STUDY OF RECRYSTALLIZATION KINETICS DURING AND AFTER HOT DEFORMATION DEPENDING ON DEFORMATION CONDITIONS FOR C45 STEEL

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Abstract

In the article examined dependence of grain growth from soak time and temperature. It is researched influence of an initial grain size on stress-strain curves behaviour of steel C45, discussed the significance of this parameter in creation of prediction models of hot forming processes. Obtained stress-strain curves were used to calculate critical strain and define coefficients of relation between initial grain size and critical strain.

Keywords: Dynamic recrystallization, stress-strain curves, hot deformation, initial gain size

1. INTRODUCTION

Control the dynamic and static recrystallization is used to regulate hot rolling processes and to achieve optimal mechanical properties of steel after deformation and optimal power energy parameters during process [1, 2]. To predict material behaviour, physical and numerical modelling are used in combination Usually with help of physical modelling, stress-strain curves are obtained and then they are used in numerical modeling in different finite elements software such as Forge, Abaqus, Deform etc. to create model of future technological process [3].

There are usually two parameters which are varied during experiments: strain rate and deformation temperature. Based on obtained results, different models of stress behaviour depending on strain rate, deformation temperature and strain using Zenner-Hollomon parameter or Henzel-Shpittel equation are used [2 - 4]. But generally, there is one more parameter that can influence on stress-strain curve via hardening mechanism and critical strain of dynamic recrystallization starting, it's initial grain size [1]. In the most articles influence of initial grain size is not usually studied. The purpose of this article is to estimate the significance of the factor influence on stress-strain behaviour.

2. MATERIAL AND EXPERIMENTS

As the material to research the influence of initial grain size on stress-strain curve behaviour during hot deformation of steel C45 with 0.45 % C, 0.74 % Mn, 0.22 % Si chemical composition was taken. Experiments by flow compression tests were conducted on cylindrical specimens 12 mm height and 10 mm diameter on thermo-mechanical equipment Gleeble 3800 at Czestochowa Technical University (Poland). Thermomechanical scheme of compression shown in **Figure 1**. To obtain different grain size heating temperature T_h was varied from 1150 °C till 1250 °C. The samples were heated at 10 ° C/sec in a vacuum (10^{-5} Torr) till a heating temperature and hold during ten-minute period than cooled with 3 °C / s rate to a

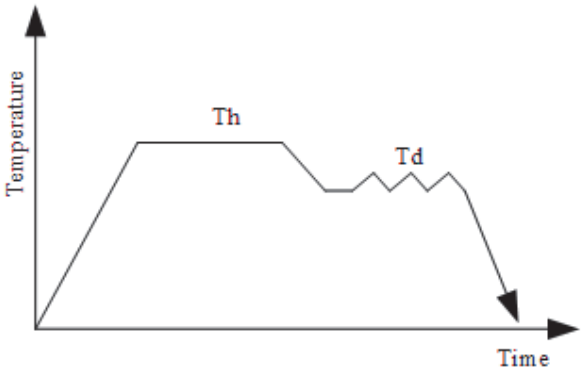

Figure 1 Scheme of thermo-mechanical processing during experiment

deformation temperature T_d (1100 °C), deformation was performed with strain rate 1 s^{-1}.

To research dependence a grain size from a temperature and soak time additional experiments were conducted at dilatometer. Cylinders 10 mm height and 6 mm in diameter were heated till three heating temperatures (1150 °C, 1200 °C, 1250 °C) and held during three different periods (10 min, 20 min, 30 min) and quenched to obtain microstructure of prior austenite grain.

3. RESULTS AND DISCUSSION

3.1. Grain size

Polished and pickled samples were investigated under microscope, an average grain size was measured for several types of heat treatment. A graph with dynamics of grain growth depending on soak time and temperature is given in **Figure 2**. Results are completely in accordance with general theory of grain growth [5].

