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Proposed model for predicting abrasive wear in hot forging dies

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Abstract
In this paper, we proposed a new model for predicting the abrasive wear (wear module) in a die during hot forging processes starting with Shaw's model. The model takes into consideration the deformation energy, sliding velocity and coefficient of friction of the die material and other parameters which was modeled into a differential equation (DE) and can be solved numerically with all necessary boundary conditions and validated against experimental data or through the exact solution method.

Keywords: abrasive wear, deformation energy, sliding distance, wear module, DE

1. Introduction

Abrasive wear involves the loss of material by the formation of chips as in abrasive machining, a convenient way of studying abrasive wear is in terms of specific energy u in MPa which is the energy required to remove a unit volume of material Shaw M.C. (2005) [1]. Since abrasion is rapid and severe forms of wear can result in significant cost if not adequately controlled, it is necessary to consider material selection for wear resistance due to the different microscopic mechanism of wear occurring in abrasion Kovarikova *et al.* (2017) [4].

The service lives of dies in forging are limited by wear, plastic deformation and fatigue fracture, of this wear is the predominant factor in the operating lives of dies, to predict die life and profitability, a finite element base technique to determine the steady-state process parameters was proposed Jose Luis (2008) [7]. Other researchers have come up with models that investigate die wear profile in hot forging Biglari and Zamani (2008) [6], while Oviawe and Akpobi (2017) [5] has developed differential equation model starting with the Archard equation. Furthermore, the amount of wear in dies can be forecasted using a proposed model which composed of the cumulative friction work of the metal flow on the surfaces of the dies and the yield strengths of the die materials at elevated temperatures Toshiaki *et al.* (2017) [8].

Since the load required in forging are a function of size, shape, frictional characteristics and deformation resistance of the metal, simulation and modeling in LS-DYNA was carried out to explore forging load in closed-die which shows close matching with the experimental results Sheth (2014) [9]. Finite element analysis is a power tool in determining the wear in die and predicting the service life in forge die, by starting with the basic steps associated with the tool Mana (2005) [10].

2. Model formulation for abrasive wear

The model developed is a differential equation derived from Shaw (2005) [5] who introduced the energy of deformation into the system in predicting abrasive wear in forge die which is given below:

$$B = \frac{\mu F L}{u} \qquad (1)$$

Where
B = Wear module (mm)
L = Distance traveled by abrasive particle (ds) (mm)
F = Applied force (N)
μ = Coefficient of friction
u = Specific energy to produce a chip

In formulating the model, we take the deformation energy value (u) as $109 \times 10^6 MPa$, as suggested by Shaw (2005) [5] and using the experimental coefficient of friction μ as 0.5 Burwell and Strang (1952) [3], factors like the Rockwell hardness of the die H^m (Pa) was ignored which is temperature dependent as proposed by Archard (1953) [2],

2.1 Modeling assumptions

In the development of the mathematical models, the following assumptions and conditions for hot forging die was taken as:

- homogeneity of the die was assumed possessing isotropic hardness
- heat loss billet from finance to die was negligible
- initial temperature of billet was 1100^0C
- initial temperature of die was 300^0C
- abrasive wear was assumed to be dominant

Taking an elemental piece of the die eq. 1 becomes:

$$dB = \frac{\mu F ds}{u} \qquad (2)$$

$$\text{Let } c = \frac{\mu}{u} \qquad (3)$$

Therefore

$$dB = cFds \quad (4)$$

But $F = ma$ (5)

Where
ds = sliding distance (mm)
F = Applied force (N)
m = mass of the forging equipment (kg)
a = acceleration of the die (m/s^2)

but

$$a = \frac{dv}{dt} \quad (6)$$

Therefore, eq. 4 becomes

$$dB = cm\frac{dv}{dt} \bullet vdt \quad (7)$$

$$dB = cmvdv \quad (8)$$

$$\frac{dB}{dv} = cmv \quad (9)$$

Differentiate wrt v

$$\frac{d^2B}{dv^2} = cm \quad (10)$$

Adding eq. 9 and eq. 10 we have

$$\frac{d^2B}{dv^2} + \frac{dB}{dv} = cm + cmv \quad (11)$$

$$\frac{d^2B}{dv^2} + \frac{dB}{dv} = cm(1+v) \quad (12)$$

Recall

$$\frac{dB}{cF} = vdt \quad (13)$$

$$v = \frac{dB}{dt} \bullet \frac{1}{cF} \quad (14)$$

Substitute into eq.14 into eq.12 we have

$$\frac{d^2B}{dv^2} + \frac{dB}{dv} = cm\left(1 + \frac{dB}{dt} \bullet \frac{1}{cF}\right) \quad (15)$$

$$\frac{d^2B}{dv^2} + \frac{dB}{dv} - cm = \left(cm \bullet \frac{dB}{dt} \bullet \frac{1}{cF}\right) \quad (16)$$

Therefore eq. 17 becomes the governing equation for the abrasive wear of a forge die with respect to time (t).

$$\frac{d^2B}{dv^2} + \frac{dB}{dv} - \frac{\mu}{u}m = \frac{m}{F}\left(\frac{dB}{dt}\right) \quad (17)$$

3. Conclusion

If the wear module (wear depth) is to be found with respect to time, the force applied, the sliding velocity, the mass of the forging equipment and the coefficient of friction must be known and can be solved numerically using all necessary boundary conditions. Future work will address the implementation issues of this model as it will solved the transient problem associated with hot forging dies and results compared.

4. References

1. Shaw MC. Metal cutting principles. Oxford Science Publishers, 2005, 170-175.
2. Archard JF. Contact and rubbing of flat surfaces. Journal of applied physics. 1953; (24):981-988
3. Burwell JT, Strang CD. Journal of applied physics. 1952; (23):18.
4. Kovarikova I, Szewczykova B, Blaskovits P, Hodulova E, Lechovic E. Study and characteristics of abrasive wear mechanism, 2017.
5. Oviawe CI, Akpobi JA. Analysis of one-dimensional abrasive wear rate in hot forging process. Journal of Nigerian Association of Mathematical Physics. 2017-2015, 45-56.
6. Biglari FR, Zamani M. Die Wear Profile Investigation in Hot Forging. Proceedings of the World Conference in Engineering, on, U.K, 2008, 2-4.
7. Jose Luis GM. Predicting of Die Wear in Warm Forging Process with Forward Extrusion Operations. Thesis to Instituto Tecnologico Y De Estudios Superiores De Monterrey, 2008.
8. Toshiaki T, Koukichi N, Yasuhiro Y, Sayuri K, Yoshinari T, Toshiyuki S, *et al*. Prediction of Hot Forging Die Life Using Wear and Cooling. R&D Review of Toyota CRDL. 2017; 40:1.
9. Sheth D, Das S, Chatterjee A, Bhattacharya A. Exploring Forging Load in Closed-Die Forging. 5th International and 26th All India Manufacturing Technology, Design and Research Conference (AIMTDR), IIT Guwahati, Assam, India, 2014.
10. Mana S, Gracious N, Gangshu S. Process Modeling in Impression-Die Forging Using Finite-Element Analysis. ASM International. Cold and Hot Forging: Fundamentals and Applications (#05104G), 2005.