MICROSTRUCTURE CHARACTERIZATION AND EVALUATION OF PHYSICAL PROPERTIES OF WC CLADDED AISI 304 STEEL BY TIG WELDING.

Gopal Krishna U B[1*], Vinay Dayanand Chalawadi[2], Madhusudhan Khamitkar[2], Bhushan Dayannavar[2], Aishwarya P Bhandarkar[2]

[1]*Assistant Professor, Department of Mechanical Engineering, Alva's Institute of Engineering & Technology, Moodbidri-574225, Karnataka, India*

[2]*UG Scholar, Department of Mechanical Engineering, Alva's Institute of Engineering & Technology, Moodbidri-574225, Karnataka, India*

ABSTRACT

In this present work an attempt has been made to increase the strength of the steel specimen with the increment of carbon percentage using TIG welding process. The present research done by merging welding and brazing process together, whereas the specimens were prepared by considering parameters like end clearance, welding temperature, filler material etc... After welding, the specimens are subjected to microstructural characterization using SEM & EDAX and evaluated in the region of a welded, heat affected zone. Also physical properties are evaluated by Brinell hardness test which shows significant improvement in the physical properties.

Keyword: - *TIG Welding, WC, SEM & EDAX, Hardness*

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1. INTRODUCTION

Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by using high heat to melt the parts together and allowing them to cool causing fusion.

TIG welding is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere by an inert shielding gas (argon or helium), and filler metal is normally used. The power is supplied from the power source (rectifier), through a hand piece or welding torch and is delivered to a tungsten electrode which is fitted into the hand piece. An electric arc is then created between the tungsten electrode and the work piece using a constant-current welding power supply that produces energy and conducted across the arc through a column of highly ionized gas and metal vapours. The tungsten electrode and welding zone are protected from surrounding from the surrounding air by inert gas. The electric arc can produce temperatures of up to 20,000°C and this heat can be focused to melt and join two different part of material. The weld pool can be used to join the base metal with or without filler material.

F. Madadi and M. Shamanian et..al investigated on the cladding on top of the composite, the tungsten inert gas (TIG) surfacing process was carried out in two, pulse and constant current modes to produce Satellite/WC composite claddings. To evaluate the coating, phase composition, microstructure, hardness and wear behaviour of the clad layers were investigated. The results showed that the microstructure of the cladding was composed of a hypoeutectic structure (γ+(γ+WC)). The added WC was completely melted into the weld pool and the solidified structure contained α-Co, σ-CoCr and some types of carbides. It was indicated that the use of pulsed current leads to a decrease in dilution and formation of a finer microstructure having higher hardness. Several significantly different solidified microstructures were characterized by dendrites, eutectics and faceted dendrites in the claddings. The faceted dendrites contained the majority of was well as Cr and Co while the matrix had higher Cr and Co content. The presence of faceted dendrites caused improvement in wear behaviour of claddings, with more WC content introduced, more faceted dendrites was obtained.[1]

2. EXPERIMENTAL DETAILS

2.1 Raw Materials Used:

The following materials have been used in welding AISI 304 steel cladded with tungsten Carbide (WC) by TIG welding.

2.1.1 Composition of each steel:

Table 2.1: Chemical Composition of AISI 304 steel in Wt%

Grade	C	Mn	Si	P	S	Cr	Ni	N	Fe
304									
Max	0.7	2.0	0.75	0.045	0.03	17.5	8.0	0.10	Bal
Min						19.05	10.5		

The grade steel with the series of AISI 304 was procured from the industry with a dimension of 150×32×32mm and set for the welding operation. For the application of the parameters considered the specimen was grinded with an angle of 45˚ to use as a raw material for the welding process.

Figure 2.1: Grinded Specimen

2.1.2 Cladding Process adopted

In the present work the cladded material used is tungsten carbide with particle size of 3-5µm size by mixing it with silver brazing flux and made a layer of 1mm thickness and allowed for settled/dried for small duration and the testing for both with coating and without coating has been performed.

Figure 2.2: WC cladded specimen

Figure 2.3: Performing the Welding operation

Table 2.2: Properties of Tungsten Powder

Chemical formula	WC
Density	15.63 g/cm3
Melting point	2785-2830 ℃
Boiling point	6000 ℃
Thermal conductivity	110 W/(m-K)
Heat capacity	39.8 J/(mol-K)
Young’s modulus	530-700 GPa
Grain size	3-5μ

