International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 3 Mar. 2021, pp: 557-569 www.ijaem.net ISSN: 2395-5252

Experimental Analysis of Cladding for Wc-Al_2o_3 on AISI 1040 En Steel

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Submitted: 01-03-2021 Revised: 11-03-2021 Accepted: 14-03-2021

ABSTRACT: Cladding is an operation of making a layer of one material over another to control the infiltration of weather elements. In production and manufacturing industries, breakdown and wear of the products can be seen therefore, a technique is used name as cladding to overcome this type of problem. Cladding is a process in which metallurgical bonding between the object or substrate and the deposits is formed.
It is different from fusion welding or gluing as a method to fasten the metals together. Most common used technique is laser cladding generally applied in surface engineering. In this thesis cladding of WC-AL_2O_3 is applied on AISI 1040 EN steel by using microwave heating. The Cladding process was obtained by exposing the powder for 15min to radiation at 2.45 Ghz at a frequency of 900W in microwave system. The analysis of cladding can be characterized by field emission scanning electron microscope (FESEM) and XRD (X-ray crystallography) method. The results were carried out in the form of micro structural for further studies. Experimental results show a clear interface and complete deposition of WC particles. To confirm the presence of metal carbides, X-ray diffraction method is applied.
KEYWORDS: Cladding, X-ray diffraction, X-ray crystallography, WC-AL2O3, AISI 1040 EN steel.

I. INTRODUCTION

1.1. Cladding

Cladding refers to a process where a metal, corrosion resistant alloy or composite (the cladding material) is bonded electrically, mechanically or through some other high pressure and temperature process onto another dissimilar metal (the substrate) to enhance its durability, strength or appearance. The majority of clad products made today uses carbon steel as the substrate and aluminium, nickel, nickel alloys, copper, copper alloys and stainless steel as the clad materials to be bonded. Typically, the purpose of the clad is to protect the underlying steel substrate from the environment it resides in. Cladded steel plate, sheet, pipe, and other tubular products are often used in highly corrosive or stressful environments where other coating methods cannot prevail.

Cladded metal can be produced by many methods including explosion bonding, roll bonding, diffusion bonding, mechanical bonding, forging, laser, welding, friction welding or co-axial extrusion. The resultant clad products have either a mechanical or metallurgical bond to their substrate. Increase in thermal and kinetic energy increases chances of metallurgical bonding. The strength of the bond as well as the strength retention of the backing steel substrate determines the usefulness of the layered composites in subsequent metal forming processes or end user environments. Cladded metal can be produced by many methods including explosion bonding, roll bonding, diffusion bonding, mechanical bonding, forging, laser, welding, friction welding or co-axial extrusion. The resultant clad products have either a mechanical or metallurgical bond to their substrate.

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1.2. Surface engineering methods

A) Nitriding:

This process of nitriding is used in many industrial applications. Nitriding is used in the manufacturing of aircraft, bearings, automobile parts and textile machinery, and also turbine. Carbon does not play any part in the nitriding operation but influences the machinability of steel. In nitriding process there is no change of phase from ferrite to austenite and no further change from austenite to martensite. In nitriding process, nitrogen is introduced to the steel by passing ammonia gas through a muffle furnace containing the steel to be nitrided .We can say that steel remains in its

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previous form during the process. Therefore, there is no change in its molecular structure. No change in molecular size and most important no change in dimensions, changes can be only seen are volumetric. Twisting and bending can be seen due to the presence of induced surface stress.

Process parameters for nitriding are:-

•Furnace temperature
•Process control
•Time
•Gas flow
•Gas activity control
• Maintenance of Process chamber

B).Carbonizing:

Carburization is a heat treatment process in which iron or steel absorbs carbon when heat is applied to materials like charcoal or carbon monoxide, to make the metal harder. Total number of area which gets affected is totally dependent on the time and temperature. The amount of carbon diffusion typically increases on high temperature on rapid cooling, the phase change occurs from austenite to martensite, which results in harder outer surface. This process can be characterized by: It can apply to low-carbon materials; materials are in contact with a high-carbon gas, liquid or solid; hard material surface; toughness and ductility is obtained; hardness depths of up to 0.25 inches can be obtained.

