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Characterization of casting inclusions in superalloys by BSE and EDS

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Background incl. aims
Superalloys exhibit remarkable properties such as exceptional mechanical strength, resistance to thermal creep deformation, and robustness against corrosion and oxidation, allowing them to operate efficiently in extreme environments. Their compositions primarily include nickel, cobalt, iron and chromium, whit addition of tungsten, molybdenum, tantalum, niobium, titanium, and aluminum. Innovations in the chemical development of superalloys have enabled the precise tailoring of their properties, ensuring they meet the specific demands of their applications. These materials are crucial in applications demanding high performance at elevated temperatures, such as in aerospace turbine engines and marine engineering.

Superalloys are typically processed by investment casting (also known as lost-wax casting) under vacuum conditions to ensure the highest quality of the casting. During casting, different ceramic materials are used for crucible in which an alloy is melted, for cup in which a molten material is transported, for shell in which casting is performed, or for ceramic slurry used for coating a wax model. All of this is made of different size ceramic particles which during operation could chip and make inclusion in the cast part. For that reason, this work is performed to identify inclusions, and thus identify critical place in casting procedure.

Methods
The casting inclusion are observed at different cross sections of superalloy casted parts which were metallographically prepared and afterwards preliminary examined on Light Microscope Leitz Orthoplan, and further studied in backscatter electrons (BSE) mode on scanning electron microscope JOEL JSM-6460LV equipped with EDS system INCA Oxford Instruments, at 20 kV.

Results
It is found that ceramics inclusions are primarily present in the surface of cast part, thus making a critical place for fracture in operation. In backscatter electron imaging mode it is straightforward to distinguish between the most common inclusions, like: ZrO_2 from crucible, with distinctive white appearance (Fig. 1); Al_2O_3 from cup, with dark gray appearance (Fig. 2); or $ZrSiO_4$ inclusion, originating from ceramic slurry, which could be also simply identified due to the gray shade (Fig. 3). On figure 4, the presence of multiple different inclusions could be observed, also. All observed inclusions are also positively identified by quantitative EDS point or area analysis.

Conclusion
At the end, it could be summarized that backscatter electron (BSE) analysis is a fast and convenient method to identify casting inclusions in superalloys, and thus to identify an origin of inclusion and casting error. Further EDS analysis positively confirms identification of inclusions, and gives additional data about oxidation or other impurities present.

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Graphic:

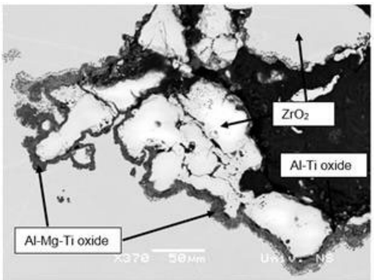

Fig 1. ZrO_2 inclusion (white)

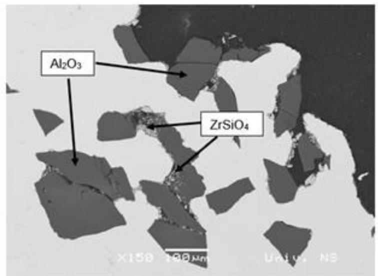

Fig 2. Al_2O_3 inclusion (dark grey)

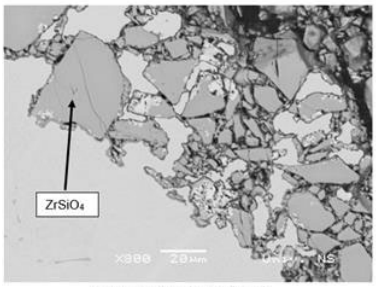

Fig 3. $ZrSiO_4$ inclusion (grey)

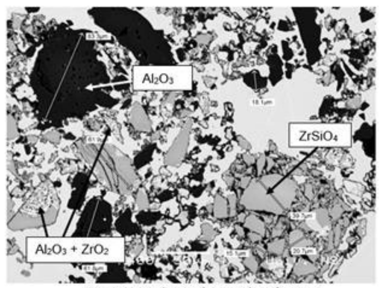

Fig 4. Complex inclusion distribution

Keywords:

Superalloys, casting inclusions, BSE, EDS