Chair of Metal Forming and Casting
TUM School of Engineering and Design
Technical University of Munich

Local Material Properties of Aluminium

Development of a methodology for determining local component properties for aluminium casting materials

Motivation

As a construction material, aluminium is characterised in particular by its low density and high strength, good corrosion properties and high thermal and electrical conductivity. These properties predestine age-hardenable aluminium-silicon alloys for lightweight construction applications with high mechanical requirements in many industrial sectors. Due to the requirement of these components for the lowest possible component weights with constant mechanical characteristics, a profound understanding of the mechanical material behaviour is desired in order to enable, for example, a targeted further development of the properties. The basis for this development of material properties is the control and targeted influencing of the macro- and microstructure. This influence is achieved by consciously defining process parameters and offers great potential for optimising component behaviour and innovation. The manufacturing process for aluminium castings offers the necessary variety of influenceable process parameters. Different thermal conditions already lead to different microstructures locally within a component and thus to different material properties.

These local component properties have so far been taken into account in simulations using formulaic descriptions, whereby the determination of a large number of characteristic values is associated with a high level of experimental effort. A holistic approach to the manufacturing process, including heat treatment, offers great potential for optimisation, but requires in-depth understanding due to its complexity and the many interdependencies. Microstructure simulations offer the possibility of expanding this understanding, but are rarely used in foundry technology to evaluate the microstructure.

Goals

The aim of this project is to establish a new testing methodology for the rapid and precise prediction of local mechanical properties of cast components. The basic idea behind this is that it is possible to draw conclusions about the mechanical characteristics based on the local temperature history of the resulting microstructure and morphology. While these characteristic values are currently determined by complex casting tests, this project pursues the goal of experimental characterisation with reduced testing effort, low material usage and reproducible test results.

In the first part, the most precise and comprehensive process and material data possible is generated through conventional casting tests, optical and mechanical component analyses and simulative modelling of the process. In the second part, a test set-up already used at the chair will be expanded to enable targeted tracking of process-related temperature curves. This allows the temperature curve to be visualised at different positions in the component over the entire production process, starting from the melt to the ageing in the heat treatment and ensures that these samples can be examined mechanically. In addition, methods for a fast characterisation of the microstructure, independent of the inspector, are developed using machine learning. This characterisation of the microstructure as well as further investigations are used for the development of a microstructure model with a three-dimensional RVE (Representative Volume Element).

Alexander Bissinger, M.Sc.
Walther-Meissner-Str. 4
85748 Garching, Germany

Tel. +49 89 289 14555
alexander.bissinger@tum.de
www.mec.ed.tum.de/utg

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