International Journal of Mechanical and Electrical Engineering
ISSN: 3005-9615 (Print), ISSN: 3005-7132 (Online) | Volume 2, Number 2, Year 2024
DOI: https://doi.org/10.62051/ijmee.v2n2.14
Journal homepage: https://wepub.org/index.php/IJMEE/index

Research on Key Technologies for Optimization of Forming Parameters of Aluminum Alloy Hood Outer Panel

Congbiao Liu *

Tianjin University of Technology and Education, Tianjin, China
* Corresponding Author: Congbiao Liu

ABSTRACT

At present, computer technology and finite element software analysis technology have been widely used in the stamping and forming process of aluminum alloy hood outer plate to predict the possible quality defects in the stamping process, and effectively improve the quality and production efficiency of parts. The stamping and forming of the outer plate of the automobile aluminum alloy hood is a highly nonlinear process, and its forming quality involves many forming factors, if the variable design is not reasonable, it may lead to quality defects such as wrinkles or cracks of the molded parts. Due to the relatively complex shape and structure of the aluminum alloy hood outer plate and its high requirements for the quality of forming, it is difficult to obtain the optimal process parameters in a short time if the finite element software simulation optimization is carried out manually. The machine learning algorithm is applied to the research on the stamping and forming of the outer plate of the aluminum alloy hood, and the multi-objective genetic algorithm is used to optimize the stamping process parameters of the covers, which can meet the maximum thinning rate of the formed parts and control the rebound of the formed parts to a certain extent. How to combine machine learning algorithms with finite element simulations to reasonably adjust the process parameters in the stamping and forming process by using machine learning algorithms to meet the forming quality requirements of aluminum alloy hood outer plate has always been a research hotspot and difficulty in the field of aluminum alloy hood outer plate stamping.

KEYWORDS

Stamping and Forming; Process Parameter Tuning; Genetic Algorithm.

1. INTRODUCTION

As one of the important components of modern industrial production in China, the automobile manufacturing industry is of great significance in promoting the development of China's economy and improving the living standards of its people. With the acceleration of economic globalization and marketization, the automotive manufacturing industry is facing unprecedented and severe challenges. In the current era, exploring ways to improve the efficiency of automobile manufacturing, reduce automobile production costs, and improve the quality of automobile production is of great practical and long-term significance.

The aluminum alloy engine hood outer panel, as an important component of the car's appearance, not only protects the internal components of the car, but also affects the overall aesthetics and safety of the car [2,3]. Aluminum alloy engine hood outer plate stamping is a process of stamping metal sheets into various specified shapes through molds, widely used in fields such as automobiles, electronics, and home appliances. In the process of automobile manufacturing, compensation for the mold surface of the covering parts is one of the crucial links, and its quality directly affects the overall performance

Content from this work may be used under the terms of CC BY-NC 4.0 licence (https://creativecommons.org/licenses/by-nc/4.0/).
Published by Warwick Evans Publishing.

and safety of the car [5,6]. Therefore, studying and mastering the surface compensation of aluminum alloy engine hood outer panel molds is of great significance for improving the quality and production efficiency of automobile manufacturing [7].

In recent years, with the integration of computer technology and manufacturing, a digital production form has been formed, and the compensation of the aluminum alloy engine hood outer panel mold surface has become an important part of the automotive manufacturing industry production [8].

2. ALUMINUM ALLOY ENGINE HOOD OUTER PANEL FORMING BASED ON DYNAFORM

2.1. Process Analysis of Aluminum Alloy Engine Hood Outer Panel

The main research content of this article is to analyze the problems that may occur during the stamping process of the automotive hood outer panel (Figure 1), such as tensile cracks or wrinkles, which affect the forming quality.