C). Thermal spraying:

Thermal spraying is now regarded as one of the key enabling surface engineering technologies. It is an environmentally friendly process that uses the minimum of strategic materials. The use of thermally sprayed coatings has grown enormously and they are extensively used across the whole spectrum of engineering and manufacturing. From automobiles to airplanes, from surgical implants to golf clubs, the list is almost endless. Thermal coatings play an important part in everyday life every time you drive your car, every time you fly, every time you switch on a fluorescent light then you are probably relying on a thermally sprayed coating. Any material that has a well-defined melting point and does not decompose when heated can be thermally sprayed. The resultant coating can be applied to most substrates to provide a functional surface exactly where it's needed, enabling the designer to specify low cost, lightweight and easily workable base materials.

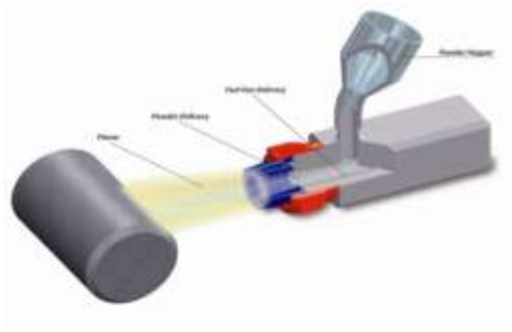

Figure 1: Representation of thermal spraying process

D). Laser cladding:-

Laser cladding is a method of depositing material by which a powdered or wire feedstock material is melted and consolidated by use of a laser in order to coat part of a substrate or fabricate a near-net shape part (additive manufacturing technology) .It is often used to improve mechanical properties or increase corrosion resistance, repair worn out parts, and fabricate metal matrix composites. Laser cladding / clad re-melting can form metallurgical bond between two materials and lead to new microstructure with desirable properties at the surface.

As laser with its function of producing high power densities, it will have the ability to generate heat reaching to melt the substrate and some of the cladding particles. With controlled power density, fusion of metal onto another metal with minimal thermal input can be attained. Selection of suitable cladding materials can increase the component wear, hardening and corrosion resistance with well-established parameters of laser processing. In principle there are two possibilities of realizing the process of cladding.

- Pre-placed powder process (two stages) as meant of clad re-melting.
- Blown powder process (one stage) as meant of cladding with surface re-melting.

E) Process:

Metallic powder are generally used in this process, and applied into the system by nozzles. When laser and metal powder interact melting occurs and a molten pool is formed. Thus a layer gets deposited on substrate and on solidifying a layer of solid is produced.

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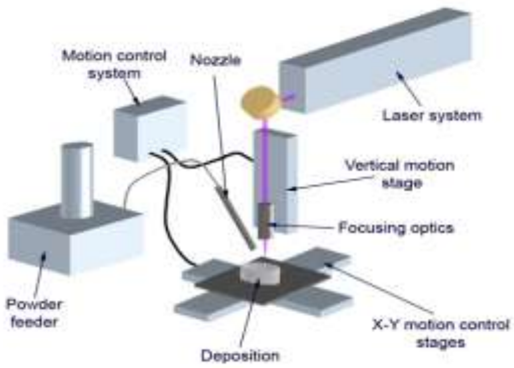

Figure 2: Representation of Laser cladding process

1.3. Microwave assisted synthesis of WC-AL_2O_3:

0915 GHz and 245 GHz frequencies are commonly used for microwave heating. These frequencies are chosen for the microwave heating based on two reasons. The first is that they are in one of the industrial, scientific and medical (ISM) radio bands set aside for non-communication purposes. The second is that the penetration depth of the microwaves is greater for these low frequencies. Generally, materials can be classified into three categories based on their interaction with microwaves:

- Materials that reflect microwaves, typified by bulk metals and alloys, e.g. copper
- Materials that are transparent to microwaves, typified by fused quartz, several glasses, ceramics, Teflon, etc.
- Materials that absorb microwaves which constitute the most important class of materials for microwave synthesis, e.g. aqueous solution, polar solvent, etc.

In microwave heating, unlike conventional heating, heat is generated internally within the material instead of originating from external sources. In this method the thermal gradients and direction of heat flow in microwave heated materials can be just the opposite of those in conventional methods**.** It gives clean, hazard proof, cheap and convenient method of heating often resulting in higher yields and short process durations. Applications of microwave processing are increasing widely. For instance, it can include processing of solution and suspension, drying, organic material burnout, clinkering, sintering of ceramics and ceramic composites, preparation of specialty ceramics, plasma processing, processing of polymers and polymer composites, fabrication of functionally graded materials, joining, fibre drawing, melting, reaction synthesis of ceramics and a host of very promising, new, advanced applications. The advantages of this technology have, more recently, also been exploited in the context of multistep total synthesis and medicinal chemistry/drug discovery , and have additionally penetrated related fields such as polymer synthesis, material sciences, nanotechnology and biochemical processes. The use of microwave irradiation in chemistry has thus become such a popular technique in the scientific community that it might be assumed that, in a few years, most chemists will probably use microwave energy to heat chemical reactions on a laboratory scale.