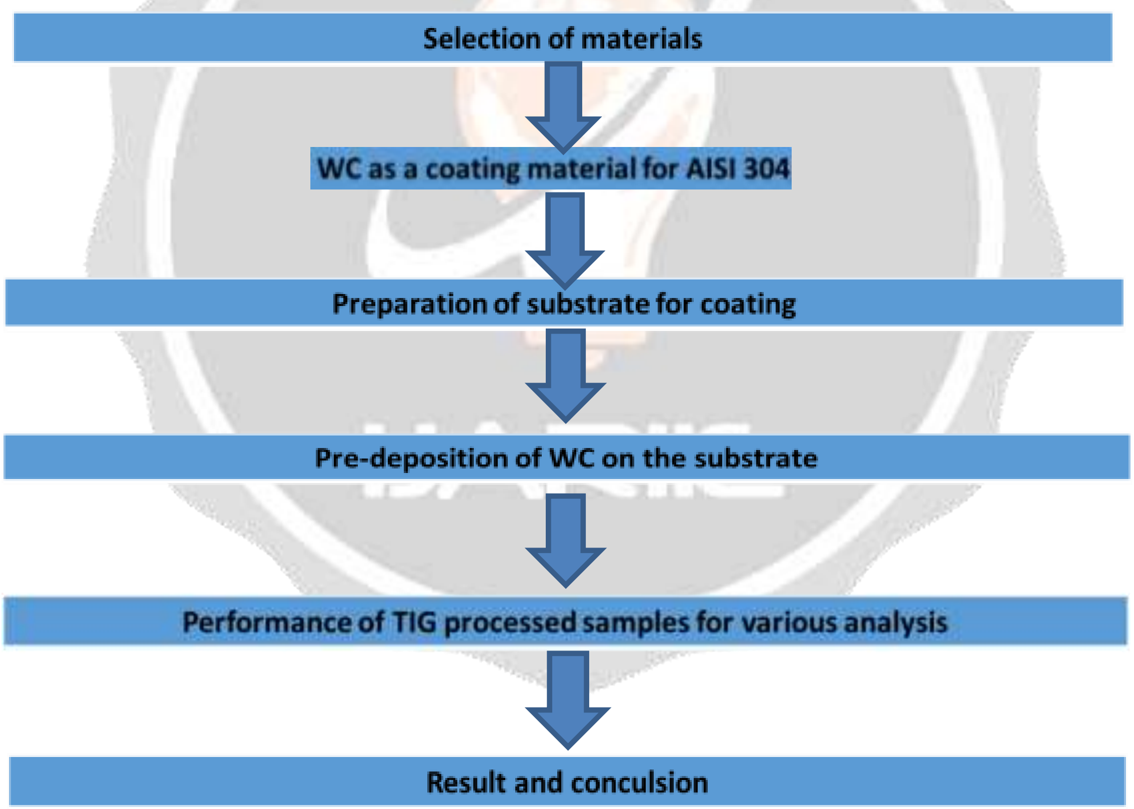
2.2 Process Parameters Considered.

In order to establish the working range before coating the input parameters that has to be considered for welding process, experiments were conducted by providing clearance between two stainless steel bars. The process is carried out in constant current mode, constant temperature, and welding speed and with a particular time taken for welding.

Table 2.1: Parameters of Welding Process

Parameters	Range
Current	60-100 amp
Scan speeds	1.01-7.15 mm/s
Voltage	10-20 V
Shielding gas	Argon
Current type	DC
Electrode diameter	2.4 mm
Electrode – workplace distance	3mm
Temperature	85-150 ℃
Argon gas flow rates	12.0 L/min

3. METHODOLOGY



The dimension of 150mm×32mm×32mm is the raw material used. The material is grooved and then 5gm of Brazing flux was mixed with 10ml of water to make fine paste which is used as a bonding agent and then the WC of 3-5 microns is cladded on the specimen. Then the specimen is allowed to dry the coated flux and then TIG welding process is done with the use of 308L as the filler material and the material is chopped into 62mm×15mm×15mm for coated and non-coated material for hardness, SEM & EDX tests.

Table 3.1: Heat input during TIG welding (without coating)

Item	Current (amp)	Scan speed (mm/s)	Heat input (J/mm)
1	100	3.13 (Single pass)	313
2	100	7.74 (Multi pass)	774

Table 3.2: Heat input during TIG welding (with coating)

Item	Current (amp)	Scan speed (mm/s)	Heat input (J/mm)
1	100	3.39 (Single pass)	339
2	100	5.38 (Multi pass)	538

3.2 Specimen Preparation for Testing:

Preparation of substrate for coating and non-coating: AISI 304 stainless steel of dimensions 62mm×15mm×15mm. The surface of samples were grinded with surface grinder for producing groove.

Figure 3.1: Cutted specimen of AISI 304 without coating (62mm×15mm×15mm)

Figure 3.2: Cutted specimen of AISI 304 with coating (62mm×10mm×10mm)

Figure 3.3: Cut Specimen without coating for SEM and EDAX

Figure 3.4: Cut Specimen with coating for SEM and EDAX

3.3 Brinell testing machine

Figure 3.5: Brinell Hardness Testing Machine

Brinell hardness test was conducted on uncoated and coated specimen of AISI 304 (62mm×15mm×15mm), was tested by using the ball indenter of diameter 2.5mm by the application of load 187.5 kg/cm^2. The indentation are taken on 6 side of specimen, 2 on welded section, 2 on heated affected zone and 2 on unheated zone.

4 RESULTS AND DISCUSSION

4.1 Hardness Testing

Hardness testing was conducted to all the specimens of the welded grade steels with coating and without coating. Brinnell hardness testing is adopted to find the physical properties of the samples. Hardness was conducted over 06 different location on each welded region, Heat affected zone and unheated zone and in each the average value is tabulated in Table

It is observed from the hardness table that incremental in physical strength found in welded and heat affected zone region in all the passes. When it is compared with single pass and multi pass region, single pass region shows better hardness over multi pass. When comparison done between different grade steels with only welded region with constant pass grade steel AISI 304 steel exhibit greater hardness.

