Stress Relaxation Measurements of Meta-dynamic and Static Recrystallization of Alloy 80A

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INTRODUCTION

The stress relaxation method has been applied to the nickel-based alloy 80A to predict meta-dynamic (MDRX) and static recrystallization (SRX) kinetics. Compression tests were performed on a Gleeble 3800 system at different temperatures (950-1200°C). The strain rate was varied in the case of MDRX and the pre-strain in the case of SRX. To investigate MDRX, the pre-strain was set to twice the peak strain in order to reach steady state before holding. To focus on the interaction of MDRX and SRX, the pre-strain was set to the peak strain, where dynamic recrystallization (DRX) starts but does not yet reach steady state. Avrami type equations for the prediction of both the MDRX and SRX were adapted to feed a semi-empirical grain structure model.

EXPERIMENTS

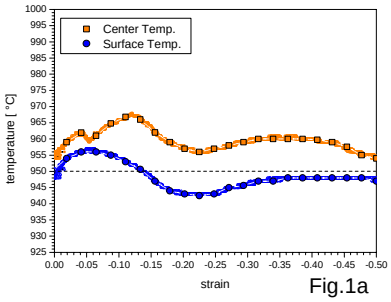


Fig.1a

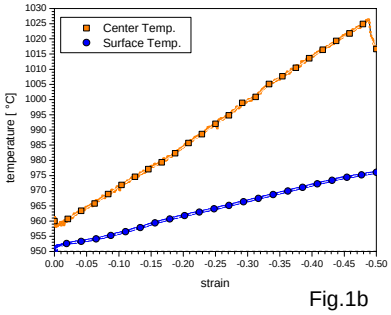


Fig.1b

In this work, cylindrical compression tests were conducted with a Gleeble 3800TM system. Above a strain rate of about 1s^{-1} and for nickel based alloys, the Gleeble system changes from isothermal to adiabatic behavior (Fig.1a,b)
In the case of adiabatic heating (strain rate of 10s^{-1}) the heating control experiences variations from the set point as a function of the strain and the initial temperature. The diameter to height ratio of the sample also changes during deformation and thus influences the thermal control. Unfavourably, the thermal control board usually reacts on these influences during stress relaxation and recrystallization, respectively. The dynamic of the thermal control can not be increased arbitrarily because of the fixed heating frequency of 50Hz. On the other hand, the reaction behavior of the thermal system can be altered by a temporary variation of the power angle, which is in proportion to the energy release of the transformer. The power angle together with the stress relaxation and the temperature development is depicted in Fig. 2a for a single test and in Fig. 2b for different pre-strains.

Fig. 1: Measured temperature evolution in the center and on the surface of the specimen for a target temperature of 950°C and for strain rates of 0.1s^{-1} (a) and 10s^{-1} (b).
Fig. 2: Measured signals of a stress relaxation test with the initial surface temperature of 1050°C of the specimen at a logarithmic strain of 0.3 and a strain rate of 10s^{-1} (a) and at pre-strains of 0.10, 0.15,..., 0.30 (b).

