Research on deburring technology for cross hole on automobile brake master cylinder

Haiyan Hu*

College of Mechanical and Electrical Engineering, Changchun University of Science and Technology, Weixing Road 7089, 130000, Changchun, China and College of Engineering, Jilin Business and Technology College, Changchun, Kalunhu Street 1606, 130507, Changchun, China Email: 1146682054@qq.com *Corresponding author

Chunlin Tian and Jiandong Yang

College of Mechanical and Electricals Engineering, Changchun University of Science and Technology, Weixing Road 7089, 130000, Changchun, China Email: 174763298@qq.com Email: 1135324452@qq.com

Abstract: Burrs on cross hole on automobile brake master cylinder have an impact on service life and stability of the hydraulic braking system. Therefore, as for how to remove burrs on cross hole, this paper provides a flexible machining technology for deburring with the liquid impact-based fatigue fracture method. Firstly, a reasonable 3D model was established. Then Fluent software was used to conduct a numerical simulation analysis on inner flow passage of brake master cylinder in order to calculate the force condition of burrs surrounded by hydraulic oil. Next, modal analysis and harmonic response analysis on burrs were further conducted to calculate and analyse resonant frequency of burrs and verify feasibility of this method, which provides a reliable theoretical foundation for deburring methods for automobile brake master cylinder. In addition, machining technology of this method was optimised and a more reasonable machining plan was put forward, which was then applied on a machining platform and achieved great machining effect.

Keywords: automobile brake master cylinder; deburring; fatigue fracture; fluid-impact.

1 Introduction

Brake master cylinder refers to the hydraulic actuator used to generate braking force in the braking system of a vehicle. Generally, the main hole of a master cylinder intersects with four to five cross-drilled holes and burrs may be generated at intersections during machining process (Zhang, 2003). Because of existence of a seal ring on the piston in the main hole, it is possible that such seal ring may be damaged by burrs (if any) and burrs may enter into the main hole under the effect of pressure oil and thus damage such seal ring or accelerate wear of seal ring, which will result in decrease of output pressure of pressure oil, change of its output performance curve and thus cause reduction of braking effect or even cause braking failure and serious traffic accidents (Zhu, 2015). Brake master cylinder is a key component concerning safety of a finished vehicle, which is directly related to personal safety of the driver and all passengers in a vehicle (Liu et al., 2015). Therefore, research in this paper is of great significance in improving efficiency and quality of processing of brake master cylinder and reducing traffic safety hazard.

At present, there are many commonly used deburring methods, such as manual, high temperature, electrochemistry, ultrasonic, etc. But the burr at the cross hole is difficult to be removed by conventional methods, the waste rate of manual deburring is high, high temperature deburring has safety problems, the removal ability of ultrasonic deburring is limited, electrolysis pollution are serious and it is difficult to operate, so it is difficult to completely remove burrs. Fluid-impact fatigue fracture method refers to realising fatigue fracture of the root of a burr under repeated alternating load generated by direction-changing and high-pressure fluid on such burr and then removal of such burr by
the fluid (Wang, 2009). The method is more suitable for deburring of the automobile brake master cylinder. An excessively small impact cannot ensure successful deburring, but an excessively large impact will require a more powerful high pressure generator and thus result in increased initial cost and cost of use. Therefore, finite element analysis software should be used to conduct a numerical simulation analysis on internal passageway in the brake master cylinder and burrs, which provides a theoretical basis for research on deburring through fluid-impact fatigue fracture method.

2 Hydrodynamic basis of computation

Hydraulic oil in an automotive brake master cylinder is viscous incompressible fluid and the hydraulic fluid is turbulent fluid flow at the cross bore on a brake master cylinder, so the standard double equation model $k$-$\varepsilon$ (Juretic and Kozmar, 2013) based on the Navier-Stokes (RANS) equation (Balogh et al., 2012) is adopted to control the flow, for which the specific control equation is as can be seen in equation (1).

Equations for mass, momentum, kinetic energy and dissipation rate equations for kinetic energy are shown in equation (1):

$$\frac{\partial(\rho \phi)}{\partial t} + \frac{\partial(\rho U_j\phi)}{\partial x_j} = \frac{\partial}{\partial x_j} \left( \Gamma_\phi \frac{\partial \phi}{\partial x_j} \right) + S_\phi$$

(1)

In this equation, $\phi$ represents the variable, $\Gamma_\phi$ represents the coefficient of diffusion and $S_\phi$ represents the source term.

The expressions for variables, diffusion coefficients and source terms in equation (1) depicted in Table 1.

