PERTURBATION FACTORS OF UNIAXIAL COMPRESSION TEST IN GLEEBLE 3800 SYSTEM

KWAPISZ Marcin, KNAPIŃSKI Marcin, DYJA Henryk, KAWAŁEK Anna, SAWICKI Sylwester

Czestochowa University of Technology, Faculty of Production Engineering and Materials Technology, Czestochowa, Poland, EU, mkwapisz@wip.pcz.pl

Abstract

The paper presents results of research concerning the impact of different values of friction coefficient on pressure during an uniaxial compression test. The study was conducted using a simulator of metallurgical processes Gleeble 3800 located at the Institute of Metal Forming and Safety Engineering in Czestochowa University of Technology. Cylindrical samples with dimensions of φ 10 x 12 mm were upset at 1100 °C with a deformation of 15, 30, 45 and 60 %. During the test such parameters like: temperature, strain, stress and pressure were recorded. In order to perform numerical simulations the flow curves obtained in the form of a table were loaded into the program Forge 2011. In the numerical simulation the coefficient of friction was varied in the range 0.05 ÷ 0.4 and friction factor in the range 0.1 ÷ 0.8. The obtained results allowed to compare changes of barreling deformation of the sample and the pressure. The results allowed also to modify the plastometric curves and to continue the process of the numerical studies of real metal forming processes.

Keywords: Uniaxial compression test, plastometric curves of steel, physical and numerical simulations, system Gleeble 3800

1. INTRODUCTION

Intensive development of industry forcing research on new materials and technologies for producing finished products. Due to the high production costs, most research is carried out using numerical simulation and physical [3, 5]. When carrying out laboratory tests should be pursued to the maximum elimination of errors. The article presents the results of research on the impact of changes on the value of the coefficient of friction forces when trying to uniaxial compression. The study was conducted using a simulator metallurgical processes Gleeble 3800 located at the Institute of Plastic Working and Safety Engineering Technical University of Czestochowa. General view of the metallurgical process simulator is shown in **Fig. 1**.

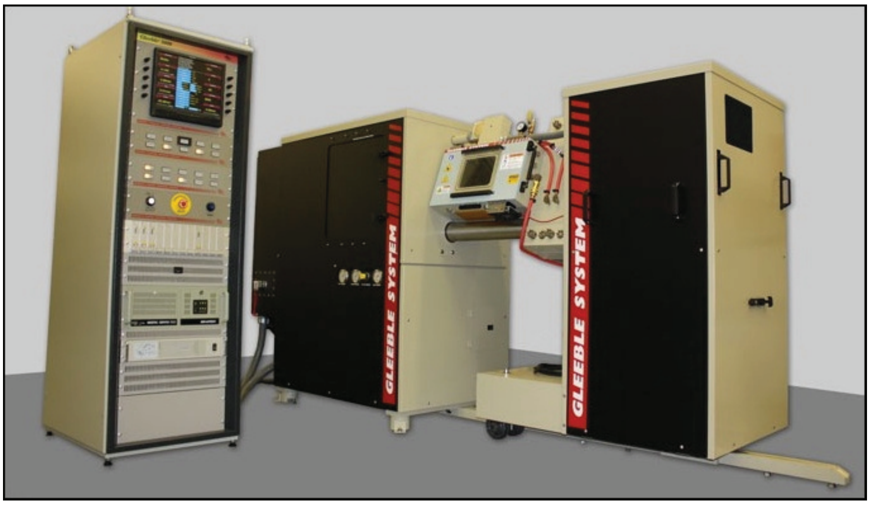

Fig. 1 The simulator metallurgical processes Gleeble 3800

2. EXPERIMENTAL AND RESEARCH

The material used for the research was steel grade C72. Cylindrical samples with dimensions of ϕ 10 x 12 mm upset at 1100 ° C with a deformation of 15, 30, 45 and 60 %. During the test, the recorded temperature, strain, stress and pressure [6]. View of the sample placed in the simulator Gleeble 3800 shown in **Fig. 2**.

