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原型炉ダイバータ用酸化物分散強化銅合金の大型化に関するフィージビリティ研究

Feasibility study on mass-production of oxide dispersion strengthened Cu alloys for the divertor of DEMO fusion reactor

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【 **Introduction** 】 Zr-doped oxide dispersion strengthened (ODS) Cu alloys will have a high potential to be used 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. 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 Zr-doped ODS Cu alloys was proved to be effectively restored by controlling the oxygen content and heat treatment process. 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. Considering their future use as large-size components in fusion reactor divertor systems, the purpose of this study is to investigate the feasibility of large-scale production of ODS-Cu alloys by improving the production process in cooperation with steel manufacturers, based on the already established large-scale production process of ODS-Fe 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. After determining the optimal MA process, including the optimal ball milling time, stir bar rotation speed, 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**】Even at the Kobelco Research Institute using a modified water-cooled attritor ball mill to prepare the ODS-Cu powder, it was found that refining the MA-ed Cu powder was difficult without a process control agent (PCA). Based on the study of MA parameters and PCA addition, it was confirmed that the optimal MA parameters were a ball milling time of 24 h, a rotation speed of 175 rpm and a PCA addition of 1 wt.% stearic acid. The mass-production of MA-ed Cu powder was successfully achieved with a recovery rate of over 90% and around 600 grams powder in one batch production. The sintered ODS-Cu bulk alloys were analyzed and higher density was obtained in the HIP-ed alloys, which was attributed to the high sintering pressure of 150 MPa in HIP. However, the expected refinement of oxide particles with the formation of Y-Zr composite oxide did not occur according to TEM observations, and the analysis revealed that the carbon contamination caused by the PCA addition consumed Zr through the formation of ZrC. This suggests that suitable carbon-free PCA or improved cooling efficiency of the MA process is required for large-scale production of the Zr-added ODS-Cu alloys. Detailed characterization results of the mass-produced ODS-Cu alloy, including mechanical properties and microstructure, will be presented.