A study on Electron Beam Welding of Stainless steel (03X12H10MTPY) with Russian copper alloy

Sreekuttan M[1], Sharos H[2], A Manickavasagam[3], K M Gopalakrishnanan[4]

[1]Computer Integrated Manufacturing, TKMCE, Kollam, Kerala, India
[2]Department of Mechanical Engineering, TKMCE, Kollam, Kerala, India
[3, 4]Liquid Propulsion Systems Center, Indian Space Research Organization, Trivandrum, India

Abstract— *Modern age demand for flexible design and high quality structures. Different properties are essential for different parts and use of dissimilar metals joints gives possibilities of flexible design and products by using each material efficiently. EBW is one of the most widely used application in industries for joining dissimilar materials .The advantages of EBW welding is its high energy density, high depth to width ratio, low HAZ and result in very strong weld and low residual stress .The quality of weld depend upon the parameter accelerating voltage, beam current, focus current, welding speed, beam shifts and vacuum levels. The beam shift, focus current and vacuum level are fixed parameters .The primary objective of the project is to optimizing the parameter to obtain best quality weld based on Taguchi L9 array. Micro-indentation hardness and Electron spectroscopy is also carried out in selected welding sets to study the joint characteristics. It is observed that the optimum parameter levels for 3mm penetration in both parent metal are Accelerating voltage 50KV, beam current 38mA, welding speed 1 m/min.*

Keywords— Accelerating voltage, beam current, EBW-Electron Beam Welding, HAZ-Heat Affected Zone, weld, welding speed.

I. INTRODUCTION

Modern age demand for high quality of structure with maximum flexibility .Dissimilar metals joints give possibilities of flexible design of products by using each material efficiently. However dissimilar welding takes problems when the thermal, mechanical and metallurgical, and properties have huge difference in the joining materials. Formation of intermetalic compound during welding also affects the strength of weld [1] .In the service condition stress induced corrosion and fatigue corrosion also be considered in dissimilar joining.

EBW is the one of the widely used method for joining of dissimilar materials. The advantages of EBW welding is its high energy density ,high depth to width ratio, low HAZ and result in very strong weld and low residual stress. EBW is used for fabricating structure that has precise, quality, strength and joint reliability requirement [8].This process is used in aerospace shipbuilding and instrument manufacturing. Compared with arc welding process EBW improve joint strength up to 25%.[3] But fusion welding has certain drawbacks in the case of dissimilar metal joints like formation of brittle phases, the segregation of high and low melting phases due to chemical mismatch and large residual stresses due to physical mismatch.[4]

Stainless Steel (03X12H10MTPY) is a martensite precipitation stainless steel capable of high strength and hardness along with good levels of resistance to both general corrosion and stress-corrosion cracking. The excellent properties of Stainless Steel (03X12H10MTPY) are obtained through close control of chemical composition and micro structure plus specialized melting which reduces impurities and minimizes segregation. This alloy offers a high level of useful mechanical properties under severe environmental conditions Stainless Steel (03X12H10MTPY) has been used for valve parts, aircraft components, nuclear reactor components and petrochemical applications requiring resistance to stress-corrosion cracking.

Russian copper alloys (БрхЦрТ-В) which are heat treated and cold worked to provide electrical conductivity and hardness. They are used in applications that require deformation resistance at high temperatures.. Oxyacetylene welding, gas shielded arc welding, coated metal arc welding and spot welding are not preferred for this type of alloys.. The major applications of Chromium copper alloys are Tips, Clamps of preheater of rockets. Wheel rim of racing cars, Electrical and thermal Conductors Requiring Greater Strength than Copper, Switch Gears, Electrical Connectors, and mechanical power transmission devices, Circuit breaker parts, High-strength fasteners [10]

The primary object of the project is to optimizing the parameter so as to obtain best quality weld with different combination of parameters based on Taguchi L9 array .After sorting the acceptable pieces with finding depth of penetration, die penetration test, the optimum parameters are reported using tensile test. Micro-indentation hardness and Electron spectroscopy is also carried out in selected welding sets to study the joint characteristics.