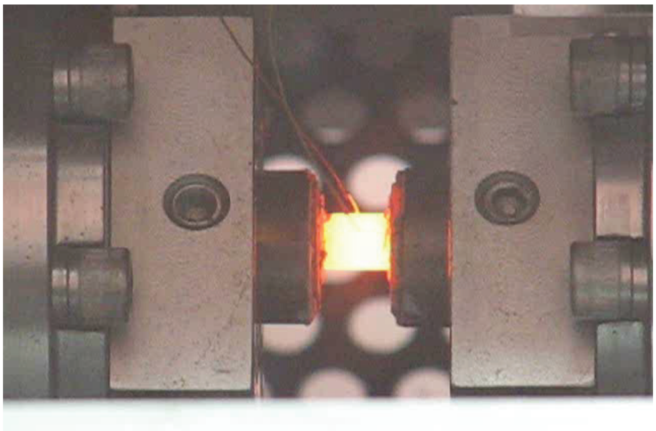

Fig. 2 View of the cylindrical sample placed in the simulator Gleeble 3800

Gleeble Simulator 3800 has a resistive heating system samples. Measuring the temperature of the test material is done by a thermocouple placed in the center of the sample. In order to determine the temperature distribution over the entire height of the sample provided three thermocouples. Thermocouple TC1 - control thermocouple is located in the center of the sample, thermocouple TC2 was placed in ¼ of the height and thermocouple TC3 located right at the base.

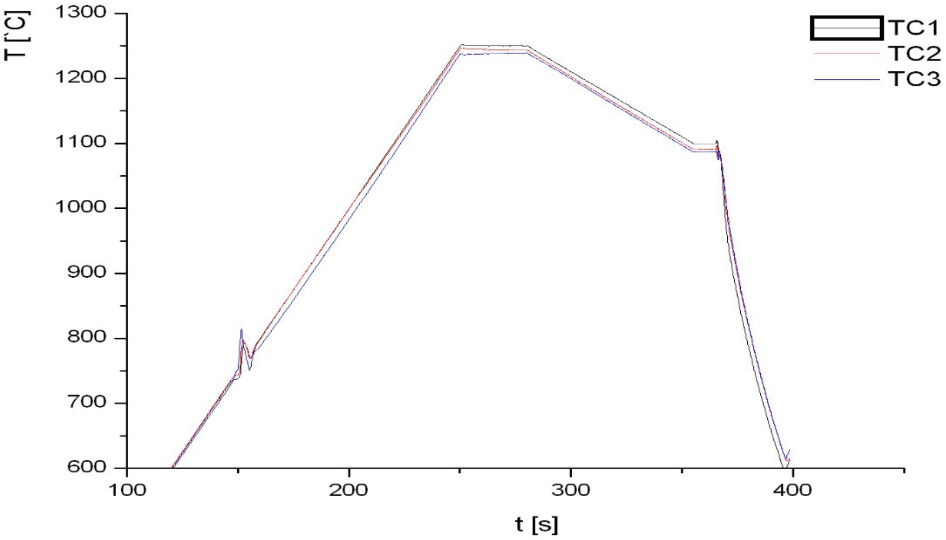

Fig. 3 Temperature distribution for the three thermocouples

On the basis of temperature changes shown in **Fig. 3** it can be concluded that the difference between the center of the sample and the face is about 30 ° C. This is due to the fact that the clips are cooled and performs these lower temperatures.

