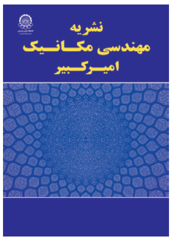

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Numerical and Experimental Investigation of Lubricant Effect in an Isothermal Precision Forging Process of a Titanium Blade Using Open Die Compression of Cylindrical Rod Test

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ABSTRACT: Friction has an important role in both plastic flow of workpiece material and the determination of the required force during the forging process. Therefore, in order to increase the accuracy of the numerical simulation results in the process of die designation as well as predicting the required force, it is necessary to perform suitable tests to estimate the friction coefficient of the process. In this research, a new testing method called open die compression of a cylindrical rod has been presented and the calibration curves have been developed. Then, this test and the well-known ring compression test have been used to predict the friction coefficient in the isothermal forging of a gas turbine compressor Ti-6Al-4V blade sample. The friction coefficient determined by the ring compression test has been applied for the root region and the coefficient determined by the rod compression test was employed for the airfoil region of the blade. Finally, the forging process was numerically and experimentally investigated. Comparison of the maximum forces from the numerical and the experimental results showed an acceptable agreement. The results showed that the open die compression of cylindrical rod test is a reliable method for evaluating the friction. The difference between the friction coefficients determined by the two mentioned testing methods showed the dependence of friction coefficient value on the deformation condition of the workpiece.

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1- 1. Introduction

Until now, various tests have been designed and proposed for the quantitative evaluation of friction in the die/workpiece interface in the forging process [1]. These methods include the ring compression test, backward-extrusion test, T-shape compression test, double-cup extrusion test, compression-wear test, etc. [2, 3]. To invest the friction condition in hot forming, a proper test should provide the following two important requirements, in addition to the general requirements such as the equality of temperature, die material, etc.[4]:

1) The contact time between the sample and the die should be approximately the same as the desired forming operation. 2) The surface expansion of the sample (the ratio of the deformed surface area to the initial surface area of the sample) should be approximately the same as its value in the desired process. 3) The deformation speed of the workpiece relative to the dies should have approximately the same amount and direction as the desired forming process. Therefore, it can not be expected that a single friction test predicts friction in all regions of a workpiece.

In this paper, a new method called open die compression of cylindrical rod test is presented for evaluating the friction coefficient in the forging process. The results of this test have been used in the simulation of the deformation of airfoil region and the results of the ring compression test have been employed in the simulation of the deformation of root region of a titanium compressor blade in the isothermal forging process. The obtained results were compared with those obtained from the ring test.

2- Methodology

The as-forged titanium blade is shown in Fig. 1. As can be seen, this workpiece is composed of two distinct regions i.e., the root and the airfoil.

Fig. 1: Forged titanium blade after burr cutting.

The surface to volume ratio in the root region is not high and a high surface expansion in this region does not occur. However, there is a very high surface to volume ratio in the airfoil region and during deformation, a high surface expansion is generated in this region.

It is evident that the lubricant behavior and the frictional condition in these two regions will be different. In the airfoil region, due to the large surface expansion as well as the almost plain strain condition that governs its deformation, the lubricant flows through the width of the airfoil. However, the deformation in the root zone is in such a way that the

*Corresponding author's email: m_khandaei@mut.ac.ir lubricant is to some extent imprisoned in the contact space between the die and the workpiece. The above explanations require that two friction tests be used to evaluate the friction effect of these two regions. Therefore, the ring compression test was used to evaluate the friction at the root of the blade, and a rod-compression test was employed for the evaluation of the friction in the airfoil region. For lubrication, a 0.1 mm thick glass was used in all the tests. All tests were carried out at 900 ° C in an isothermal condition at 0.03 mm/s.

The dimensional ratio of 3:20:27.5 was used the ring-compression test. The calibration curves of the ring-compression test have been extracted according to the method used in reference [3].

