CuCrZr for blanket and divertor applications

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LUVATA
Partnerships with a Promise

Luvata

- Luvata was founded is 1910 in Finland
- It is owned by Mitsubishi Materials Corporation
- It was part of Outokumpu until 2005

1500 employees 11 locations 6 countries

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Luvata

- Luvata is a producer or specialty coppers such as
  - Oxygen Free Copper grades, including high purity electronic and cryogenic coppers.
  - LTS Superconductor Cables
  - Hollow conductors
  - Welding electrodes
  - Projects for metallurgical industry

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Luvata journey with fusion development

- Already some 50 years ago Luvata started superconductor development
- During these decades Luvata has been involved with almost all global public projects
- Luvata has supplied NbTi and Nb_3Sn superconductive cables for magnets and also specialty hollow conductors, cryogenic copper profiles, and various other copper components for fusion reactors

- Luvata products are found today for example from ITER central solenoid, Wendelstein 7X stellarator, JT-60 and K-STAR tokamaks.

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Luvata and CuCrZr(CCZ)

- Luvata had supplied CuCrZr components in 90’s even to JET, but had stopped that production line soon after that.
- In 2007 semicontinuous casting of this alloy started and regular sales started to welding electrode business
- Since 2019 further process development has been made to expand to other areas

Data sheet
General description
Subject to changes or deviations

Chromium Zirconium Copper CuCrZr – Luvata KrK101

Alloy description

Luvata KrK101 alloy is a precipitation hardening alloy for high temperature applications where material need to have a combination of high electrical and thermal conductivity and mechanical properties. Mechanical and electrical properties of chromium zirconium copper are obtained through thermomechanical treatment which typically consists of following steps: solution annealing followed by rapid quenching to water bath and cold working to final dimensions. The final metallographical structure of zirconium copper consists of finely dispersed Cu_5Zr and chromium precipitates which develop during the aging treatment. Aging treatment is therefore essential to achieve high resistance against softening at elevated temperature and high electrical conductivity. KrK101 alloy can be supplied as aged temper or without heat treatment.

Typical applications:

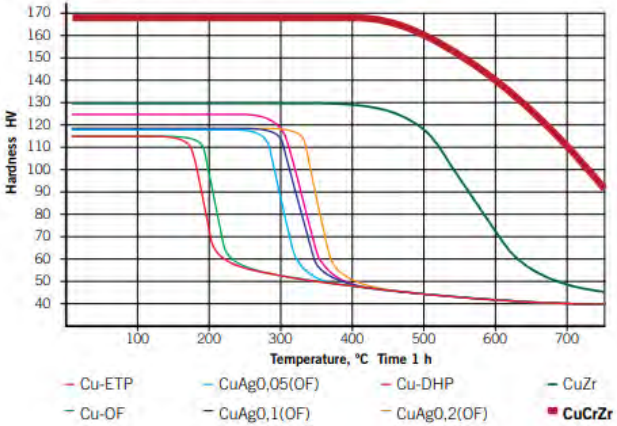
- Resistance welding electrodes
- Spot welding adaptor shanks
- Other applications where high conductivity and good resistance against softening are needed

Product / Shapes:

Round rods, wire coils, rectangular bars, tubes, forgings, machined components and solid profiles in age-hardened temper.

Softening behaviour – resistance against softening:

Room temperature hardness is presented in the following figure as a function of annealing temperature. Material at hard or aged temper.



