NUMERICAL SIMULATION OF FORGING PROCESS OF SPIRAL BEVEL GEAR

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ABSTRACT

In this paper different cold forging processes of spiral bevel gear are studied based on the patent analysis. First of all, various design concepts are analyzed and classified according to the type of raw material and the motion of die during the forming process. Then, focused on the bulk billet, the parameters such as the mode of die motion, the size and shape of initial billet, the speed of punch and the coefficient of friction are selected to study their effects on the cold forging process. Finally, following the Taguchi method, numerical simulations are carried out to find out the suitable combination of process parameters. Material flow, stress and strain distributions as well as forging load are analyzed.

INTRODUCTION

Spiral bevel gears are widely used in the vehicle transmission system due to the high load capacity and low noise, and up to now the main process of producing spiral bevel gears in different types is the cutting with special machine tools [1,2]. Because of the remarkably high cost and lengthy processing time with poor yield rate for the cutting processes, forging spiral bevel gear has been studied [3,4] and many related patents have been issued in the past decades. To study the different design concepts for further development of cold forging process, some parameters are chosen based on the patent analysis, and different combinations are simulated numerically after Taguchi method with the goal of reducing the forging load.

METHODOLOGY

The patented forming processes of spiral bevel gear were analyzed and classified according to the type of materials [5,6] and the motion of dies during the forming process [7,8] (Fig. 1). The spiral bevel gear could be formed in the way of back cone up (Fig. 1(a)) or back cone down (Fig. 1(b)).

Fig. 1: The type of die motion during the forming process

To study the different design concepts, a right hand spiral bevel gear with the following specification is taken to simulate the effect of process parameters on the forming load: module 2, spiral angle 35°, pressure angle 20°, and 20 teeth (Fig. 2). The spiral bevel gear is formed in the way of back cone up. Schematic die set is shown in Fig. 3. The die elements are taken to be rigid, and the upper or lower die can have rotary movement corresponding to the pitch of spiral bevel gear, if necessary. The material of round billet to be considered is AISI 1020, and the forging temperature is 20°C. The friction between die and billet is assumed to be constant. The parameters to be studied include the mode of die motion (factor A), the size of initial billet (factor B), the speed of punch (factor C) and the coefficient of friction (factor D). Each factor has 3 levels (Table 1). The numerical simulations are carried out with the aid of FEM software DEFORM 3D, and the parameter combinations to be investigated are arranged according to the orthogonal array of $L_{9}(3^{4})$ type [9] with the forging load as the target function, the quality characteristic of which is the type of “the smaller, the better”.

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RESULTS

The S/N ratios of the results (not shown here) indicate that the minimum forging load will appear with the parameter combination $A_1B_1C_2D_1$. The curve of forging load and the stress distribution at the end of forging according to the best parameter combination is shown in Fig. 4. After analysis of variance (ANOVA) with regards to the forging load it is found that the contribution ratio of factor B amounts to 50.4%, factor D 30.6%, factor C 11.8%, and factor A 6.7%. In other words, the forging load for the specific gear is significantly influenced by the size of billet and then by the lubrication condition. Although the die rotation seems to play little role for the goal of reducing the forming load, the material flow would be improved with the die rotation. Material flow within rotational die will be more even and smooth than that in a fixed die (Fig. 5).

![Fig. 2: Geometric layout of spiral bevel gear](image1)

![Fig. 3: Schematic die set](image2)

![Fig. 4: Curve of forging load and stress distribution at the end of forging with the parameter combination $A_1B_1C_2D_1$](image3)

![Fig. 5: Comparison of material flow within die cavity](image4)

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<th>Table 1: Process parameters (factors) and their levels</th>
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REFERENCES