Welding of 24 mm thick Oxygen Free Copper Plates for Large Size Turbo-generator

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Abstract

In this article, the process of fabrication of 24mm thick Copper welded and fully machined part of 2500 MW Turbo-generator is discussed. The challenge faced to make Copper Parts for turbo-generator through welding and the ways to overcome them are briefed. discussed. The challenge faced to make this large size turbo-generator through welding and the ways to overcome them are briefed.

Keywords: Welding; fabrication; oxygen free copper; turbo-generator.

1.0 Introduction

This paper deals with **Oxygen Free Copper** Fabrication for components of Turbogenerator (2500 MW). Oxygen Free Copper has highest electrical conductivity among other Pure Copper grades.

Large section **(24mm thk plates, Dia 3200 mm)** of CopperGrade SB 152 UNS C10200 is welded using GTAW Process. Project Involve Fabrication of **11 Tons of Copper** which has Waterjet Cutting, WEP, Welding, Radiography, Forming, Finish Machining and Trial assembly.

Total 16 Nos Welded, machined round disc of 20 mm thick were manufactured from Plate segments.

This paper focuses on challenges faced during Welding, Preparation of Fixtures, Distortion Control techniques used during execution of the project.

Enormous planning is involved in Pre-heating arrangement, Distortion Control Fixtures, Safety Precautions to be taken to work at temperature as high as 350°C, Selection of Welding Wire with maximum electrical conductivity, Optimal use of Helium Gas and Extensive training of Welders to produce first time Radiographic Acceptable Quality Welds.

Being fully machined component, Distortion control is directly proportional to savings in cost of raw material. Small addition of allowance for machining has huge effect on Cost of Raw material. Optimal balance between maximum distortion possible and minimum allowance to be provided for machining is important.

Machining of Welded disc involve multiple holes drilling, which need to be matched within 0.2 mm tolerance. Various fixture prepared for machining as well as lifting to avoid damage / scoring marks etc. Machining work carried out with outmost precision by 100 points check on job, correction of local high / low point before start of machining. Intermediate checks being added during machining operation to achieve final machined thickness without un-machined patch.

When It comes to Welding of Copper and its being use as electric part, very little data is available on "Effect of Change in Volume resistivity on Welded Pure Copper". Trials conducted to check effect of volume resistivity on Welded component is also illustrated in this paper.

2.0 Base Material & Welding Consumable Details

Grade	UTS (N/mm^2)	Type	Conductivity % IACS	Supplied Condition	ASME P-No.	Filler Wire
Cu-OF (CW008A)/ SB 152 : C 10200	205 (min)	O2 : 0.0010 Cu : 99.95%	100	Annealed	31	CuSn-1

3.0 Selection of Welding Process

Welding Process considered G : Good for Oxygen Free Copper are GTAW, GMAW and EBW.

Since our job is large in diameter (more than 3000 mm), Large size Vaccum Chamber is not available and hence the Possibility of EBW (Electron Beam Welding) is ruled out.

We need to Select a Process between GMAW and GTAW.

Since thickness involved is 20 mm plus, there is possibility of fast heat dissipation which can cause LF in Welding. Being Weld joint has RT of All butt joints, GTAW Process is selected for Final Welding of the job.

Following table (from AWS Handbook) may be referred for Suitability of Welding Process for Oxygen Free Copper Grade

Applicable Joining Processes for Copper and Copper Alloys										
Alloys	UNS No.	Oxygel Gas Welding	SMAW	GMAW	GTAW	Resistance Welding	Solid-State Welding	Brazing	Soldering	Electron Beam Welding
ETP Copper	C11000-C11900	NR	NR	F	F	NR	G	3	G	NR
Oxygen-Free Copper	C102000	F	NR	G	G	NR	E	E	E	G
Deoxidized Copper	C12000 C123000	G	NR	E	E	NR	E	E	E	G

4.0 Selection of Weld Consumables

As per the literature, ERCu copper is recommended for GTAW of cooper. Theses electrodes have the highest conductivity of any copper electrode but contain minor alloying elements to improve weldability.

