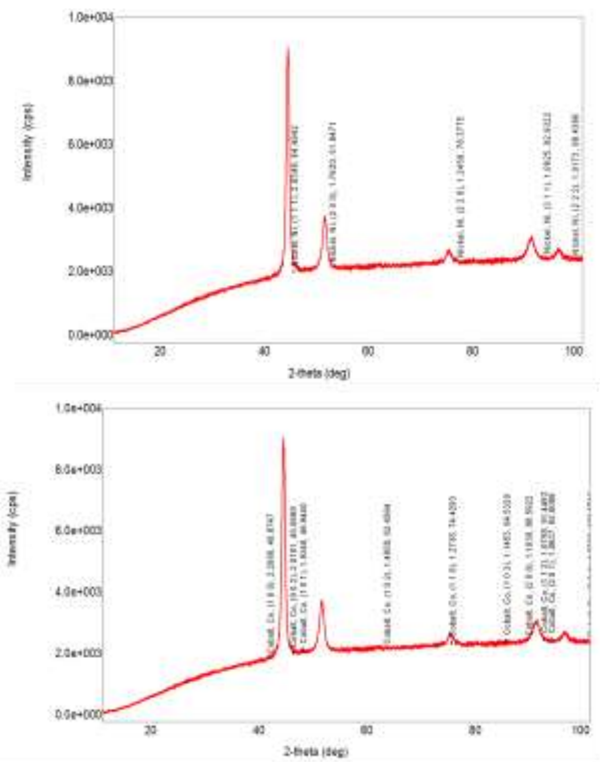

Fig.1- Typical XRD Spectrum of Ni-Based Super alloy

C. Microwave cladding process

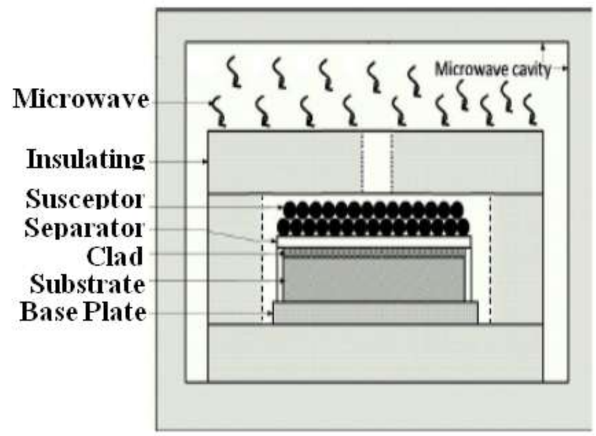

Fig.2- Experimental setup of microwave cladding process

Table3: Exposure time with microwaves effect on substrate

Trial Number	Exposure time (min)	Observation
01	07	Powder particles just started to melt,but no cladding.
02	10	Partially melted powder particles, poorly bonding.
03	15	Better melted powder particles, but poorly bonding.
04	18	cladding with good metallurgical bonding .
05	25	Clad sample starts to melt.

In this current work, substrate was cleaned in alcohol before deposition; the wc-co powder was placed manually on the substrate by maintaining an approximately same thickness. The experiments were conducted in domestic microwave oven with the help of Al2O3 shield (specimen enclosures) in order to keep away the reflection of microwaves with metal. The wc-co powder approximately 1.5mm thick layer was been uniformly sprayed over substrate material. The developed clad thickness of approximately 500µm has been explored by the exposure of microwave radiation

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at frequency 2.45 GHz. The entire setup was exposed to microwave environment for about 25min.The preplaced powder was melted by Microwave hybrid heating. In Microwave hybrid heating both conventional and microwave heating modes are active to get the effective heating of the target. In this process, usually, susceptor is used to absorb microwaves. In order to keep away possible contamination of the clad by the susceptor (charcoal powder) used in the MHH, a pure thin graphite sheet was used as a separator between the subsector and the nickel based powder. In the present work, experimental trials were conducted by maintaining a constant power of 900W and a constant thickness of preplaced powder layer was exposed with alternating time from 15min to 30min. It was noted that the cladding process method majorly depends on the microwave exposure time. Accordingly, it was absorved that lesser the exposure time there was better melting of the powder particles but poor bonding with substrate and it was also observed that the exposure time for Cladding with good metallurgical bonding was obtained with exposure time of 15min which was maintained throughout the cladding process.

The developed clads was been polished using standard metallographic techniques, The cut samples were cold mounted for polishing using resins. The samples were first polished by using emery paper of 200 ,600, 800, 1000, 2000,4000 grit size and lastly with diamond paste cloth polishing .then its cleaned with water and dried in hot air. Marble etch-ing ($CuSO_4$+ HCl concentrated + H_2SO_4+ Few drops distilled water) is done prior to the microstructure analysis; the specimens were immersed in etchant for about 10 s. The polished clad samples are shown .

