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# Quantification of the influence of factors on abnormal grain growth in carburized steel parts for drivetrain: partⅢ

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In carburizing, quenching, and tempering treatments of steel parts (hereafter collectively referred to as carburizing treatment), abnormal grain growth (AGG) of austenite can occur. When AGG takes place, the mechanical properties of the part deteriorate markedly, adversely affecting product lifetime and reliability.

Consequently, numerous prior studies have investigated the mechanisms of AGG occurrence, identifying precipitate distribution, deformation introduced during plastic forming, and heat-treatment temperature as major controlling factors.

However, many of these studies evaluated individual factors in isolation, and it is therefore difficult to derive optimal manufacturing conditions for real part production processes−where multiple factors interact−from those findings alone.

In a previous report, we attempted to predict AGG occurrence using test pieces (TPs) that simulate parts subjected to carburizing after cold forging; a combinatorial experiment was performed in which multiple parameters were varied.

That study showed that factors with high influence could be extracted using artificial intelligence (AI), enabling prediction of AGG occurrence. Building on those findings, the present study focuses on hot forging, a principal manufacturing process for large drive-train parts.

We analyzed multi-factor experimental data obtained from TPs simulating hot forging using AI, and report here the results of investigations into manufacturing conditions that can suppress AGG occurrence in actual production.

Materials for the experiments were an Nb-added steel based on JIS G 4105 SCr420 with increased Si; hot forming was conducted by uniaxial compression at elevated temperature (heating rate 27.4 ℃/s, formed at 1220℃ and 1260℃). After forming, carburizing was carried out at either 970℃ or 1000℃.

Microstructural observations were performed on regions with differing strains determined by finite element analysis. Grain size was evaluated by grain-size number according to JIS G 0551, and a grain-size number of 5 or lower was defined as AGG.

The acquired data were systematically organized into factors corresponding to energies relevant to AGG occurrence (grain-boundary energy, strain energy, thermal energy, and grain-growth suppression), and these factors were analyzed by AI to determine interrelationships and to predict AGG occurrence.

The results revealed that the dynamic recrystallization temperature of the γ phase exerts a very strong influence.

Conversely, some samples in which AI predicted no AGG nonetheless exhibited AGG in practice. The discrepancy with experimental observations was attributed to pronounced carbon segregation, which had not been sufficiently recognized by the AI as an important factor during training.

This study identified controllable manufacturing factors during part production that affect AGG in carburized drive-train parts, and established practical conditions that suppress AGG occurrence.

The conditions are as follows:Perform hot forging at temperatures above the dynamic recrystallization temperature of the γ phase.

Alternatively, ensure the starting material microstructure meets the following criteria:

Use Nb-added steel, with a fine-NbC / coarse-NbC ratio of at least 36.7, and minimal carbon segregation.

Together with the results of the previous report, these findings indicate that AGG occurrence in carburized drive-train parts can be suppressed in both cold-forging and hot-forging routes.