

Technical Specification

CuCrZr-IG forgings for Electrical Straps for ITER Blanket Application

This specification covers the supply of forgings of oxygen free low alloyed copper type CuCrZr - ITER Grade for the ITER Blanket System electrical strap components. Product form is forged bars or rods.

Approval Process			
	Name	Action	Affiliation
Signatory	Eaton R.	21 Apr 2016:signed	IO/DG/COO/TED/INC/BKT
Co-signatories	Barabash V.	21 Apr 2016:signed	IO/DG/COO/CIO/AS
Reviewers	Chappuis P.	02 May 2016:recommended	IO/DG/COO/TED/INC/BKT
	Egorov K.	21 Apr 2016:recommended	IO/DG/COO/TED/INC/BKT
	Jung C. Y.	02 May 2016:recommended	IO/DG/RCO/QAA
	Raffray R.	27 Apr 2016:recommended	IO/DG/COO/TED/INC/BKT
Approver	Merola M.	03 May 2016:approved	IO/DG/COO/TED/INC
Document Security: Internal Use RO: Barabash Vladimir			
Read Access	LG: Blanket add right persons, LG: Blanket Materials, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: EMAB, AD: IC Review Group 2016, AD: Auditors, AD: ITER Management Assessor, project administrator, RO		

Table of Contents

1	<i>Scope.....</i>	<i>2</i>
2	<i>Referenced Documents.....</i>	<i>2</i>
3	<i>Ordering Information.....</i>	<i>3</i>
4	<i>Manufacture.....</i>	<i>3</i>
5	<i>As Delivered Heat Treatment.....</i>	<i>3</i>
6	<i>Chemical Requirements and Physical Characteristics.....</i>	<i>4</i>
6.1	Chemical composition.....	4
6.2	Electrical conductivity	4
6.3	Grain Size.....	4
7	<i>Mechanical Properties Requirements.....</i>	<i>4</i>
8	<i>Dimensions and Permissible Variations.....</i>	<i>5</i>
9	<i>Non-Destructive Examination.....</i>	<i>5</i>
9.1	Visual examination.....	5
9.2	Liquid penetrant examination	6
9.3	Ultrasonic examination.....	6
10	<i>Summary and Frequency of Required Tests</i>	<i>6</i>
11	<i>Acceptance</i>	<i>7</i>
12	<i>Documentation.....</i>	<i>7</i>
13	<i>Marking.....</i>	<i>7</i>
14	<i>Cleanliness, Packaging and Transportation.....</i>	<i>8</i>
15	<i>Quality Assurance Requirements.....</i>	<i>8</i>
16	<i>Access of Inspectors.....</i>	<i>8</i>

1 Scope

This specification covers the supply of forgings of oxygen free low alloyed copper type CuCrZr - ITER Grade for the ITER Blanket System electrical strap components. Product form is forged bars or rods.

The addition of “ITER Grade - (IG)” to name this alloy means that the chemical composition of standard CuCrZr alloy (UNS Number C18150 or CW106C in EN standard EN 12420:2014) is modified. However, the specified range of alloying elements and impurities are within the ranges of the standard grades.

The amount of the CuCrZr-IG forgings to be procured shall be specified by the concerned Domestic Agency (DA) and shall include appropriate contingency to face unexpected difficulties, to remake rejected parts and to repair parts with insufficient quality.

The supply covers the following items:

- a) Manufacture of CuCrZr-IG alloy forgings for electrical straps;
- b) Organisation of quality at works. Elaboration of all procedures required for the manufacturing, inspection (including analysis), packaging, storage and delivery. Time schedules and documentation;
- c) Perform all the inspections and tests during and after manufacturing envisaged in this specification;
- d) Storage, packaging and delivery.

2 Referenced Documents

The following Codes and Standards shall be used (referred applicable version is the latest released versions as of 1 Jan 2016, unless agreed by the IO and DA). Other equivalent national or international standards and codes may be acceptable with prior written ITER approval, provided all criteria are satisfied.

ASME Edition 2013, Section V, Article 6	Liquid Penetrant Examination
ASME Edition 2013, Section V, Article 9	Visual Examination
ASME Edition 2013, Section V, Article 5	Ultrasonic Examination Methods for Materials

ASME Edition 2013, Section III, Division 1 Subsection NG-2540, Examination and Repair of Forgings and Bars

- Subsection NG-2546, Liquid Penetrant Examination
- Subsection NG-2542, Ultrasonic Examination

ASTM E 112 - 13	Standard Test Methods for Determining the Average Grain Size
ASTM E 21 - 09	Standard Test Methods for Elevated Temperature Tension Tests of Metallic Materials
ASTM E 8/8M -15a	Standard Test Method for Tension Testing of Metallic Materials
EN ISO 6892-1:2009	Metallic materials, Tensile testing, Part 1: Method of test at room temperature
EN ISO 6892-2:2011	Metallic materials, Tensile testing, Part 2: Method of test at elevated temperature