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Why is CuCrZr often chosen for fusion reactor heat transfer

- CuCrZr is a grade that has existed long time and it's very well known.
- It has a combination of high strength and high conductivity that both remain up to 600°C without softening. It works well under heavy heat fluxes.
- In-reactor tests have shown that it can withstand fatigue and creep under irradiation and strain to good level
- It can be manufactured into any shape and joined with different joining technologies.
- ITER Material property handbook has had this alloy since 1993

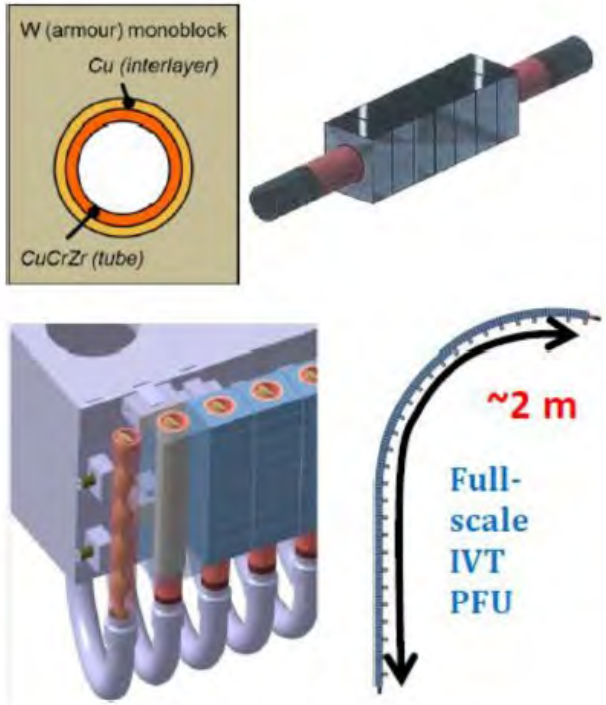

Fig. 11. Divertor monoblock concept.

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ECO Fusion project 2021-2023 at Luvata

- Luvata decided 2020 to participate to ECO Fusion co-innovation consortium
- That time many fusion research device builders had approached Luvata
- Also investment decision was in place to re-new old extruder, which could mean major steps towards improvements
- VTT had demonstrated knowhow in material modelling that seemed promising for Luvata needs
- Project had good timing and real value for Luvata

Early customer case examples that lead to development

- ITER Grade (IG) CuCrZr enquiries were received. From these documents we were able to understand what was missing from existing Luvata alloy CuCrZr

- IG specified tighter chemical composition requirements for alloy elements Cr and Zr
- It also set maximum levels for some elements we couldn’t measure Ta and Nb

- High temperature tensile tester was needed and during project it was purchased

- Some specified grain size limits and there was no practise in Luvata to handle those.

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New 55MN press

- One of the main machines in Luvata Pori is the hot extruder
- Replacement investment was starting at the project start 2021
- During project transition of CuCrZr was also planned to happen
- New press is larger in every way, so process development is needed with every moved product

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Project highlights at Luvata

- New casting moulds for larger billet and for cake were made and test rounds were cast
- Forging and hot rolling trials were made with new alloy CuCrZr
- New tensile tester is up and running
- New extrusion press build-up was delayed and the planned model validation testing wasn't made during project
- ITER Grade CuCrZr is now available from Luvata

VTT Propertune for Copper Alloys in Fusion Applications

- During the ECO Fusion three-year project model was built for Copper alloys
- Microstructural and micromechanical models were developed after actual material characterization was made.
- Additionally process models were made for various manufacturing processes

- With this model it is possible to design and optimize microstructures

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PT-CAFA
Manufacturing to performance analysis

VTT

Casting simulations

Microstructure from casting (CA-method)

Grain structure input

Taylor factor analysis of cast defects

Material state / inputs

Hot extrusion model + quenching

Extrusion rate

Temperature

Die geometry

Input state

Cold drawing model

Feed rate

Die geometry

Processed grain structure + residual state

Heat treatment thermodynamical model

Heat treatment temperature & duration

Grain structure + precipitates

Micromechanical analysis of material behavior

Computational microstructures

Microstructure regeneration for mechanical analysis

Mechanical tests (exp)

Material characterization

Current status of activities

- Application for Eco Fusion R4B project is sent to BF
- PT-CAFA model is ready to be used at VTT.
- HIP bonded CuCrZr parts for ITER first wall blanket have brough us a new set of requirements that we want to overcome
- Private fusion reactor builders have increased, and number of enquiries is higher than ever