The Forge 2009® software relies on the finite element method and is designed for modelling of plastic working processes [1]. The software enables modelling of plastic working processes in a spatial strain state. A plastically deformed medium is described by the equation based on the Norton-Hoff law [2]:

$$S_{ij} = 2K_0\left(\bar{\varepsilon}+\varepsilon_0\right)^{n_0} \cdot e^{(-\beta_0 * T)}\left(\sqrt{3}\dot{\bar{\varepsilon}}\right)^{m_0-1}\dot{\varepsilon}_{ij} \quad , \qquad (1)$$

where: Sij - stress tensor deviator; $\dot{\bar{\varepsilon}}$ - strain rate intensity; $\dot{\varepsilon}_{ij}$ - strain rate tensor; $\bar{\varepsilon}$ - strain intensity, ε0 - base strain, T - temperature, K0, m0, n0, β0 - material constants specific to the plastically worked material.

A general form of this law is as follows:

$$\boldsymbol{\sigma} = 2K\left(\sqrt{3}\dot{\varepsilon}_i\right)^{m-1}\dot{\boldsymbol{\varepsilon}} \quad , \qquad (2)$$

The coefficient m in Eq. (3) may assume the following values: m = 1 corresponds to a Newtonian liquid with a viscosity of η = 2K, m = 0 gives a plastic flow law for a material satisfying Huber-Mises' plasticity criterion with a yield stress of σp = $\sqrt{3}K$, that is Levy-Mises' rigid-plastic law:

$$\boldsymbol{\sigma} = \frac{2}{3}\frac{\sigma_p}{\dot{\varepsilon}_i}\dot{\boldsymbol{\varepsilon}} \quad , \qquad (3)$$

The conditions of friction between the material and the tools are described by the Coulomb friction model and Treska's friction model, in which respective values of the friction coefficients and the friction factor are taken:

$$\tau_j = \mu \cdot \sigma_n \quad \text{for} \quad \mu \cdot \sigma_n < \frac{\sigma_0}{\sqrt{3}} \quad , \qquad (4)$$

$$\tau_j = m\frac{\sigma_0}{\sqrt{3}} \quad \text{for} \quad \mu \cdot \sigma_n > m\frac{\sigma_0}{\sqrt{3}} \quad , \qquad (5)$$

where: τj - unit friction force vector, σ0 - base stress, σn - normal stress, μ - friction coefficient, m - friction factor.

The boundary conditions of the heat transfer model are assumed as the combined limiting conditions of the second and third kinds, and are described by the formula:

$$k_x\frac{\partial T_s}{\partial x}l_x + k_y\frac{\partial T_s}{\partial y}l_y + k_z\frac{\partial T_s}{\partial z}l_z + q + \alpha(T_s - T_o) = 0 \quad , \qquad (6)$$

where: lx, ly i lz - directional cosines of the normal to the strip surface, q - heat flow rate on the cooled strip zone, α - heat transfer coefficient, To - ambient temperature.

The Forge2009® software enables the determination of the fields of temperature, stresses, strains and strain rates in the analyzed zone of metal being deformed. A substantial advantage that influences the accuracy of obtained computation results is the possibility of inputting the rheological properties of the deformed metal, either in the form of a mathematical function or in a tabularized form, reflecting the actual stress - strain relationships.

In order to perform numerical simulations of flow curves obtained with the simulator Gleeble 3800 in tabular form Forge loaded into the program 2011. In order to shorten the calculations in simulations deformation of the sample 1/8 with 2 axes of symmetry [4]. An example of the temperature distribution for a sample deformed in 15 % shown in **Fig. 4**.