Usually De-oxidised Pure copper is used for manufacturing welding wires. Many of the wire manufacturer gives the welding wire for welding Base metal as Oxygen Free Copper.

Sr	Specification	Class	Grade
1	AWS	A5.7	ERCu
2	BS EN	EN 14640	S Cu 1898 / CuSn1
3	BS	BS 2901 pt 3	C7
4	DIN 1733	DIN 1733	SG-CuSn (2.1006)

Chemical Composition of the Welding Wire used on job

Weld Wire Class	Cu	Sn	Mn	Si	P	Al	Pb	Fe	Ni	A/C	A/T
ER Cu: AWS 5.7 & CuSn1: 1898	Bal	0.83	0.21	0.20	0.012	<0.001	<0.001	0.001	<0.001	<0.05	<0.1

Base Metal Electrical conductivity (as per AWS Welding Handbook, Table 3.8)

Sr	Deposited metal conductivity	Electrical Conductivity % IACS
1	Oxygen Free Copper	95 - 101
2	Phosphorous De-oxidised Copper	83
3	Phosphor Bronze	37
4	Silicon Bronze	26
5	Beryllium Copper	22

From the table, its clear that, Base Metal, Oxygen Free Copper has highest Electrical Conductivity

5.0 Test Specimen Preparation to Check Electrical Conductivity

Method of measurement of Electrical conductivity and volume Resistivity of copper

The electrical conductivity was measured using a small-signal 4-wire Ohm meter (RS Pro RM-805) and via large-signal 4-wire measurement method in the range from 10A to 60A DC (Fluke Norma 4000) in accordance with ASTM B193-16.

The electrical resistivity was measured in two methods having small and big resistance to test the range of conductivity of the additively manufactured samples. The ends of the samples were manually polished to ensure maximum and uniform contact with the testing probes. From the resistance measurements, the conductivity of the samples was calculated. This measurement is mainly influenced by the surface roughness and density of the sample. Materials 2022, 15, 7563 6 of 19 The presence of peaks and valleys can disrupt the contact area with the testing probes and pores, and any unfused powders are a clear obstruction to the conduction of electricity.

Method followed by us for Specimen Preparation

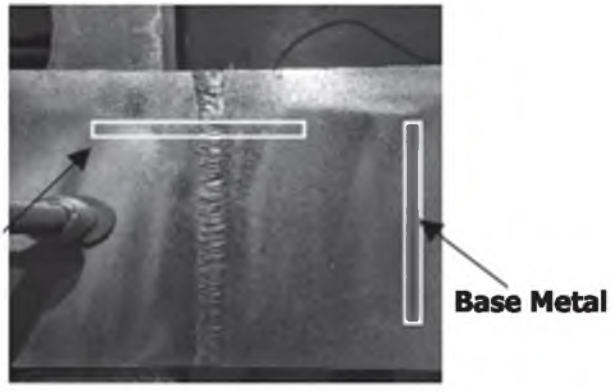
Welding carried out on Single Vee Grooved Test plate having thickness 12 mm. After Completion of Welding, Dye Penetrant Test and Radiography Test were carried out to ensure sound Weld.

Two Nos Round Specimens Prepared. One from Base Metal and Other with Weld Joint at the Centre of the Weld as per the location shown in below photographs (Location shown in Yellow box). Both the specimens were machined to 10 mm diameter bar so that Comparative results were obtained.

Sample Weld Sample Base Metal Test Values Observed:

Report

Welded Test Coupon



Results : Base Metal : 95.93 % IACS

Prepared Test Specimens

Transverse, Weld Metal : 83.88 % IACS

Drop in Conductivity : 12.6% after Welding (Using Welding wire CuSn-1)

(Conductivity measured at @ 20.8ºC, M/s ELCA Report no R-2764)

Drop in Conductivity : 19.8% after Welding (Using Commercially Pure Copper wire)

6.0 Welding Qualification & NDT

Welding Qualification is conducted as per ISO 15609-1. Welder Test as per 9606-3

Preheating of 350ºC is applied before welding. Shielding gas used is 99.995% Pure Helium.

