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NUMERICAL MODELING COUPLED DESIGN STUDIES TO INCREASE FORGING DIE & TOOL LIFE OF M8x21.5 HEXAGONAL HEADED SPECIAL BOLTS

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Abstract

In this study, the effects of die and tool design on life of cold forging dies were investigated. Simufact.forming was used as finite element modeling software to examine material flow and the level of stresses generated on the dies during cold forging of M8x21.5 special fasteners. According to the initial simulations, it was seen that the maximum principal stresses acting in the fourth forging stage were above the die material static limit. After employing different tool designs, a significant decrease in maximum principal stresses from about 900 MPa to 400 MPa was achieved. The designed tools and dies in this study were used in serial production up to number of 260.000 bolts. The production was completed without any failure of dies and tools which was predicted by the simulations.

Keywords: Cold forging, tool and stage design, finite element modelling

1. Introduction

Cold forging is the one of the mass production processes based on plastic deformation of materials at room temperature. Near-net shape products with high structural integrity can be obtained by cold forging without conducting any secondary machining operation [1]. As the geometry of the products to be cold forged becomes complex, the press force required for forming generally increases leading to decrease in fatigue life performance of the dies. Therefore, forging stage and tool designs becomes more crucial in cold forging for production of complex-shaped products. Improvements in forging stage and tool designs based on trial-and-error method leads to significant time and cost loss. Numerical simulations are employed to avoid trial-and-error so that the final form can be obtained in a faster and economical manner [2]. With numerical studies, material flow as well as stresses acting on dies and possible damage locations can be detected prior to production [3]. In addition, it was shown that tensile stresses on the dies could be reduced by employing the shrink fitting procedure [4]. In another study, it was shown that carbon fiber material could be used as stress ring material in cold forging leading to better fatigue performance [5]

In this study, forging stage and die & tool designs of cold forged M8x1.25x21.5 bolt was examined to maximize tool and die life. Finite element simulations were carried out to reveal the material flows of each forging stage. In addition, different die systems were investigated based on stresses acting on the dies to obtain the highest fatigue life.

2. Sample

M8x1.25x21.5 bolts were cold-forged at Norm Cıvata, Turkey. The technical drawing of the fastener was given in Figure 1. 23MnB4 low carbon alloy steel was used in production. Spheroidizing heat treatment was applied to materials before cold forging in order to increase forgeability by increasing ductility and to decrease forces required to plastically deform the material. After cold forging, fasteners were heat treated to obtain desired mechanical properties, as defined by the standards.

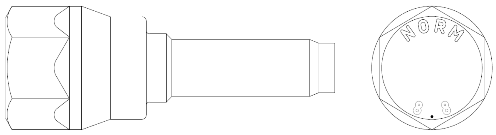

Fig. 1 2D technical drawing of the product.

3. Finite Element Modelling

3.1. Stage Design

The cold forging process was designed and modelled in five forging stages. Simulations were carried out using Simufact.forming finite element software. The material model and the friction coefficients, obtained from the previous production experiments, were used in the simulations. The first four stations were simulated in 2D, and the fifth stage was modelled in 3D due to symmetry conditions (Figure 2). For the stage design, rigid dies were used and workpiece was modelled as elastic-plastic material. Quad and hex type mesh were used in 2D and 3D models, respectively. The effective plastic strain distribution of the each five stages can be seen in Figure 3.

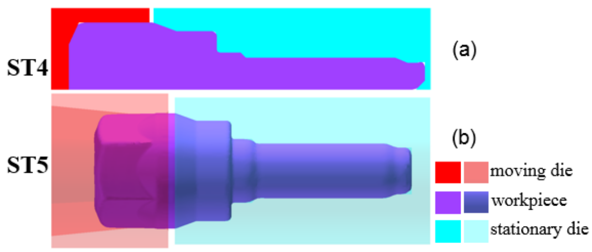

Fig. 2 a) 2D axisymmetric, b) 3D models.

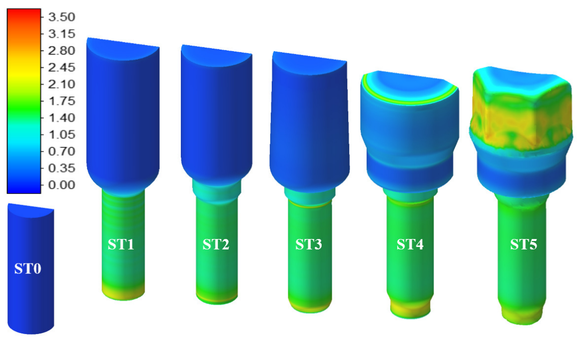

Fig. 3 Distribution of effective plastic strain on forging stages.