(a)

(b)

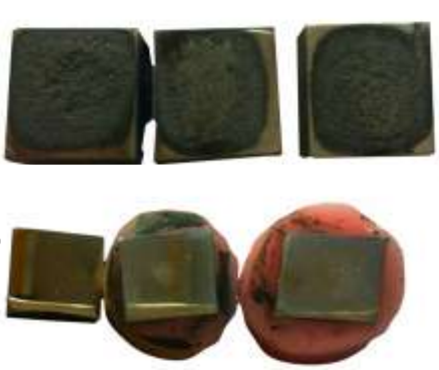

Fig.3- The image above (a) the developed microwave clad and (b) Polished Samples

III. RESULT AND DISCUSSION

The clads of wc-co is developed on nickel based super alloy(inconal738).this developed clad gives strong metallurgical bond with the substrate and various characteristic studies for developed clads are summa-rized in the following

A. XRD Study's

The typical XRD spectra of the starting Ni-based super alloy are shown in the Fig(a)and fig(b). The x-ray diffraction results of the substrate before cladding is been presented in the fig shown . It shows the dominant presence of Ni (2θ = 43.3508, 50.476, 90.051),co(2θ = 40.87,45.06,62.45,84.53,92.80).This is used for phase identification of the Ni-based super alloy. It takes approximately one hour for obtaining the XRD spectra for Ni-based super alloy. We can clearly see the highest peak at 2θ.peaks of cobolt was also observed in fig(b).The x-ray diffraction result of the clad powder (wc-co) is been shown in fig-7. The XRD spectrum clearly shows the presence of wc (40.27 ,58.26, 73.20 ,87.01 ,100.65) and co (41.93 ,44.76, 47.57 ,62.58, 75.94,98.74) this shows the dominant presence of wc-co powder. The highest peak is at 2 theta 41.93 for co and 40.27 for wc. The XRD patterns were obtained at room temperature. The scan rate used was 1°min−1 and the scan range was from 20° to 100°.

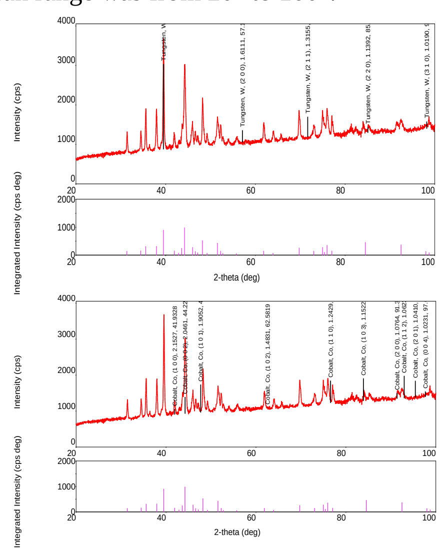

Fig.4- XRD Spectra Of WC –12Co Powder

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B. Optical Microscopy Study

Observation through optical microscopy : The microstructural study of the clad section was carried out through optical microscope. Information of different structure, morphology, grain boundaries and porosity of the developed surface is been investigated through microstructural observation. It shows white phase, dark phase and brown phase. Microscopy is a category of characterization techniques which probe and map the surface and subsurface structure of the material. It is a primary observation of surface of the material but it is not trustful. We can observe the structure at various portion of the specimen and also at various magnification and see the structure of the specimen after etching. We can clearly observe the grain size and over etched surface which is dark phase and perfectly etched surface which sown brown phase

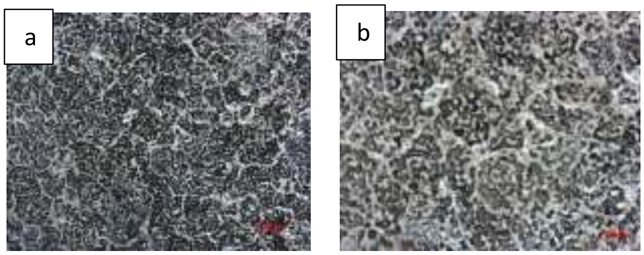


fig.5- Microstructure Of The Developed Clad observed through Optical Microscope

c. SEM studys

SEM characterization is done for both substrate and clad power.the scanning electron miocroscope is used for observation of specimen surface.the specimen is observed at high magnificvation in an electron microscope.specimen size is 12mm×10mm×4mm.the specimen inconal 738 is shown below. SEM shows microscopic image of samples. SEM characterization is done for both claded and uncladed samples . the scanning electron microscope is used for surface observation of specimen after cladding and before cladding . The developed clads were polished using diamond paste. The cut samples where cold mounted for polishing using resins . The polished samples were cleaned thoroughly with acetone in an ultrasonic cleaner prior to proceeding for characterizations. The analysis of clad microstructures and chemical composition of the clads were carried out using a scanning electron microscope and also inspected under microscope.images of SEM of developed clad at different magnification Is taken as shown in fig.

