

Chapter 48

Optimization of Design Parameters of Circular Burring

Wenshan Fu, Yinzhi He and Chunyang Lu

Abstract The paper presents an example of an automotive handle bracket. The design parameters of burring include fillet radius R , burring diameter D and burring height H , which are all analyzed in this paper. The objective function is thinning rate of parts. By using quadratic regression, a mathematical model between objective function and design parameters can be established, which can be guidance while selecting design parameters of burring.

Keywords Burring · Quadratic regression · Numerical simulation

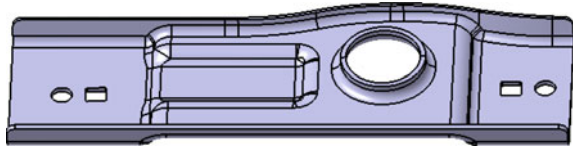
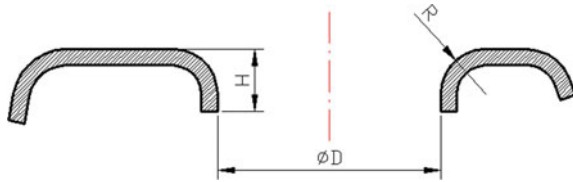
48.1 Introduction

Burring is one of the most commonly used features for stamping parts. It can not only increase the local strength of parts, but also reduce the requirements of the sections' quality, such as assembly holes, threading holes, etc.

Burring, a special kind of flanging, belongs to stretch flanging. The deformation of material is much severer than ordinary flanging. In the stamping process, some defects are very likely to occur, such as crack, thinning, non-perpendicularity [1, 2] etc. There are some methods of eliminating those defects: Adding one or more preforming process to ensure that there is enough material in the process of deformation [3]; using smaller clearance to ensure the burring perpendicularity; adding fine blanking technology to ensure the quality of the burring [4], etc. These methods can reduce the defects of burring, but also lead to rising costs and shorter service life of dies.

Nowadays in the design stage of products, the design of burring is based on experience or optimized to the performance target. The feasibility of manufacturing and cost are controlled by SE engineers [5–7]. This paper uses the automotive handle bracket as an example, establishes the mathematical model between the

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Fig. 48.1 Handle bracket**Fig. 48.2** Burring design parameters (section)

design parameters and manufacturing process, in order to find out the best design parameters that require simpler manufacturing process and lead to lower cost and stabilized products.

48.2 Burring and Design Parameters

Figure 48.1 shows the automotive handle bracket. Burring can not only eliminate the influence of the burr on the assembly precision, but also increase the local strength of surrounding area of the hole.

The main design parameters of burring include fillet radius R , burring diameter D and height H , as Fig. 48.2 shows. In addition, material also plays an important part in the design of burring. In this research, the influence of material is neglected. The handle bracket's material is B250P1, and the yield strength is 250–360 MPa, the tensile strength is not less than 440 MPa and the elongation is approximately 30%.

48.3 Process Analysis and Numerical Simulation

48.3.1 Process Analysis

Manufacturing process analysis was carried out on the handle bracket. Figure 48.3 shows the preliminarily determined manufacturing processes: blanking, forming, piercing and burring.

In the manufacturing process, external flanging is primarily formed, which eliminates the influence of external material flow on the performance of the hole. In this paper, only the influence of three design parameters (burring diameter D , height H and fillet radius R) is considered. The main effect of diameter D and height H lies in their ratio, i.e. H/D [8]. Considering the particularity of the part, this paper makes

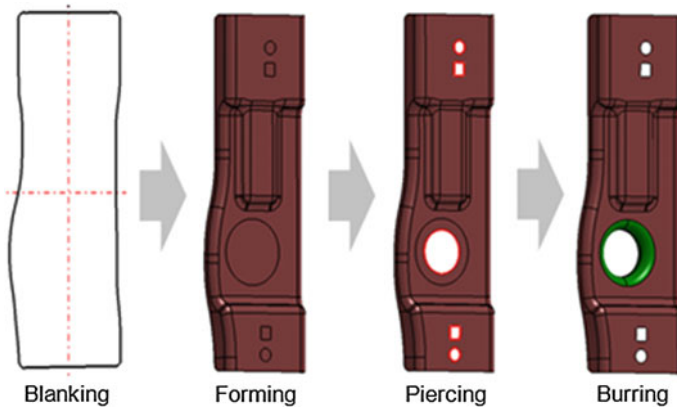


Fig. 48.3 Manufacturing process of handle bracket

an analysis within a scope, namely $H/D \in [0.08, 0.48]$, $R \in [2.5, 7.0]$ and sets the maximum thinning rate as objective function to optimize the parameters.