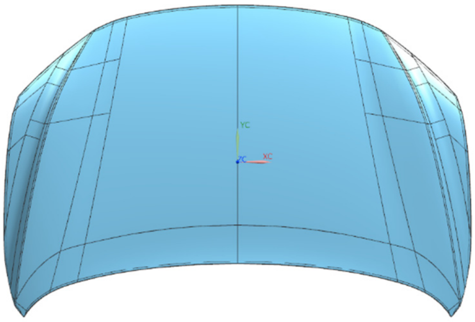

Figure 1. Top view of the three-dimensional model of the car hood outer panel

The part is symmetrical as a whole, with complex shapes and relatively large surface area, and the overall changes during stamping forming are relatively small. There are two obvious edges on the surface of the part, while the other areas are relatively flat. The overall height difference of the part is not large, and it is not easy to undergo plastic deformation during the forming process, which can easily cause rebound and cause changes in the overall shape of the part. Due to the fact that the aluminum alloy outer panel is equivalent to a car facade, it has high requirements for forming quality. During the forming process, it is necessary to select the optimal forming parameters to ensure sufficient surface forming of the parts and reduce rebound. Therefore, it is necessary to ensure that the thinning rate of the formed parts is not higher than 25% and the thickening rate is less than 10%. In order to ensure the quality of the formed parts, it is necessary to carry out integrated design from material selection to optimization of stamping parameters.

2.2. Material Properties

Based on the aluminum alloy engine hood outer plate blank provided by a certain automotive mold company, it is determined to be E170 aluminum plate. The specific properties of this aluminum plate are as follows:

Table 1. Performance of E170 Aluminum Plate

Sheet thickness/mm	Yield strength/MPa	Tensile strength/MPa	Elongation rate/%	N-value	R-value
0.9	121	238.2	22.0-25.6	0.249	0.585

3. ESTABLISHMENT OF RESPONSE SURFACE MODEL

3.1. Constructing an Approximate Model

According to context analysis, the sampling spaces for edge holding force, stamping speed, and mold clearance are set to [150, 250], [2000, 4000], and [0.99, 1.12], respectively. Use Isight software to randomly select 30 sets of data from the interval range of the above parameters, and input the data into the finite element simulation software Dynaform for simulation to calculate the maximum thinning rate, providing data support for subsequent model construction.

Table 2. Optimal Latin hypercube sampling data

number	Edge pressure force kN	Stamping speed mm/s	Mold clearance mm	Maximum thinning rate%
1	230	2697.132	1.102	27.451
2	219	2802.026	0.996	26.796
3	236	2865.353	0.991	28.625
4	211	2865.353	1.071	26.435
5	193	2994.632	1.136	24.921
6	150	2585.289	1.009	18.498
7	236	2593.462	1.118	27.422
8	179	2994.632	1.085	19.673
9	248	3862.899	1.136	32.853
10	190	3790.568	1.085	24.784
11	205	2699.038	0.995	26.131
12	202	2660.77	1.034	26.582
13	183	2673.435	1.102	19.231
14	155	2994.632	1.001	19.514
15	190	2697.132	0.992	20.229
16	180	2585.289	0.991	19.013
17	241	2152.929	0.969	24.043
18	187	3890.806	1.053	24.021
19	208	2994.632	1.042	26.679
20	247	2560.723	1.106	28.664
21	199	2487.256	0.995	23.221
22	167	2673.435	1.001	18.151
23	203	3232.022	1.041	27.754
24	172	2394.256	0.995	18.507
25	250	3883.093	1.115	32.861
26	152	2560.723	1.009	18.583
27	228	2593.462	1.115	27.211
28	197	2994.632	1.042	26.012
29	224	2115.412	1.026	23.182
30	158	2340.965	0.991	18.098

4. OPTIMIZATION OF OPTIMIZATION PARAMETERS BASED ON MULTI-OBJECTIVE GENETIC ALGORITHM

4.1. Mathematical Model Construction

For the research object of this article, the optimization objectives of the aluminum alloy engine hood outer plate are determined to be the thinning rate of the formed part and the springback amount of the formed part, while the blank pressure, stamping speed, and mold clearance are the parameters that need to be optimized. The range of values and correlation of these parameters have been studied in the previous chapters, and a quadratic response surface model has been established for these parameters in Chapter 4 of this article. Based on the above research, the fitness function for genetic algorithm optimization of the aluminum alloy engine hood outer panel can be summarized as formula (1):

$$\begin{gathered} \min F(x) = G \\ 150 \le x_1 \le 250 \\ 2000 \le x_2 \le 4000 \\ 0.9 \le x_3 \le 1.2 \end{gathered} \tag{1}$$

4.2. Genetic Algorithm Optimization

Import data through the program and first initialize the population. Then, further optimization will be carried out based on the optimization methods mentioned in the appeal. As the end conditions in genetic algorithms are mainly set to two levels, one is to achieve the specified fitness, and the other is to achieve the specified number of iterations. The main application of this algorithm is to optimize the parameters of the aluminum alloy engine hood outer panel, obtain the optimal thinning rate and smaller rebound amount, and thus obtain the optimized stamping parameters. Through extensive program tuning, it was found that when the population size is 50, the algorithm tends to stabilize after 120 iterations, and converges after 150 iterations.