II. OBJECTIVE

To determine the optimum welding parameters for Stainless Steel (03X12H10MTPY) with chromium copper alloy for EBW based on Taguchi method and optimize the performance characteristics of collected data by ANOVA.
Study the joint behaviour of Stainless Steel (03X12H10MTPY) with chromium copper alloy by Die Penetration test, Tensile test, Micro hardness, Electron spectroscopy(ESCA).

III. SCOPE OF THE THESIS

The work will help to joining of Stainless steel to copper alloy in a feasible way of minimum Heat Affected Zone with higher mechanical strength, this work will help for future joining of different materials in aerospace, ship building and high thermal resistant applications.

IV. EXPERIMENTAL PROCEDURE

The quality of weld varies with the input parameters in EB weld. The parameters of the welding varied in order to determine the best combination of weld parameters for given thickness of the weld. Specimen here we are welding stainless steel ((03X12H10MTPY) with Russian copper.In the experiments, the parameters varied according to the level in Taguchi methods. This parameters are selected depend upon the machine constraints, material requirements. The welding is carried out in EBW Machine Techmeta (France)

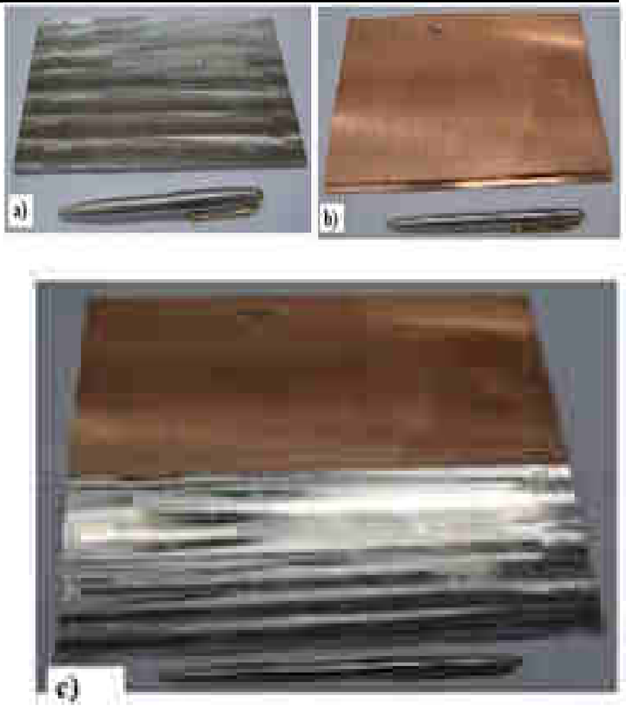

Fig .1:Specimen sample before welding, a) Stainless steel sheet b) Russian copper sheet c) specimen after mating as per weld condition

4.1 Dimension of specimen.
Stainless Steel (03X12H10MT) = 105 mm X 40mm X 3 mm,Chromium copper alloy (БрхЦрТ-ТВ) = 110 mm X 40mm X 5 mm, Weld length – 40 mm

Table 1 Parameters and their respective levels

	Level 1	Level 2	Level 3
Accelerating voltage (KV)	45	50	55
Welding speed (m/Min)	0.8	1.0	1.2
Beam current (mA)	30	34	38

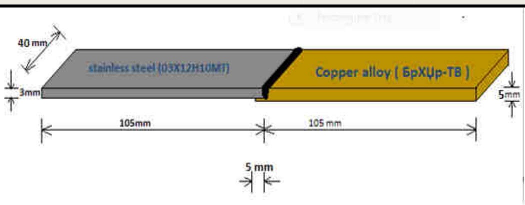

Fig.2: schematic diagram of EBW welding

4.1. Properties of Materials
4.1.1Chemical composition

Table. 2 Chemical composition of Stainless Steel (03X12H10MTPY)

Element	**C**	**Cr**	**Ni**	**Mn**	**Ti**	**Mo**	**Si**
Max%	0.03	12.5	10.3	0.25	.25	0.8	0.15
Element	**P**	**S**	**Al**	**B**	**Ca**	**Zr**	**Fe**
Max%	0.01	0.01	0.2	0.05	0.05	0.05	balance

