Investigation of DMW Joints Using Buttering Deposits Prepared with Paste Technique

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Abstract: *The main objective of present work was to study the micro-structural changes due to buttering deposit on AISI 1020 steel for dissimilar metal joint of AISI 1020 steel to SS 304 steel. Dissimilar metal joints are extensively used in many industrial applications but due to weldability related issues, they cannot perform satisfactory life. The difference in chemical composition, coefficient of thermal expansion and mechanical properties affects the weldability of the joint. For maintaining elemental compatibility, buttering technique is often used for such joint. It is quite difficult to select the consumables for the buttering layers, which will satisfy the requirement of desirable chemical composition. Carbon migration is one of the major causes for buttering layer deposits. Nickel act as a barrier for carbon migration, so paste technique was used to deposit the buttering layer. The paste was prepared with Nickel powder, ferro-vanadium and ferro-titanium powders and deposited using Tungsten Inert Gas (TIG) welding and Shielded Metal Arc (SMAW) welding. Subsequent layer deposit was made using SMAW using Inconel 182 consumables. Weld joint was prepared between said base metals using SMAW process and Metal Inert Gas (MIG) welding. Micro-structural analysis and micro-hardness analysis were carried out. Nickel rich paste layer deposited using TIG observed micro-cracks or solidification cracks. When deposited with SMAW, due to dilution effect, nickel composition reduced and ferrite content changes in buttering layer hence no any cracks observed. Nickel paste with controlled parameters with direct deposit using SMAW can be successfully applied for such dissimilar metal joints.*

Keywords: *Paste technique, Dissimilar Metal Joint, Buttering, Carbon migration, welding.*

I. INTRODUCTION

The use of welding in the world of technology is extensive. It has a phenomenal rise since 1930; this growth has been faster than the general industrial growth. Practical applications of welding include automobile cars, aircrafts, ships, nuclear power plants, refineries, electronic equipment, machinery, household appliances, etc.

Dissimilar joints between Austenitic Stainless steel and carbon steel are extensively utilized in many applications in energy conversion systems. In central power stations, in nuclear reactors and in petrochemical plants the parts of the boilers that are subjected to lower temperature are made of carbon steel for economic reasons. The other parts, operating at higher temperatures, are constructed with austenitic stainless steel. Therefore, the transition welds are needed between the two materials. The various techniques have been developed to join different materials by welding but still joining of dissimilar metals Austenitic Stainless steel with carbon Steel by welding is the bottleneck. The reason is that the metallurgical factors like Thermal expansion, galvanic corrosion, Metallurgical stability due to properties of alloy phases as well as dilution and design factors must be viewed in terms of how the joint will operate under specific stresses and environments. Ul-Hamid et. al. investigated the failure mechanism for carbon steel and SS 304 pipe material and reported the failure due to development of high hardness localised region of martensite. It was also reported that, the crack propagation occurs in decarburised region of carbon steel[1]. Carbon steel HAZ weakened due to carbon migration and the low oxidation resistance of ferritic/ carbon steel at elevated temperature increases the susceptibility to low ductility failure for oxide notch effect[2]. The Ni base filler metals reduces the thermal stresses and also reduce the extent of carbon migration due to decrease in carbon activity gradient and low diffusion coefficient of carbon in Ni base alloys[3]. The Nickel base filler cannot completely prohibit the formation of soft zone (carbon denuded) but it can greatly decrease the growth rate of soft zone[4].

Carbon migration mainly occurs due to elemental differences, especially due to chromium content in weld and base metal. Carbon diffusion from low chromium base metal side to high chromium side (filler metal) and forms chromium carbide adjacent to the weld interface. Lundin reported that, carbon depleted zone appears in the carbon / ferritic steel material adjacent to fusion line and carbon enriched zone occurs in the stainless steel or Ni base filler metal. These zones are not present in the as welded conditions (diluted) but appears as after PWHT or elevated temperature exposure[5]. Carbon migration resulting from the dilution due to welding process and the consequent formation of an alloy having neither the composition of base metal nor that of consumable. The Nickel filler barrier reduced but did not prevent carbon migration[6].