After 150 iterations of the genetic algorithm, its minimum fitness value approaches 18.354%, which means using the genetic algorithm to optimize its minimum prediction value to be 18.354%. The corresponding parameter sizes for this result are: edge holding force=165KN, stamping speed=2585.34mm/s, and mold gap=1.004mm. At these values, the maximum thinning rate and rebound amount of the aluminum alloy engine hood outer plate perform well.

4.3. Optimization Results and Experimental Validation

4.3.1. Finite Element Simulation of Optimization Results

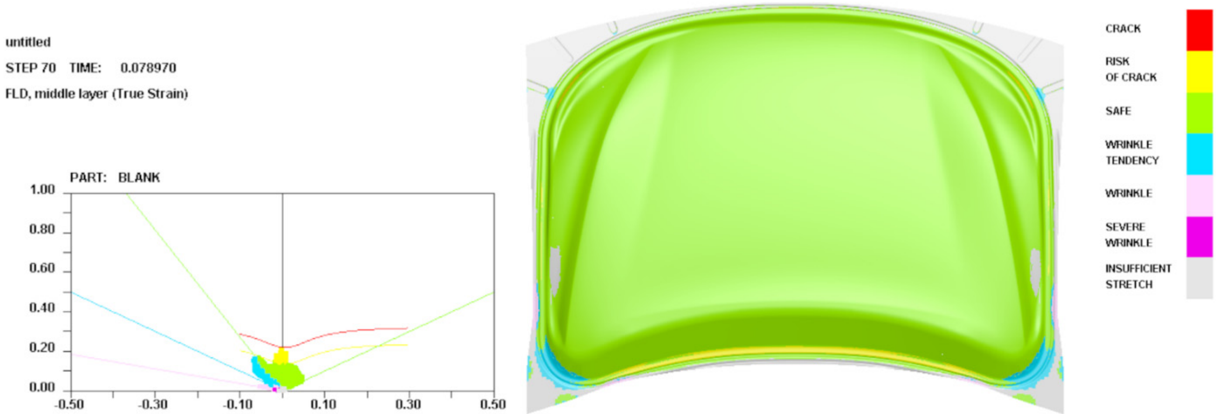

Figure 2. Forming Limit Point Cloud of Aluminum Alloy Engine Hood Outer Panel

The results of the genetic algorithm solution in the previous section, namely the blank holding force=165KN, stamping speed=2585.34mm/s, and mold gap=1.004mm, were imported into the finite element software Dynaform. Finite element simulation was performed on the aluminum alloy engine hood outer plate, and the simulation results were exported to obtain the forming limit diagram (2).

Analysis of the results of Dynaform shows that under this parameter combination, the overall forming quality of the aluminum alloy engine hood outer panel is good, with most areas within the safe zone and no defects. The maximum thinning rate of the aluminum alloy engine hood outer panel is 17.554%, fully meeting production requirements. By comparing and analyzing the predicted values of the genetic algorithm with the simulation values using Dynaform, it can be concluded that the error between the two is 4.557%, with an error range within the 5% standard. It can be concluded that the response surface model is used to construct the fitness function of the genetic algorithm, and then genetic algorithm is used to optimize the stamping parameters of the aluminum alloy engine hood outer plate. The obtained optimization parameters can be directly applied to the stamping production of the aluminum alloy engine hood outer plate, providing relatively accurate forming quality prediction support for enterprise production.

4.3.2. Experimental Verification

According to the finite element analysis of the optimization parameters in the previous section, the error between the predicted results and the simulation results is within 5%, which meets the standard error requirements. The mathematical model obtained through response surface modeling and based on this, a fitness function is constructed for genetic algorithm, and parameter optimization is carried out to accurately predict the quality of stamping forming of aluminum alloy engine hood outer panels.