Process 141 (TIG) is used. Qualification is conducted on 14 mm thk and 24mm thk Plate.

Test Coupon during Welding Test Specimen Preparation

All butt and Fillet welders undergone Dye Penetrant Test and Butt Joints are Radiographically Tested. Ultrasonic Testing also carried out for Butt joint.

7.0 Preheating

High thermal conductivity of Copper results in the rapid conduction of heat from the weld joint into the surrounding base metal. This makes achieving fusion and weld penetration difficult.

Out Base metal thickness in 24 mm and the diameter of the plate to be welded is more than 3000 mm. Heat dissipation is very fast. Verly slow and Uniform heating method is applied. Electric Resistance heating (multiple coils) used to ensure uniformity in heating. At the time of tack weld also, we need to preheat for long time.

Placement of Heating coils at set-up stage and after root pass welding is different. At set-up stage, being base metal is not connected, heat do not pass to adjacent metal. Whereas after root run welding, Base metal is connected and heat passes through it.

Expansion of base metal shall be considered during preheating. For example, dia of around 2500 mm, for Preheating to 300 degree C, the expansion will be as high as 5 mm (OD will increase by 7-8 mm).

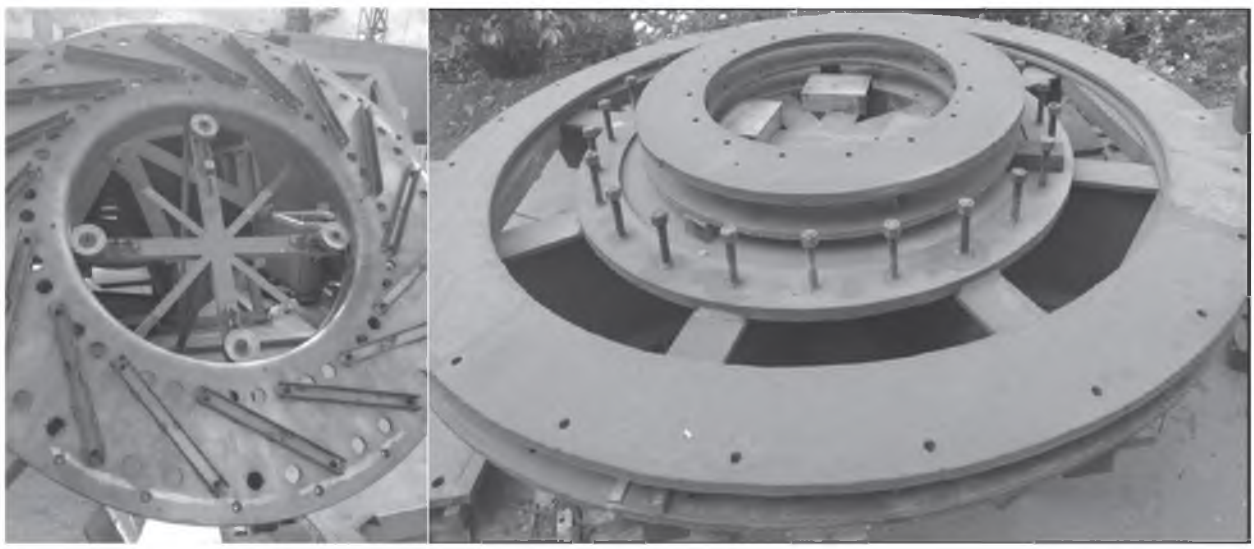
In this case, authors have issued Pre-heating plan for each component to shop floor, so that Placement of Coil, No. of Coils to be placed, wrapping area etc. is clear.