In dissimilar austenitic stainless steel and carbon steel welded joint, weld metal and HAZ were subdivided into austenitic single phase, austenite and martensite mixture, martensite like structure, ferrite and pearlite like structure and small grained fine pearlite. This caused due to the convection and stirring effect and the diffusion process during welding cycle[7]. Taban et. al. was worked on ferritic stainless steel and carbon steel dissimilar joint. The satisfactory welding was done without any defect despite of any buttering layer on carbon steel[8].

Nickel base filler metals are often used to prolong the life of austenitic / ferritic dissimilar welds. The use of nickel base filler metals produces the thinner martensite layer compared to stainless steel filler metals due to steeper concentration gradient in partially mixed zone compared to Fe- based austenitic alloys[9]. Due to such various problems encountered in welding of carbon steel to stainless steel, this work is carried out to control the chemical changes in buttered layer as well as in weld metal.

II. EXPERIMENTAL PROCEDURE

AISI 1020 and SS304 plates of size 150mm x 50mm x 10mm were used in this work. The chemical composition of base metals and filler metals are given in Table 1. Weld deposit of 6mm thickness was buttered on one of the edge of 10mm thick AISI 1020 plates using Nickel paste as a initial layer on both plates. For both of the plates A and B, the Nickel powder paste composition was kept same as 100gm Ni + 5gm Fe-V + 5gm Fe-Ti with potassium silicate as binder.

Table 1: Chemical Composition (wt %) of materials used

Element / Material	AISI 1020	SS304	Inconel 182	Inconel 82
Fe	98.75	73.65	9.708	7.515
C	0.207	0.101	0.03	0.022
Si	0.141	0.369	0.744	0.582
Mn	0.391	0.30	9.081	2.863
Cr	0.038	14.34	14.26	16.71
Ni	0.023	9.446	62.51	68.35
Mo	-	0.025	0.592	-
V	-	0.054	-	-
Cu	0.102	0.106	0.01	0.013
P	0.035	0.055	0.014	0.003
S	0.0293	0.011	0.01	0.001
Co	-	-	0.234	0.255
Nb+Ta	-	-	1.661	2.45
W	-	-	0.322	0.084

After drying of paste, the paste of first plate A was melted using GTAW process and subsequent built up was made by SMAW process using 4mm dia. Inconel 182 electrode. The paste on second plate B was directly melted by SMAW process using Inconel 182 electrode and the subsequent deposit as well. The process parameters used for buttering operation are given in Table 2.

The buttered faces were then machined to a square edge. The SS304 plates were machined with 45^{o} single bevel edge with 1 mm land. The dissimilar plates of SS304 and buttered AISI 1020 were then setup for 45^{o} single half V-type groove geometry (Fig.1).

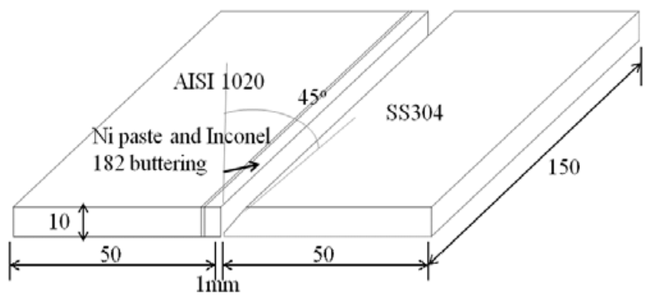

Fig. 1: Schematic diagram of AISI 1020 / SS304 weld pad showing Ni paste and Inconel buttering and edge preparation

The root pass welding was carried out using GTAW process with Inconel 82 filler wires, no any hot cracking and related defects was observed during root welding of both plates. Subsequently fill passes were carried out using Inconel 182 electrode with SMAW process. The process parameters for root pass and fill pass were same for both of the plate joints and given in Table 3.