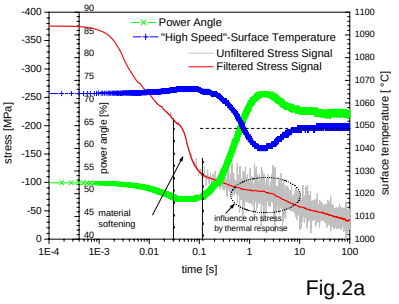


Fig.2a

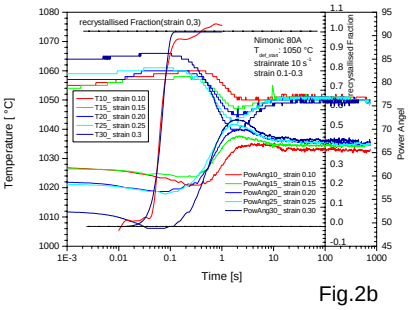


Fig.2b

RESULTS

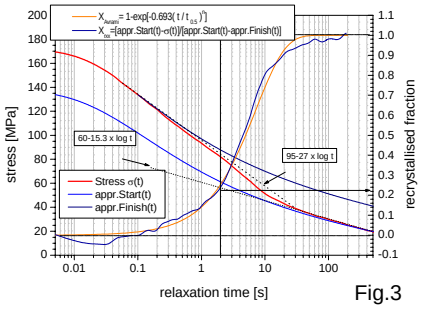


Fig.3

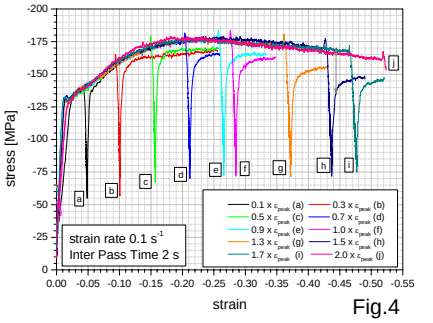


Fig.4

In general, the shape of a stress relaxation curve consists of three stages. On the logarithmic scale, linear parts represent stress relaxation due to recovery, whereas a fast decrease of the stress level can be ascribed to SRX or MDRX kinetics. The linear parts can be easily described by tangents. The fraction of the recrystallized matrix is calculated at first by a rule of mixtures and is subsequently fitted via an Avrami approach (see Fig. 3: T=1050°C, dε/dt=0.1s^{-1} and ε=0.7xε$_{peak}$). To validate the applied stress relaxation method, a series of double hit tests with constant pre-strains was carried out. The interval time was set to 2 seconds. Fig. 4 depicts the stress-strain history and shows the increasing softening with increasing pre-strain at 1050°C. If the pre-strains are high enough to produce steady state dynamic recrystallization, saturation of the softening will occur. A comparison of the double hit test and the stress relaxation method showed that the double hit test leads to slightly higher fractions of recrystallization. A reason for this could be the difference in microstructure in the first and second deformation hit. Fig. 5 and Fig. 6 show the obtained Avrami plots for different pre-strains at a constant strain rate of 0.1 s^{-1} and temperature of 1050°C and for different strain rates (dε/dt=0.01, 0.1 and 10 s^{-1}) at a constant pre-strain (ε=ε$_{peak}$) and temperature (T=1050°C), respectively.

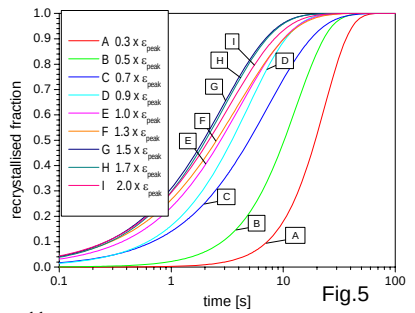


Fig.5

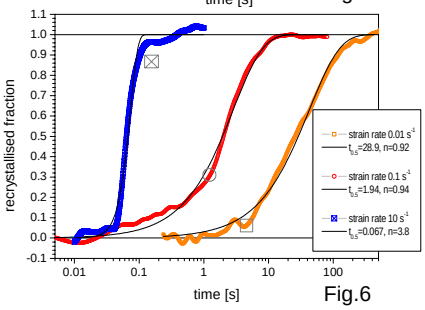
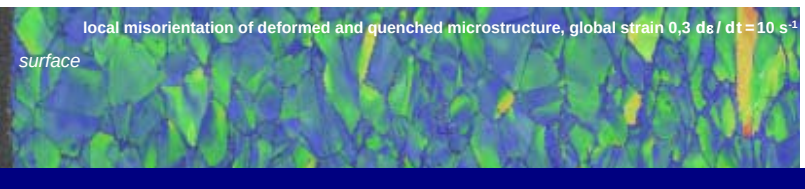


Fig.6



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