48.3.2 Numerical Simulation

Process data are imported into numerical simulation software AutoForm and relevant process parameters and tools are set [9, 10], and then begin to analyze the forming performance. The results can be seen in Fig. 48.4.

Figure 48.4 shows the thinning rate of the burring. The maximum thinning rate can be seen in the left figure, and the right one is the Forming Limit Diagram (FLD) [11]. When the thinning rate is not more than the limit value, there will be no crack.

The design parameters fillet radius R and H/D are grouped, and numerical simulation was carried out on the thinning rate of the part. Table 48.1 shows the result.

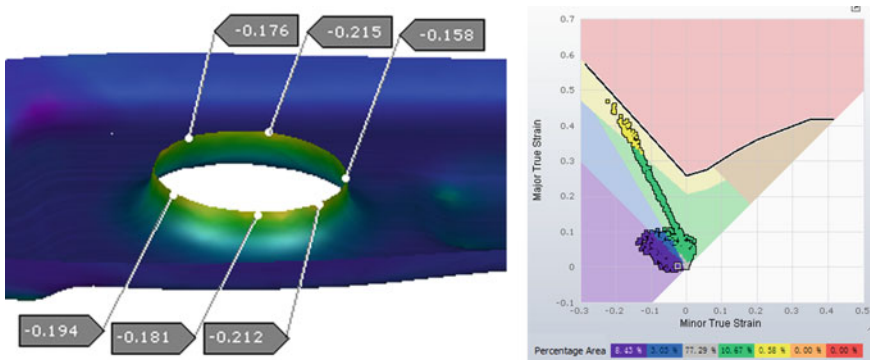
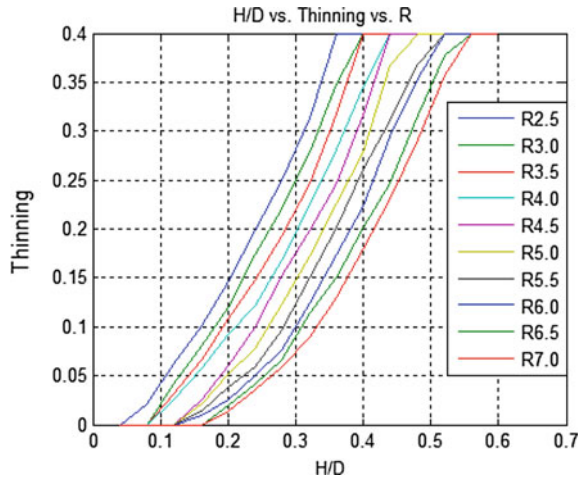


Fig. 48.4 The result of forming thinning rate of the part

Table 48.1 Design parameters and maximum thinning rate

R	H/D										
	0.08	0.12	0.16	0.20	0.24	0.28	0.32	0.36	0.40	0.44	0.48
2.5	0.021	0.062	0.101	0.146	0.199	0.250	0.313	–	–	–	–
3.0	0.010	0.045	0.081	0.125	0.174	0.221	0.278	0.349	–	–	–
3.5	0.006	0.030	0.066	0.108	0.148	0.193	0.246	0.318	–	–	–
4.0	0.003	0.015	0.053	0.086	0.121	0.168	0.225	0.281	0.365	–	–
4.5	0	0.006	0.035	0.065	0.099	0.146	0.199	0.252	0.317	–	–
5.0	0	0.002	0.021	0.045	0.078	0.123	0.173	0.226	0.279	0.368	–
5.5	0	0	0.012	0.035	0.059	0.097	0.148	0.201	0.250	0.330	0.385
6.0	0	0	0.005	0.025	0.050	0.077	0.125	0.174	0.224	0.294	0.354
6.5	0	0	0	0.019	0.041	0.066	0.105	0.150	0.202	0.260	0.316
7.0	0	0	0	0.014	0.035	0.059	0.090	0.130	0.179	0.230	0.292

Fig. 48.5 The relationship among maximum thinning rate, R and R/D



From the result of Table 48.1 can be seen, when the maximum thinning rate is controlled within a certain range, the larger R is, the larger H/D becomes (as shown in Fig. 48.5).