After completion of welding, non-destructive testing like dye penetrant test was carried out for both plate joints A and B. The samples for metallographic examination and micro-hardness examination were cut from plates and prepared. Metallographic examination was carried out using optical microscope LEICA DMLM and the micro-hardness measurement was done with LEICA VMHTAUTO.

III. RESULTS AND DISCUSSION

In visual observation no any significant defect has been observed during welding. Dye penetrant testing of both A and B plates was performed for root joint and complete welded joint. No any cracks was observed with root pass and fill pass. Due to small groove angle, little bit problem was occurred during root pass welding, but it was rectified by adjusting the arc at root face and land.

Table 2: Process Parameters used for Buttering of Ni paste and deposit on AISI 1020

Process **Plate A**	Electrode	Layer	Current (amps)	Voltage (Volts)	Welding Speed (mm/sec)	Polarity	Gas flow rate (lit/min)
GTAW	-	Ni paste	120	10-12	0.887	DCEN	8-9
SMAW	Inconel 182 □ 4 mm	1	112	27-32	0.882	DCEP	-
SMAW	- do -	2	109	25-30	0.728	DCEP	-
SMAW	- do -	3	109	25-30	0.753	DCEP	-
SMAW	- do -	4	109	25-30	0.778	DCEP	-

Process **Plate B**	Electrode	Layer	Current (amps)	Voltage (Volts)	Welding Speed (mm/sec)	Polarity	Gas flow rate (lit/min)
-	-	Ni paste	-	-	-	-	-
SMAW	Inconel 182 □ 4 mm	1	112	27-32	0.886	DCEP	-
SMAW	- do -	2	109	25-30	0.756	DCEP	-
SMAW	- do -	3	109	25-30	0.789	DCEP	-
SMAW	- do -	4	109	25-30	0.772	DCEP	-

Table 3: Process parameters used for welding of buttered AISI 1020 and SS304

Type of Pass	Process	Consumable	No. passes	Current (amps)	Voltage (Volts)	Welding speed (mm/sec)	Polarity	Gas flow rate (lit/min)
Root	GTAW	Inconel 82 □ 1.1 mm	1	120	10-12	2.1	DCEN	6-8
Fill	SMAW	Inconel 182 □ 4 mm	2	109	25-30	0.88	DCEP	-