The optimized parameters, including edge pressure, stamping speed, and mold clearance, are provided to a certain automotive mold factory for experimental verification. Figures 3 show the finished product images verified by physical experiments. By observing the entities in Figures 5-10, it can be seen that the aluminum alloy engine hood outer panel has a good forming effect under this parameter, with a smooth forming surface and no defects such as wrinkles or cracks. The genetic algorithm based on response surface model can provide effective support for parameter optimization of aluminum alloy engine hood outer plate stamping forming, effectively improve quality defects and other problems that occur during the stamping forming process, and shorten the optimization cycle of aluminum alloy engine hood outer plate parameters. For the optimized parameter combination, during the physical experiment, the final formed part meets the production standards of the enterprise.

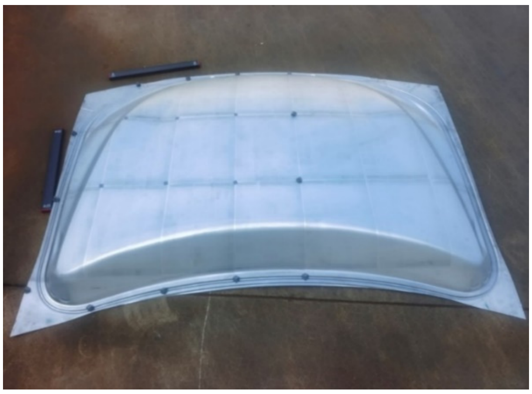

Figure 3. Experimental Results

5. SUMMARY

The stamping forming of aluminum alloy engine hood outer panel is a highly nonlinear process, as this component is prone to defects such as wrinkling and cracking that affect the quality of the formed part during the stamping forming process. These quality defects in the formed parts pose certain safety hazards for subsequent automotive assembly. This article takes the aluminum alloy engine hood outer panel of a certain automobile mold factory as the research object. The optimal Latin hypercube sampling method is used for data sampling. Based on this, a response surface model is used to construct the fitness function of the genetic algorithm. Finally, a genetic algorithm program is written to optimize the stamping parameters of the aluminum alloy engine hood outer panel.

REFERENCES

[1] Duan Lei, Cai Yujun, Mo Guoqiang, et al. Research on Springback Simulation and Die Surface Optimization of Automotive Panel Forming [J]. Forging Technology, 2010,35 (02): 34-38.

[2] Huang Juan, Huang Bo, Qiao Xiaobing, et al. The Application and Challenges of Deformed Aluminum Alloy in Automotive Lightweight [J]. Automotive Technology and Materials, 2022, (09): 15-18.

[3] Park, Dong Hwan, Kwon, Hyunk Hong Development of warm forming parts for automotive body dash panel using AZ31B magnetic alloy sheets [J] International Journal of Precision Engineering and Manufacturing, 2015, 16 (10): 2159-2165.

[4] Yang Yugui, Ding Zhe, Hu Jianquan. Research on Standardization of Stamping Process Plan for Automotive Cover Parts Top Cover [J]. Mold Manufacturing, 2021,21 (07): 8-12.

[5] Dong Y Optimization and Prediction of Aluminum Alloy Stamping Forming Parameters Based on Gray Correlation [J] International Journal of Frontiers in Engineering Technology, 2023,5 (5).

[6] Yanmin X, Kai F, Meiyu D, et al. Analysis and optimization of the stamping process with pretreated 7A09 aluminum alloy [J] The International Journal of Advanced Manufacturing Technology, 2023128 (1-2): 669-683.

[7] Wei L, Wenchao X, Yong L, et al. Machine learning in the prediction of formability in aluminum hot stamping process with multiple variable blank holder force [J] International Journal of Computer Integrated Manufacturing, 2023,36 (5): 702-712.

[8] Wenchao X, Hanrong C, Wei L, et al. Multi objective optimization with automatic simulation for partition temperature control in aluminum hot stamping process [J] Structural and Multidisciplinary Optimization, 2022, 65 (3).

[9] Cai, Hanrong, Xiao, et al. The prediction of part thickness using machine learning in aluminum hot stamping process with partition temperature control [J] The International Journal of Advanced Manufacturing Technology, 2022119 (5-6): 1-12.

[10] Francisco A S D, Silva A F M, Benedito J O S D, et al. Multi objective optimization and fine element method combined with optimization via Monte Carlo simulation in a stamping process under uncertainty [J] The International Journal of Advanced Manufacturing Technology, 2021117 (1-2): 305-327.