INVESTIGATION OF THE PLASTIC REGION BEHAVIOR OF AA 1100 MATERIAL

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Abstract

In this study, uniaxial tensile tests at strain rates of 1, 10, 20 and 40 s-1 were applied to AA-1100 material and the hardening behavior was observed. With the obtained tensile test data, the plastic region equation constants of the Johnson-Cook material model of the AA-1100 material were found. The Johnson-Cook plastic region coefficients of the AA-1100 Material, which differ in the literature, were recalculated in this study. The aim is to model the Johnson-Cook plastic region material coefficients mathematically in the ABAQUS package program using the Finite Element method.

Keywords: AA-1100, Johnson-Cook, Tensile Test, Plastic Deformation

1. Introduction

Aluminum alloy materials are widely used in engineering, aerospace, transportation, defense and medical fields. These alloys have an important place in engineering due to their light weight, durability and ease in manufacturing processes [1,2]. For these reasons, the mechanical behavior of aluminum alloys is very important in mechanics and materials science. [3] Mechanical properties of aluminum alloys vary according to the material composition, production method and heat treatment of the alloy.

Many experimental methods are used to determine the mechanical behavior of materials [4]. With these methods, the mechanical properties of ductile metal materials are determined. It is possible to classify the mechanical behavior with elastic, plastic and fracture behaviors with these tests. As a result of these tests, it is possible to model materials mathematically and to explain material behavior for elastic and plastic regions with some coefficients.

Many material models are used mathematically to explain the plastic behavior of materials. These are Zener-Hollomon, Johnson Cook and Zerilli-Armstrong material models. [5-7]. Mathematically modeling the plastic zone behavior of materials is very important in engineering designs in order to make design optimization before manufacturing processes. The Johnson-Cook material model, which has been used in recent years to make these optimizations, is one of these material models [8].

The Johnson-Cook material model is often used to predict the dynamic behavior of materials. These dynamic behaviors are collision, interference (penetration) and plastic deformation behaviors and are very important in engineering designs [9]. The Johnson-Cook material model is mathematically divided into two classes for plastic and fracture behavior.

Determining the mechanical behavior of the material by experimental methods is an expensive and time-consuming process. The necessity of experimental methods is undisputed, but the determined mechanical properties should be able to be used in the design phase for the engineered product before the manufacturing stages. Eliminating these revisions will enable the product to emerge in shorter processes and at very low costs. In this way, financial losses will be minimized. However, before performing such an optimization study, experimental and numerical results should be compared and verified [10].

The aim of this study is to determine the plastic region coefficients of the Johnson-Cook material model with uniaxial tensile tests applied to the AA-1100 material in order to measure the accuracy of the experimental and numerical data.

2. Experimental Studies

2.1. Johnson-Cook Material Model

The Johnson-Cook model has been studied in two parts. The equations for the plastic region of the material and the fracture region are derived separately. Johnson and Cook proposed this material model in 1983. This is a commonly used model for static and dynamic analysis in most numerical calculations; metal cutting, cold spraying, crash tests, etc. It is relatively easy to calibrate in experiments and can predict the behavior of material flow stress at different strain rates and temperatures.

The Johnson-Cook model was the first to describe the plastic zone stress as a function of plastic strain, strain rate, and temperature. Equation 1.1 is the definition of flow stress based on Johnson-Cook. Here, A, B, n, C and m are material constants, ε is the unit strain value in the equivalent plastic region, έ* is the plastic deformation rate, is the deformation rate at which the material constants are obtained, and is known as the reference strain rate, is the homologous temperature, and is shown in equation 1.1.

$$\sigma = (A + B\varepsilon^n)(1 + CIn\dot{\varepsilon}^*)(1 + T^{*m})$$

Equation 2 can be obtained if reference temperature and reference strain rate are disabled in Equation 1.

$$\sigma = A + B\varepsilon^n$$

Equation 3 is obtained with the natural logarithm of both sides..

$$In(\sigma - A) = InB + nIn\varepsilon$$

From here, he can obtain the coefficients A and B. The slope of the resulting curve and the coefficient n are found.

Equation 4 is obtained if the reference temperature region is neutralized in the equation.

$$\sigma = (A + B\varepsilon^{n)}(1 + CIn\dot{\varepsilon}^*)$$

Equation 5 is obtained from here. C coefficient is obtained with the slope of the curve formed.

$$\frac{\sigma}{A + B\varepsilon^n} - 1 = CIn\dot{\varepsilon}^*$$

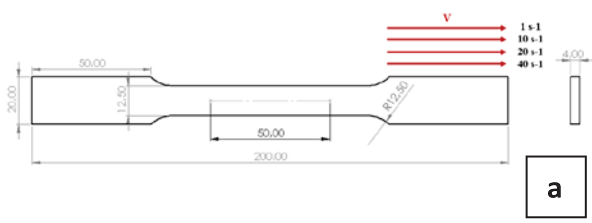
This model can be used for simulations to regularly predict the dynamic behavior of materials in the literature.

The advantage of the Johnson-Cook model is that strain, strain rate and temperature are considered simultaneously and are directly proportional to the flow stress predicted by this model. However, it is stated that the model will not work correctly when the strain rate of the system is above 104 s-1. Therefore, Johnson-Cook material constants are calibrated to predict the behavior of materials over a certain range of deformation rates.

2.2. Tensile Tests

The produced samples were subjected to tensile test at 1, 10, 20, 40 s-1 velocities, respectively. Tensile tests were carried out at Necmettin Erbakan University Scientific Research Center (BİTAM).