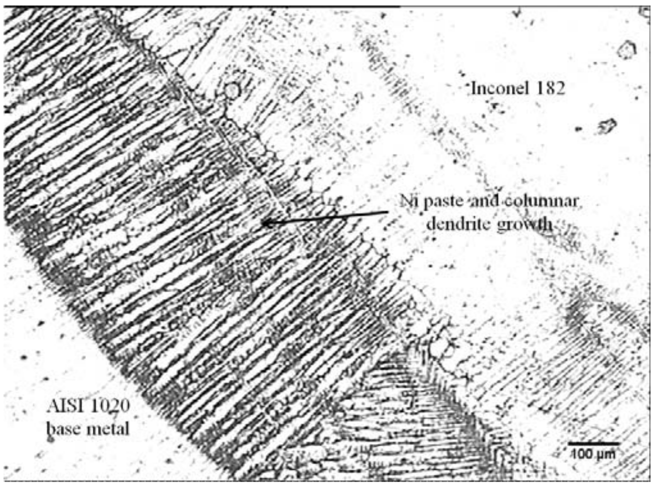

Fig. 2: Microstructure of Ni paste deposited plate A

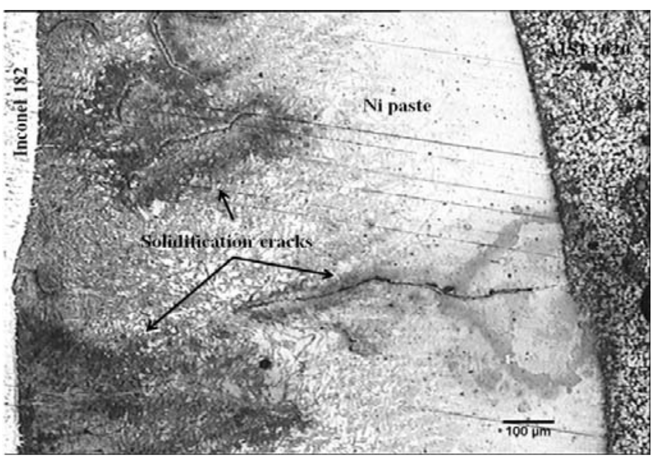

Fig. 3: Microstructure showing solidification cracks in Ni paste layer of plate A

Fig. 2 shows the microstructure of Ni paste deposited with GTAW process on the AISI 1020 plate A. Columnar dendrite growth of nickel crystals has been clearly observed. The complete austenitic structure is also seen. Lack of ferrite or ferrite content mismatch in the layer causes solidification cracking in the buttered layer. Due to GTAW process the homogeneous mixing of base metal with Ni paste was not possible and high nickel content causes solidification cracks in the layer and can be seen in Fig. 3.

The Ni paste deposited directly with Inconel 182 using SMAW process has been observed with complete mixing of Ni paste, Inconel 182 filler and AISI 1020 base metal. Figs. 4 and 5 shows the microstructure in the buttered layer of plate B. Required dilution and Ni paste mixing can be clearly seen in the figures. The austenitic structure of preferred orientation of grains with primary ferrite has been clearly revealed. The proper mixing ensures the ferrite content compatibility and hence no any micro-crack or fissure has been observed in the layer.

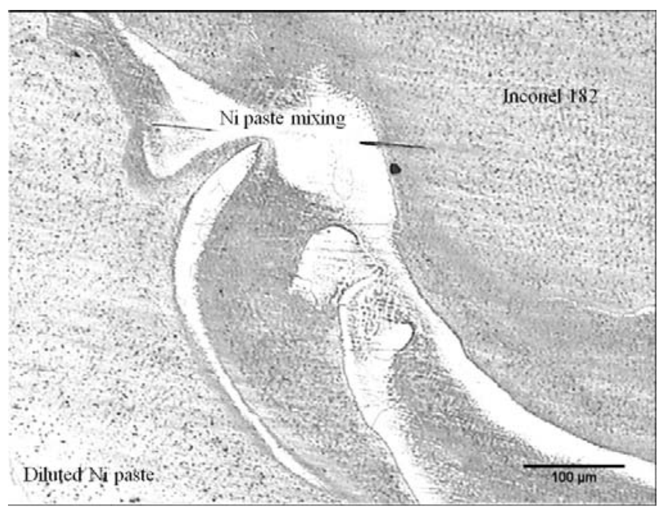

Fig. 4: Microstructure showing mixing and dilution of Ni paste with Inconel 182 of Plate B

The complete weldment was then subjected to Vicker's micro-hardness measurement. The micro-hardness of AISI 1020 base metal, HAZ of AISI 2010, buttering layer, weld metal, HAZ of SS 304 and SS 304 base metal was recorded. For each of the zone of weldment five indentations were taken. The hardness of plate B zone found to be consistently higher in each