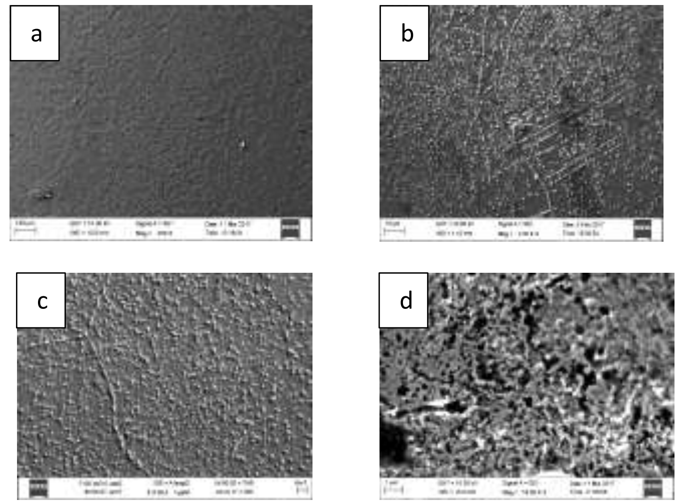
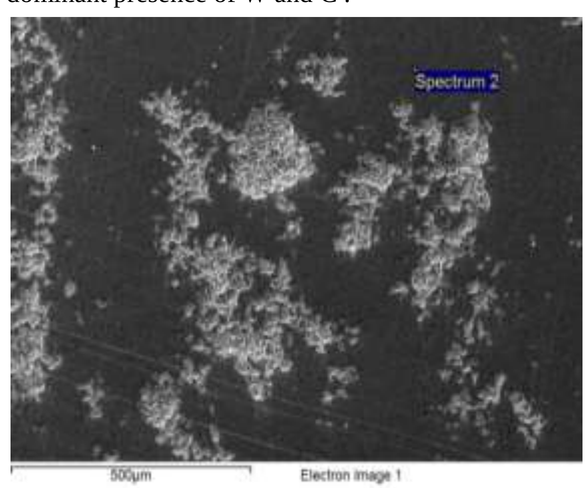


Fig. 6- SEM image of developed clad(a-d) shows - Microstructure Of The Developed Clad by SEM at different magnification.

D. EDS studys

EDS for both clad and unclad sample is shown in above fig(a),(b).it shows the chemical composition present on the surface of clad and unclad surface . The elemental dilution was further studied by EDS composition for both zones. EDS analysis was carried out at selected locations in the clad as indicated in Fig.The elemental distribution of the clad area reveals the dominant presence of W and C .



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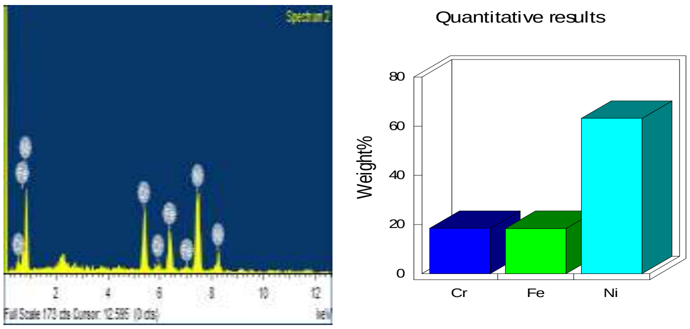
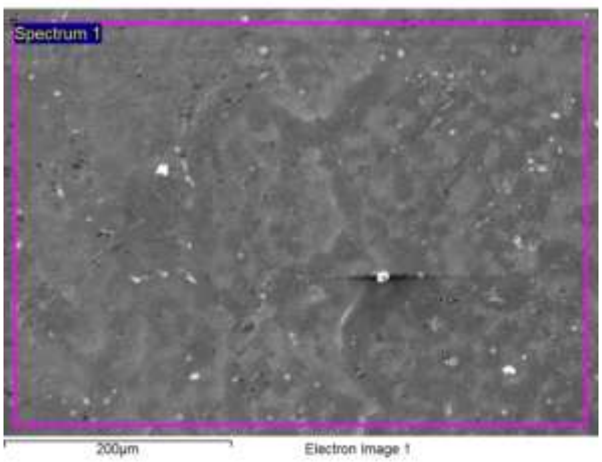