Table. 3 Chemical composition of Chromium copper

Element	**Cr**	**Zr**	**Ti**	**Fe**	**Pb**
Max %	0.7	0.05	0.05	0.015	0.003
Element	**Zn**	**Mg**	**Si**	**Ni**	**Others**
Max %	0.001	0.001	0.01	0.01	0.02

4.1.1 Mechanical properties

Table.5: Mechanical properties Stainless Steel (03X12H10MTPY)

Form	**Properties at RT**			**Supply condition and approximate hardness value**
	UTS (Mpa)	0.2%YS (Mpa)	EL %	
Rod, plates	930	785	12	The product in annealed condition 900-950^0 ,holding for 1-2 hours followed by air cooling ,hardness less than 260BHN

Table.6: Mechanical properties Chromium copper alloy

Form	**properties at RT**			**Supply condition and approximate hardness value**
	UTS (Mpa)	**0.2% YS**	**% EL**	
Rods and plates	220	-	20	Solution treatment **65-85** BHN

V. RESULT& DISCUSIONS

5.1 Result Based on Penetration level

The depth of penetration of each welded portion was clearly visible under optical microscope and depth and width of weld is measured using optical microscope with the help of Nikon V12B Profile Projector. The observations from 'Table 7' are noted below

Sample 1-Low penetration is noticed. in the sample no undercut noticed .weld bead is not symmetrical, 0.578 mm to copper side and 0.633mm to stainless steel side and height of bead is 0.074 mm

Sample 2-Low penetration noticed weld bead is not symmetrical, 0.633mm, from copper side and 0.676 mm to stainless steel side. Height of bead is 0.087mm

Sample 3-Low penetration noticed. No undercut noticed. Weld is not symmetrical, 0.561 to copper side and 0.617 on stainless steel side noticed

Sample 4 -The penetration is in the range of required value. No undercut noticed. Weld is not symmetrical, 0.587 to copper side and 0.612 on stainless steel side noticed

Sample 5-The penetration is in the range of required value. No undercut noticed. Weld is not symmetrical, 0.549 mm to copper side and 0.682 mm on stainless steel side noticed

Table.7: Depth of penetration of weld for each combination of parameters

Sl. No	**Accelerating voltage (KV)**	**Welding speed (m\Min**	**Beam current (mA)**	**Beam shift (mm)**	**Depth of penetration (mm)**
1	45	0.8	30	0.2 5	2.328
2	45	1	34	0.25	2.516
3	45	1.2	38	0.2 5	2.582
4	50	0.8	34	0.25	3.201
5	50	1	38	0.25	3.168
6	50	1.2	30	0.25	2.186
7	55	0.8	38	0.25	4.340
8	55	1	30	0.25	3.327
9	55	1.2	34	0.25	3.695

Sample 6 -Low penetration noticed. Weld bead is not symmetrical, 0.567 mm from copper side and 0.707mm from stainless steel side. Weld bead height is 0.076

Sample 6 -Low penetration noticed. Weld bead is not symmetrical, 0.567 mm from copper side and 0.707mm from stainless steel side. Weld bead height is 0.076

Sample 7 -high penetration found .It is above than required level .undercut is noticed(0.092 mm) weld is not symmetrical 0.430 to copper side and .868 to stainless steel side

Sample 8 -High penetration found under cut noticed.(0.082 mm),Copper side to center line -0.431,Stainless steel to center line -0.918.

Sample 9 -High penetration noticed .undercut noticed (0.068), Copper side to center line-0.0429,Steel side to center line -1.052.

From the above Table.7, sample 4 and sample 5, qualified for tensile test (DOP in range of $3.1^{+0.2}$mm). The tensile specimens are prepared from the penetration level specimen as per ASTM E 8M-04 using wire cut EDM.