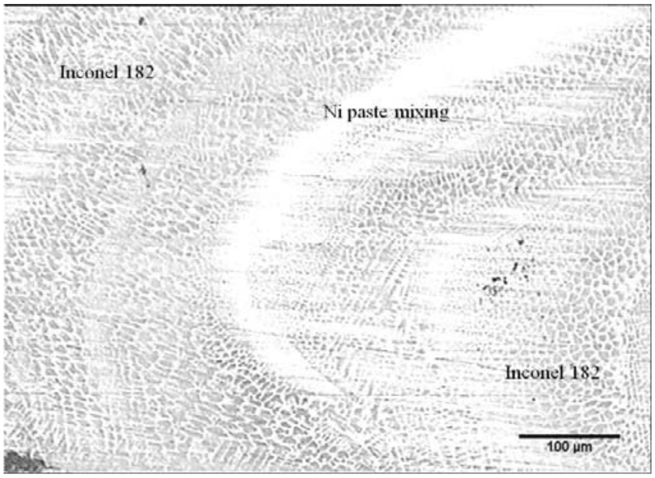

Fig. 5: Microstructure showing mixing of Ni paste with Inconel 182 of plate B

zone of HAZ od base metals, buttered layers and weld metal. The trend of hardness observed with both plate joint A and B can be seen in figure 6. The reason for this hardness change is that, the homogeneous mixing of Inconel with Ni paste. As the Inconel filler having more amount of alloying content, especially chromium than the Ni paste. The dilution and mixing effect as well as the cooling effect changes the hardness of various zone of plate B than the hardness of plate A joint. Such hardness change was also recorded by Dupont in the study of Austenitic/ferritic dissimilar alloy weld [9].

IV. CONCLUSIONS

1. High Nickel content in buttered layer can cause the solidification cracks.
2. GTAW process cannot ensure the higher dilution for the dilution and mixing of Ni paste.
3. SMAW process ensures the required dilution and homogeneous mixing of Ni paste with Inconel 182 filler and with base metal as well.
4. Ferrite content change may take place due to improper dilution and mixing.
5. Improper mixing and dilution affects the hardness of buttering layer and the weld metal.

V. ACKNOWLEDGEMENT

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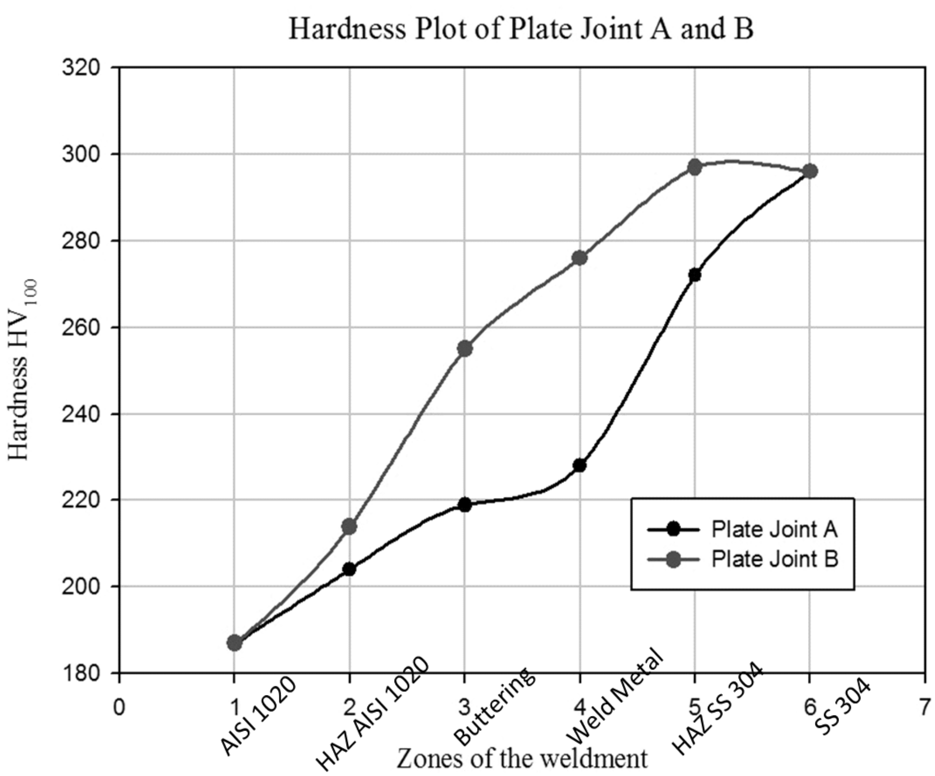

Fig. 6. Micro-hardness plots for complete plate joint of Plate A and Plate B

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