Table 4.1: AISI 304 Specimen without coating

Clearance	Region	Hardness [BHN]
1 mm Single pass	Welded	**285.96**
	HAZ	187.23
	Unheated	125.79
	Welded	150.67

2 mm Multi pass	HAZ	**187.23**
	Unheated	155.61

Table 4.2: AISI 304 Specimen with coating

Clearance	Region	Hardness [BHN]
1 mm Single pass	Welded	**187.23**
	HAZ	171.42
	Unheated	155.61
2 mm Multi pass	Welded	**170.39**
	HAZ	155.61
	Unheated	143.28

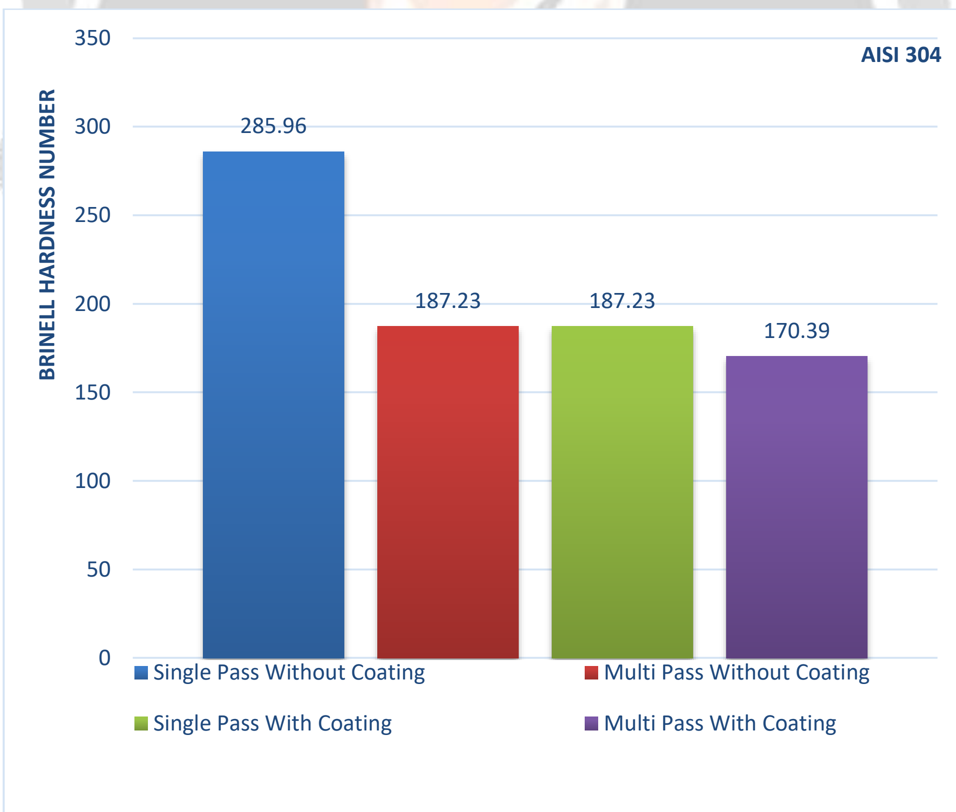


Figure 4.1: Brinell Hardness Number (BHN) Comparison for AISI 304 Steel with different parameters

4.2 Microstructural analysis

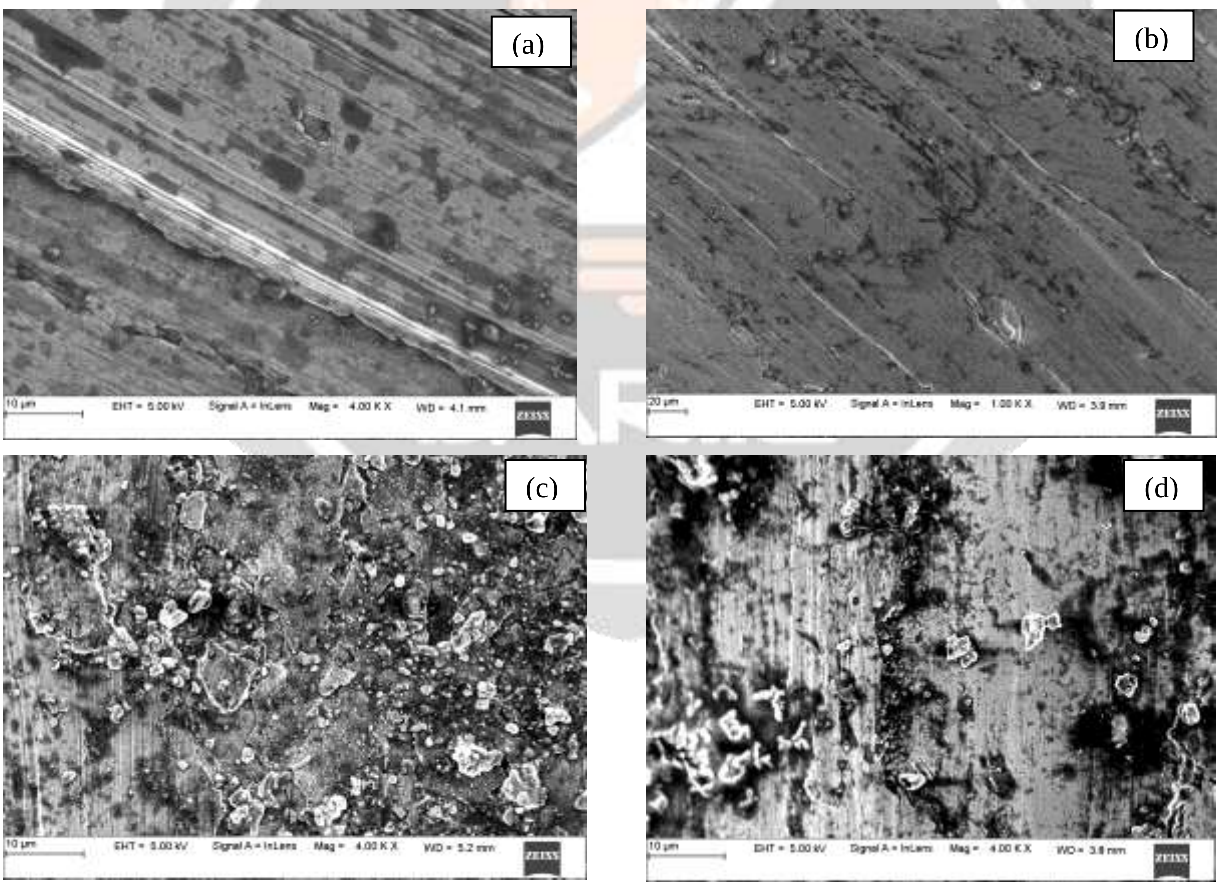
Microstructural analysis for the AISI 304 steels under various parameters are carried out. The analysis involves, specimen with coating & without coating and with 1mm clearance: single pass & 2mm clearance: multi pass. During the analysis specimens were not taken into any modifications by mixing with the chemical reagents like etchants or reagents. Since the main view of the work is to investigate the behavior of the steel structure with the addition of WC material in adopted method. Henceforth in all the analysis of SEM, EDAX is also performed to confirm the presence or increment of the carbon percentage in the steel material.

