JEAS
Journal of Economics and Administrative Sciences
E-ISSN: 2148-1792 P- ISSN: 1302-2024
Volume 5, Supplement Issue 2
www.jeasweb.org

Investigating and Analyzing the Production Process of Bevel Gear Blanks by the Precision Forging Method in ABAQUS software

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ABSTRACT

In Iran, bevel gears are produced by casting and hobbing, which are not economically viable due to the high cost of raw materials and significant waste. In recent years, the production of gears through precision forging has attracted much attention. This process results in the indent with final tolerances, which, compared to traditional machining methods, increases the savings in raw materials, production time, and shank mechanical properties. In contrast, as discussed in this study, using precision forging for producing gears is associated with problems in the geometry and volume of the preform and the evaluation of the necessary force and energy. Also, ABAQUS software analyzes forging dies designed to produce a sample of the blanks of conical gears.
Keywords: Forging, Bevel Gear Blank, Abaqus

1. Introduction:

Gears are mainly produced through two methods: a) machining and b) combining traditional hot forging with post-forging. [1]

These methods are very costly and time-consuming. However, recent advances in the forging industry have provided an opportunity for producing gears with precision forging technology [1, 2, 5]. Using precision forging for producing gears has many advantages compared to the traditional shaping method. Since the precision forging method lacks pleats, produced pieces do not need machining stages. Preventing material loss, saving machining costs, and reducing production steps and higher mechanical properties of the produced piece are other advantages of precision forging. In contrast, the disadvantages of precision forging include high initial investment, the need to construct expensive tools and dies, and long preparation time due to the complexity of the production process and consideration of more parameters compared to conventional forging [2].

2- Materials and Methods:

The steel used in this research is 4340 with AISI standard [3]. This steel is known in DIN standard as 1.6511 steel and is classified as heat-treatable steel.

The die material in the forging method was H11 hot-rolled steel (containing 5% chromium with the nitrified surface), with a hardness of approximately 55-60 (HRC) and high wear resistance [3].

1-2- Method

Bevel gear blanks were produced in two stages: In the first stage, open forging die was performed on the piece, and the height was reduced to the desired value. In the second stage, the blank piece (unlike the first stage) was produced by the closed forging die method.

1-1-2- Calculating the Workpiece Temperature:

A) Calculating the Workpiece Temperature at the Time of Placement in the Final Die

The temperature of the preformed piece when placed at the time of placement in the final die should be around 850 ° C [6-4]. Because the preformed piece loses heat due to contact with the die walls and convection, these heat losses must also be considered in the calculations to obtain the initial belite temperature. To calculate the initial temperature of the preform piece, it is necessary to start from its final temperature, i.e., 850 ° C, and gradually turn back and add the temperature decrease to the previous step. Finally, according to the necessary calculations, the temperature of the workpiece at the time of taking out of the preform die was T_t = 850.7 °C.

Then, the temperature reduction due to the piece contact with the preform die walls was calculated, and the temperature of the piece for putting it in the final die was measured, T_t = 875.98 °C.

B) Calculating the Temperature of the Workpiece at the time of Placement in the Preform Die:

According to the necessary calculations, as above, the temperature of the piece when leaving the furnace was T = 876.87 °C

2-1-2- Analysis with ABAQUS software:

First, the elastic and plastic properties of the workpiece at f 900, 1000, 1100 °C, and then the temperature information - including the temperature of the piece and die, the amount of heat transfer between the piece and die, between the piece and the environment, and between the die and environment were defined for ABAQUS [8].

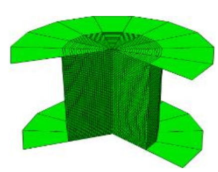

Figure 1- Elementation in the initial piece

A) Preform stage (heading): Figure (1) manifest networking in the initial piece

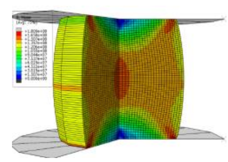

Figure 2 - Three-dimensional view of the preform stage (heading)

Figure (2) shows the final piece of the preform stage analyzed by ABAQUS

B) The final stage:

In this step, which is done in the form of closed mold forging, the volume of the piece is equal to the volume of the die after being closed, and no pleats will be produced. Figure (3) shows the final form of the piece. After leaving the die, a spring return is created in the piece, calculated by the software [9].