3.2. Tool Design

After finalizing the stage designs, the stresses acting on the dies were investigated to observe the level of stresses. Considering the stage designs, it was identified that the dies of fourth stage would experience significant stresses, due to significant loading required to obtain the final shape (Figure 4). Therefore, moving and stationary dies were modelled and investigated separately. The insert die material was chosen as WC-Co cermet having high compressive strength with limited tensile strength and H13 tool steel was used for the ring. Shrink-fitting was introduced in the models to increase the resistance of the dies particularly under tensile stresses. The forging process was carried out by making 3D modelling of the fourth stage moving die geometries. The minimum and maximum principal stresses observed in the moving die were given in Figure 5. Based on the principal stresses, it was found that the stresses at the inner edge of the insert was higher than the static yield strength of the die material. Therefore, in order to reduce the stresses at the inner edge region of the insert, the dies were split in order to eliminate stress concentration (Figure 6). Owing to revised design, the maximum principal stresses were decreased from about 900 MPa to 400 MPa so that better fatigue performance of the moving dies can be expected (Figure 7).

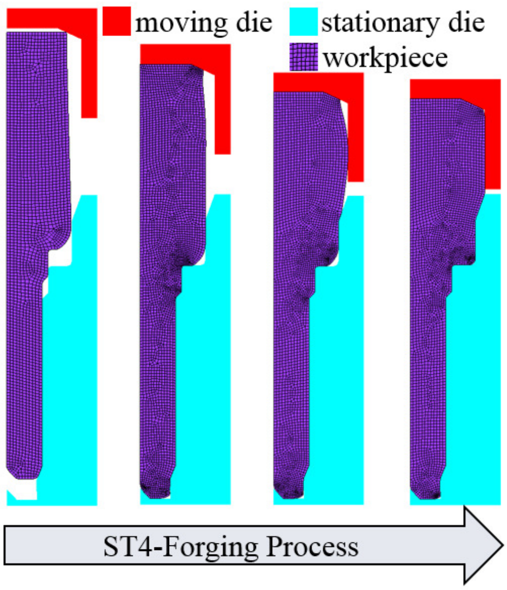

Fig. 4 Schematic representation of the fourth stage.

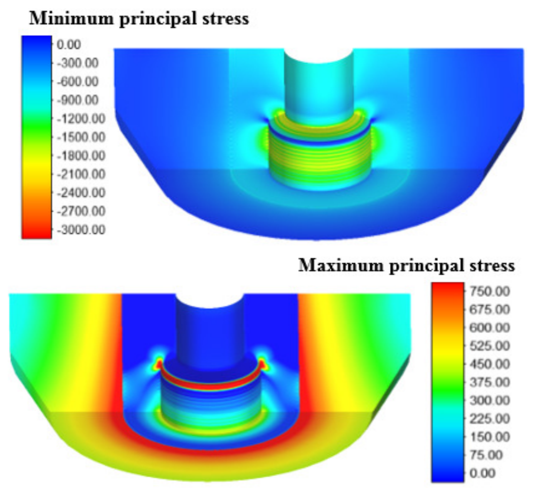

Fig. 5 Moving die; minimum and maximum principal stresses.

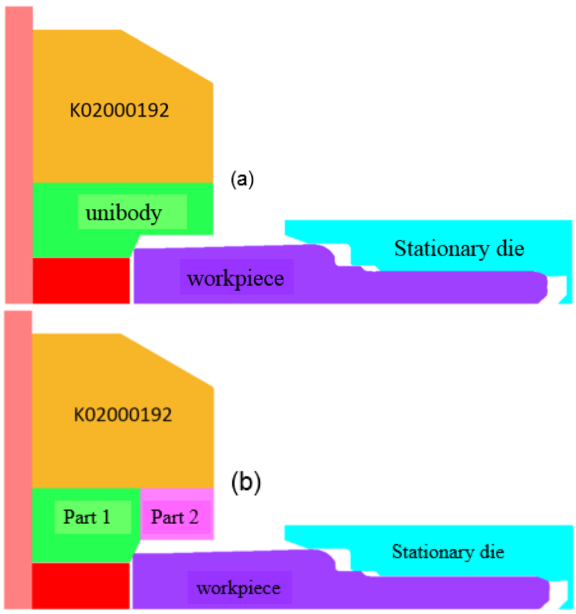

Fig. 6 Schematic representation of the moving design of fourth stage; (a) Current design, (b) Split design. Part 1 and Part 2 are the split moving dies.