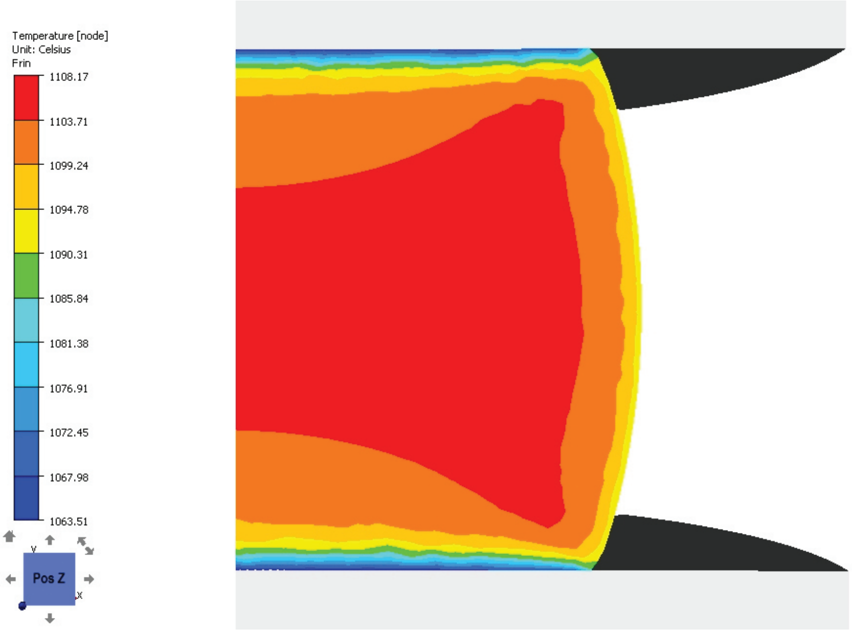

Fig. 4 The temperature of the sample in 15 % deformed

Referring to **Fig. 4**, the temperature distribution is confirmed that a decrease of temperature of the surfaces of the anvil. At the same time it can be observed temperature rise in the center of the sample which is associated with the work of deformation.

The application of the Forge2009® software using the thermo mechanical models incorporated in it requires the definition of boundary conditions which are crucial to the correctness of numerical computation. Therefore, computation results are particularly affected by: the properties of material examined, friction conditions, and the kinetic and thermal parameters describing the plastic working process.

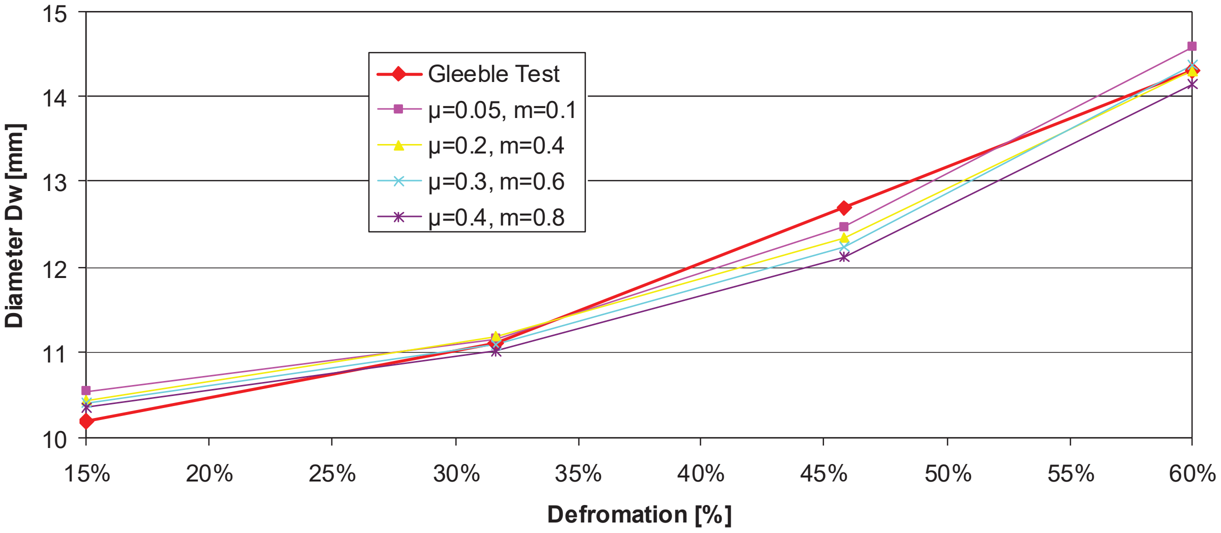

Fig. 5 The change in diameter at the base for the samples from physical and numerical simulation

The samples obtained as a result of deformations in the simulator Gleeble 3800 to the deformations 15, 30, 45 and 60 % was measured. Based on the measured diameter (D_W) and the largest diameter (D_Z) located in the mid-height. When numerical simulation program Forge changed the friction coefficient in the range of 0.05

÷ 0.4 and of friction in the range 0.1 ÷ 0.8. Upon completion of numerical measurements of all factors analyzed. The results diameter samples from the physical and numerical simulations are shown in **Fig. 5** and **Fig. 6**.

