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# Hot deformation behavior of a Nb-containing 316LN stainless steel

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ABSTRACT

A Nb-containing 316LN stainless steel was compressed in the temperature range 900–1200 °C and strain rate range 0.01–10 $s^{-1}$. The mechanical behavior has been characterized using stress–strain curve analysis, kinetic analysis, processing maps, etc. The microstructural evolution was observed and the mechanism of flow instability was discussed. It was found that the work hardening rate and flow stress decreased with increasing deformation temperature and decreasing strain rate. On the contrary, the efficiency of power dissipation increased with them; Flow instability was manifested as cracking and flow localization; The hot deformation equation and the relationships between deformation condition and dynamic recrystallization grain size and fraction were obtained; For Nb-containing 316LN stainless steel, the favorite nucleation sites for dynamic recrystallization are in sequence of triple point, grain boundary, twin boundary and intragranular deformation band; The suggested processing window is given.


## 1. Introduction

Type 316LN stainless steel has good pitting, crevice and stress corrosion resistance and excellent high temperature mechanical properties. Therefore type 316LN stainless steel is one of the candidate structural materials for fast breeder reactors [1–6], and used in many components like main vessel, safety vessel, inner vessel, auxiliary grid plate, fuel transfer machines, intermediate heat exchangers, core support structures, etc. Type 316LN stainless steel contains about 17% Cr, 12% Ni and 2.5% Mo, which leads to an austenitic structure at room temperature, good corrosion resistance and mechanical behavior. Grade denoted L contains low carbon (⩽0.03%), which can inhibit the intergranular stress corrosion cracking arising from sensitization. Grade denoted N contains nitrogen, which can improve physical, chemical and mechanical properties, especially high temperature creep properties of the steel [7].

In order to improve the corrosion resistance, Nb is added to 316LN stainless steel as alloy element. In other austenitic stainless steels, for example 25Cr–20Ni–Nb–N steel [8], 20Cr–9Ni–Nb–N steel [9], Nb is added also. In general, Z phase is predominant precipitate in Nb-containing 316LN stainless steel [10,11]. Z phase is a complex carbonitride and can forms within the matrix associated with dislocations [12]. The precipitation of Z phase can improve the creep strength significantly without lowering the creep ductility seriously [13]. The more important is that Z phase can enhance the corrosion resistance greatly. That is because Nb stabilizes C and N, and Z phase as fine dispersion of particles provides favorable nucleation sites for $Cr_{23}C_6$. Then the grain boundary corrosion mainly caused by $Cr_{23}C_6$ is delayed.

However, Mataya et al. [14] indicated that Z phase affect the recovery and recrystallization behavior significantly. The coarse Z phase particles, precipitated in the melt and had not dissolved during reheating, has been observed to act as a nucleation site for recrystallization. The precipitation speed of Z phase is small at lower temperature [15], but is high at higher temperature [12]. Moreover, stain induced precipitation is common in hot processing. These smaller particles precipitated during hot processing can delay recrystallization [16]. Precipitate and more types and high content of elements induce bad controllability of microstructure of Nb-containing 316LN steel in hot processing. Therefore, a Nb-containing 316LN stainless steel was hot compressed, and the mechanical behavior and microstructural evolution were analyzed to provide experimental warrants for optimizing the hot working process.

## 2. Experimental procedures

The test Nb-containing 316LN stainless steel was melted in an arc furnace. After vacuum refining and casting, its chemical composition is as follows (wt.%): 0.023 C, 16.61 Cr, 11.54 Ni, 2.16 Mo, 0.16 N, 0.051 Nb, 1.81 Mn, 0.61 Si, balance Fe. The ingot was forged and then machined into compression test specimens with a height

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