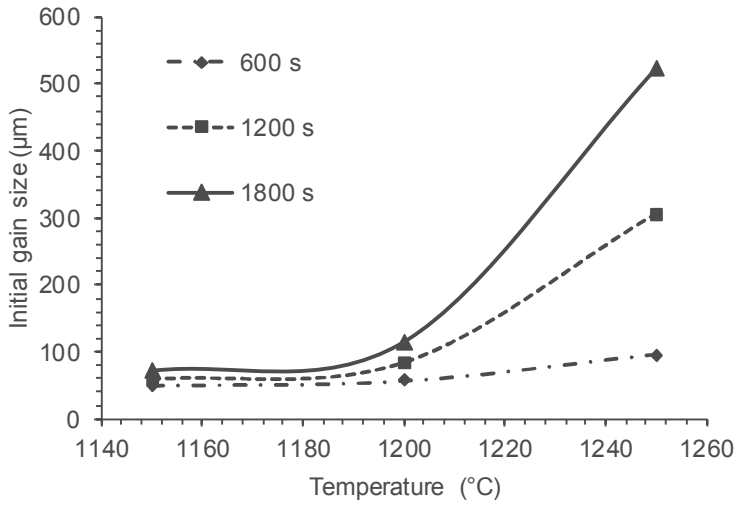

Figure 2 Dependence of C45 steel grain size from temperature and soaking time

As it was said before, grain size can influence on behaviour of stress strain curves during hot deformation mainly via two factors. The first one is grain boundary strengthening in line with Hall-Petch equation (1) [6]:

$$\sigma_y = \sigma_0 + k \cdot d^{-1/2} \tag{1}$$

where σ_y - yield stress, k - coefficient, d - grain size. According to the equation, strength rises with decreasing of an average grain size of metal.

For another thing, initial grain size influence on recrystallization kinetics during hot formation. Decreasing initial grain size accelerate starting recrystallization processes and reduce critical strain (ε_c). The general equation form for ε_c is given below [7]:

$$\varepsilon_c = A \cdot d^m \left[\dot{\varepsilon} \exp\left(\frac{Q}{RT} \right) \right]^n \tag{2}$$

where A, m, n - constants of material; $\dot{\varepsilon}$ - strain rate, s^{-1}; Q - activation energy, J / mol; T- temperature of deformation, K; R- universal gas constant, J / (K·mol); n<1.

The obtained curves for steel C45 for hot compression test (**Figure 3**) correspond to theoretical aspects described above.

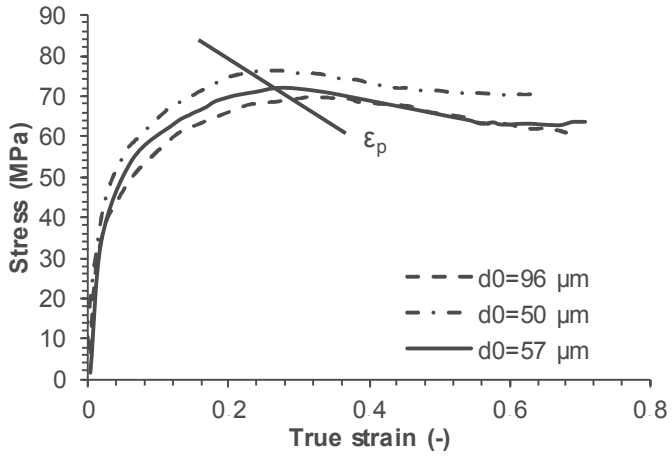

Figure 3 Stress-Strain curves obtained during hot compression tests for different initial grain size

Critical strain for every curve was determined using method of strain hardening described in [8], the results of the calculation are given in **Table 1**.

Table 1 Values of critical strains during hot deformation in different grain size conditions

Initial Grain Size (μm)	Critical Strain (-)	Peak Strain (-)
50	0.13	0.24
57	0.14	0.27
96	0.22	0.32

In diagram form it's shown in **Figure 4.**

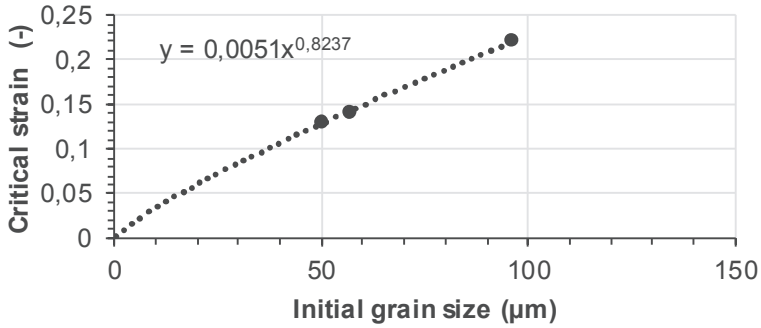

Figure 4 Power low dependence of critical strain from initial grain size

It calculated that power coefficient *n* from equation (2) is equal approximately 0.82. The obtained dependence is in good compliance with theoretical aspects described before.

4. CONCLUSION

Difference between peak values of stress is about 10 %, but the influence of initial grain size is distinguished. In other cases, it can be comparable with accuracy of stress-strain curves prediction models and accuracy of physical experiments (variation of chemistry and friction) the factor of initial grain size can be negligible, but it

still should be considered in attempt to create more accurate model of hot deformation behaviour during hot rolling. So it's recommended to examine the initial grain size factor particularly on physical modelling stage at least for one regime mode to define significance this factor on accuracy the whole research.

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