Analysis of forming process for hot stamping fuel tank bracket of commercial vehicles

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This article designs a commercial vehicle hot press forming ultra-high strength and lightweight fuel tank bracket, and formulates a hot press forming process route. The model design is carried out using Siemens NX software, and the forming process analysis is carried out using AutoForm software. The thinning, cracking, and wrinkling of the part during the hot stamping process are calculated, and the direction for improvement is determined. The fuel tank bracket structure is optimized, and the optimal structure and forming process plan are determined based on the static strength analysis and the optimized forming process analysis results, meeting the requirements of structural design and forming process.

Keywords: Hot stamping; Lightweight; Fuel tank bracket; Forming analysis.

1. Introduction

Lightweight is the most direct and effective means of energy conservation and emission reduction for automobiles. Research has shown that when the total mass of passenger cars decreases by 10%, fuel consumption ranges from 6% to 8% [1]. For every 1 ton reduction in the self weight of a commercial vehicle, fuel consumption can be reduced by 6% to 8%. Under no-load conditions, about 70% of fuel consumption acts on the self weight [2]. Against the backdrop of rapid development in the automotive industry, reducing body weight, achieving lightweighting, energy conservation, and emission reduction are increasingly receiving attention from people.

The commercial vehicle fuel tank bracket, as a fixed support component of the automotive fuel tank, bears the vibration, fatigue, and impact loads of the fuel tank and plays an important role in the entire body structure. The fuel tank bracket, made of 510L material and with a thickness of 5mm, weighs approximately 11-12kg, thus having great potential for lightweight. The use of materials with high strength and toughness and hot stamping processes can help achieve lightweight fuel tank brackets. However, due to the L-shaped structure of the fuel tank bracket, forming is difficult, and defects such as thinning, cracking, and wrinkling are prone to occur at the corners during forming.

Therefore, higher requirements are put forward for the process and mold design. This article develops a preform hot press forming process to produce lightweight fuel tank

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brackets made of ultra-high strength steel, and optimizes the design and analyzes the forming process.

2. Design of hot press forming lightweight fuel tank bracket

2.1. *Structural design of hot press forming lightweight fuel tank bracket*

The fuel tank bracket consists of two parts, one is an L-shaped fuel tank bracket, and the other is a reinforcement plate for the bracket. The assembly diagram of the bracket is shown in Fig. 1. The welding thickness of the L-shaped bracket is designed to be 2.8mm, and the thickness of the reinforcing plate is 5mm. When welded together, it becomes the assembly of the components. Due to the deep stretching depth of the fuel tank bracket, a 1 ° draft angle was set on the side wall of the bracket to facilitate product forming and demolding.

(a) Strengthening plate (b) L-shaped fuel tank bracket (c)Fuel tank bracket assembly

Fig. 1. Oil tank bracket parts and assembly diagram.

2.2. *Material selection for hot press forming lightweight fuel tank bracket*

The L-shaped bracket is made of AC1500HS hot press forming steel, with a composition (wt.%) of C-0.24Si-0.38Mn-1.27P-0.014Als-0.043Cr-0.27Ti-0.042B-0.0022N-0.0027, The typical properties of this steel are shown in Table 1.

Table 1. Typical Properties of AC1500HS Steel.

Part Name	Material	Density (t/mm^3)	Elastic modulus (MPa)	Poisson's ratio	Yield strength (MPa)	Tensile strength (MPa)	T-EI (%)	Thickness (mm)
L-shaped bracket	AC1500HS	7.85e-9	210000	0.3	≤500	≤700	＞16	1.8~4.5

3. Design and simulation analysis of the forming process for the lightweight fuel tank bracket in hot press forming

3.1. *Process design*

Due to the significant deformation at the corner of the fuel tank bracket, direct hot press forming cannot be used for forming. Therefore, the bracket adopts a combination of pre forming and hot forming processes. The forming process is shown in Fig. 2.

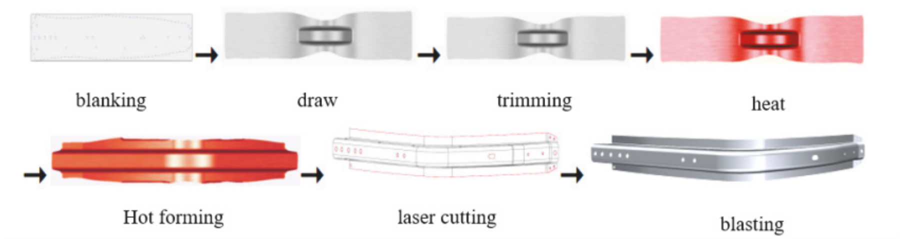


Fig. 2. Indirect hot press forming process diagram of fuel tank bracket.

3.2. *Process analysis*

3.2.1. *Establishing a model*

Design the fuel tank bracket using Siemens NX software for numerical modeling, and then create a finite element model using AutoForm software. The material parameters used in the simulation process are: elastic modulus of 200GPa, density of 7.85e-9 t/mm^3, Poisson's ratio of 0.3, and Coulomb friction coefficient of 0.35. The model adopts a single action mold type, with the convex and concave molds set as rigid bodies during the stamping process, and the sheet metal as a three-dimensional deformable entity. The forming process is reverse stretching forming. In order to facilitate the demolding of the formed parts, the draft angle for the side bending of the parts was changed from 1 ° to 3 °. The analysis model for the bending forming of the L-shaped fuel tank bracket is shown in Fig. 3. [3].