ASTM B 193 - 2014	Test Method for Resistivity of Electrical Conductor Materials
ASTM E 1004 - 09	Practice for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method
EN 12420:2014	Copper and copper alloys - Forgings
EN 13018:2004	Non-destructive testing: Visual testing
EN 10228-4:1999	Non-destructive testing of steel forgings, Part 4: Ultrasonic testing of austenitic and austenitic-ferritic stainless steel forgings
ISO 3452-1:2013	Non-destructive testing - Penetrant testing - Part 1: General principles
ISO 9712:2012	Non-destructive testing - Qualification and certification of NDT personnel
AST/ANSI SNT-TC-1A:2011 –	Recommended Practice for Personnel Qualification and Certification of Nondestructive Testing
EN 10204:2004	Metallic products: Type of inspection documents

3 Ordering Information

It is responsibility of the DA to specify the requirements for the size, tolerances, manufacturing technology, heat treatment conditions, additional testing etc. in the purchase order.

4 Manufacture

The copper shall be produced free of cuprous oxide, without use of metallic or metalloid deoxidizers.

The supplier shall develop and record a manufacturing program, which shall include in particular:

- specification of raw material and recycling scraps
- melting process
- forging processes and forging ratio
- final heat treatment: solution annealing and ageing
- final examination as described in this specification and test certificates with achieved material properties

Lot definition: A lot shall consist of all forgings made from the same heat, produced with the same manufacturing forging conditions, with the same dimensions and the same thermomechanical treatment. A lot weight shall not exceed 500 kg.

5 As Delivered Heat Treatment

The following condition is required for supply of material and for tests in accordance with current specification:

Solution annealing and aging condition (SAA):

- Anneal at $980 \pm 10/-0$ °C for $30 \pm 2 / - 0$ minutes + water quench
- Age at $475^{\circ}\text{C} \pm 5^{\circ}\text{C}$ for 3 hours ($0 / + 10$ min)

The heat treatment process shall be recorded with diagram (time and temperature) and shall be included in the Material Test Report specified in Section 12 of this Specification.

6 Chemical Requirements and Physical Characteristics

6.1 Chemical composition

The chemical composition has to satisfy the requirement given in Table 1. Test method shall be proposed by Supplier and accepted by DA and IO.

The chemical analysis shall be performed for each lot of material.

Table 1. Chemical composition of CuCrZr-IG alloy (wt. %)

Alloy Designation	Cu	Cr	Zr	Impurities
CuCrZr – ITER Grade alloy	base	0.60-0.90	0.07-0.15	*Total: < 0.15 including Co# ≤ 0.050 O – as low as possible content shall be reported (Max target value is 0.0080)

Radiation protection requirements

* The list of typically analysed impurities shall include (e.g. S, Cd, Nb, Ni, Zn, Pb, Bi, Ag, Ta, Sb, Fe, Si and other elements typically recorded by supplier) is required to be measured. These elements shall be recorded and reported in test certificate.

6.2 Electrical conductivity

The electrical conductivity at room temperature (20°C) shall be not less than 75 % of the International Annealed Copper Standard (IACS). This corresponds to a minimum value of 0.435×10^8 S/m.

The conductivity of Annealed Copper Standard is defined to be 0.58×10^8 S/m (100% IACS) at room temperature.

The specimens of CuCrZr alloy must be tested in the solution annealed and aged condition (SAA). Test method ASTM B 193 or ASTM E1004 shall be used. One sample shall be tested per lot.

6.3 Grain Size

Grain size measurement shall be done in accordance with ASTM E112 on a sample from each lot. The average grain size shall be between 0.040 - 0.070 mm.

7 Mechanical Properties Requirements

Tensile test should be performed according to ASTM E21 and ASTM E 8/8M or EN ISO 6892-1:2009 and EN ISO 6892-2:2011.

The following values shall be recorded:

Yield Strength at 0.2% offset, in MPa

Tensile Strength, in MPa

Total Elongation after fracture, %

For product supplied in solution annealed and aged condition (see Chapter 5) the tensile properties shall be in accordance with Table 2.

Table 2. Requirements for tensile properties at solution annealed and aged condition

Temperature of Test, °C	Room	250°C
Tensile Strength, MPa, min	370	280
Yield Stress, 0.2% offset, MPa, min	245	200
Total Elongation, %, min	17.0	-

Number of tests: 3 specimens shall be tested per lot (from different forgings) per testing temperature (total 6 specimens per lot).

The specimens shall be cut so that their axes are perpendicular to the main forging direction. The main forging direction is the direction, in each portion of the part, in which the forging operation produces maximum elongation.

The round proportional tension test specimens as in ASTM E8M or EN ISO 6892-1 shall be used correspondingly.

8 Dimensions and Permissible Variations

Dimension and tolerances shall be specified in purchase order. Results of dimensional measurements and roughness shall be presented in Material Test Report.

9 Non-Destructive Examination

Visual, Liquid penetrant and Ultrasonic examinations shall be carried out for each forging.