Microwave processing has gained worldwide acceptance as a novel method for heating and sintering a variety of materials, as it offers many advantages in terms of enhanced diffusion processes.

- Tungsten particles get diluted well into the substrate and are uniformly distributed in the clad region up to certain clad depth beyond which its presence is rarefied owing to high atomic weight of the particles.
- Thus this process has the potential to grow as a new surface engineering technique and provides a viable option for developing cladding.
- Therefore there no literatures on comparative study of development of cladding on WC-AL_2O_3 using microwave oven.

1.4. Objectives of Present Study:

- To study the effect of WC – AL_2O_3 on mild steel specimen by microwave assisted synthesis route.
- To study the microstructure and mechanical properties of mild steel substrate.

In this process composition of WC (particle size of 40um) and AL_2O_3 is used for the development of cladding on mild steel substrate. Process was carried out at different time intervals (minutes) till the cladding was developed. Different characteristics such as XRD, SEM and Vickers hardness test have been performed and the results are discussed in details.

II. MATERIALS AND METHODS

2.1. Structure and properties of tungsten carbide:

Tungsten carbide phases which form in WC system belong to the group of non stoichiometric interstitial compounds. Non stoichiometric interstitial compound includes carbides, nitrides and oxides of group IV, V and VI transition metals. According to the new research covalent metallic type of chemical bonds is realized in nonstoichiometric compounds.

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Due to the specific features a simple structure and high thermal and electric conductivity decreasing with temperature. Tungsten carbide (WC) is an inorganic chemical compound (specifically, a carbide) containing equal parts of tungsten and carbon atoms. In its most basic form, tungsten carbide is a fine grey powder, but it can be pressed and formed into shapes for use in industrial machinery, cutting tools, abrasives, other tools and instruments, and jewellery.

Tungsten carbide is approximately three times stiffer than steel, with a Young's modulus of approximately 550 GPa, and is much denser than steel or titanium. It is comparable with corundum (α-Al_2O_3) or sapphire in hardness and for polishing and finishing abrasives of superior hardness should be used.

Table 1- Effect of grain size on certain properties of WC – CO hard metal

Composition Properties	**97WC-3CO**	**94WC-6CO**	**94WC-6CO**	**94WC-6CO**	**90WC-10CO**	**90WC-10CO**
Grain size	1.0 – 2.0	0.5 – 1.0	1.0 – 2.0	2.0 - 5.0	0.5 – 1.0	2.0 – 5.0
Rockwell hardness (HRA)	92.5 – 93.2	92.5 – 93.1	9.17 – 92.2	90.5 – 91.5	90.7 – 91.3	87.4 – 88.2
Density (gm-cm^3)	15.3	15.0	15.0	15.0	14.6	14.5
Bending strength (MPa)	1590	1790	2000	2210	3100	2760
Relative Wear Resistance	100	100	58	25	22	7

2.2. Structure and properties of Aluminium Oxide

Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al_2O_3. It commonly occurs in its crystalline polymorphic phase α-Al_2O_3, in which it comprises the mineral corundum, varieties of which form the precious gems ruby and sapphire. Al_2O_3 is significant in its use to produce aluminium metal, and abrasive owing to its hardness, and as a refractory material owing to its high melting point. Al_2O_3 is an electrical insulator but has a relatively high thermal conductivity (30 $Wm^{-1}K^{-1}$) for a ceramic material. Aluminium oxide is insoluble in water. In its most commonly occurring crystalline form, called corundum or α-aluminium oxide, its hardness makes it suitable for use as an abrasive and as a component in cutting tools. Aluminium oxide is responsible for the resistance of metallic aluminium to weathering. Metallic aluminium is very reactive with atmospheric oxygen, and a thin passivation layer of aluminium oxide (4 nm thickness) forms on any exposed aluminium surface. This layer protects the metal from further oxidation. The thickness and properties of this oxide layer can be enhanced using a process called anodising. A number of alloys, such as aluminium bronzes, exploit this property by including a proportion of aluminium in the alloy to enhance corrosion resistance.

The aluminium oxide generated by anodising is typically amorphous, but discharge assisted oxidation processes such as plasma electrolytic oxidation result in a significant proportion of crystalline aluminium oxide in the coating, enhancing its hardness.