The images listed below shows a vital representation of the steel structure with the accumulation of all the alloying element in majorly Cr, Ni and Mn were found. Since the total investigation is for increment of carbon percentage the presence were analyzed through EDAX.

From the microstructure analysis it can be clearly observed that the steel specimen without coating shows the accumulation of minute particles in the splash form, where as in the coated specimen the welded structure resembled as the cast structure. In both the cases the improvement in the carbon percentage were found which leads to the improvement of the hardness of the steel specimen.

4.2.1 304 grade steel without coating

Parameters: 1mm clearance (single pass) & 2mm clearance (Multi pass)



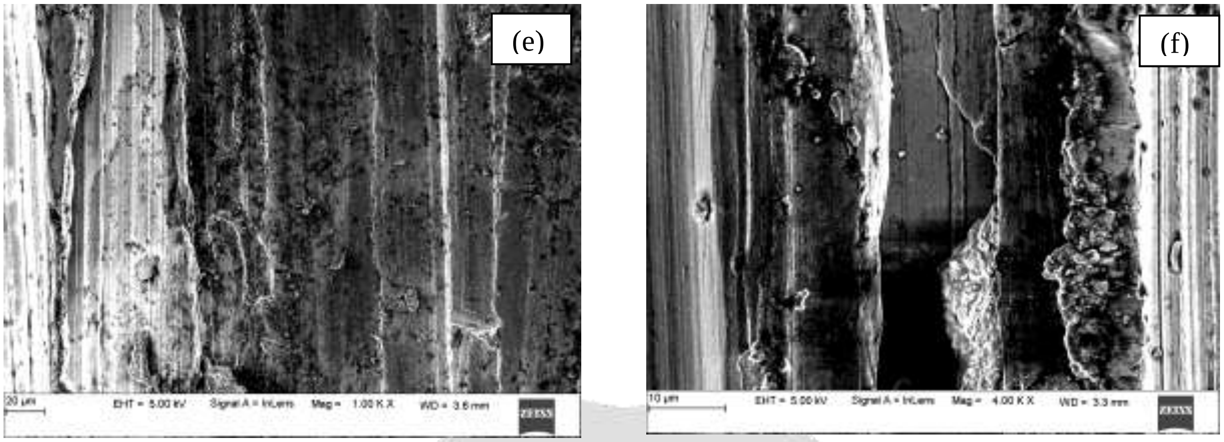
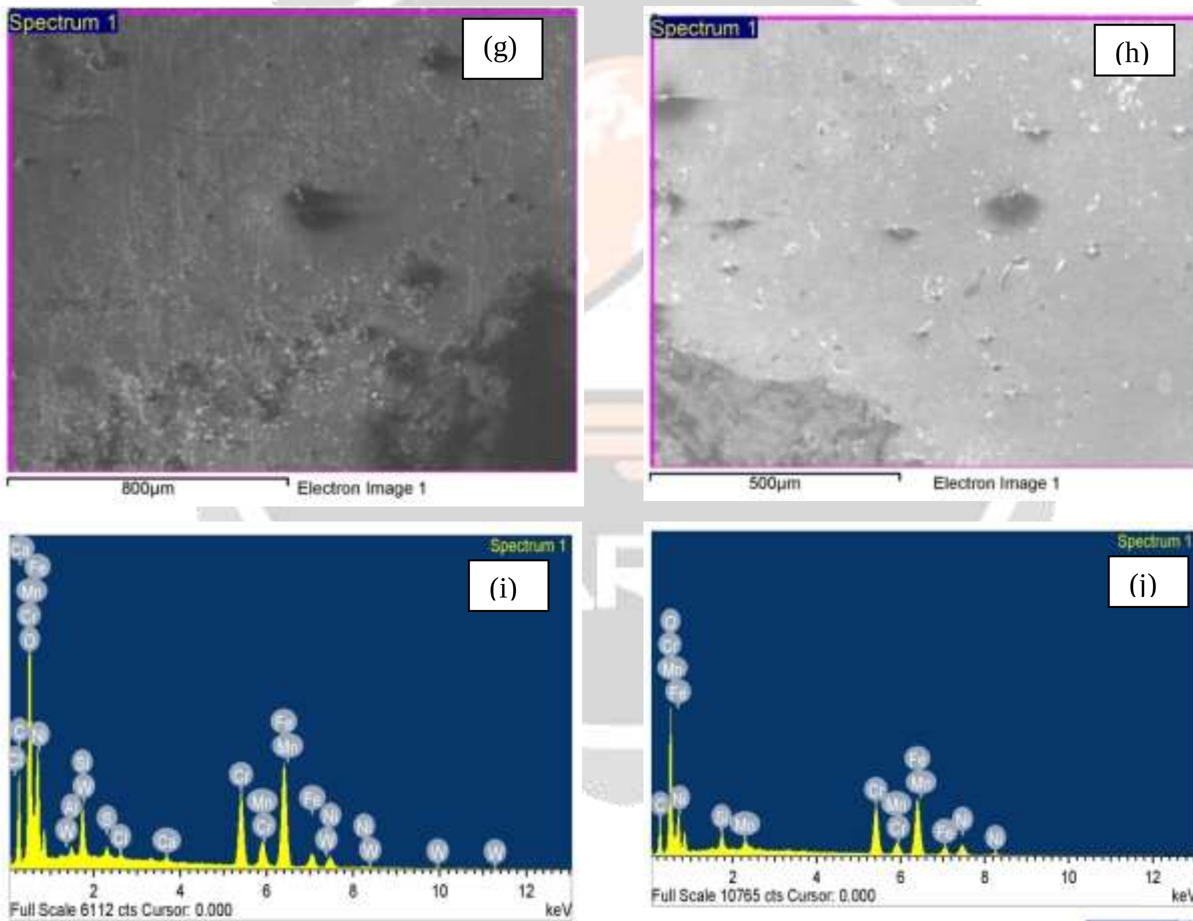


