2nd JSPS - Royal society Bilateral Joint Research Workshop

December 16-18, 2023 @ Osaka University, Shimane Institute for Industry Techno.

December 16 Saturday, 2023 @ Osaka University

11:00-12:00 Lecture (Open) @ R1-213
"Dispersion strengthened high performance alloys with in-situ and ex-situ dispersions"
/ Prof. H.B. Nadendla (Brunel Univ. London, UK)

12:00-13:00 Lecturer and students mixer (Lunch box, open) @ R1-213
Opening address / Prof. M. Kambara (Osaka Univ.)

13:00-15:00 Demonstration (closed)
Insitu observation of micro-tensile testing / Dr. T. Matsuda (Osaka Univ.)

15:00-17:00 Project Meeting (closed) @ R2-213
Progress report / Prof. M. Kambara (Osaka Univ.), S. Nishi (Osaka Univ.)

18:00-20:00 Welcome Dinner @ Taj Mahal, Senri

Dispersion strengthened high performance alloys with in-situ and ex-situ dispersions

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Two common methods for achieving dispersion strengthening are in-situ and ex-situ dispersion. In situ dispersion strengthening involves the formation of strengthening particles directly within the alloy during the solidification fabrication process. This method has been most widely used to design high performance alloys and the alloying elements are chosen in such a way that desirable precipitations can be obtained. Heat-treatment of supersaturated solid-solution ensures a uniform distribution of strengthening particles throughout the alloy matrix, enhancing its overall mechanical properties. Researchers can precisely control the composition of the strengthening phase, allowing for customisation of the alloys properties to meet specific requirements. These alloys are also can be designed to maintain their mechanical properties at high temperatures, making them suitable for use in extreme environments. However, coarsening of in-situ precipitates at higher temperature are unavoidable due to grain growth kinetic driven by solutes diffusion. This intrinsic problem can be overcome by ex-situ dispersion strengthening, which involves the introduction of pre-formed strengthening particles into the alloy matrix. Their size and distribution of strengthening particles allows to design alloys with a wide range of properties. Although choice of reinforcement material and particle size can be customized to meet specific requirements for different applications, one key challenge with ex-situ approach is lack of wetting on reinforcement particles with liquid metal. Here we first discuss a method to select reinforcement particle to overcome the technical problems associated with wetting and then demonstrate ex-situ dispersion strengthening in non-ferrous and ferrous metallic materials. For light alloys, the focus was on liquid metal processing route in which reinforcement particles are first dispersed in liquid metals and then solidified under wide range of cooling conditions noted in gravity, low pressure and high pressure die casting processes. In the case of additive manufacturing processes such as laser powder bed fusion (L-PBF) process, the solidification conditions with a rapid cooling rate (10^3-10^4 K/s) and a significant thermal gradient (10^4-10^5 K/m) favour the columnar grain growth, and the ceramic particles tend to agglomerate at the inter-grain area, pushed away by the solidification front growing at high velocity. Here a range of ceramic particle metal matrix combinations are selected and filtered using interfacial energy criteria (wetting angle, Hamaker constant, particle size, and concentration) to achieve spontaneous engulfment of the ceramic particles by the solidification front in the L-PBF process, resulting in uniform dispersion of ex situ ceramic particles within the as-built microstructure. Such dispersions contribute to further strength through dislocation cutting/bypassing (depending on the coherency of the interface) within primary grains, while maintaining the base metal's phase chemical constitution and crystallographic structure. The high-temperature stability of ceramic particles enables its strength contribution to be maintained at higher temperatures.

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