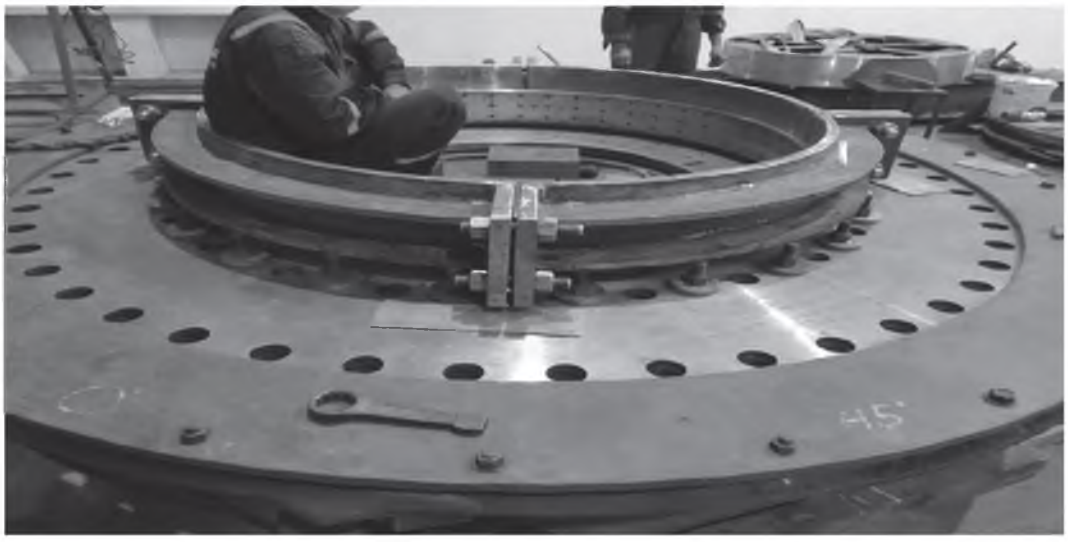
8.0 Fixturing

Thermal Coefficient of Copper is 1.5 times that of the steel, so its obvious that the distortion will be greater with copper alloys. Fixturing and Welding procedure must be designed to limit the restraint of Copper alloys that are likely to hot crack when highly restrained.

While using steel fixtures for Clamping the job, care shall be taken to avoid Steel embossing marks on the copper parts. Advised to add a Soft metal like aluminium or copper in between the fixture and the job. Clamping shall be done considering expansion of the job during heating. Sufficient allowance shall be provided for thermal expansion of the job. When clamped in heated condition and welding is started, don't miss to loosed the clamps on cooling. So that job is allowed to returned to its original position after it cool down and shrink.

4 Nos. of full size, machined fixtures have been prepared for execution of the job. OD rings were provided to avoid edges from warpping and weaviness formation.





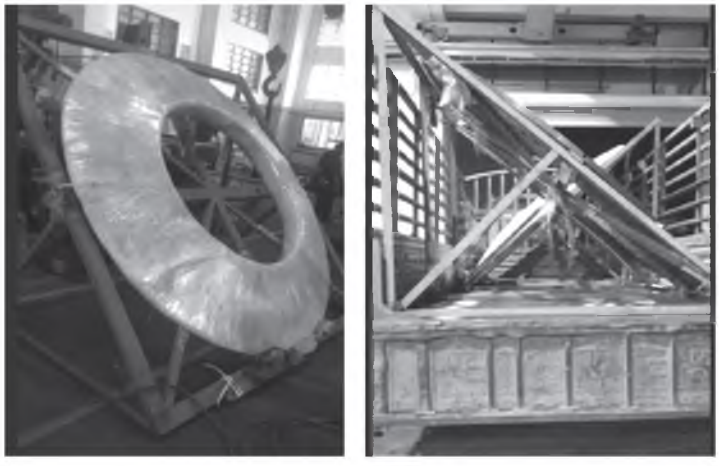
9.0 Forming

4 Nos. of Discs are undergone Forming Operation. Hot forming is carried out. There is no past experience available in Indian market for such a large diameter Copper plates forming. Precision's Design and Engineering Team conceptualized the Die and Punch design. Die and Punch are fabricated in-house. 500 Ton press used for firming

10.0 Transportation Fixture and Packing

Copper being soft, shall be properly handled during Transportation. Looking at the diameter of the job, it's a OD Consignment. Fixture is prepared in such a way that the Ring is Transported inclined.

