3D Modeling of Heterogeneous Microstructure for Super High Strengthened Low Alloy Steels by MIM Process

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Abstract

In this study, a numerical 3D modeling using FEM for typically heterogeneous Microstructure for super high strengthened low Fe-Ni alloy steel, which was obtained by metal injection molding (MIM) process, is investigated. The designing of geometry models and material properties are introduced according to the experimental data. Moreover, the predicted stress-strain curve and distribution of each model are discussed.

1. Introduction

The metal injection molding (MIM) technology has progressed substantially over the past 25 years, and the maturity of the technology is demonstrated by growing the number of components, type of alloys, size of products and shape complexity [1-5]. The MIM technology has been utilized also to fabricate ultra-high strengthened low alloy steel parts. Especially, many research related to heterogeneous microstructure by the MIM process have been reported by Miura [6-10] who had reported a result that a tempered Fe-6Ni-0.4C showed high strength of 2040 MPa with elongation of 8.1 %, which exhibited the best properties among reported data in P/M low alloy steels so far [11, 12]. The excellent mechanical properties could be attributed to two reasons: the first is the effects of solid solution of Ni and the martensitic transformation-induced-plasticity (TRIP) in the retained austenite phase [6-8, 11]; and the second is the fine heterogeneity which consists of Ni rich phase (martensite & retained austenite) surrounded by a network of tempered martensitic structure.

For modeling and predicting the high-performance materials with heterogeneous microstructure using finite element method (FEM), factors that effect on the material properties should be selected, e.g. the representative geometry model, the material properties, and the boundary condition. A unit cell (UC) model is generally used to consider such factors and to represent the heterogeneous microstructure [13-15]. In this study, an FEM simulation with a unit cell was performed to obtain comprehensive understanding about the heterogeneous microstructure of super high strengthened Fe-Ni steel compacts.

2. FEM simulation with heterogeneous microstructure

As an example of heterogeneous microstructure, images by electron probe microanalyzer (EPMA) are shown in Fig. 1. The samples were Fe-6%Ni steel with different Ni powders in which the mean particle sizes were 6 and 24 μm. The detailed process condition is available in the references [11, 12]. The morphology of higer-Ni region was classified into two types: the isolated and connected ones as