Figure 4.2: 304 (a) Base material, (b) Base material, (c) Single pass without coating(Welded), (d) Multipass without coating(Welded), (e) Single pass without coating (HAZ), (f) Multipass without coating (HAZ).



(k)

Elem...	Weight%	Atomic%	Compd%	Form
O K	32.42	43.66	44.59	O2C
Al K	0.62	0.50	0.00	
Si K	3.34	2.56	0.00	
S K	0.73	0.49	0.00	
Cl K	0.44	0.27	0.48	Cl4C
Ca K	0.51	0.28	0.00	
Cr K	18.82	7.80	0.00	
Mn K	5.96	2.34	0.00	
Fe K	44.73	17.26	0.00	
Ni K	7.83	2.88	0.00	
W M	0.66	0.08	0.00	
C	12.21	21.90		
Totals	128.28			

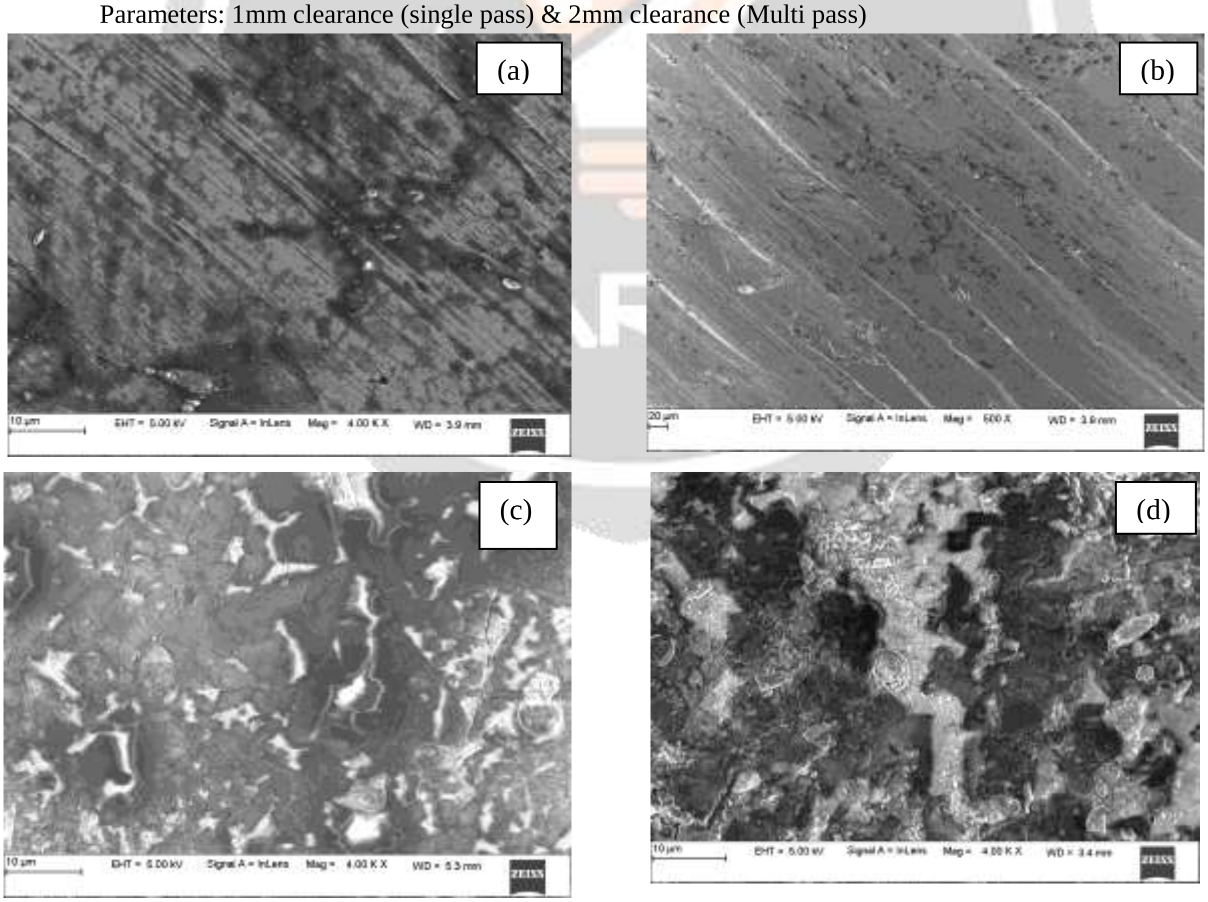
(l)

