ICTP2017 Industry Workshop 2 Briefing note.

Non-ferrous rolling:

The Industrial Application of Microstructure Modelling in non-ferrous rolling

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Integrated model based control systems are an essential part of modern plant operations. The production requirements have evolved from achieving geometric tolerances to becoming a large, flexible, but accurate metallurgical instrument. Process and microstructure monitoring systems have been realised for many years on hot strip mills and with advanced on-line systems and tailored production routes there is a relatively comfortable process window in modern steel manufacture. However, for the plant builder, light structural metals titanium and magnesium, and harder nickel based high temperature alloys represent another level of complexity and process control requirements. The aim of this workshop was to explore the potential of microstructure modelling with respect to the process design for manufacturing wrought products in alternative alloy systems. This note summarises the discussion.

A key finding of the workshop is that the business model which has sustained plant-builders in designing steel rolling mills does not transfer easily to the non-ferrous metals:

- Typically, steel rolling mills aim to achieve a specified history of strain and temperature over time. However, for the non-ferrous metals, this is insufficient.
- In addition to histories of temperature, strain and strain-rate, the properties and value of non-ferrous metals depend on texture control which may be achieved by shearing, for example created by asymmetric rolling.
- Small changes in the composition of non-ferrous metals may have dramatic impact on their properties and evolution, but material modelling is as yet unable to predict these effects except in specific cases. The generic JMAK model applied to steel processing does not transfer well, and predictive modelling of non-ferrous metal behaviour requires the connection of models spanning quite different length scales – from crystal plasticity through phase field models up to the scale of industrially measured data – but this is generally not yet available.

For magnesium alloys:

- The market for wrought magnesium is currently very small – around 8 thousand tonnes per year globally, compared to 59 million tonnes/year for aluminium and 1,600 million tonnes/year for steel.
- The hexagonal crystal structure of magnesium inhibits room temperature forming and its low volumetric heat capacity makes temperature control difficult; thus, ductile forming of magnesium remains challenging.
- Asymmetric rolling increases shear deformation which is beneficial for magnesium, but potentially there are other simpler routes that might achieve this effect. Better quality microstructural modelling of magnesium could help to design new and better optimised process routes.
- Car makers have experimented more with casting magnesium to shape than forming it, in order to exploit its potential for weight saving.
- Potentially the routes to manufacturing parts with wrought magnesium might not involve rolling mills at all - for example through drop-forging and subsequent direct shaping This would be to avoid the investment costs of a rolling plant which, at current production volumes, would be required to output only one ingot per day. Are there other approaches to creating severe plastic deformation that could operate at the required scale?

For aluminium alloys:

- Strength arises more from precipitation hardening and the control of texture than the control of grain size implied by the Hall-Petch relationship
- The ductility of aluminium can be improved by texture control, particularly if a <111>//ND texture is created by shear deformation, for example with high-friction asymmetric rolling.
- We do not know enough about the control of friction in asymmetric rolling to exploit this opportunity fully: for example, there is potential in developing new roll coatings to increase friction, but this is as yet insufficiently understood.
- Ideal control of product properties depends on through process modelling from casting through hot rolling, cold rolling, heat treatment and finishing – but except in a few cases, there are insufficient models to achieve this.

The research opportunities identified in this workshop included:

- The need to connect material models across different length scales to provide confidence for plant builders to design equipment capable of processing the more complex and less understood behaviour of the non-ferrous alloys. This is both a reflection of the need for better models, and for new stable modelling platforms that allow the integration of multiple models for commercial use, even while each individual model developers pursue improvements in their own component. Plant builders do not, historically, have capacity in model integration of this type.

- As models become inevitably more complex to cope with the many coupled effects determining the performance of non-ferrous metals, there is a need for new strategies to determine model parameters for the particular alloy and process under consideration, and for new solution strategies to create useful information in acceptable time.
- The development of better sensors (that can measure not just temperature but also microstructural properties and textures at on-line speeds) could be a compensation for uncertainty in model development – and there is a lot of space for new developments in this area. Potentially new high-quality sensors combined with the machine learning algorithms of Artificial Intelligence could rival the predictive capabilities of detailed microstructural modelling.