ACCOUNTING FOR VARIOUS MECHENISM OF FAILURE IN MODELLING OF TOOL WEAR IN HOT FORGING

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1. Introduction

Many mechanical parts, which are used in cars, airplanes and general machinery, are manufactured through forging. Quality of these products depends on many parameters but condition of the used die is particularly important. Thus, the die design and also prediction of the proper time for replacing the used die are of an importance. Life of the die is limited by such factors as the dimensional error caused by macro-wear, the overstress caused by stress concentration and the fracture due to fatigue. The mechanisms which affect the die life are abrasive and adhesive wear, mechanical and thermal fatigue, plastic deformation, corrosion and oxidation. Predictive models of various complexity have been developed for all these mechanisms. However, often combination of various mechanisms exists and hence the evaluation method for the die life should be modified. The limitations of the commonly used wear models are due to their focus on a single wear mechanisms. Designers usually have only simple numerical models describing selected mechanism. On the other hand, synergy of various mechanisms often has to be considered, what limits the possibility of using single mechanisms models. The objective of the present work was to use modern numerical simulation methods combined with experimental investigation to overcome these difficulties.

2. Mechanisms of failure

Due to the different failure mechanisms, tool durability depends on many factors often bringing about counteracting effects. It is believed that tool fatigue cracking is critical in cold forming while abrasive wear, plastic flow of material and thermal fatigue are critical in hot forming. Hot forging tools must bear high pressures (as in cold forming) and they must be resistant to high temperature (as the hot forming tools are). According to [1] tool life at high temperature depends on abrasive wear in 70% of cases. In the literature there is no comprehensive description of the changes in the die surface layer, especially in the case when various wear phenomena interact.

Tool wear models based on fundamental laws for abrasive [2] and fatigue [3] wear have some disadvantages. Firstly, they supply rather qualitative than quantitative data and their accuracy is limited. Secondly, they contain coefficients, which are difficult to determine. This paper deals with the latter aspect. The proposed model compose integration of models of various mechanisms into one system accounting for the synergy between mechanisms. The paper is a continuation of [4] where analysis of the Archard model was performed. It was shown in [4] that accounting for the changes of the coefficient in Archard equation allows to improve accuracy of the model. It was also shown that at some parts of the die, where plastic deformation and thermo mechanical fatigue were dominating, large discrepancies between Archard model and experimental data were observed. Therefore, in the present work FE analysis was used to life estimation for a hot forging die, accounting for the combined influence of various mechanisms and for the changes of hardness.

3. Results

Forging of the fork (Fig. 1a) was used as an example. The objectives of the FE analysis were twofold. The first was simulation of a large number of cycles and determination of the number of forgings, after which oscillations of stresses and temperatures stabilize. The second was accounting for the hardness decrease during forging. Fig. 1b shows die temperature variations assuming that interpasses are as short as technologically possible and that there is no additional cooling of the die during the interpass. It is seen that temperature stabilizes after about 90 forgings. Less forgings will be needed to stabilization when additional cooling during interpass is applied.

a) 

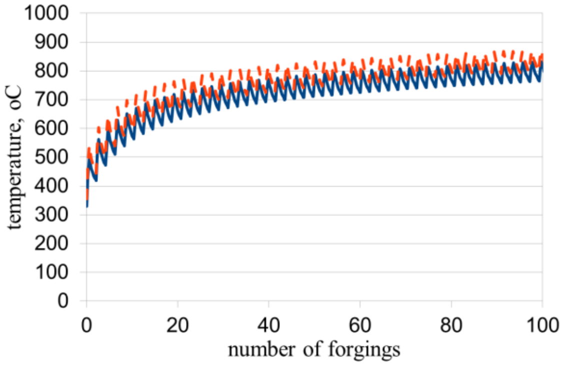
b) 

Fig. 1. View of dies for forging of the fork after 6000 of forgings (a) and changes of the die temperature during forging (b) – dashed line for a new die and solid line for a worn die.

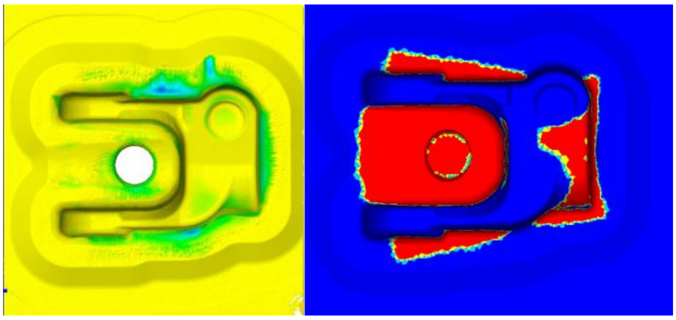


Fig. 2. The die wear measured using scanner (left) and calculated by the model (right).

Calculations of the die wear were performed next. Areas with large probability of fatigue failure were distinguished. Archard model with hardness changing during the forging was used. Corrections in the Archard coefficient were introduced for the areas where thermal and mechanical fatigue was likely. Comparison of the die wear measured using scanner and calculated by the model is shown in Figure 2. Good qualitative agreement was obtained.

4. Conclusions

Quantitative accuracy of the Archard [2] model requires determination of the coefficient *C*, which is difficult. This coefficient was determined using procedure described in [4] and changes of hardness during forging were accounted for. The following conclusions were drawn:

- Identification of the parameter *C* in the post processing, using results of a single FE simulation, is possible. Work of the tangent stresses is calculated and it is used in the identification procedure.
- Large discrepancies in the value of *C* were observed at the beginning of the process for small values of the wear. More consistent values were obtained for larger number of forgings.
- Accounting for changes of the tool hardness in predictions of the tool wear is crucial.
- FE simulation shows that temperature changes stabilize after about 90 forgings.
- Accounting for various mechanism of damage improves accuracy of the model.

6. References

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