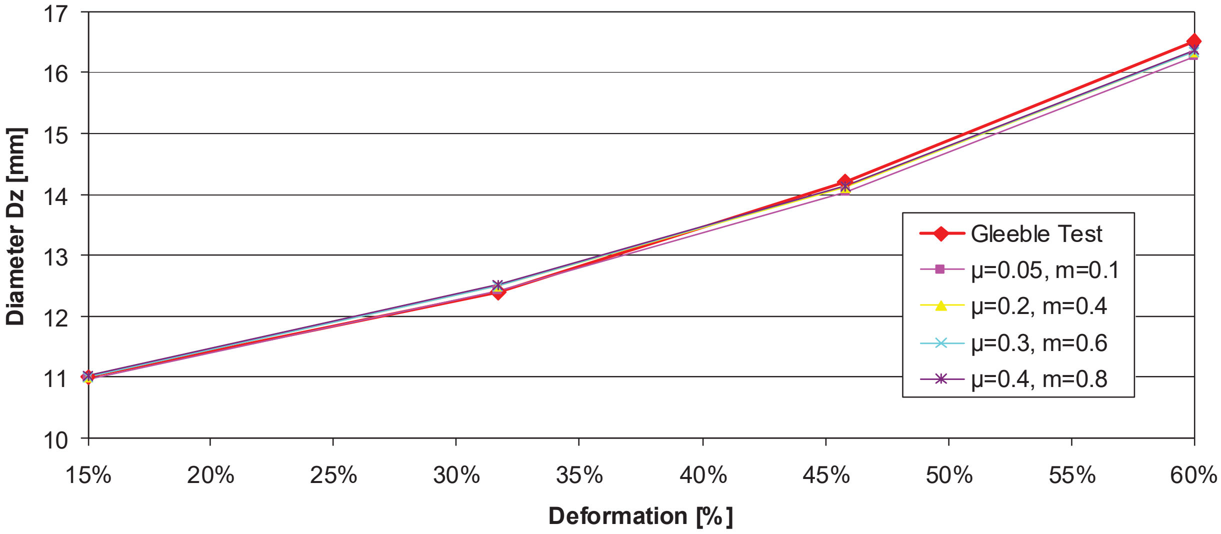

Fig. 6 Changing the maximum diameter for samples with physical and numerical simulation

In the graphs shown in **Fig. 5** and **Fig. 6** it can be concluded that the coefficient of friction in the range 0.05 ÷ 0.4 and of friction in the range of 0.1 ÷ 0.8 for the test does not result in significant differences in barreling sample. In further studies analyzed the resulting change in force during deformation in the simulator Gleeble for each strain, ie. 15, 30 and 45 % and by numerical simulations. The results of changes force shown in **Fig. 7**.

Preliminary analysis of changes in pressure forces revealed that the force obtained in numerical simulation is lower than the pressure forces generated during the deformation in the simulator Gleeble 3800. The increase in tabular stress value of 15 % allowed, for the proper execution of numerical simulations.