The NDT personnel shall be qualified in accordance with ISO 9712:2012 or recommended practice AST/ANSI SNT-TC-1A:2011.

9.1 Visual examination

All external surfaces of products shall be examined by a visual examination in accordance with ASME Section V, Article 9 or in accordance with EN 13018. The surfaces shall be smooth, plane, uniform and free from wrinkles, buckles, laps, burrs, blowholes, tears, cracks and inclusions.

9.2 Liquid penetrant examination

All external surfaces of products shall be examined by Liquid penetrant examination in accordance with ASME Section V, Article 6 or ISO 3452-1: 2013. The surfaces shall be plane, uniform and free from cracks, pittings, wrinkles, buckles, blowholes, tears. Acceptance criteria are in accordance with ASME Section III, Division 1, Sub-section NG-2546.

9.3 Ultrasonic examination

All products (irrespective of thickness) shall be 100% ultrasonically examined¹.

Option 1: Test shall be performed in accordance with ASME Section V, Article 5 and ASME Section III, Division 1, Subsection NG-2540.

Reference block calibration shall be performed using at least three holes, spaced to approximate minimum, mean, and maximum thickness as tested, and shall be used to generate a distance amplitude correction (DAC) curve. The following Flat Button Hole (FBH) sizes apply:

- 1.5 mm FBH for thicknesses 40-150 mm inclusive
- 3.0 mm FBH for thicknesses over 150 mm

The acceptance criteria shall be in accordance with ASME Section III, Division 1, Subsection NG-2542.

Option 2: 100% ultrasonic examination of each forging may be done using normal probe in accordance with EN 10228: Part 4. Scanning coverage with normal probe is type 1. Quality Class 3 as defined in EN 10228-4 shall be applicable for recording and acceptance criteria.

Supplier shall propose the ultrasonic examination procedure based on ASME or EN standards. The ultrasonic examination procedure proposed by supplier is subject to review and approval of DA and IO.

10 Summary and Frequency of Required Tests

Table 3. Frequency of tests

Test	Frequency of test	Comments
Chemical composition	1 test per lot	
Electrical conductivity	1 test per lot	
Grain size measurement	1 test per lot	
Tensile properties	3 test per lot and temperature	2 testing temperatures (total 6 specimens) From different forgings
Dimensional check and roughness	Per each product	In accordance with purchase order
Visual examination	Per each product	-
Liquid penetrant examination	Per each product	-
Ultrasonic examination	Per each product	-

¹ Existing industrial standards do not specifically address the ultrasonic examination of copper alloy forgings. It is proposed that general principles in accordance with ASME or EN standards for steel forging shall be applied.

11 Acceptance

Material Test Report have to be provided to the Purchaser prior to delivery. Material and certification shall be in compliance with this specification. Material cannot be accepted if it does not comply with this specification.

12 Documentation

The Supplier shall provide the Inspection Certificate type 3.1 in accordance with EN 10204:2004 and the Material Test Report shall include at least the following information:

- Material designation: CuCrZr-IG alloy
- Identification of Supplier
- Heat/Lot number
- Melting process method
- Manufacturing method (forging conditions and forging ratio)
- Record of heat treatments
- Results of chemical analysis
- Results of electrical conductivity test
- Results of grain size measurement
- Results of mechanical property tests at specified treatment
- Indication from where the specimens have been taken for all specified analyses/tests
- Dimensional check
- Records of Visual examinations
- Records of Liquid penetrant examinations
- Records of Ultrasonic examinations

All documents shall be in the English language and all measures shall be given in the metric system SI. Each document shall be provided as an electronic file in PDF format.

13 Marking

Each forging, or batch of forgings, as appropriate, shall be legibly marked to show:

- the manufacturer's name or trade mark
- alloy designation
- heat number
- the identification reference numbers of other identification marks by which the forgings can be related to the manufacturer's certificate

The mark shall be placed in the area indicated on the forging's drawing in accordance with purchase order.

Markings or codes which provide clear reference to documents containing the information required for production control will always be acceptable.

14 Cleanliness, Packaging and Transportation

Requirements shall be specified in the purchase order.

The supplier shall ensure that consignments comply with regulatory requirements applicable to transport and to the country of destination.

15 Quality Assurance Requirements

The quality organisation shall comply with the requirements defined in Annex A of the Procurement Arrangement as specified in the contract and purchase order.

A manufacturing and inspection plan (MIP) shall be provided for each lot in accordance with Requirements for Preparing and Implementing a Manufacturing and Inspection Plan (22MDZD).

16 Access of Inspectors

Representatives of the IO, DA and/or Third Party Inspectors (TPI) shall at reasonable notice have the right to check at the Supplier's premises or at those of the sub-contractor the progress and status of the work forming the subject matter of the procurement and to witness specified tests. The supplier shall hold at the disposal of the IO, DA and TPI and make available to them such information and documents as are necessary to determine the progress and status of the work.