

Optimization of Drawbead Resistance Based on Orthogonal Experiment

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Abstract. The impact of drawbead resistances on the stamping process of an automobile panel was investigated based on orthogonal experiment. Simulations based on Dynaform were conducted and two optimal objects that the maximum ratio of thickness reduction (MRTR) and average thickness in deformation region (ATDR) are extracted from simulation results. Optimal drawbead resistances in different weighting coefficients of the two objects have been found. Appropriate weighting coefficients are obtained by verification simulations. The results provide guidance to the practical fabrication.

Introduction

Automobile panel stamping is a typical deep drawing process. Many process parameters influence the product quality greatly [1]. Wrinkling, spring back and rupture are the main defects of automobile cover panels. So as to resolve the problem, drawbeads are widely applied in practical producing. In many cases, whether drawbeads setting is suitable or not determines the feasibility of the stamping process. The method "trial and error" is often used in practical producing, which needs repeated reparation and test, thus greatly increases the fabricating cost [2].

In the finite element analysis (FEA), if geometric drawbeads are adopted, there will be a complex task of drawbeads modeling and meshing. FEA solving time will increase significantly. Equivalent drawbeads are applied extensively in mainstream CAE software. Schematic drawing of a semicircular drawbead provided by Dynaform is shown in Fig. 1. Geometric drawbead models can be determined by equivalent drawbeads. When the required resistances are extremely large, multiple parallel drawbeads are set.

Drawbead resistances behavior of a wheel fender based on Dynaform was investigated in this paper. Different drawbead resistances set were tested in the orthogonal experiment, and two optimal objects MRTR (represented by a) and ATDR (represented by t) were selected to evaluate the forming quality. Optimal drawbead coefficients sets in different weighting coefficients of the two objects have been found and then validated on Dynaform. The results provide guidance to practical engineering application.

FEA Simulation Models

The material of the automobile panel is DQSK36 and the blank thickness is 0.7mm. Material models are established based on the Barlat (1989) yield function [3]. BT (Belytschko-Tsay) shell elements are adopted to mesh the blank, die, punch and blank holder as shown in Fig. 2. Mechanical properties of the material are shown in Table 1. A typical forming process is blanking-drawing-trimming-resaping. Spring back is not considered as there is a final reshaping

process. Equivalent drawbeads are divided into 12 sections in drawing. Drawbead resistance coefficients are set respectively. Basic resistances are forces calculated automatically when the blank is locked completely [4]. Other parameters are set automatically in Dynaform.

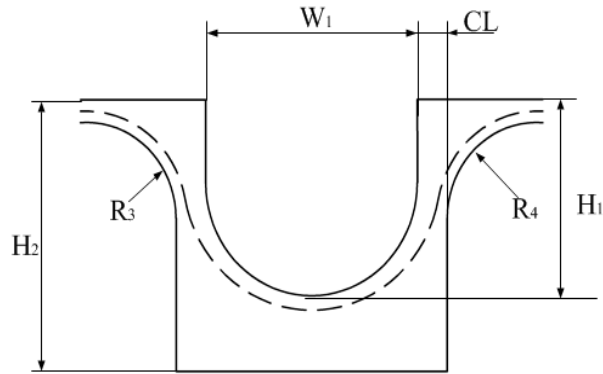


Fig. 1 Schematic drawing of a semicircular drawbead

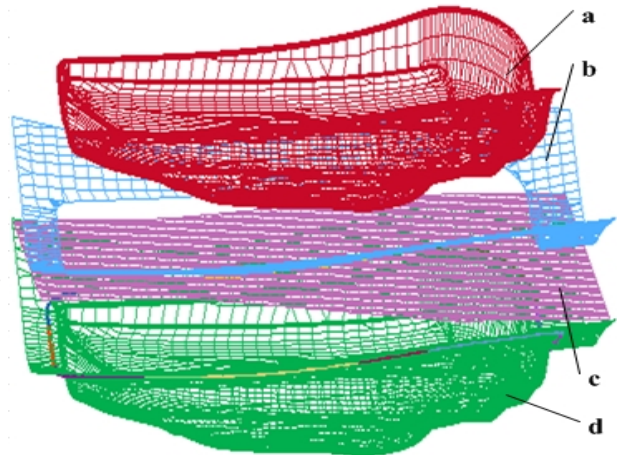


Fig. 2 Finite element models
(a) punch, (b) binder, (c) blank, (d) die

Table 1 Mechanical properties of DQSK36.

Density (t·mm ³)	Elastic modulus (MPa)	Poisson ratio	Intensity coefficient k (MPa)	Harding Index n	Anisotropy coefficient r		
					r_0	r_{45}	r_{90}
7.85e-9	2.07e-5	0.28	520.4	0.232	1.73	1.35	2.18

The Design of Orthogonal Experiment

In the orthogonal experiment, 12 drawbead resistance coefficients are set as 12 factors. The basic level 2 is based on previous experience of similar process. Drawbeads are set end to end, thus avoiding the edge-effects. Factor levels are shown in Table 2. An orthogonal table $L_{27}(3^{12})$ is used to design the orthogonal experiment.