Fixture for Transportation has Lifting hooks and Clamps provided to avoid moving of the ring during transportation



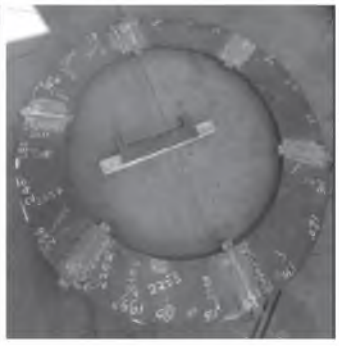
11.0 Steps in Manufacturing

WaterJet Cutting

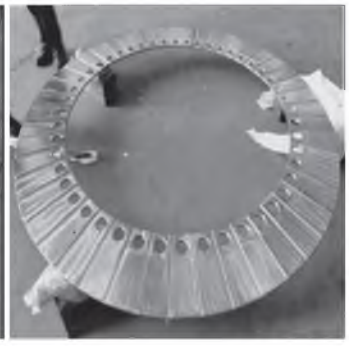
Profile Cut Segment

Electrical Preheating

Welding using Fixtures



After Weld Completion



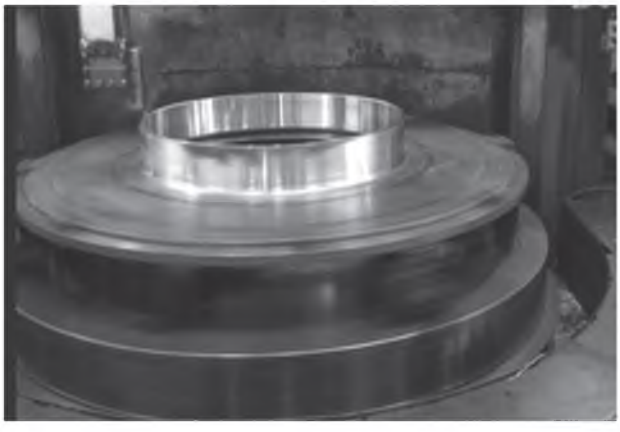
After Machining

12.0 Machining

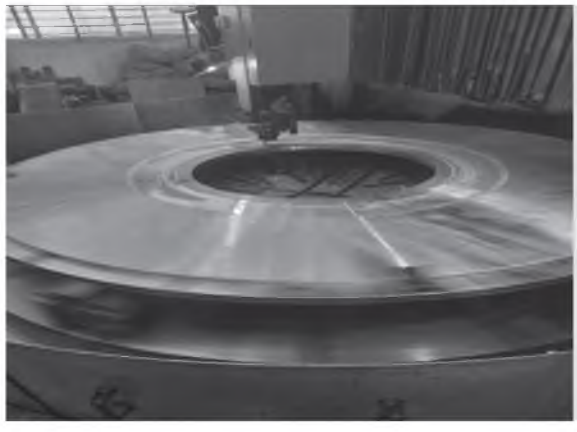
All the Welded Rings were to undergo machining. Each ring has more than 100 Holes drilled in it and the rings are assembled in stack. Holes in stack shall be matched. 3 Nos. of fixtures (fabricated and machined) used for machining Operation.

Holes are drilled using a special tool and tolerance achieving is within 0.2 mm.

Flatness of the ring after machining achieved within 0.5 mm.



Machining on VTL



Facing done on VTL

13.0 Conclusion

Heavy Walled thickness Copper Plates of 24 mm thickness can be fabricated (Cutting, Forming, Welding and Machining) with relative ease and Radiographically acceptable welds are possible. Heating arrangement, Plan is crucial at planning stage. Special Precaution to be taken while handling and transportation being soft metal. Even though Hellium is depleting rare gas, for thickness more than 20mm, authors could not find any other suitable option for Welding.

There is Drop in Electrical Conductivity after Welding. Welds made using CuSn-1 wire shows Drop of 12.6%. When welded with Commercially Pure wire, Drop Observed in 19.8%. Since there is no significant literature available on "Drop in electrical conductivity of Copper after welding", more experimental study is needed.

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