48.4 Regression Analysis

48.4.1 Regression Theory

A collection of data of the function $y = f(x)$ are known, namely $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$. But the expression of the function is unknown. The regression analysis of data is to obtain a function $\varphi(x)$, an approximate model of $f(x)$, from a certain type of function (such as polynomial function, spline function, etc.). There are two

major categories of data modeling methods: one is the interpolation methods, which requires that function $\varphi(x)$ strictly complies with the data $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$. The other is the fitting method, allowing the function $\varphi(x)$ has deviation in the data points, but requires that a certain indexes reaches the minimum value. In general, the interpolation method is suitable for accurate data or smaller amount of data, and the fitting method is more suitable when there are data deviations or a larger amount of data.

Least square method is the most commonly used fitting method, which is described as followed.

Assume that function $y = f(x)$ has m function values,

$$y_i \approx f(x_i); \quad (i = 1, 2, \dots, m)$$

The least square method is to obtain a simple approximation formula $\varphi(x)$, which makes $\varphi(x_i)$ minus y_i

$$e_i = \varphi(x_i) - y_i; \quad (i = 1, 2, \dots, m)$$

has the smallest sum of the square.

$\varphi(x)$ is the least square fitting function of $(x_i, y_i), i = 1, 2, \dots, m$, $f(x)$ is the fitted function.

$y' = \varphi(x)$, namely empirical formula or mathematical model, approximately reflects the function between variable x and variable y , i.e. $y = f(x)$.

48.4.2 Regression Analysis

The maximum thinning rate above is calculated by CAE simulation software, there may be some deviations, and hence the regression is used to modeling. In this study, the least square method is selected.

General regression equation is:

$$f(x, y) = a_1x^2 + a_2y^2 + 2a_3xy + a_4x + a_5y + a_6$$

x stands for the fillet radius R , y stands for height and diameter ratio H/D , $f(x, y)$ stands for the maximum thinning rate, a stands for quadratic regression coefficient. After calculation, the regression coefficients are shown in Table 48.2.

Table 48.2 Quadratic regression coefficient

Coefficient	a_1	a_2	a_3	a_4	a_5	a_6
Value	0.00375	2.24033	-0.09265	-0.02729	0.76012	0.03702

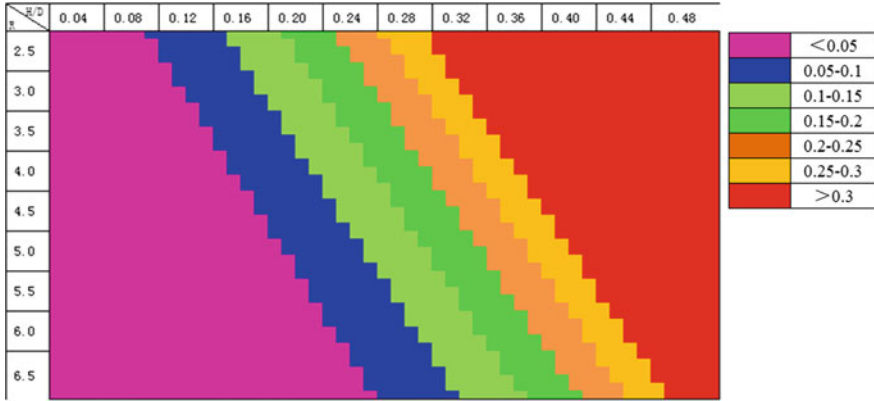


Fig. 48.6 Fillet radius R, H/D and thinning rate

Put the regression coefficient into the general equation, and the thinning rate function is obtained as follows:

$$f(x, y) = 0.00375x^2 + 2.2403y^2 - 0.1853xy - 0.02729x + 0.76012y + 0.03702$$

Burring radius R is on horizon axis, burring height and diameter ratio H/D is on vertical axis, $f(x, y)$ is expressed with different colors in the inner area, as shown in Fig. 48.6. The chart can directly reflect the relationship among H/D, R and rate thinning. In the design stage of burring, the manufacturability of the part can be intuitively estimated based on Fig. 48.6. For example, when the value of R is 4.0, if the thinning rate of burring is smaller than 0.2, the maximum value of H/D can be decided as 0.28.

48.5 Conclusion

In the design process of burring, the manufacturability should be fully considered. It is better to achieve the function of the parts with the lowest cost and the simplest form.

- (1) In the design process of products, the mathematical model between design parameters and manufacture process is established. Forming performances are calculated under the condition of different parameters;
- (2) According to the regression analysis graphics, the design parameters of burring can be intuitively chosen;
- (3) Before the design, a relevant design parameters database of burring can be established.

At the same time, we also can integrate the burring design mathematical model and performance analysis model for a multi-objective optimization, in order to select reasonable design parameters.

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