2.3. Properties of Mild steel (Plain carbon steels)

Mild steel, also known as plain-carbon steel, is now the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. Low-carbon steel contains approximately 0.05–0.25% carbon making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and easy to form; surface hardness can be increased through carburizing.

It is often used when large quantities of steel are needed, for example as structural steel. The density of mild steel is approximately 7.85 g/cm^3 (7850 kg/m^3 or 0.284 lb/in^3) and the Young's modulus is 210 GPa (30,000,000 psi).

Low-carbon steels suffer from yield-point run out where the material has two yield points. The first yield point (or upper yield point) is higher than the second and the yield drops dramatically

after the upper yield point. If low-carbon steel is only stressed to some point between the upper and lower yield point and the surface develop Lüder bands.Low-carbon steels contain less carbon than other steels and are easier to cold-form, making them easier to handle.
The plain steels are generally classified in following 3 types.

A) Low carbon steel: - up to 0.30% of carbon.
Properties: Malleable and ductile, and therefore bends fairly easily
Uses: It is used for nut, bolts, screws, automobile body panels, tin plate, wire product, tubes, girders etc.

B) Medium carbon steel: - From 0.30 to 0.60% of carbon.
These are less ductile but harder and have greater tensile strength than low carbon steel. It balances ductility and strength and has good wear resistance. They have also better machining qualities.

Properties: Harder, better tensile strength, good wear resistance.
Uses: Shafts, connecting rods, spindles, gears, crank shaft, couplings, rail wheels, rail axle etc.

C) High carbon steel: - From 0.60 to 1.70% of carbon.
They have higher tensile strength and harder than other plain carbon steels. They also readily respond to heat treatment. These steels can be tempered to great hardness. Used for special purposes like (non-industrial-purpose) knives, axles or punches. Most of these steels with more than 1.2% carbon content are made using powder metallurgy.

Properties: Tough rather than hard, and fairly ductile
Uses: Used for making hand tools such as wrenches, chisels, punches, files, cutting tools such as drills, wood working tools, rail road wheels, springs, high strength wires etc.

III. EXPERIMENTAL DETAILS

3.1 Materials and Apparatus used

(a) Silica Brick:
It is a type of refractory brick formed of at least 90% silica cemented with, for example, slurred lime; used to line furnace roofs. It is mostly used in making casting surrounding of the furnace.
(b) Graphite:
The mineral graphite is an allotrope of carbon. Graphite is an electrical conductor, a semimetal. It is useful in applications as arc lamp electrodes.
(c) Charcoal:
Burning temperature of charcoal is up to 2700 degrees Celsius. On comparison the melting point with iron it is approximately 1200 to 1550 degrees Celsius. Its sensitivity for flow of air and generation of heat is generally controlled because of porosity. Because of this reason charcoal is an ideal fuel for forging and widely used by blacksmiths.

3.2 Apparatus for Experiment-

A) Microwave:
Microwave is an apparatus which is generally used in home and somewhere in industries. It is based on magnetron, a device which converts electric energy to microwave energy the magnetron has to be cooled down through air by a fan. In the chamber waves get reflected by inside walls and absorbed by the object placed inside. For metal casting, microwave oven of power 800 to 1000 W is required with some changes. Microwave can be sometimes dangerous and should be treated with proper instructions.

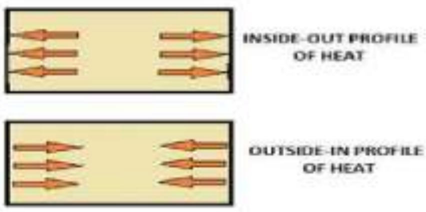

Figure 10- Heat process in microwave during processing

For this experiment LG MP-9889FCR Microwave Oven is used-

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Figure 11- Actual view of LG MP-9889FCR Microwave Oven

