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Tribological Analysis of Hot Forging Dies

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ABSTRACT: Forging is the manufacturing method that is applied to the wide variety of high strength automotive components. To reduce the cost and shorten the production time, it is important to predict the life of the forging dies. In hot forging, die wear is the main cause of failure. In this paper, the wear analysis of a closed hot forging die used at the final stage of a component has been realized. The simulation of forging process was carried out by commercially available software based on finite element method and the depth of wear was evaluated with a constant wear coefficient. Three wear models have been introduced. By comparing the numerical results with the measurement taken from the worn die, the wear coefficient has been evaluated for different points of the die surface and finally a value of wear coefficient is suggested. The introduced model is proved to be applicable in wear estimation of hot forging dies over a large number of operating cycles.

Keywords: Die failure, hot forging, wear, wear coefficients.

1. INTRODUCTION:

Hot forging is the manufacturing process that is applied to the huge variety of the high strength automotive components such as crank shafts, connecting rods and transmission gears. In forging, wear is the most dominating factor which needs to be controlled to reduce the manufacturing cost, shorten the production time and increase the die life. According to an investigation regarding die life, as much as 70% of the tools have to be replaced because of wear. Another 25% are due to mechanical fatigue, and the remaining 5% are due to plastic deformation and thermal-mechanical fatigue (Siamak Abachi, 2010). It is estimated that the wear is responsible for the direct losses of 7% of the gross national production in the industrial countries. In Germany alone, wear causes the total loss of about 35 billion euros per year (Subhash Chander, 2017).

Hence, prediction of the die failure is very important. In this study, three wear models are analyzed through simulation and results are discussed.

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2. LITERATURE REVIEW:

In hot forging, the abrasive particles are the main cause of die wear which is developed by the mechanical friction between die surface and work-piece. These particles can damage the die surface progressively during each die stroke. The abrasive particles may be hard oxides or scales, external-contaminating particles or other hard carbides dislodged from the die surface. Abrasive wear results in removal of die material from the surface and its amount depends on numerous parameters such as temperature, surface roughness, sliding length, relative velocity, material, contact pressure and lubrication. Due to its complicated nature, it is difficult to formulate relationship between parameters and the amount of die wear (F. R. Biglari, 2008).

In the present paper two well-established wear models are used. Model 1, proposed by Archard (Archard, 1953) is based on the assumption that wear is proportional to the contact pressure and sliding length. This model is presented in the following formula.

$$z = \frac{k * P * v * dt}{H} \quad \text{..(1)}$$

Model 2, proposed by Felder Montagut (E. Felder, 1980), aims to specifiy the importance of the friction and wear problems which occur during the hot forging process. This model was modified by including hardness coefficient in the following equation

$$z = \frac{k * \sigma * V * dt}{H^m} \quad (2)$$

Model 3, proposed by B. A. Behrens (Behrens, 2008), is derived from Archard's wear model. Behrens modified the equation by claiming the hardness coefficient (m) as the power of normal stress(σ) and Hardness (H).

$$z = k * \left(\left(\frac{\sigma}{H}\right)^m\right) * V * dt \quad (3)$$

Where,

z = Wear amount
k = Wear coefficient
P = Pressure
σ = Normal stress
v = Sliding velocity dt = Time
H= Hardness
m = Hardness coefficient