From 'Table 8', only specimen 7 has surface defects due to high beam current

5.3 Tensile test report

Table.9: Tensile Test Report

Sl. no	Specimen number	Specimen ID	UTS (Mpa)	Failure location
1	**4**	**IV_1**	**310**	
		IV_2	**311**	**Adjacent to weld Cu side**
2	**5**	**V_1**	**333**	
		V_2	**336**	

From TABLE. 9 ,Sample 5 give highest tensile strength among the samples, so this is the optimum penetration level for 3mm thick plate joining

5.4 Results of Electron Spectroscopy (ES)

Table.10: Results of Electron Spectroscopy (ESCA)

SAMPLE	Weight % of element in parent metal copper				Weight % of element in weld					Weight % elements in parent metal S.S			
	Cu	**Cr**	**Ti**	**Zr**	**Fe**	**Cr**	**Ni**	**Si**	**Cu**	**Fe**	**Cr**	**Ni**	**Si**
SAMPLE 1 (Highest penetration level)	99.67	0.18	0.01	0.14	68.81	11.02	7.94	1.45	9.78	77.11	12.29	9.39	1.21
SAMPLE 2 weld (optimum penetration level)	99.63	0.22	0.03	0.13	51.72	8.51	6.39	0.46	32.92	78.22	11.25	9.19	0.64
Bulk analysis	-				54.60	8.15	-	-	37.25	-			
SAMPLE 3 (Lowest penetration level)	99.44	0.32		0.24	62.40	9.64	6.63	-	21.32	78.16	11.69	10.15	-

Electron spectroscopy line diagram shows the chemical composition of weld is a mixture of parent metals, indicating that metals are well diffused to the weld bead in the all the sample and optimum penetrating sample gives the highest weight percentage in the weld (37.25).

5.5Micro -Indentation Hardness Testing

Table.11: Result of Micro -Indentation Hardness Testing.

Sample No.	Region	Trial 1	Trial 2	Trial 3	Trail 4	Trial 5	Average
SAMPLE 1) (Highest penetration sample)	**Cu side**	**72.5**	**75.1**	**76**	**74.6**	**76**	**.74.84**
	Cu HAZ	**74.7**	**75.6**	**71.5**	**71.8**	**74.8**	**73.64**
	weld	**154**	**151**	**152**	**153**	**155**	**153**
	Stainless steel HAZ	**297**	**297**	**293**	**293**	**298**	**295.6**
	Stainless steel	**330**	**335**	**330**	**331**	**330**	**331.5**

SAMPLE 2 (optimum penetration sample)	**Cu side**	**65**	**66.8**	**67.6**	**70**	**66.5**	**67.18**
	Cu HAZ	**70**	**67.5**	**72.4**	**72.7**	**74.6**	**71.44**
	weld	**144**	**147**	**156**	**144**	**146**	**147.4**
	Stainless steel HAZ	**323**	**323**	**329**	**327**	**332**	**326.8**
	Stainless steel	**330**	**331**	**331**	**334**	**347**	**334.6**
SAMPLE 3 (Lowest penetration sample)	**Due to high distorted Vickers indentation the micro hardness not possible in this sample**						

From **Table 7** Micro -Indentation Hardness Testing reveals that the weld bead have the strength between the parent metals, indicating that metals are well diffused to the weld bead in the all the sample.

VI. CONCLUSION

The optimum parameters for Electron Beam Welding of Stainless steel (03X12H10MT) with Chromium copper alloy(БрхЦрТ-В) weld 3mm thick specimen with maximum strength is 336 Mpa in a parameter combination of 50 KV accelerating voltage, 38 mA beam current 1. m/Min welding speed and 0.25 mm beam shift From liquid Penetrant inspection test no surface cracks or spatters are noticed in the weld bead of optimum penetration sample

The tensile test reveal that the weld bead have the strength between the parent metals ,indicating that metals are well diffused to the weld bead

Electron spectroscopy chemical analysis the chemical composition of weld is a mixture of parent metals, In optimum penetrating sample gives the highest weight percentage in the weld (37.25%)

From the Micro -Indentation Hardness Testing the HAZ is very low region and shows a slight variation of hardness from the parent metal. Micro hardness test reveal that the weld bead have the strength between the parent metals ,indicating that metals are well diffused to the weld bead in all the sample

This work will help for future joining of different materials in manufacturing applications, in aerospace and ship building, high thermal resistant applications.

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