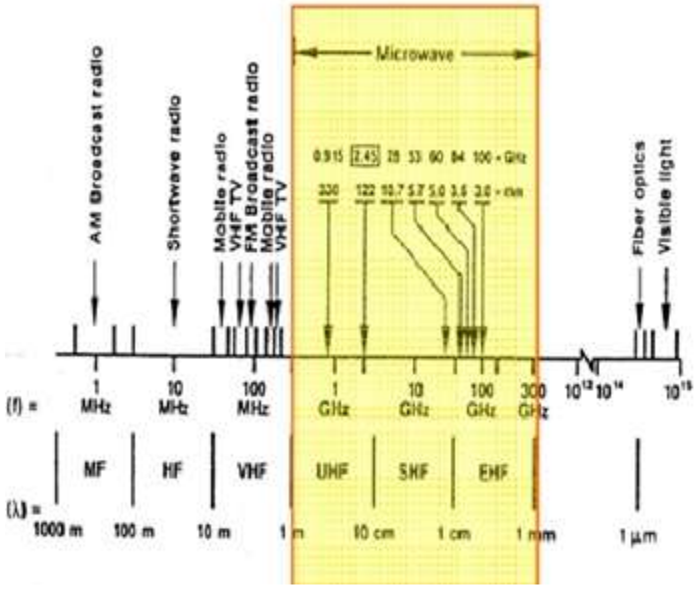

Figure 12- Range of microwave

3.3. Technical specification of Microwave oven

Some of the technical specifications of the LG MP-9889FCR Microwave Oven are-

Table 3- highlights of the LG MP-9889FCR Microwave Oven (Highlights)

1.	Type	Solar Dom
2.	Capacity (Litre)	38
3.	Colour	Floral Red Pattern
4.	Cavity	Stainless Steel
5.	Control Type	Tact/Dial Type Controls
6.	Auto Cook Menu	151
7.	Indian Auto Cook Menu	101

Table 4- Specifications of the LG MP-9889FCR Microwave Oven General Specifications

1.	Microwave Frequency (MHz)	2450
2.	Watts Microwave	1650
3.	Watts Grill	1600
4.	Watts Convection	2300
5.	Watts Combination	2350

Table 5- Dimensions of the LG MP-9889FCR Microwave Oven Dimensions

1.	Turntable Diameter	G/Tray-305, M/Tray-405
2.	Product Dimensions	527*392*480

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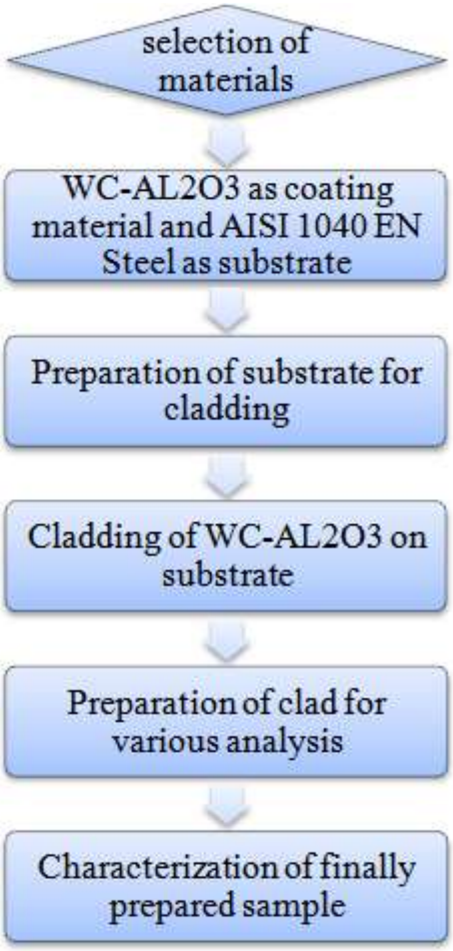
3.4. Experiment procedure of cladding:

In this project an AISI 1040 EN is used having 0.25 % carbon and about 0.4 to 0.7 % Mn, and some other residual elements. AISI 1040 EN is the most commonly used material in industry. Low cost and ease availability make it more liable to be considered first. The flow chart below shows the experimental steps.



A). Sample Preparation

The substrates were cut into size of 20mm×20mm pieces. The thickness of substrate was 5mm. Emery paper were used for polishing. Acetone oil is used for the cleaning of surface.

B). Development of Cladding

Mild steel substrates were cleaned for approx. 5min in an acetone before deposition. The composite powder of average size 40 micron is used and preheated to remove the moisture from powder. After this preparation powder is sprayed on the substrate .Graphite flakes also kept over the powder. The diagram show the complete overview of the process

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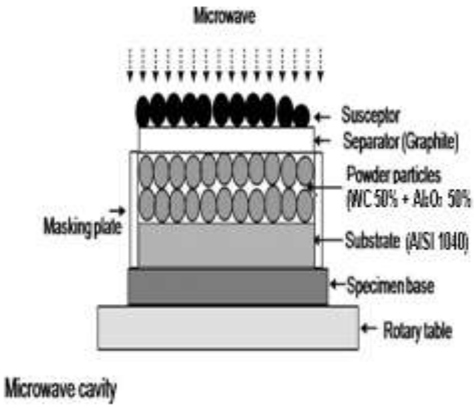