3. METHODOLOGY:

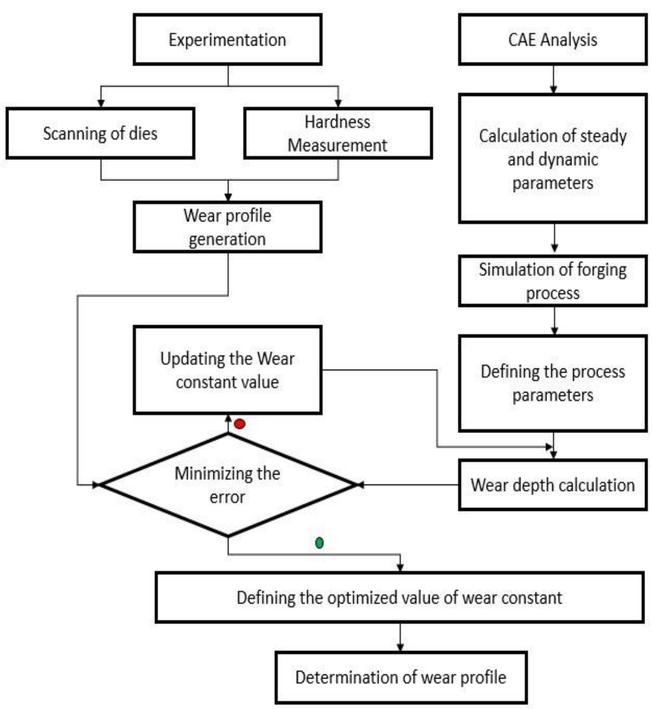

Fig.1: Process flow diagram

Fig.1. shows the flow of the process carried out. Experimentation and simulation is done simultaneously. Both the results are compared analytically and optimized parameters are used to obtain the final wear profile through simulation

4. EXPERIMENTATION:

Table No. 1 Forging details

Sr. No.	Description	Details
1	Billet Material used	En8
2	Die Material used	H11
3	Billet Heating Temperature	1200°C
4	Die Heating Temperature	250°C -300°C
5	Process Timing	12 secs
6	Lubricant used	Water + Graphite

Table No. 1 gives the details about the experimentation work

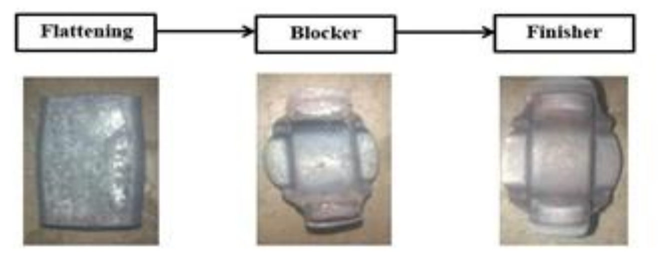

Fig.2: Process steps.

Fig.2. shows the process steps of forging to be carried out along with component pictures after each forging step Hardness Measurements and Scanning of the dies.The die was used for 2750 times for a single production batch. The worn die was examined on a 3D Scanner to be able to compare the results of wear analysis with the worn die for seven times. The hardness of the die was also been examined using Hardness (HRC) testing rig simultaneously.

5. CAE ANALYSIS:

CAD Model :-

Fig.3. shows the CAD model of component which is developed with reference to the drawings provided. CAD Model of the dies is developed with respect to the model of component.

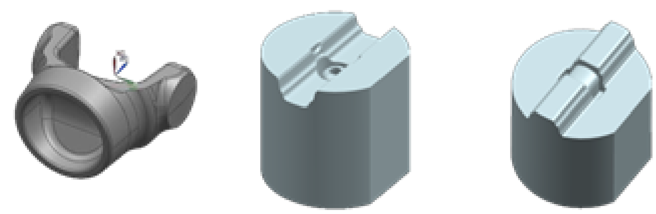

Fig.3: CAD model of component and dies

Simulation Details :-

Commercial software based on the Finite element method is used for this simulation. Fig.4. shows the initial setups of all the forging steps. All the Boundary conditions and material properties are same as that of experimentation. The analysis is carried out considering the constant "k" value initially as 1 for all the wear models.

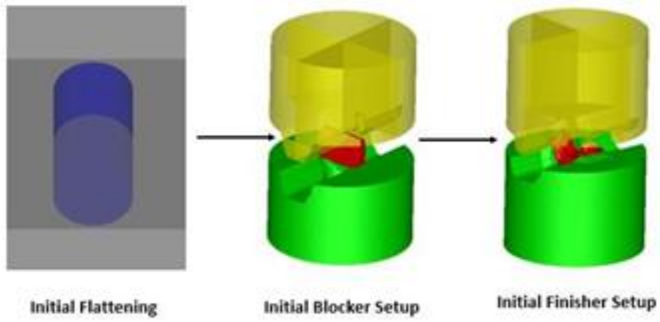

Fig.4: Simulation Process Steps.

