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原型炉ダイバータヒートシンクへの適用を目指したZr添加ODS-Cu合金の開発
(1)酸化物分散強化銅合金の大型部材製造に向けたフィージビリティ研究

Development of Zr-doped ODS-Cu alloys as divertor heat-sinks for DEMO fusion reactor
(1) Feasibility study on mass-production of oxide dispersion strengthened Cu alloy

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【Introduction】Oxide dispersion strengthened (ODS) Cu alloys are considered as promising heat sink materials for the divertor system in DEMO fusion reactors because they are expected to meet the requirements of high thermal conductivity, superior high-temperature strength and resistance to neutron irradiation at simultaneously. Novel Zr-added ODS Cu alloys were developed by our group, which have a 1.5-fold increase in Vickers hardness compared to the conventional Y_2O_3 ODS Cu alloys. Ultra-fine Y-Zr complex oxide particles with a diameter of 4 nm are densely dispersed in the Cu matrix and remain well coherency with the Cu matrix. Besides, the thermal conductivity of the ODS Cu alloys was proved to be effectively restored by controlling the oxygen content and heat treatment process. Thus, Zr-doped ODS Cu alloys will have a high potential to be used in future fusion reactors. Since the fabrication of ODS Cu alloys is still at the stage of small batch laboratory production, only smaller bulks of about 10 grams can be obtained, which is not enough for later neutron irradiation and large-scale experimental characterization. In addition, considering their future use as large-size components in fusion reactors, it is necessary to investigate the feasibility of mass production of the ODS Cu alloys.

【Experimental】 Against the background of scale-up of Cu-ODS alloys, the mechanical alloying (MA) using an industry-level attritor ball mill installed at Kobelco Research Institute was performed to produce the ODS Cu powder. The MA tank was cooled by circulating water with a temperature below 25 °C. Pressurized argon atmosphere (150 mm H_2O) was used during the MA process. A total of 10 batches of preparatory MA experiments were conducted to obtain optimal parameters for the MA process, including the optimal ball milling time, stir bar rotation speed, and process control agent (PCA) addition of stearic acid. After determining the optimal MA process, the Zr-added ODS Cu powders were manufactured and then consolidated with the hot isostatic pressing (HIP) in Kobelco and the large-scale spark plasma sintering (SPS) in Tohoku Uni., respectively.

【Results and discussion】 Based on the optimization of MA process, the recovery rate of MA ODS Cu powder has increased to over 90% and around 600 grams powder could be obtained in one batch. The best MA parameters with the ball milling time of 24h, rotation speed of 175rpm and 1 wt.% PCA addition were obtained. Besides, Zr doping was confirmed to be able to improve the recovery rate of the MA ODS Cu powder. **Fig. 1** shows the pictures of the produced MA ODS Cu powders and the consolidated ODS Cu bulks. The mass-production of ODS Cu alloys has been proven to be feasible and the details of the production will be presented in the report.

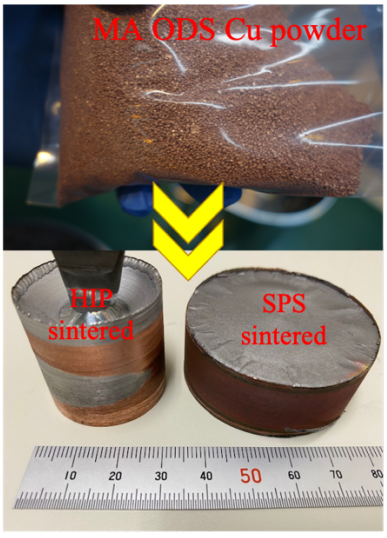

Fig.1 Manufactured MA powders and bulks of ODS Cu alloys