Figure 13- Schematic diagram of microwave hybrid heating used for developing (WC-AL_2O_3) cladding)

3.5. General characterization

A) X-ray diffraction:

X-ray crystallography is a tool used for identifying the atomic and molecular structure of a crystal, in which the crystalline atoms cause a beam of incident X-rays to diffract into many specific directions. By measuring the angles and intensities of these diffracted beams, a crystallographer can produce a three-dimensional picture of the density of electrons within the crystal. From this electron density, the mean positions of the atoms in the crystal can be determined, as well as their chemical bonds, their disorder and various other information.

XRD analysis is based on constructive interference of monochromatic X-rays and a crystalline sample: The X-rays are generated by a cathode ray tube, filtered to produce monochromatic radiation, collimated to concentrate, and directed toward the sample. The interaction of the incident rays with the sample produces constructive interference (and a diffracted ray) when conditions satisfy Bragg's Law ($n\lambda=2d \sin \theta$). This law relates the wavelength of electromagnetic radiation to the diffraction angle and the lattice spacing in a crystalline sample.

The characteristic x-ray diffraction pattern generated in a typical XRD analysis provides a unique "fingerprint" of the crystals present in the sample. When properly interpreted, by comparison with standard reference patterns and measurements, this fingerprint allows identification of the crystalline form.

MACHINE DETAILS-

Figure 14:X-Ray diffraction machine

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Instrument configuration:

- 3.0 KW high voltage generator
- Fine focus, Copper target X-Ray tube
- Programmable divergence and Anti – scatter slits
- Monochromator with curved crystal for Cu radiation
- Zero background sample holder
- Ultra high speed detector X'Celerator

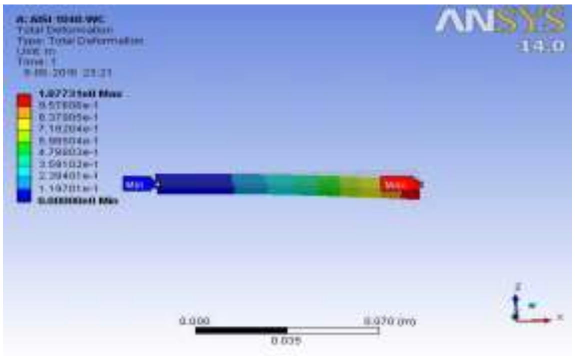
(B) Scanning Electron Microscopy:

SEM - is a powerful technique in the examination of materials. It is used widely in metallurgy, geology, biology and medicine, to name just a few. The user can obtain high magnification images, with a good depth of field, and can also analyse individual crystals or other features. A high-resolution SEM image can show detail down to 25 Angstroms, or better. When used in conjunction with the closely-related technique of energy-dispersive X-ray microanalysis (EDX, EDS, and EDAX), the composition of individual crystals or features can be determined.

IV. RESULT AND DISCUSSION

4.1. Structural analysis of WC-$AL_2 O_3$

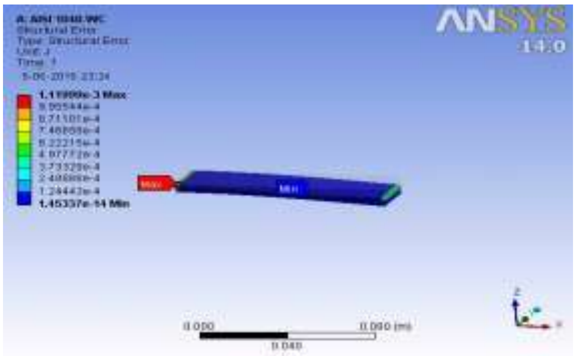
A) Total deformation:



Above figure shows the total deformation of substrate .The deformation is maximum at value 1.07731e-1 and minimum at other corner point of substrate. The figure shows the variation of deformation from maximum distance to minimum distance. The value of deformation depends on distance and load.

B) Structural error:

The Structural error at substrate is minimum at mid-section at maximum at corners .It shows the WC-AL2O3 Clad is fine at steel and structural error is minimum in substrate.



C) Equivalent elastic strain:

The equivalent elastic strain is plotted from the top clad surface to the base material. The graph shows drop of elastic strain from one side to other. Maximum elastic strain is observed at the one corner point and minimum at the other corner point.