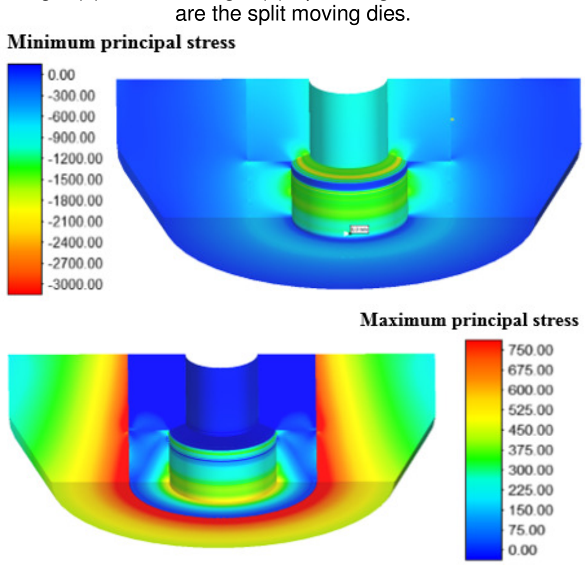

Fig. 7 Revised tool design; minimum and maximum principal stresses.

After the simulations of the moving dies, the stationary dies were also modelled with the same procedure defined for the moving dies. The minimum and maximum principal stresses obtained for the stationary dies can be seen in Figure 8. The stress levels obtained for the dies were below the yield point for both in tension and compression. Therefore, no revision was required for the stationary dies.

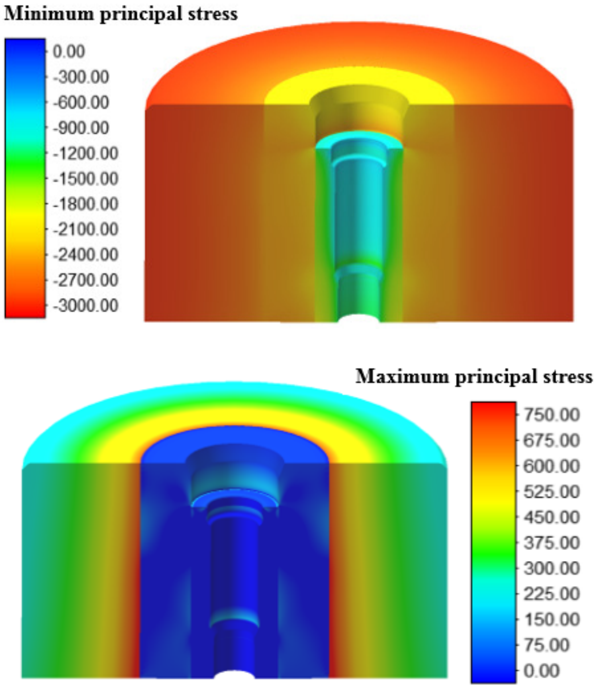

Fig. 8 Stationary die; minimum and maximum principal stresses.

Based on the finite element modelling, both moving and stationary dies were examined and required improvements were conducted. After confirming the designs of the dies and tools, the M8x1.25x21.5 bolts were produced by cold forging. The stage designs and final product can be seen in Figure 9. The cold forging of 260.000 products were carried out and the production was completed without any failure of the dies.

Fig. 9 Stage designs and final product obtained from the production.

4. Conclusions

In this study, modeling of die designs for M8x1.25x21.5 bolt was investigated and finite element simulations were carried out to maximize the tool life. After the initial insert design leading to very high tensile stresses, the die design was improved by splitting to eliminate stress concentration. After confirming the lower stress levels for revised design by finite element simulations, cold forging was carried out for 260.000 products and no failure of the tools was observed. Therefore, it can be concluded that instead of try-and-error approach which is not only time consuming but also costly, numeric simulations can be preferred to reduce the time-to-production duration and cost of the new products.

Acknowledgment

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