Parameters listed below are gathered from the simulation results for further calculations.

- Time (s)
- Normal Stress (MPa)
- Von-Mises (Yield Stress) (Mpa)
- Simulation Shear Stress (Mpa)
- Pressure (Mpa)
- Sliding Velocity (mm/s)
- Die Temperature (°C)
- Die HV
- Simulation Wear

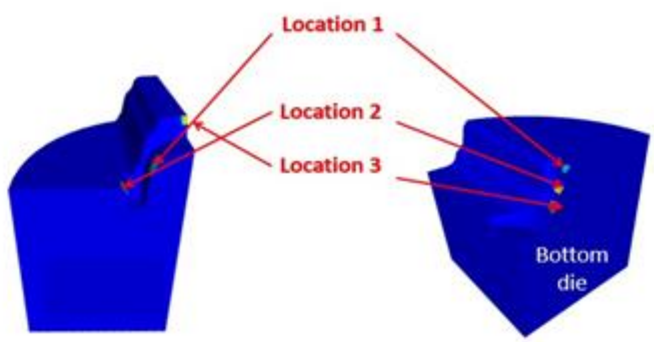

Fig.5: Identified locations of wear.

Identified locations of wear are shown in the Fig.5. on each die based on the wear intensity. Wear is calculated using parameters listed above by solving the equations separately. The analytically calculated value of wear is compared with the experimental wear value and the error (difference) is calculated. The error is minimized by changing the value of wear constant "k". The modified value of wear constant "k" is used in simulation to obtain final wear profile.

6. RESULTS:

The process of analytical result calculation is carried out for regular intervals (Number of cycles) separately. The value of wear constant "k" of all the regular intervals is averaged out. Fig.6. shows the graphs of comparison of simulation and experimentally calculated results of wear.

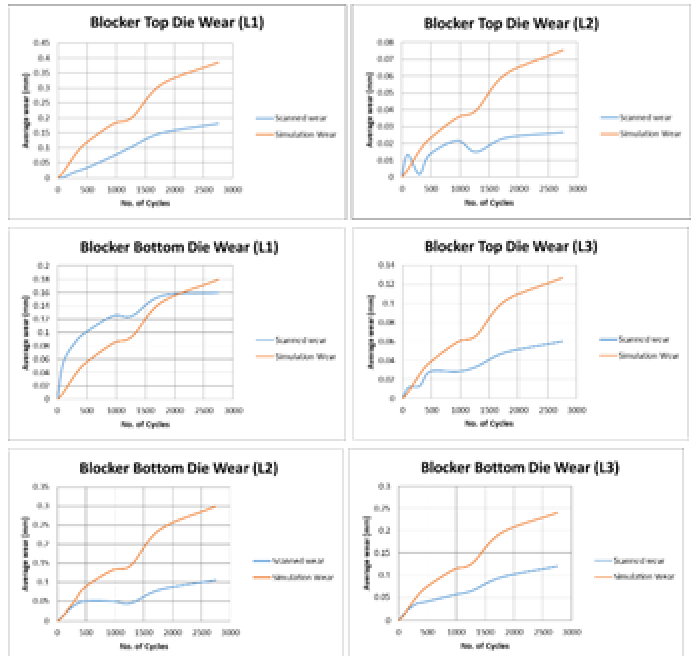

Fig.6: Comparison of analytical and experimental wear results

7. CONCLUSION:

The analytical determination of the die wear profile in the hot forging operation are presented in this paper. From this study , it is found that these three models are in agreement with each other. They are also consistent in the prediction of the location of heavily worn areas on the die surface. Among these three models Archard model and Felder Montagut model give closer results to the experimental results. It is also seen that the variation of the friction factor/ coefficient of friction does not have any effect on the amount of wear on the dies

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