Fig.7- (a) EDS result for unclad sample



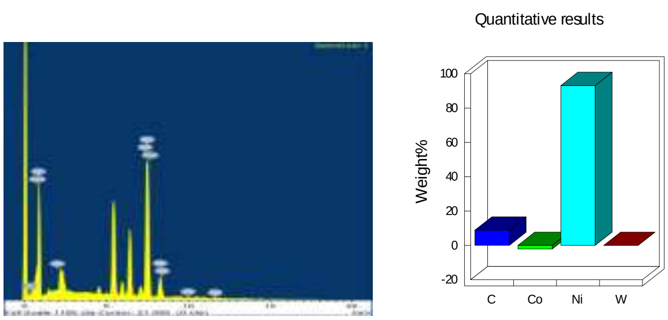


Fig.7- (b)EDS result for clad sample

E.Microhardness observation

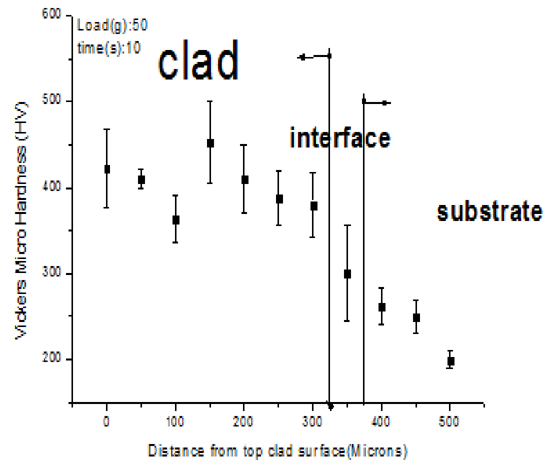


Fig.8- Developed Clad Vicker's Microhardness distribution across the typical Section.

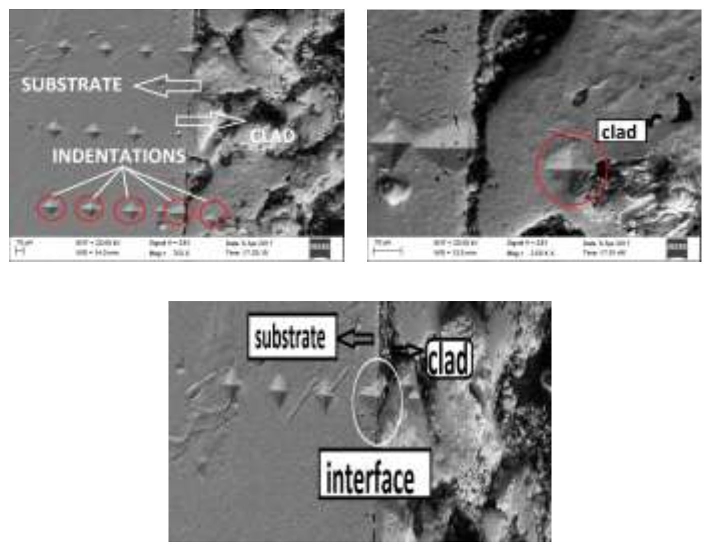


Fig. 9 – The microstructure of SEM image shows typical Vicker's indentations on (a) intermetallics, substrate and clad region (b) clad surface (c) interface region.

Hardness of a material is the most important factors, which influences wear performance of the material. Generally, increasing the hardness of components can enhance the wear resistance ability, although the effect of hardness is not straight forward . The developed wc-

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co based microwave clad cross-section and the substrate was tested through Vicker's micro hardness tester . The distance between two successive indentations was kept a constant value of 100µm. The distribution of the observed micro hardness of the developed clad surface is illustrated in Fig. It shows the distribution of the obtained micro hardness values of the developed clad surface is not uniform, which is due to the presence of various complex metal phases formed during microwave irradiation. [5]

The average micro hardness of the developed clad surface was obtained to be 403 ± 55 HV, which is much higher than the substrate hardness (237HV). it is observed from the profile that hardness value increased from an interface region of the clad surface, which is due to the formation of fine grain size and uniform crystal structure . these factors lead to increase the hardness value of the developed surface than the substrate. However,the microhardness at the interface region reduces which is due to possible intermixing of the elements from the WC-12Co powder and the substrate. typical indentation morphology of microhardness is shown in fig.9.

IV. CONCLUSION

The present work conclusions is been summarized as follows.

Cladding is been demonstrated through microwave as a novel surface engineering approach.WC-12Co powder was melted To form the clad on substrate inconl738 in demostic microwave oven Of 900W power and 2.45 GHz frequency.The elements controlled dilution such as clad or substrate results in good metallurgical bonding of the molten particles with the substrate.Due to volumetric nature of heating during microwave processing, the various phases and intermetallic,carbides of chromium are formed.The average microhardness of the clad section is 403±55 HV, which is due to the formation of carbides and intermetalic as observed in XRD.

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