Elem...	Weight%	Atomic%	Compd%	F
O K	26.80	40.86	36.86	O2C
Si K	1.92	1.67	0.00	
Cr K	22.07	10.35	0.00	
Mn K	3.74	1.66	0.00	
Fe K	42.79	18.69	0.00	
Ni K	13.16	5.47	0.00	
Mo L	3.38	0.86	0.00	
C	10.06	20.43		
Totals	123.93			

Figure 4.3: 304 (g) Single pass without coating (Welded), (h) Multi pass without coating (Welded), (i) Single pass without coating (Welded), (j) Multi pass without coating (Welded), (k) Single pass without coating (Welded), (l) Multi pass without coating (Welded).

4.2.2 304 grade steel with coating

Parameters: 1mm clearance (single pass) & 2mm clearance (Multi pass)



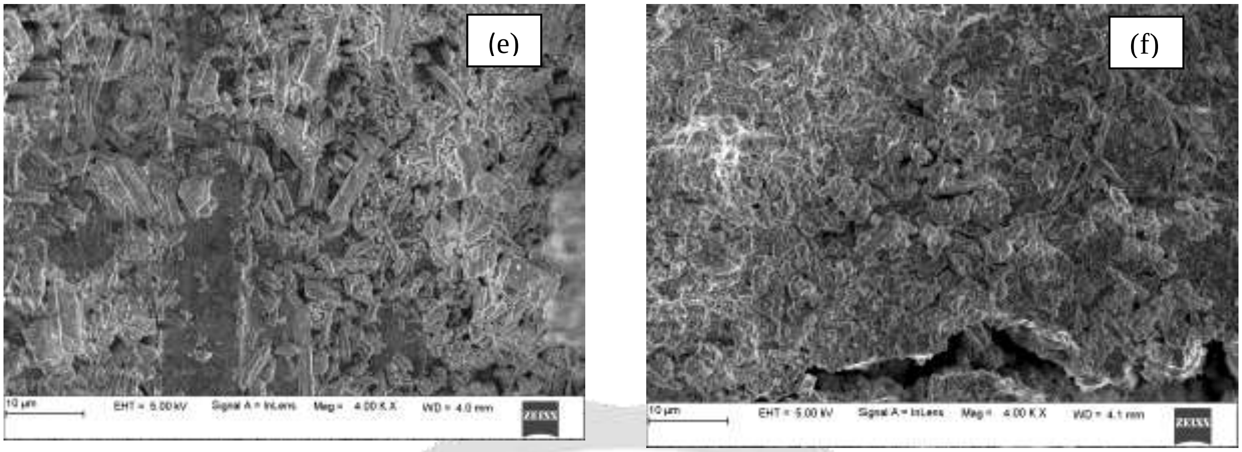
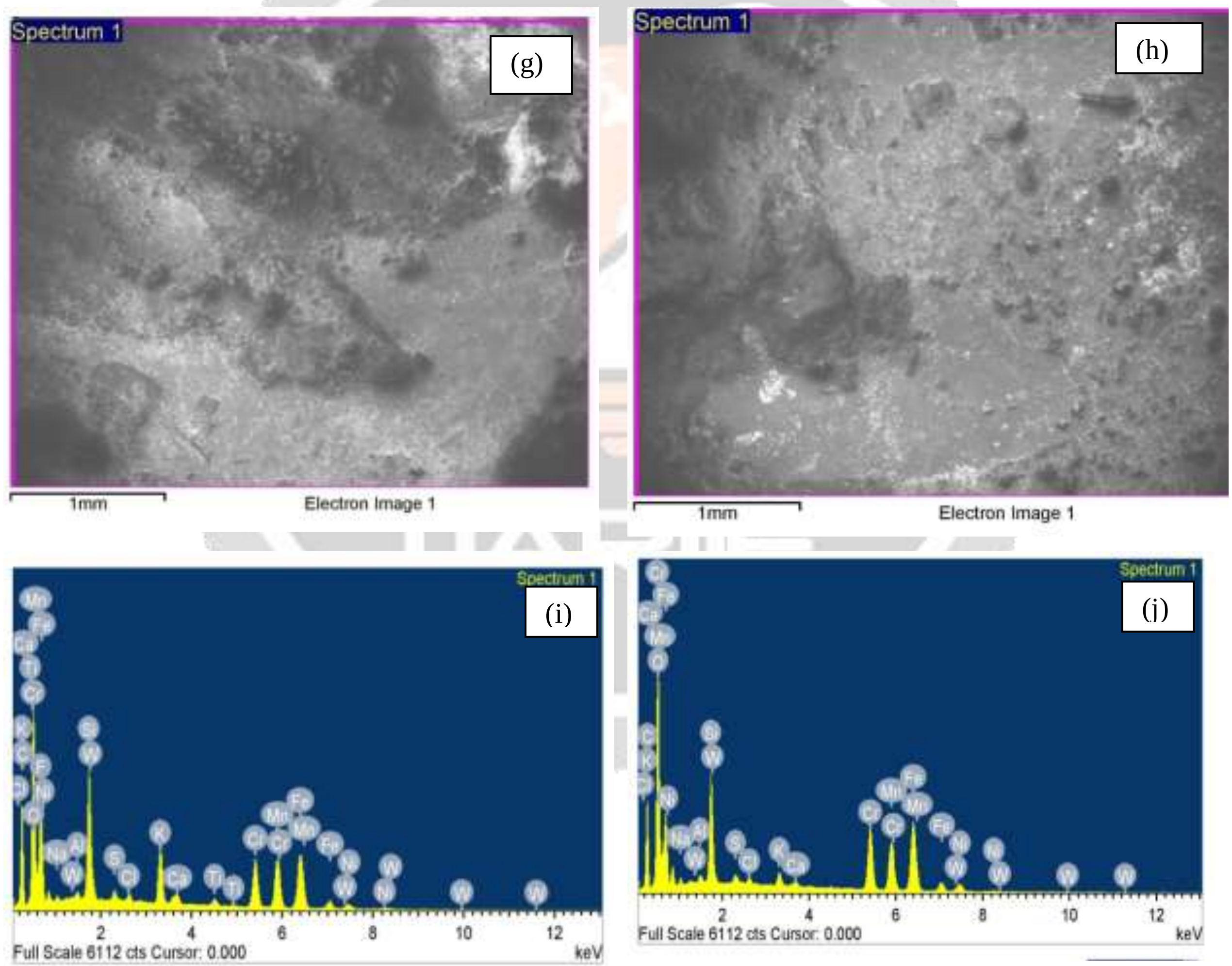