The increase in the length of a short rod during the deformation between two flat dies will be a function of the friction coefficient between the die and the rod. Therefore, in this test, the increase percentage in the rod length during the deformation was considered as the main parameter showing the friction coefficient. In order to obtain the calibration curve, the percentage increase in the rod length was plotted against the height drop percentage. The percentage of height reduction and the percentage increase in the rod length can be calculated by Eqs. (3) and (4), respectively.

$$\frac{H_0 - H}{H_0} \times 100 \tag{3}$$

$$\frac{L - L_0}{L_0} \times 100 \tag{4}$$

where H is the instantaneous sample height (which equals the sample diameter) and L is the instantaneous sample length.

3- Results and Discussion

The calibration curve for the ring compression test and the calibration curve for the rod compression test using the results of the finite element simulations and the obtained relations are presented in Figs. 2 and 3, respectively.

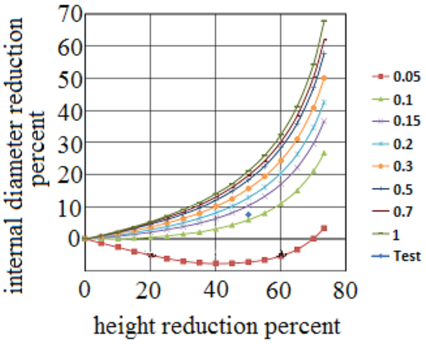

Fig. 2: The Calibration curves of the ring test and the experimental result

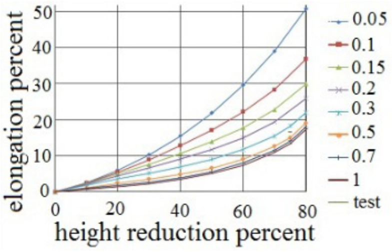

Fig. 3: The Calibration curves of rod compression test and the experimental result.

The friction coefficient of the ring compression was 0.115 and the rod compression test was 0.39. The forging process of the blade was analyzed using the DEFORM software. These simulations were performed once, taking into account the friction coefficient obtained from the ring compression test for the whole blade (the first method) and once again, taking into account the friction coefficient obtained from the ring compression test for the root region and the friction coefficient obtained from the rod compression test for the airfoil region (the second method). The forces obtained from both methods were compared with the experimental results. The result of this comparison is shown in Fig. 4.

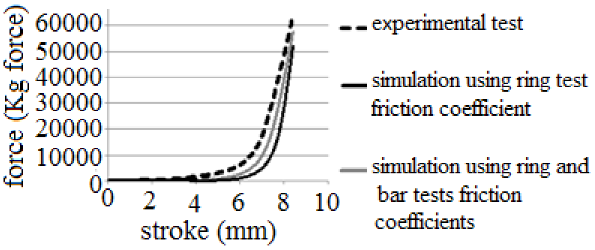

Fig. 4: Comparison of the displacement-force curve obtained from experiment and Finite element method.

As it is seen in Fig. 4, the results obtained from the second method provide more accurate results due to the different friction coefficient for the root region and the blade airfoil which is closer to the real condition.

4- Conclusion

In this research, the open die compression of cylindrical rod test was first introduced for measuring the friction coefficient. This test was successfully used evaluating the friction coefficient. The friction coefficients obtained from the ring test and the cylindrical rod compression test were 0.115 and 0.39, respectively. This indicates that choosing the appropriate friction test for the forming processes is very important. Comparison of the results of the isothermal forging of the titanium blade with the simulation results showed that using two different tests to measure the friction coefficient in the root region and the airfoil region of the blade increased the precision of the obtained force and showed better proximity to the experimental results.

5- References

[1] G. Shen, "A method for evaluating friction using a backward extrusion-type forging," vol. 33, pp. 109–123, 1992.

[2] B. Buchner, G. Maderthoner, B. Buchmayr, "Characterization of different lubricants concerning the friction coefficient in forging of AA2618", Journal of Materials Processing Technology, vol. 198, pp. 41-47, 2008.

[3] Y. Zhu, W. Zeng, X. Ma, Q. Tai, Z. Li, and X. Li, "Determination of the friction factor of Ti-6Al-4V titanium alloy in hot forging by means of ring-compression test using FEM," Tribol. Int., vol. 44, no. 12, pp. 2074–2080, Nov. 2011.

[4] T. Altan and G. Ngaile, "Cold and Hot Forging", 2005.