Table 2 Values of factor and level used in orthogonal design.

level	Drawbead resistance coefficient (%)											
	1	2	3	4	5	6	7	8	9	10	11	12
1	35	40	35	30	40	10	15	60	55	30	40	25
2	45	50	45	40	50	20	25	70	65	40	50	35
3	55	60	55	50	60	30	35	80	75	50	60	45

Data Analysis & Simulation Results

The experiment result is shown in Table 3. For a multi-objective optimization, there will be a transformation into single-objective optimization, and establishment of a comprehensive evaluation. Therefore, two objects are mapped to a numerical scores range [0,100] [5]. The proper reduction of thickness is generally considered to be from 2% to 30%, so the proper ARTR in this case is from 0.4900 to 0.6860. A synthetic weighted mark method was adopted to evaluate the experimental data. The overall indicator q is calculated by Eq. 1.

$$q=\mu_1 y_1+\mu_2 y_2. \quad (1)$$

Where μ_1 and y_1 are the weighting coefficient and mapping value of MTRT and μ_2 , y_2 are the weighting coefficient and mapping value of ATDR.

Meanwhile, there is a relation between μ_1 and μ_2 in Eq. 2.

$$\mu_1+\mu_2=1. \quad (2)$$

Mapping values y_1 and y_2 are calculated respectively by Eq. 3 and Eq. 4.

$$y_1=-357.14a+107.14, \quad (3)$$

$$y_2=510.20t-250.00. \quad (4)$$

When μ_1 , μ_2 are in different value, optimal coefficients of drawbead resistance obtained by Eq. 1 are shown in Table 4.

Table 3 Orthogonal experiment results.

Test	Factors												MTRT	ATDR
	1	2	3	4	5	6	7	8	9	10	11	12	(%)	(mm)
1	35	40	35	30	40	10	15	60	55	30	40	25	30.9414	0.6608
2	35	40	35	30	50	20	25	70	65	40	50	35	34.6436	0.6473
3	35	40	35	30	60	30	35	80	75	50	60	45	67.7245	0.6269
4	35	50	45	40	40	10	15	70	65	40	60	45	47.3406	0.6462
5	35	50	45	40	50	20	25	80	75	50	40	25	60.2538	0.6379
6	35	50	45	40	60	30	35	60	55	30	50	35	76.9011	0.6358
7	35	60	55	50	40	10	15	80	75	50	50	35	58.5451	0.6359
8	35	60	55	50	50	20	25	60	55	30	60	45	45.0074	0.6374
9	35	60	55	50	60	30	35	70	65	40	40	25	80.3156	0.6265
10	45	40	45	50	40	20	35	60	65	50	40	35	64.6967	0.6447
11	45	40	45	50	50	30	15	70	75	30	50	45	55.9325	0.6412
12	45	40	45	50	60	10	25	80	55	40	60	25	80.9712	0.6335
13	45	50	55	30	40	20	35	70	75	30	60	25	61.0946	0.6423
14	45	50	55	30	50	30	15	80	55	40	40	35	34.4612	0.6441
15	45	50	55	30	60	10	25	60	65	50	50	45	47.7795	0.6404
16	45	60	35	40	40	20	35	80	55	40	50	45	66.5534	0.6343
17	45	60	35	40	50	30	15	60	65	50	60	25	47.6287	0.6412
18	45	60	35	40	60	10	25	70	75	30	40	35	75.3569	0.6363
19	55	40	55	40	40	30	25	60	75	40	40	45	46.4354	0.6461
20	55	40	55	40	50	10	35	70	55	50	50	25	54.0149	0.6412
21	55	40	55	40	60	20	15	80	65	30	60	35	71.7069	0.6351
22	55	50	35	50	40	30	25	70	55	50	60	35	41.0041	0.6409
23	55	50	35	50	50	10	35	80	65	30	40	45	64.5327	0.6332
24	55	50	35	50	60	20	15	60	75	40	50	25	78.4393	0.6391
25	55	60	45	30	40	30	25	80	65	30	50	25	36.8041	0.6395
26	55	60	45	30	50	10	35	60	75	40	60	35	58.7977	0.6387
27	55	60	45	30	60	20	15	70	55	50	40	45	49.9884	0.6398

Table 4 Optimal drawbead resistances in different weighting coefficient of MRTR and ATDR

μ_1	Optimal drawbeads resistance coefficient level											
	1	2	3	4	5	6	7	8	9	10	11	12
0.9	1	1	3	1	1	3	2	1	1	3	1	3
0.8	1	1	3	1	1	3	2	1	1	3	1	3
0.7	1	1	3	1	1	3	2	1	1	3	1	3
0.6	1	1	3	1	1	3	2	1	1	3	1	3
0.5	1	1	3	1	1	3	2	1	1	3	1	3
0.4	1	1	3	1	1	3	1	1	1	3	1	3
0.3	1	1	3	1	1	3	1	1	1	3	1	3
0.2	1	1	3	1	1	3	1	1	1	3	1	3
0.1	1	1	1	1	1	1	1	1	1	3	1	3

Verification experiments were conducted and results are shown in Table 5. From Table 5 we can conclude that the proper weighting coefficients range of μ_1 in this case is likely to be [0.2, 0.4].

Table 5 Verification results of different weighting coefficient.

μ_1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
a (%)	35.530	35.530	35.530	35.530	35.530	29.9252	29.9252	29.9252	30.6460
t (mm)	6.6710	6.6710	6.6710	6.6710	6.6710	6.6581	6.6581	6.6581	6.6582

Conclusions

No significant variations of MRTR are observed in different drawbead resistances, but variations of ATDR are remarkable. A feasible method based on orthogonal experiment is proposed for multi-objective optimization about drawbeads in metal sheet forming. Proper weighting coefficients of MRTR and ATDR are found, which provides guidance to the practical fabrication.

Acknowledgments

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