The prepared tensile specimens (Figure 1a) were attached to the device jaws and the tensile test was performed at the specified strain rates. The degrees of freedom applied in the tensile tests are shown in Figure 1b mathematically.



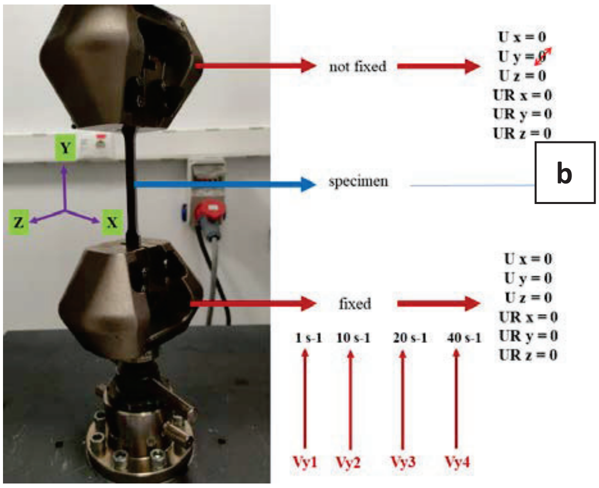


Figure 1. Tensile test; a) Test sample, b) Applied degree of freedom

3. Experimental Results

The visuals of the test specimen obtained from the tensile test results are shown in Figure 2. As a result of the tensile tests, the results in Figure 3 were obtained due to the strain hardening. Although there was no significant change up to yield points, there was a significant change in ultimate stress and plastic zone behavior.

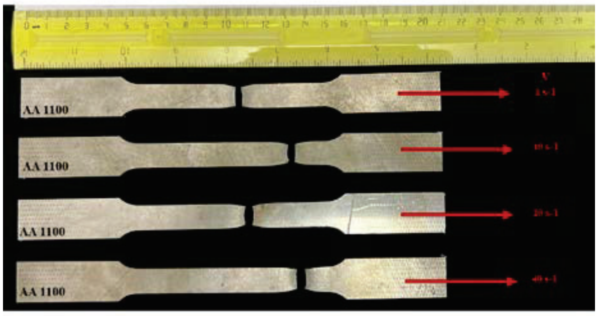


Figure 2. Test specimens after tensile test

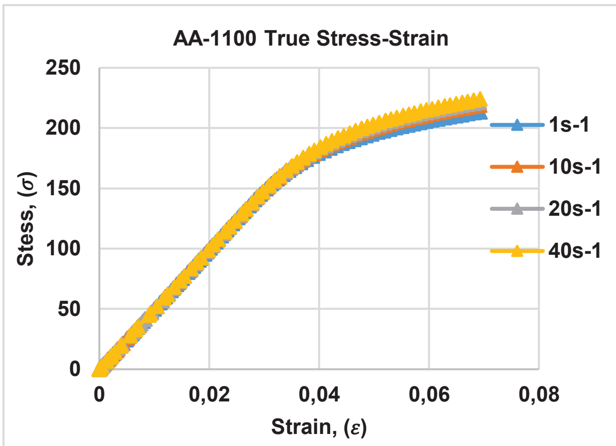


Figure 3. True Stress-Strain

A, B and n constants were found with the help of natural logarithms from the obtained graphs. These constants found are shown in Figure

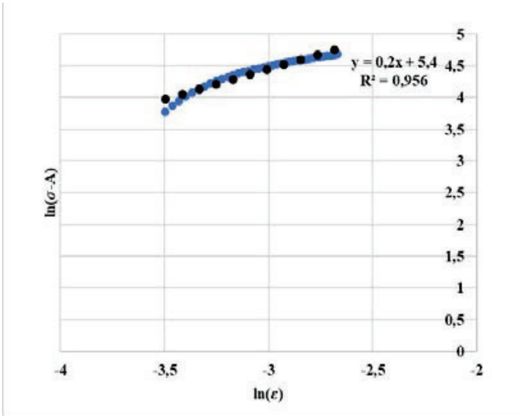


Figure 4. Determinaton of A,B,n

Then, the constants A, B and n were put into the equation and the constant C was obtained with the natural logarithm. And the obtained constant C is shown in Figure 5.

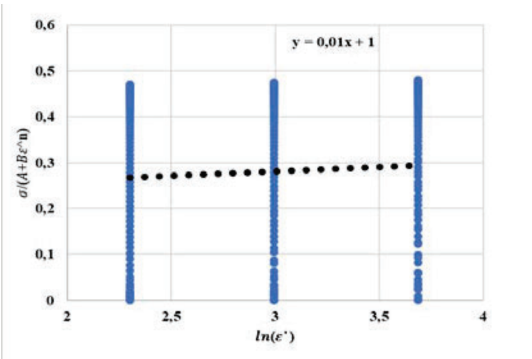


Figure 5. Determinaton of C

The obtained Johnson-Cook plastic model constants are given in Table 1.

Table 1. Johnson-Cook model

Parameter	A(MPa)	B(MPa)	n	C
Değerler	106	222	0,2	0,02

3. Conclusions

As a result of the experimental studies and numerical examinations, the following results were found for the AA1100 material;

- The hardening behavior of the material was observed as a result of tensile tests performed at different speeds.
- Johnson-Cook plastic material model coefficients showed different results from the literature.
- The tensile strength value has changed significantly.
- The unit deformation sensitivity of the materials is quite high.

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