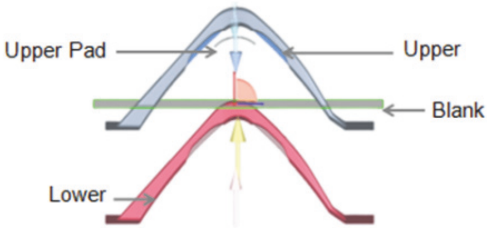


Fig. 3. Analysis model of forming process.

3.2.2. *Parameter settings*

According to relevant research from Ansteel, the AC1500HS material has a temperature point of 822 ℃ for Ac3, a temperature point of 394 ℃ for Ms, a heating temperature of 950 ℃, an austenitization holding time of 10 minutes, an initial deformation temperature controlled between 800~900 ℃, a deformation rate of 0.4/s, and a quenching cooling rate of 35 ℃/s. The other parameters of AC1500HS material are shown in Table 2, and its CCT curve is shown in Fig. 4. Set the cooling rate to 35 ℃/s and the final temperature of the plate to 20 ℃.

Table 2. Relevant parameters of AC1500HS material.

Parameter	Coefficient of expansion (1/K)	Young's modulus (GPa)	Volume hot melt ($mJ\cdot mm^{-3}\cdot K^{-1}$)	Thermal conductivity coefficient ($w\cdot m^{-2}\cdot K^{-1}$)	Coulomb friction coefficient
Numerical value	1.3×10^{-5}	105	4.37	20℃ 20 950℃ 75	0.35

3.2.3. *Analysis results*

Based on the above settings, simulation analysis was conducted, and the results are shown in Fig. 5. There are thinning and cracking phenomena at the corners.

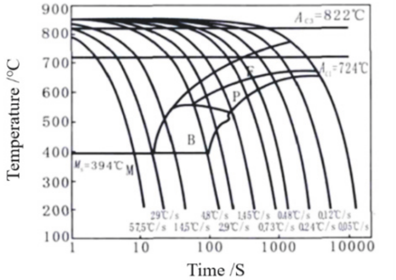


Fig. 4. CCT curve of AC1500HS material.

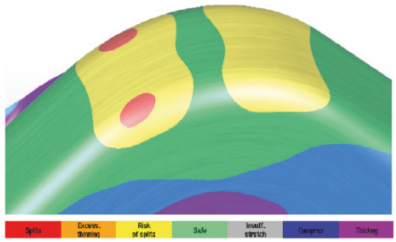
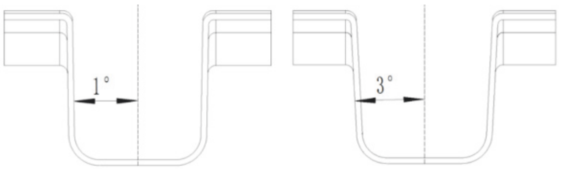


Fig. 5. Analysis results of forming process.

4. Optimization design

After analysis, it was found that the stretching depth and deformation at the corners of this product were significant, with a draft angle of 1 ° on both sides. The draft angle was too small, which was not conducive to product forming and demolding. Based on experience, the draft angle was optimized to 3 °, and the comparison of optimization schemes is shown in Fig. 6.



(a) Optimized draft angle of 1 ° before optimization (b) Optimized draft angle of 3 °

Fig. 6. Comparison of design schemes before and after optimization.

5. Simulation analysis of forming process

After optimizing the product structure, simulation analysis shows that the hot press forming process meets the design requirements. The simulation results of the forming process are shown in Fig. 7. After the forming is completed, there is no wrinkling phenomenon on the surface of the part.

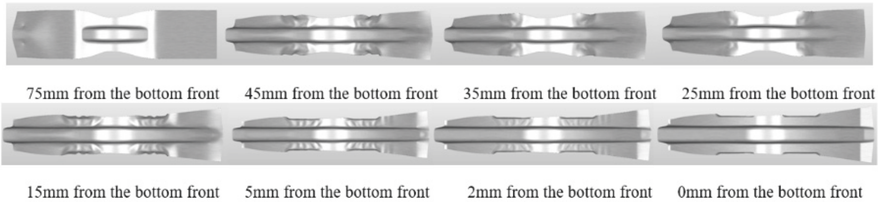


Fig. 7. Forming process diagram.

The analysis results such as the distribution map of thinning amount and the forming limit map are shown in Fig. 8. The distribution cloud map of the thinning amount of the fuel tank bracket is shown in Figure 8a, with a maximum thickening of 15.5% and a maximum thinning of 19.6%. The cracking phenomenon at the corner disappears. Therefore, the optimization plan is effective and the results meet the design requirements.

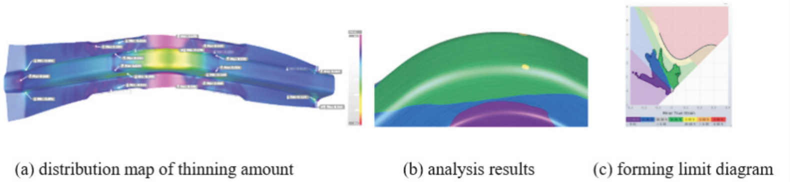


Fig. 8. Analysis results of forming process.

6. Conclusion

Combining the difficulty of demolding during the production process of fuel tank brackets and the problem of thinning and cracking analyzed by CAE, the demolding angle of the bracket is changed from 1 ° to 3 °. This not only ensures smooth demolding, but also avoids serious thinning and cracking problems during part forming.

The L-shaped structure of the fuel tank bracket has certain difficulties in forming during hot stamping, so it is determined to adopt a stamping process of local pre forming first and then hot press forming to ensure the formability of the workpiece during the forming process.

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