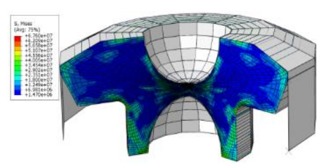

Figure 3 -Three-dimensional view of the piece's final form

3- Results and Discussion:

3-1- Force curves in each step:

After analysis with ABAQUS, the force-time curves of the forging process can be obtained in each step, and finally, the tonnage of the press machine can be obtained. According to the defined conditions (friction value, material, and temperature of the part and mold) and taking into account the time of one step equal to 0.2 S, the force-time curves for each step are in accordance with Figures (4 and 5). According to these curves, the maximum force required is 60 ton for the performance stage and 2402 ton for the final stage.

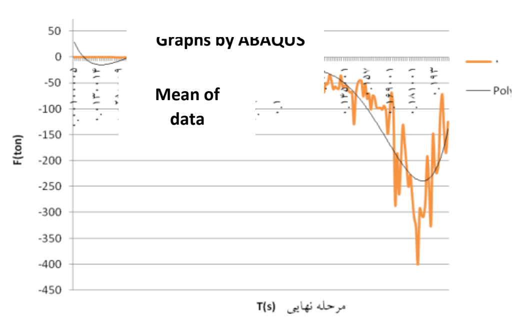

Figure -4 Force-time curves in the final stage

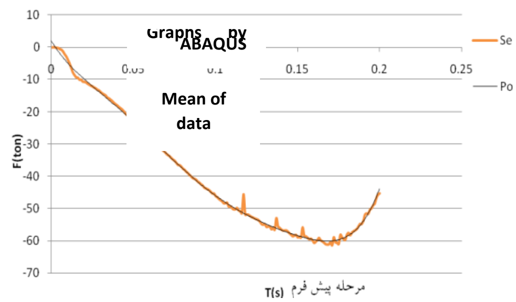

Figure 5 - Force-time curves in the preform stage

To validate the results obtained by ABAQUS, they were compared with the DIN standard experimental diagrams. The force value for each stage in the experimental diagrams was F_1= 70 ton in the open die forging and F_2 = 260 ton in the final mode [5, 7]. Therefore, compared to the experimental curves, the percentage of the software data error is 14.28 in the open die forging and 7.69 in the final die forging.

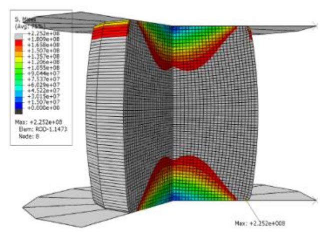

Figure 6- Maximum stress in the preform piece

Figures (6 and 7) manifest the amount of von Mises stress (S; Mises) in Pascals in the piece at each stage of forging.

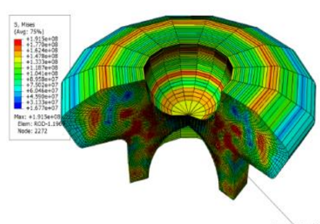

Figure 7- Maximum stress in the final piece

4 - Conclusion

1) Since in hot and cold forging methods, pieces are produced in net shape and near net shape, unnecessary costs, production time, and waste of raw materials are reduced. As a result, gear manufacturers have tended to use this method to survive in a competitive market.

2) With the help of various software, including ABAQUS, the forging process can be analyzed, and optimal forces can be obtained. Also, this softwares allow designers to see defects (e.g., folds), reducing production error percentage.

Since gear is used in heavy working conditions in fatigue and dynamic loads, its strength must be high. So, only the forging process can meet these demands. Therefore, conducting such studies as a practical step for examining precision forging for producing bevel gears, and introducing this kind of manufacturing process, is very useful.

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