Figure 4.4: 304 (a) Base material (b) Base material, (c) Single pass with coating(Welded), (d) Multipass with coating (Welded), (e) Single pass with coating (HAZ), (f) Multipass with coating (HAZ).



Elem...	Weight%	Atomic%	Compd%	Formula
O K	28.52	32.92	39.22	O2C
F K	18.10	17.60	20.96	F4C
Na K	0.56	0.45	0.00	
Al K	0.44	0.30	0.00	
Si K	6.92	4.55	0.00	
S K	0.70	0.41	0.00	
Cl K	0.73	0.38	0.79	Cl4C
K K	5.59	2.64	0.00	
Ca K	1.06	0.49	0.00	
Ti K	1.23	0.47	0.00	
Cr K	12.82	4.56	0.00	
Mn K	15.49	5.21	0.00	
Fe K	23.25	7.69	0.00	
Ni K	3.19	1.00	0.00	
W M	3.88	0.39	0.00	
C	13.63	20.95		
Totals	136.11			

(k)

Elem...	Weight%	Atomic%	Compd%	Formula
O K	29.10	42.02	40.02	O2C
Na K	0.76	0.76	0.00	
Al K	0.48	0.41	0.00	
Si K	6.81	5.60	0.00	
S K	0.60	0.43	0.00	
Cl K	0.55	0.36	0.60	Cl4C
K K	1.34	0.79	0.00	
Ca K	0.64	0.37	0.00	
Cr K	16.41	7.29	0.00	
Mn K	15.03	6.32	0.00	
Fe K	29.64	12.26	0.00	
Ni K	5.33	2.10	0.00	
W M	1.31	0.16	0.00	
C	10.97	21.10		
Totals	118.99			

(l)

Figure 4.5: 304 (g) Single pass with coating (Welded), (h) Multi pass with coating (Welded), (i) Single pass with coating (Welded), (j) Multi pass with coating (Welded), (k) Single pass with coating (Welded), (l) Multi pass with coating (Welded).

5. CONCLUSIONS

1. TIG welding operations on 304 grade steel have been done successfully
2. Coating on AISI 304 steel specimen with the use of flux has completed successfully
3. Preparation of the specimens for the physical and microstructural characterization has successfully completed
4. Brinell hardness testing on welded, Heat affected zone and unwelded region for both coated and non-coated region has completed.
5. Characterization using SEM, EDAX reveals the addition and incremental of carbon percentage and the modification in the welded structure in the similarity of cast structure.

