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Preform design for the warm forging of the precision bevel gear

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The aim of warm forging is to capitalize on the advantages of both hot and cold forging. In this paper, the warm forging process sequence has been determined to manufacture the warm forged product for the precision bevel gear used as the differential gear unit of a commercial automobile. The preform shape of bevel gear influences the dimensional accuracy and stiffness of final product. So, the design parameters related preform shape such as aspect ratio and chamfer length having an influence the forgeability of forged product are analyzed. To evaluate the forgeability of bevel gear, simulations of bevel gear have been carried out using SUPERFORGE™, which is commercial finite volume analysis code. Then the optimal conditions of design parameters have been selected by artificial neural network (ANN). Finally, to verify the optimal preform shape, the experiments of the warm forging of the bevel gear have been executed. The result of experiment for the selected condition of design parameters is in good agreement with the predicted results of the ANN. The proposed method can give more systematic and economically feasible means for designing preform shape in metal forming process.

1. INTRODUCTION

Gears are mainly manufactured by metal cutting or by a combination of conventional hot forging with metal cutting, which is expensive and requires a lot of manufacturing time. Newer developments in the forging industry allow the manufacturing of gear parts with precision forging technology [1,2]. Precision forging of gears has a lot of advantages when compared to conventional gear shaping, because it allows the manufacture of gear parts without flash and consequently without the need for subsequent machining operations. However, there are some critical limits for the process. Among the many factors that affect the dimensional accuracy of the warm forged bevel gear, an important factor is well-designed preform shape. In this study, the preform shape that improved the dimensional accuracy of the warm forged bevel gear is presented and applied to the die design. The analysis ofplastic deformation is performed by finite volume simulation. In order to find the optimal design parameter, the design parameter and the characteristics are used as input and output to the ANN, respectively [3,4]. The results are experimentally verified.

2. PROCESS DESIGN FOR THE WARM FORGING OF BEVEL GEAR

As shown in the figure 1, the bevel gear rolls distribution the rotation power in the right and left wheel in coupled gear pinion and gear side. In this study the gear pinion as straight bevel gear that has 11 teeth is considered. Figure 2 is the drawing of machined and forged bevel gear as pinion. Table 1 is the forging conditions. The warm forging process sequence for bevel gear is performed as shown in figure 3. The diameter and height of initial billet is 45.0, 66.0*mm*, respectively.

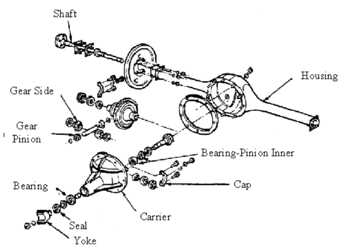

Figure 1. Schematic of differential gear unit for rear axle driven truck and bus

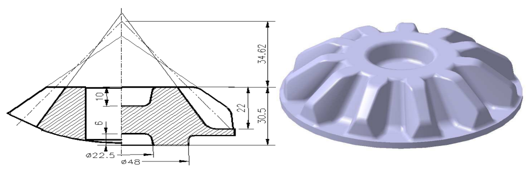

Figure 2. Machined (left) and forged (right) drawing for the warm forged bevel gear

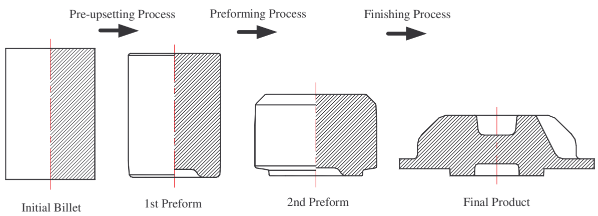

Figure 3. Process sequence for bevel gear in warm forging process

Table 1 Process conditions for the warm forged bevel gear

	Billet	Die
Material	AISI 4140H	YXR 33
Preheating temperature(°C)	850	300
Deformation velocity(mm/s)	70	

2.1 Determination of 2nd optimal preform shape by ANN

It is important to design the preform shape to improve stiffness and dimensional accuracy of final product. Especially, bevel gear is required to improve stiffness using plastic material flow in the gear tooth. Also, in order to improve a dimensional accuracy, the die cavity has to be filled with material completely, and the forming energy must be reduced to prolong a die life. First, design parameters for designing preform shape should be determined. In the forging process filling conditions depend on a ratio of width to height, i.e. the aspect ratio($s=b/h$). Figure 4 shows design parameters of 2nd preform shape.

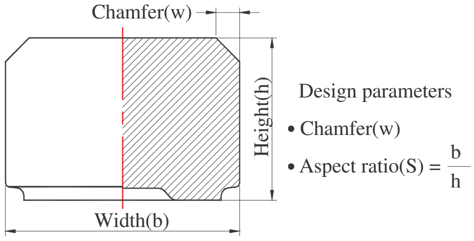

Figure 4. Design parameters for 2nd preform shape of bevel gear

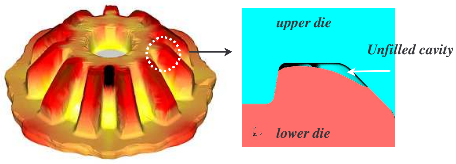

Figure 5. Unfilled cavity when aspect ratio is 2

Table 2
Stress strain-rate properties of AISI 4140H with respect to the temperature and strain

T(°C)	700(°C)		800(°C)		900(°C)		1000(°C)	
Strain	C (Kg/mm^2)	m	C (Kg/mm^2)	m	C (Kg/mm^2)	m	C (Kg/mm^2)	m
0.10	23.28	0.022	19.41	0.051	15.54	0.080	11.67	0.109
0.30	30.04	0.035	24.90	0.056	19.76	0.077	14.62	0.098
0.50	30.93	0.033	25.73	0.054	20.53	0.075	15.33	0.096
0.70	29.32	0.036	24.54	0.058	19.76	0.080	14.98	0.102

Table 3
Analysis conditions of 2nd process

	1 case	2 case	3 case	4 case
Aspect ratio (S)	1.07	1.5	2	2.5
Preform height(h)	48.24mm	38.71mm	31.95mm	27.54mm
Preform width(b)	52.01mm	58.06mm	63.91mm	68.84mm

```
ERROR: rangecheck
OFFENDING COMMAND: .buildcmap

STACK:

-dictionary-
/WinCharSetFFFF-V2TT9BF4ACCAt
/CMap
-dictionary-
/WinCharSetFFFF-V2TT9BF4ACCAt
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