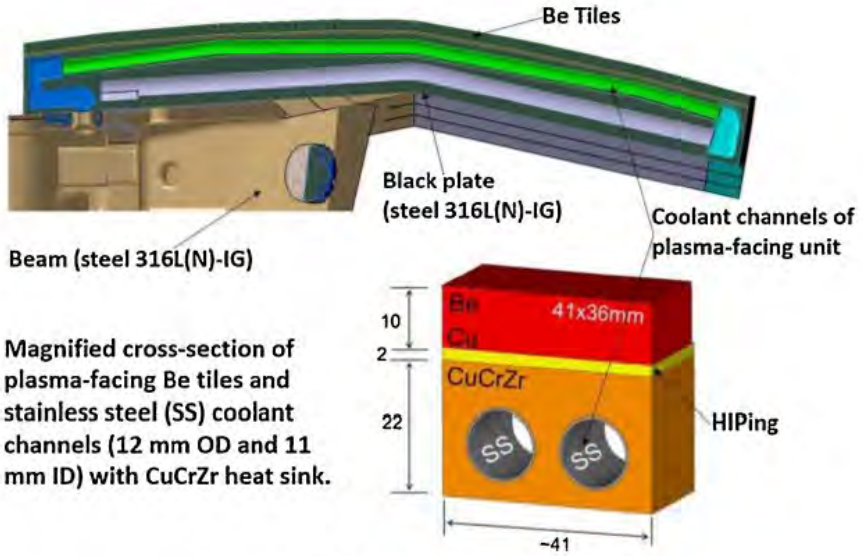
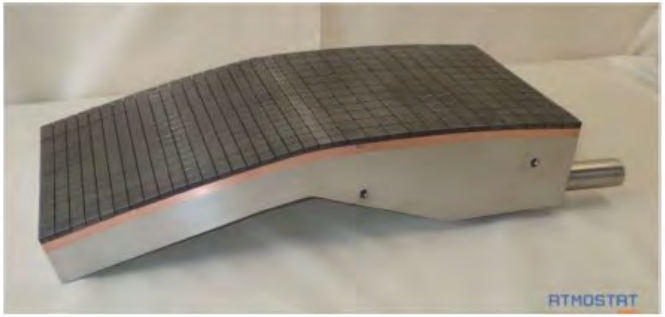


Fig. 3. Normal Heat Flux first wall panel design.



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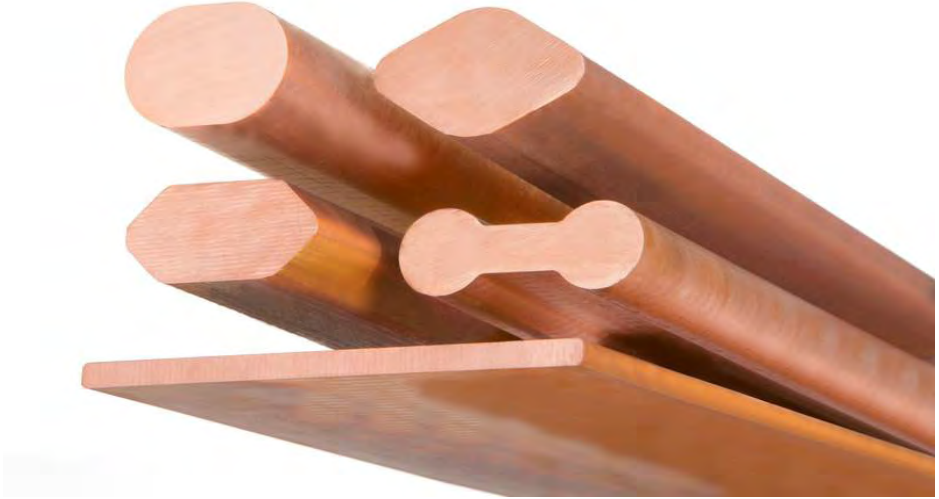

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