6. REFERENCES

[1] F. Madadi, M. Shamanian , F. Ashrafizadeh, "Effect of pulse current on microstructure and wear resistance of Stellite6/tungsten carbide claddings produced by tungsten inert gas process" At ScienceDirect, Surface & Coatings Technology, Elsevier Ltd. In Iran, 8 April 2011, Page no 4320–4328

[2] S. Mridha, T. N. Baker, "Overlapping tracks processed by TIG melting TiC preplaced powder on low alloy steel surfaces" At Materials Science and Technology, Maney on behalf of the Institute. In Kuala Lumpur, Malaysia, VOL 31 NO 3, 21 Mar 2014, Page no 337-343, ISSN: 0267-0836 (Print) 1743-2847 (Online).

[3] P.H. Lailatul, M.A. Maleque, "Surface Modification of Duplex Stainless Steel with SiC Preplacement Using TIG Torch Cladding" At ScienceDirect, Advances in Material & Processing Technologies Conference, Elsevier Ltd. In Kuala Lumpur, Malaysia, 2017, Page no 737 – 742.

[4] Everett M. Criss, Marc A. Meyers, "Braze welding of cobalt with a silver–copper filler" At ScienceDirect, Journal of Materials Research & Technology, Elsevier Editor Ltd. In proceedings of the Pan American Materials Conference, Sao Paulo, Brazil, 4(1), July 21st to 25th 2014, Page no 44–59.

[5] Jun Yan, Ming Gao, Xiaoyan Zeng, "Study on microstructure and mechanical properties of 304 stainless steel joints by TIG, laser and laser-TIG hybrid welding" At ScienceDirect, Optics and Lasers in Engineering, Elsevier Ltd In China, 26 September 2009, Page no 512–517.

[6] A. Shanmugasundaram, Sanjivi Arul, R.Sellamuthu, "Study on the Effect of GTA Surface Melting and SiC Reinforcement on the Hardness, Wear and Corrosion Properties of AA 5086" At ScienceDirect, International Conference on Emerging Trends in Materials and Manufacturing Engineering (IMME17), Elsevier Ltd. In India, 2017, Page no 6597–6606.

[7] Mustafa Ulutan, M. Mustafa Yildirim, Soner Buytoz, Osman N. Celik, “Microstructure and Wear Behavior of TIG Surface-Alloyed AISI 4140 Steel” At Tribology Transactions, Society of Tribologists and Lubrication Engineers, Informa Ltd. In England and Wales, 2011, Page no 67-79.

[8] Essam R. I. Mahmoud, Hashem F. El-Labban, “Microstructure and Wear Behavior of TiC Coating Deposited on Spheroidized Graphite Cast Iron Using Laser Surfacing” At Engineering Technology & Applied Science Research, In Egypt, Vol. 4, No. 5, 2014, Page no 696-701.

[9] E. Abakay, S. Sen and U. Sen, “Properties of the Surface Alloyed AISI 1020 Steel with Fe(15-x)MoxB5 Alloy” Proceedings of the 3rd International Congress APMAS, In Antalya, Turkey, Vol. 125 No 2, April 24_28, 2013, Page no 584- 586.

[10] R. Arabi Jeshvaghani, E. Harati, M. Shamanian, “Effects of surface alloying on microstructure and wear behavior of ductile iron surface-modified with a nickel-based alloy using shielded metal arc welding” At ScienceDirect, Materials and Design, Elsevier Ltd. In Iran, March 2011, Page no 1531–1536.

[11] Chinmaya Kumar Sahoo, Manoj Masanta, “Microstructure and wear characteristic of hard and wear resistance TiC coating deposited on aluminium by tungsten inert gas (TIG) cladding process” At Springer, Journal of the Brazilian Society of Mechanical Sciences and Engineering, In India, 20 April 2018, Page no 247.

[12] Vharkate C. B, Kale M. L, Mate A. K, Narwade V. B, Rathod N.R, “TiC COATING ON AISI 304 STAINLESS STEEL BY TUNGSTEN INERT GAS (TIG) CLADDING USING PREPLACED POWDER” At IJARIIE, In India, Vol-3 Issue-1, 2017, Page no 1382- 1386, ISSN(O)-2395-4396.

[13] N. Yuvaraj, “Surface Composite Fabrication through TIG arc Process: A Review” At International Journal of Emerging Technologies in Engineering Research (IJETER), EverScience Publications In India, Volume 6, Issue 5, May 2018, Page no 59-62, ISSN: 2454-6410.

[14] R. Saravanan, S. Srihari, A. Arvind, P. Sreeranj, K. S. Dheeraj, R. Sellamuthu and Sanjivi Arul, “ Microstructure, Hardness and Wear Rate of A356 Aluminium Alloy Surface Alloyed with Nitrided Titanium using GTA” At Indian Journal of Science and Technology, In India, Vol 9(34), September 2016, Page no 1-7, ISSN (Print) : 0974-6846 (Online) : 0974-5645.

[15] Osman Nuri Celik, Mustafa Ulutan, Hakan Gasan, Umit Er, Soner Buytoz, “Effects of graphite content on the microstructure and wear properties of an AISI 8620 steel surface modified by tungsten inert gas (TIG)” At ScienceDirect, Surface & Coatings Technology, Elsevier B.V. In Turkey, 16 September 2011, Page no 1423–1429.