IWCC Technical Seminar 2023

A total of 105 delegates from 22 countries met in Osaka, Japan from 26 February - 2 March to attend this Melting, Casting and Refining Seminar, the first in-person IWCC Technical Seminar since 2019, writes Chris K. Holding

The twenty expert speakers emphasised the use of technology to support sustainability. Plant visits included Sumitomo Electric Industries, Mitsubishi Materials Corporation and Daikin Industries, Ltd.

Central Osaka. Photo: IWCC

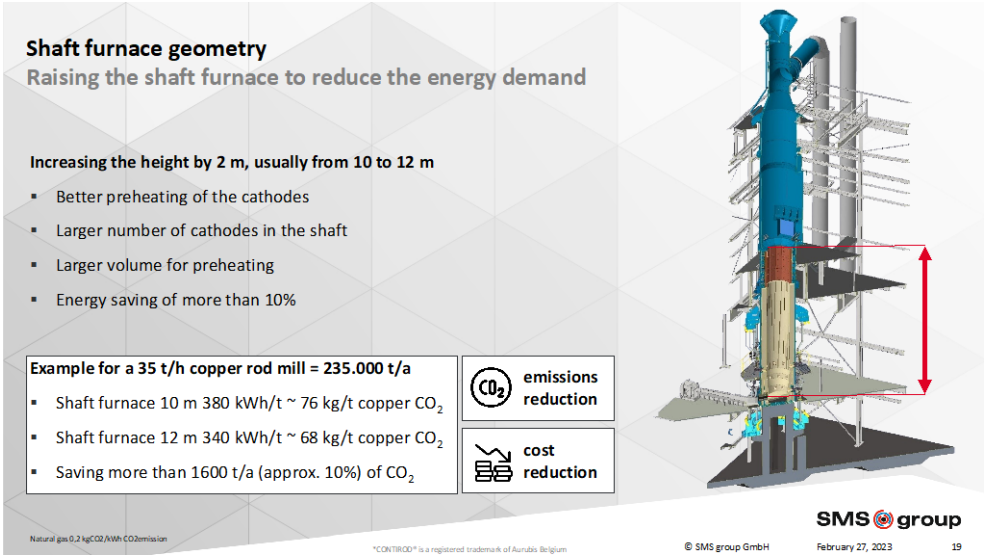
Copper in Japan

The welcome talk was given by *Hiroshi Kuwayama, Vice Executive Director, Japan Copper & Brass Association (JCBA)*. Japanese car and other sector outputs have been stalled by lockdown and supply chain issues such as semiconductor shortages. Whilst some manufacturing is relocating overseas, homeworking has boosted downstream demand. Semis demand was 720 kt in 2022. The JCBA sees consistent growth in tubes and rods mid-term.

Delegates attending the visit to MMC Sambo plant. Photo: IWCC

Sustainable melting

In the Melting Session, *Markus Ecker of SMS Group* looked at decarbonisation of wire rod plants. CONTIROD employs continuous shaft melting of cathodes / clean scrap with natural gas fuel. Since Ecoplants launched 10 years ago, shaft furnace fuel consumption is down 27% and electrical consumption 67% respectively. Adding 2 m to shaft furnace height for preheating and increasing diameter has enabled a 10% reduction in CO_2. Individually controlled nozzle mix burners benefit from 3D printing design.



Shaft furnace geometry. Image reproduced courtesy of SMS group

Sebastian Esser of INDUGA said a coreless CO_2 neutral induction furnace is better for stirring copper alloys, channel-type is better for continuous. Wet chip melting is possible with up to 6% moisture. INDUGA's wet chip charging system gives lower metal losses for brass. An OF production line comprising a cathode charging unit, drum holding furnace and forehearth casting furnace can achieve <3 ppm oxygen with a >5 hour dwell time. For wet chip moisture removal, a flame cover is used. Moderating chips for oil/water content and clumping addresses flaming and breaching issues.

Nikolaos Marinakis of ElvalHalcor looked at vertical casting into copper billets for extrusion, and flue gas treatment. Dioxins are adsorbed by activated carbon. Post combustion at 850 °C gives complete destruction but requires rapid cooling. Halcor presently uses a fixed activated carbon bed to achieve the limit. Thermal oxidation is better than activated carbon filters for TOC removal. A 3-canister Regenerative Thermal Oxidiser is used, with 3 ceramic-packed heat exchange chambers. Autothermal operation is possible with high TOC levels.

