ABSTRACT

The hot workability, deformation behavior, and microstructure evolution in high alloyed austenitic stainless steels such as super-304H austenitic stainless steel (super-304H SS) and phosphorus modified super austenitic stainless steel are studied over a wide range of temperatures (1173 – 1423 K) and strain rates (0.001 – 10 s^{-1}). The flow behavior is analyzed, and constitutive analyses are performed in both the alloys to adequately characterize the hot deformation behavior. The processing maps are developed using various stability/instability criteria, and detailed microstructure analyses have been performed at different processing domains. Microstructural analyses have revealed that continuous dynamic recrystallization (cDRX) is the primary restoration mechanism in super-304H SS at lower temperatures (<1273 K). The cDRX in super-304H SS is identified by progressive misorientation increase, and deformation microbanding. The progressive misorientation increase is dominant in the fine-grained super-304H SS (~8 μm) at the low strain rates, which occurs together with discontinuous dynamic recrystallization (dDRX). The cDRX characterized by microbanding (~96 μm) is dominant in the coarse-grained super-304H SS at all strain rates (0.001 – 1 s^{-1}). A sharp transition from cDRX to dDRX is also observed in super-304H SS following deformation at higher strain rates (0.5 – 10 s^{-1}) and temperatures (1350 – 1423 K). This dDRX domain in super-304H SS is identified as optimum for processing due to its higher efficiency levels (30 – 35%), lower activation energy (450 – 550 $kJmol^{-1}$), and evolution of defect-free fine and equiaxed grains. The unstable region (i.e., at 1173 – 1300 K/0.003 – 10 s^{-1}) in super-304H SS is characterized by low DRX fraction and micro-crack formation due to intergranular coarse Nb-rich precipitates in the deformed microstructure. Meanwhile, the dominant DRX mechanism in super austenitic stainless steel is identified as dDRX at all strain rates (0.001 – 10 s^{-1}) and temperatures (1173 – 1423 K) investigated in this study. The evolution of fine grains due to dDRX with near-random texture is evident in super austenitic stainless steel following deformation at strain rates 0.001 – 10 s^{-1} and temperatures 1173 – 1273 K. The deformed grain in this domain is exhibited the typical formation of <110>//ND or α fiber, and its volume fraction has gradually increased when the resistance to deformation increases. Weak deformation texture is persisted in the fine DRX grains (≤3 μm) of super austenitic stainless steel, which is gradually converted to a strong <001>//ND fiber following grain growth. The deformation texture in super austenitic stainless steel is simulated by employing a crystal plasticity finite element method (CPFEM). The texture inhomogeneity is observed in a typical compressed specimen, which is associated with the variation in stress/strain paths at different locations of the hot compressed specimen. Additionally, the ∑3 twin boundary evolution is examined employing Pande's relationship and twin related domains (TRDs) analysis. The growth accident is identified as the major mechanism of ∑3 twin boundary evolution during DRX in super austenitic stainless steel. Moreover, the ∑3 regeneration is also evident in a small domain of hot working (1323 K/0.001 s^{-1}), which is substantiated by texture randomization and the formation of relatively larger TRDs in the microstructure. Based on the processing map, microstructure, TRD, and texture analyses, the optimum domain for hot deformation in this steel is identified as the strain rate ranges of 0.001 – 0.1 s^{-1} and temperature ranges of 1300 – 1350 K. Further, the DRX behavior of super austenitic stainless steel is simulated employing novel combined cellular automaton (CA), artificial neural network (ANN), and finite element method (FEM). In this approach, the CA model has been modified by introducing a new temperature-strain rate-dependent mobility parameter for numerically considering the solute drag effect. This modified CA model has been optimized for super austenitic stainless steel at different strain rates (0.001 – 10 s^{-1}) and temperatures (1173 – 1423 K) under isothermal deformation conditions. The output of the CA simulation has been used for establishing ANN-based constitutive models. The trained ANN-based constitutive models have been further implemented in FEM software (ABAQUS 6.14) to evaluate flow behavior and microstructure response of the alloy under various non-isothermal deformation conditions. The simulation has revealed that the increase in DRX fraction due to adiabatic heating is dominant at intermediate temperatures (1273 – 1373 K) and high strain rates (1 – 10 s^{-1}) while it is not significant in other deformation conditions.

***Keywords*:** Super-304H SS; Super austenitic stainless steel; Hot deformation; Processing map; Instability; Activation energy; Continuous dynamic recrystallization; Discontinuous dynamic recrystallization; Microbands; Texture; Twin related domain; $\sum 3$ regeneration; Crystal plasticity finite element method; Cellular automaton; Artificial neural network; Finite element method.