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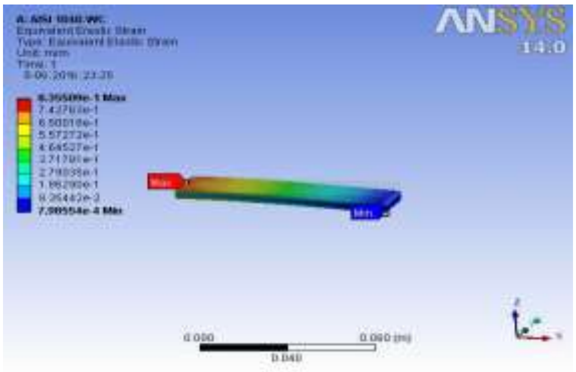
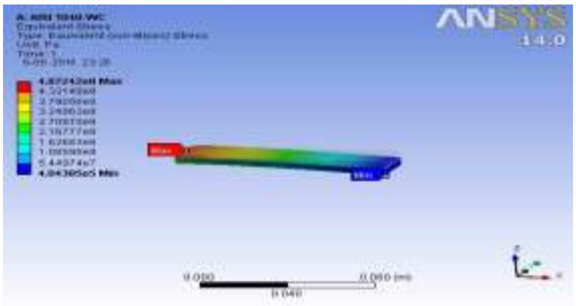


D) Equivalent Stress:



The equivalent Stress variation shown in substrate .The value of stress varies from maximum value to minimum value form on side to another side in substrate sample.

4.2. Characterization of cladding:

In order to assess the characteristics and wear performance, the microwave processed clad were evaluated through various techniques. Hardness of mating surfaces plays an important role in the process of material loss from the interacting surfaces. Micro hardness of the transverse section of the claddings and substrate were evaluated using a Vickers micro hardness tester at the load of 50 g applied for 30 sec.

4.3. XRD Analysis:

A typical XRD spectrum of the composite clad developed through microwave hybrid heating as presented in figure. The XRD pattern of composite clad shows the presence of chromium, aluminum oxide, hematite and tungsten carbide phases. The presence of $Fe_2 O_3$ phases could be due the dilution of iron from the substrate to clad which confirms the metallurgical bonding of clad with substrate.

Following analysis can be done from XRD:

1) Phase determination- Identification of crystalline phases.

2) Phase analysis and Relative composition of mixed phases quantitatively.

3) Calculation of lattice parameters-Structural variations under different conditions.

4) Analysis of size and strain of the crystallite - Estimation of size of crystalline structure and disorder.

5) Structure solution and structure refinement of unknown crystal phases.

By using the data obtained from the XRD tests, 2θ values were plotted on the X-axis and the corresponding graph with peaks representing the available compounds in the sample was generated. The following figure shows the presence of different compounds in the clad metal.

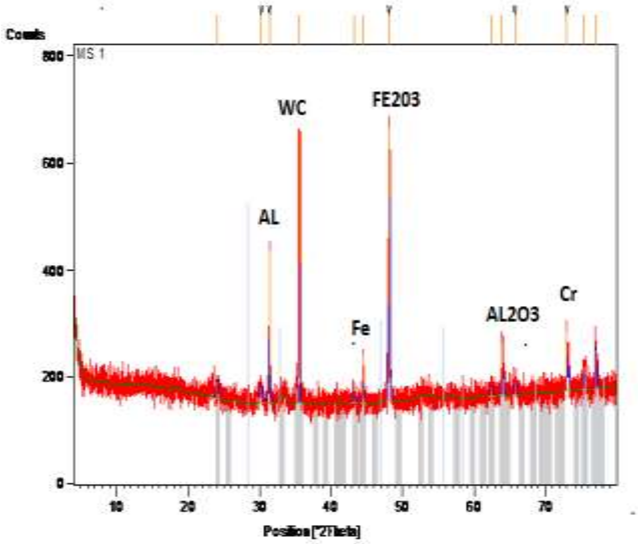


Figure 15-A typical XRD spectrum of the composite cladding

In the above graph diffraction angles are on the X-axis and the corresponding peaks were marked in the format "2θ (corresponding compound representation)". From the above figure we can see the formation of compounds like FE_2O_3, Al_2O_3, and Cr on the steel substrate which implies that the aim of coating on steel substrate through reaction is a success. The following table shows the 2θ values, height,d-spacing etc. at different position of XRD-analysis of substrate.

XRD analysis also gives the results about materials compositions in the substrate. The following table shows of materials observed in substrate after XRD analysis.