Optimal computation

In the Digitalisation and Computation Session, *Itaru Hasegawa of YKK Corporation* said the fastener Cu-Zn element is made from copper and zinc cathode melting and casting into wire, followed by rolling to a Y-shape and finally shearing. Their Cu-Zn-Mn alloy is melted with a flux to prevent oxidation. Optimal flux is determined by combining a hierarchical neural network on the refractory side and thermodynamic calculation on the MNO_x side. Apparent refractory density and porosity represent flux penetration. It was found low viscosity and low activity of MnO accelerates MnOx dissolution, and mapping viscosity versus activity yields an optimum flux composition.

Toshimitsu Okane, Professor of Institute of Technologists, said normally it takes a day to make an additive manufactured part and a few hours to calculate. A mould and core set produces a hollow shape. Powder bed fusion might reach 500 cc/h, whilst binder jetting with 3D printers gives 100,000 cc/h output. Multiple molds can be used in prototyping and small-lot production without wooden/core molds. Reliability of complex shapes can be improved

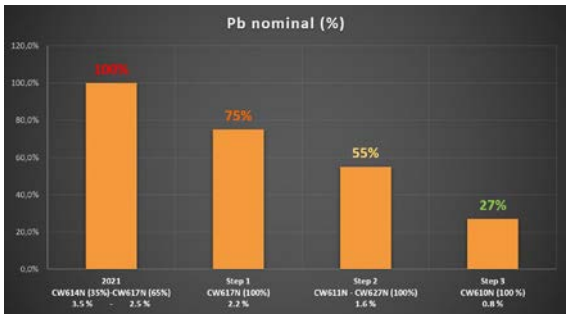
by AM. The SPH Particle Method was developed for more rapid calculation. The shape deformation method (FFD) allows the shape to be altered during computation. Augmented Reality (AR) can capture motion to model flow. Analysis during production in a cyber-physical system is desired. For normal copper alloy casting, yield is 50%. A 20% improvement is the target.

Circular economy

Scrap, Refining and the Circular Economy were addressed in Session 4. *Luis Tercero Espinoza of Fraunhofer ISI* said primarily it is a thinktank which works by integrating specific datasets and filling in gaps. For global copper flows, we need to simplify semis and end-users. Approximately 470 Mt of copper was in use in 2020, and 30% copper is sourced from recycling (50% new, 50% old). EoL scrap more than doubled between 1990 and 2020. The main driver is profitability. A 2021 patent search showed PGM recovery and pyro improvement themes.

Dimitri Cordublas of Continuus-Properzi said they offer EPC services as well as being a one stop shop for refining. For Properzi FRHC rod and ingots plants, Rohel carries out the automation. Exus Filtering was set up recently for NF fumes filtration. The company patented top charging of the Refining Furnace at >10 t/min. The shaft furnace is optimised for efficiency. Casting machines are supplied according to rate and operating environment. Rod geometry is ensured by three work rolls with easy changeover. Ingots or rods can be cast with the caster. Brass wire C260 / C274 can also be produced. Fumes filtration heat recovery is via ORC.

Mark Loveitt of IWCC presented the industry-led Lead-Free Brass Initiative and Roadmap and said EU regulation and industry trends combined to push lead out. A 5 ug/l limit at the tap by 2036 also means a 2.5 ug/l limit in utility supply (50:50 with installation). Over 70% of EU brass rod (700 kt) goes into drinking water applications. The industry has a four step Roadmap to gradually reduce brass lead content by at least 70%, retain scrap recycling circular economy, and maintain brass rod functionality. Four low-lead alloys of similar Cu-level and expected performance were identified to replace leaded brasses, e.g. CW610N-DW is 0.2-0.8% level. For drinking water, the ECHA positive list is expected to take over from 2025. Roadmap regulatory testing runs from November 2022 - May 2023. The www.leadfreebrass.org website has the latest information.



The Roadmap: the impact. Image reproduced courtesy of IWCC

Decarbonising casting

In Casting Session 5, *Juan-Carlos Bodington of UPCAST* said there are EU incentives for decarbonisation and near net shape casting, such as Upcast. Process parameters include heat exchange and withdrawal rate. In particular, <0.8 ppm H_2 is necessary. GREENerCAST was first developed in 2008, covering refractories, inductors and power control. Refractories must give melt insulation, containment, and thermal control. Upcast developed a lining with a precast working layer and self healing dry silica mix backup/insulation layer. There is also an energy saving. The inductor magnifies the induced current in the melt directly. Power control is via IGBT. The system can run from 100% ETP scrap to 100% cathode.