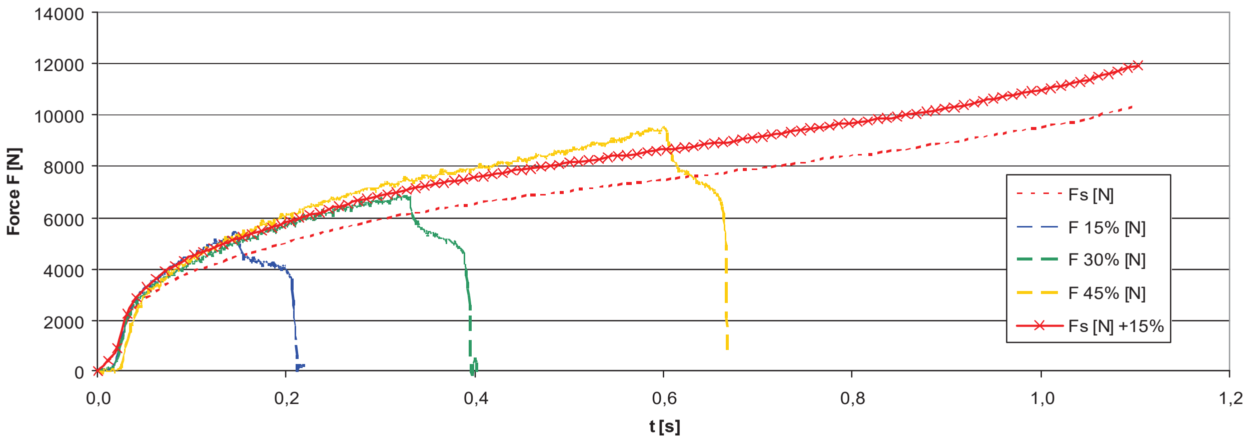

Fig. 7 Changing the force

3. SUMMARY

The article presents the results of research on the impact of changes coefficient of friction and friction factor on the value of force while trying to uniaxial compression. The study was conducted using a simulator metallurgical processes Gleeble 3800 located at the Institute of Plastic Working and Safety Engineering

Technical University of Czestochowa. Cylindrical samples with dimensions of ϕ 10 x 12 mm upset at 1100 °C with a deformation of 15, 30, 45 and 60 %. During the test, the recorded temperature, strain, stress and pressure. Numerical simulations were performed in the Forge, 2011. During the numerical simulations changed the friction coefficient in the range of 0.05 ÷ 0.4 and of friction in the range 0.1 ÷ 0.8. The results obtained allowed to conclude that a change in the coefficient of friction and friction factor over the range does not significantly affect the change barreling of the sample and the pressure. Analysis of temperature changes on the amount of deformation of the sample with three thermocouples leads to the conclusion that the difference between the middle and the end of the sample is about 30 °C.

ACKNOWLEDGEMENTS

This scientific study was financed from the resources of the National Research and Development Centre in the years 2013÷2016 as Applied Research Project No. PBS2/A5/32/2013.

REFERENCES

[1] KNAPIŃSKI, M., KOCZURKIEWICZ, B., DYJA, H., KAWAŁEK, A., KWAPISZ, M. The Basic Research of Experimental Steels for Pipelines. *Solid State Phenomena*, 2013, Vol.199, pp.518-523.

[2] FORGE3® Reference Guide Release 6.2. Sophia-Antipolis, November (2002).

[3] KNAPIŃSKI, M., DYJA, H., KAWAŁEK, A., KWAPISZ, M., KOCZURKIEWICZ, B. Physical Simulations of the Controlled Rolling Process of Plate X100 with Accelerated Cooling. *Solid State Phenomena*, 2013, Vol. 199, pp.484-489.

[4] KWAPISZ, M. Analysis of the Shape of Stamp on the Distribution of Deformation in the Process of Alternate Pressing and Multiaxial Compression. *Solid State Phenoma*, 2015, Vol. 220-221, pp.963-968.

[5] DYJA, H., KNAPIŃSKI, M., KWAPISZ, M., SNOPEK, J.Physical Simulation of Controlled Rolling and Accelerated Cooling for Ultrafine-Grained Steel Plates. *Archives of Metallurgy and Materials*, 2011, Vol. 56, No .2, pp.447-454.

[6] System Gleeble 3800 Manual