Table 6- Peak list of the compositions present in substrate

Pos. [°2Th.]	**Height [cts]**	**FWHM [°2Th.]**	**d-spacing [Å]**	**Rel. Int. [%]**
24.0856	33.18	0.3779	3.69501	5.13
30.1923	31.22	0.5038	2.96014	4.83
31.3419	288.26	0.1260	2.85414	44.58
35.5290	646.63	0.0551	2.52679	100.00
43.2164	19.93	0.3779	2.09347	3.08
44.5109	93.72	0.0630	2.03555	14.49
48.1559	513.60	0.1417	1.88965	79.43
62.3947	16.22	0.7557	1.48833	2.51
63.8876	98.82	0.1574	1.45711	15.28

65.7409	26.53	0.3779	1.42045	4.10
72.9730	113.26	0.1260	1.29649	17.52
75.3617	46.01	0.1889	1.26122	7.11
76.9644	73.43	0.1536	1.23788	11.36

4.4. Micro hardness study

Hardness of a material is one of the most important factors which we have to study and which is responsible for the wear of the material. The increasing hardness of components can enhance the wear resistance ability although the effect of hardness is not straightforward. Through Vickers micro hardness test hardness of clad layer over the surface has been evaluated. Micro-hardness values of the WC –AL_2O_3 clad/alloy layers were measured at the cross section .The distance between two indentations was kept 90 µm with an additional indentation at the interface and the substrate. An average distance of the three indentations was considered for the testing. Tungsten Carbides (WC) can provide coating hardness well above 1000 HV (Vickers). In this respect, commercially available WC powders normally contain spherical micro particles consisting of crushed WC agglomerates. The results show a large variation in the hardness value when position changes from one point to other. The load is applied of 50 g for 30 sec and the graph shows the peak point at Vickers hardness axis in clad. The following graph shows variation of Vickers hardness distribution in clad sample

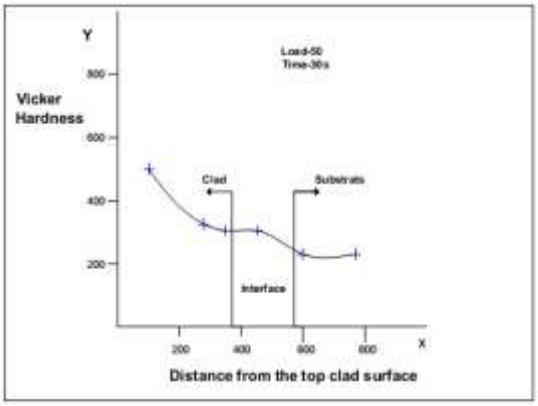


Figure 16- Vickers's micro hardness distribution through a typical section of composite Clad.

V. CONCLUSION

Using the realistic approach the mechanical properties of AISI 1040 were also considered for the analysis.

The FEA simulation based analysis provides satisfactory results after cladding. The microwave clad is characterized by partial dilution of the substrate and shows good metallurgical bonding with substrate by mutual diffusion of elements. The presence of Fe_2O_3,WC and Cr carbides are due to dilution of cladding material with substrate. Intermetallic is not observed in the XRD pattern, which is usually found in the deposition process like laser cladding (rapid solidification).

Presence of such stable and complex carbides could be enhance the sliding wear resistance of the claddings, for wear in sliding environment is basically dominated by the abrasion and adhesion. The developed microwave clad can be effectively used in wear resistant applications.
Thus. it is now concluded that microwave cladding is now emerging innovative techniques of cladding process.

5.1. Scope of Future work:

A stainless-steel-clad metal or alloy is a composite product consisting of a thin layer of stainless steel in the form of a veneer integrally bonded to one or both surfaces of the substrate. The principal object of such a product is to combine, at low cost, the desirable properties of the stainless steel and the backing material for applications where full-gage alloy construction is not required. While the stainless cladding furnishes the necessary resistance to corrosion, abrasion, or oxidation, the backing material contributes structural strength and improves the fabric ability and thermal conductivity of the composite. Stainless-steel-clad metals can be produced in plate, strip, tube, rod, and wire form. This process has the potential to grow as a new surface engineering technique and provides a viable option for developing cladding. The heat treatment of steel after cladding process can be carried out to examine the stress relaxation in the coating. This may allow accommodating high percentage of WC concentration in the coating while improving the mechanical properties of the coating in the surface region.

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International Journal of Advances in Engineering and Management
ISSN: 2395-5252

IJAEM

Volume: 03 Issue: 03 DOI: 10.35629/5252