Hendrik Busch of KME Mansfeld said its Conti-M strip casting line combines conventional process steps in a continuous way. Cu-ETP, Cu-DLP, Cu-DHP, Cu-PHC, Cu-OF/ OFE can all be cast into coils. The aim is to improve the carbon footprint. Direct GHG (Scope 1) and indirect (Scope 2) emissions are company-specific, whereas supply chain (Scope 3) emissions are more difficult. Hydrogen can substitute natural gas but has only one third of the calorific value. The natural gas grid will carry 20% hydrogen in Germany in future. The KME deslagging induction furnace fully separates the slag.

Christian Wertli of Alfred Wertli said their plants can produce strip, bars, billet, wire, and more. Lower energy consumption Channel furnaces are used for billets or wire, Coreless inductors allow for easy emptying and alloy change. There is hidden energy consumption in the lining materials, melt cover and cooler attachment area (HCC). Higher heat transfer occurs in the furnace upper body as materials have been developed for longer lifetime and better melt resistance. Heat transfer capability from 2.0 W/mK rises up to over 3.0 W/mK for materials used in furnace upper bodies. Customers want reduction of the furnace body outside temperature to figures below 100°C, but this presents an issue with the solidus point moving towards the furnace wall.

Carsten Bretz of SMS Group said semi-continuous is batchwise and more flexible, but has an energy and scrappage (5-15%) cost. Full-continuous is lower power and uses an inner graphite plate or tube for lubricating over several days or weeks. A 4-Strand HC billet caster

(up to 25 t/h) is presently being commissioned in Italy. A vertical full-continuous caster for Cu-DHP billets for tube production uses a shaft furnace to achieve >60 ktpy output. Reproducible high quality production is a main focus. A '2-circuit mould' was developed with independently adjustable primary- and secondary cooling water to aid optimisation, along with further split of the cooling zones into small and wide slab sides.

The *Yuki Muto of JX Nippon Mining & Metals Corporation* paper looked at the Cu-Ni-Si (Corson alloy) and how dendrite formation affects hot crack generation. The RDG model (Rappaz et al) assumption is that voids between dendrites initiate cracks by pressure during shrinkage. Primary and secondary dendrite arm spacing (P-DAS and S-DAS) can be estimated by cooling conditions. The MIZUTA method is used for testing. Induction melted alloy in a crucible is water or air cooled via a shower ring. The cooling rate is faster near the crucible walls, e.g. For water, 11.7 °C/s at 5 mm. The conditions of this study lie inside the casting and dendrite range (Inoue, et al.). The dendrite structure differs for air to water, and the size is much larger. The Corson alloy P-DAS $= (CR \cdot G)^{-0.34}$ and S-DAS $= CR^{-0.60}$, where CR is Cooling Rate and T is temperature gradient.

Brian Frame of Rautomead Limited said Continuous NF metals horizontal and vertical casting machines are pre-assembled and tested in Dundee, Scotland. Materials include OFCu rod, conductor alloys, progressive alloys, brass and bronze. Typical output is 3-6 ktpy with near net size production. Rautomead has a full range of in-house R&D continuous casting capabilities using the RM 050 HCC Machine and the RS 80 single strand upward casting pilot plant. Successes include copper magnesium in high speed rail, alloys for automotive wire, and the patented 'sealed lid' furnace for volatile CuZr / CuCrZr alloys. R&D projects are in extending process capability, developing process capability, new production modules and machines, and developing process capability non-Cu. Development work for nearer net size below 8 mm dia. is on the rise.

Measurement and Consumables

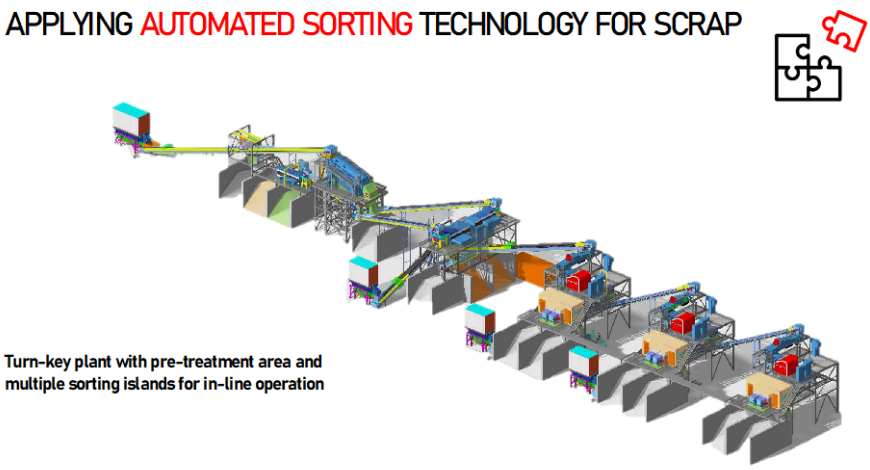
Tomoo Tokuno of Toyo Tanso, isotropic graphite for electronics, and carbon electrodes maker, opened Session 6 on Measurement, Technology and Consumables. Coke and binder is kneaded then pulverised and sieved to powder. This is pressed cold-isostatically with water pressure to form blocks which are baked and pitch-impregnated as necessary, and finally graphitised. The process takes 1.5 to 2 months but can be up to 9 months. Isotropic graphite is light, stable at high temperature (non-oxidising atmosphere), and has high specific strength at high temperature (peak at 2,500°C). It has both excellent chemical resistance and machinability. In copper and its alloys, it is used (mostly IG-11, IG-12, IG-15 grade) for the continuous casting crucible, and for graphite dies for strip, wire and pipe. Toyo high-purity graphite material is reduced 20 mass ppm or less and oxidation resistance can be increased. Only six companies supply isotropic graphite. Equipment is custom-made.

Stefan Theobald of Wieland-Werke covered existing sensor principles for melt level measurements, and the melt level control system developed and used at Wieland. The electromagnetic sensor working range is 10 mm to 50 mm, with a stable signal for more than 10 hours. Probes are not sensitive to dust, smoke, cover or even short contact with the melt. Signal depends on the type and size of the probe, size of the mould, and conductivity of the melt. The Wieland melt level control is small, cheap and robust, fast and easy to

adjust. A parameter data bank leads to reproducible behaviour for different alloys and dimensions. It is modular construction, easy maintenance, with independent measurement.

Hirokazu Yoshida of Furukawa Electric looked at methodology for determining the thickness of the glass interlayer between the bottom of the copper block and the top of molten metal in continuous casting - the boundary thermal-resistance between mold and solidified shell. Experimental and theoretical analysis was undertaken on a Southwire continuous casting process (SCR) and Vertical continuous casting process (VCC), including the effect of composition. For SCR, the next stage is a real-time inverse analysis of thermal-resistance with a simple model. On the VCC-system, the aim is creating a database of physical properties of multicomponent glasses and heat transfer coefficient between flux and mold. Accordingly, digital twin creation is to be undertaken, to minimise CO_2 emissions.

Thomas Diesenreiter of REDWAVE, A division of BT-Wolfgang Binder GmbH said using pre-sorted recycled copper in production presents challenges and opportunities, such as how to integrate automated sorting technology for scrap into a plant via, e.g. multiple in-line sorting islands. Silver and tin solderings, zinc, nickel and lead-content need to be sorted out. Hand-picking is skilled but low capacity. X-Ray Fluorescence (XRF) allows capacity of up to 10 t/h. Small grain size (5-20 mm) can be sorted too. A library of elements allows varying threshold levels for each alloyed element. It is then possible to increase profitability by higher scrap intake.



Turnkey REDWAVE plant design with pre-treatment area, and multiple sorting islands for in-line operation each equipped with a REDWAVE XRF sorting machine. Image reproduced courtesy of REDWAVE.

Takamichi Nakayama, Thermo-Fisher Scientific K.K. said material verification is mission critical. A 'trust but verify' method is recommended. Handheld analysis by XRF & LIBS analysers is offered. The XRF unit is more suited for copper-based alloy analysis. The alloy library contains over 510 materials, with grade ID for different standards. Quadrupling measurement time will provide 2-times better precision and cut in half the limits of detections. A 1-2 s measurement time sorts copper alloys. Some light element alloys can be deductively identified. Pass / fail analysis screening is a good application. Others include

rough and fine scrap sorting, incoming materials inspection and product quality control, and positive material identification.

Mark Loveitt, IWCC President and Peter Böhlke, Chair IWCC Technical Committee oversaw the proceedings.
www.coppercouncil.org