Table 1 Variables, diffusion coefficients and source terms in equation (1)

<table>
<thead>
<tr>
<th>Equation</th>
<th>$\phi$</th>
<th>$\Gamma_\phi$</th>
<th>$S_\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuity equation</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Momentum equation</td>
<td>$u$</td>
<td>$\mu_e$</td>
<td>$-\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j} \left( \mu_e \frac{\partial U_i}{\partial x_j} \right) + \frac{\partial}{\partial x_j} \left( \mu_e \frac{\partial U_j}{\partial x_i} \right) + \rho g_i$</td>
</tr>
<tr>
<td>$k$ equation</td>
<td>$k$</td>
<td>$\frac{\mu_e}{\sigma_k}$</td>
<td>$G_k - \rho \epsilon$</td>
</tr>
<tr>
<td>$\varepsilon$ equation</td>
<td>$\varepsilon$</td>
<td>$\frac{\mu_e}{\sigma_\varepsilon}$</td>
<td>$\frac{\varepsilon}{k}(C_1G_k - C_2\rho \varepsilon)$</td>
</tr>
</tbody>
</table>

In this table, $u$ represents fluid velocity, $m/s$; $\mu_e$ represents effective viscosity $kg/(m\cdot s)$, $\mu_e = \mu + \mu_s$; $p$ represents pressure, $Pa$; $x_i, x_j$ represents the coordinates of the x and y directions; $\rho$ represents density, $kg/m^3$; $k$ represents turbulent kinetic energy, $m^2/s^2$; $\varepsilon$ represents turbulent dissipation rate, $m^2/s^2$ (Versteeg, 2010); $C_1, C_2, \sigma_k, \sigma_\varepsilon$ represents constant of standard $k$-$\varepsilon$ equation, respectively; $C_1 = 1.44$, $C_2 = 1.92$, $\sigma_k = 1.3$, $\sigma_\varepsilon$ represents turbulent kinetic energy generation.
3 Analysis on flow field in pipe of automotive brake master cylinder

3.1 Geometric modelling
The three-dimensional model of the brake master cylinder of a certain type of automobile as shown in Figure 1. The internal wall surface of the brake master cylinder is extracted by using ANSYS fluid analysis software, based on which fluid area can be generated.

Figure 1 3D model of automotive brake master cylinder (see online version for colours)

3.2 Mesh generation
Mesh is spatial discretisation of a geometric model, for which rationality of mesh generation can determine reliability of result of computation in a direct way (Yan and Long, 2017). In this paper, meshing software is used to conduct mesh generation for the above geometric model and the method of tetrahedral mesh generation is chosen to realise mesh generation, in addition to which an expanding layer is set at the wall surface. There are 90,862 mesh cells and 31,501 nodes in the mesh and result of mesh generation is as shown in Figure 2.

Figure 2 Mesh generation

3.3 Setting of boundary conditions and relevant fluid parameters
Boundary conditions for fluid computation area of the model include boundary conditions of pressure inlet, pressure outlet and solid wall surface (Li et al., 2008). Operating environment under standard atmospheric pressure, the inlet pressure is 30 MPa
and the outlet pressure is 0 MPa. Contact boundary between fluid and wall surface is non-slipping wall surface. Hydraulic oil herein used should be incompressible viscous fluid (Xu, 2010). Density and dynamic viscosity of hydraulic oil are set as 872 kg/m³ and 0.028 kg/(m.s) respectively, based on which the phenomenon of no heat transfer in the pipe is computed without consideration of the gravity effect. Finite volume method is used to conduct numerical simulation of fluid channel and field inside the brake master cylinder and standard turbulence model and SIMPLE algorithm are chosen to achieve numerical solution of the control equation (Kwon et al., 2016).

4 Discussion and analysis on result of numerical simulation

4.1 Fluent analysis

Fluent software is used to achieve solution for the model, for which the result is shown in Figure 3.

Obviously, Figure 3(a) indicates that pressure has order-based progressive decrease in the brake master cylinder and outlet pressure is far less than inlet pressure, which meets the set boundary conditions. There is an obvious pressure difference at the intersecting bore of the brake master cylinder, which facilitates deburring.

Figure 3 Numerical simulation analysis nephogram of flow field, (a) static pressure (b) dynamic pressure (c) velocity (d) turbulence intensity (see online version for colours)
Research on deburring technology

Figure 3  Numerical simulation analysis nephogram of flow field, (a) static pressure (b) dynamic pressure (c) velocity (d) turbulence intensity (continued) (see online version for colours)

Figure 3(b) indicates that as for the brake master cylinder, dynamic pressure at the inlet of cross bore is the largest, while dynamic pressure at the outlet is the smallest and dynamic pressure in the main bore decreases progressively. The larger the dynamic pressure, the higher the ability of hydraulic oil in deburring with fluid impact-based fatigue fracture method in the area will be. It can be seen in the figure that at the intersection of main bore and cross bore on the brake master cylinder, pressure at the inlet is the largest because of the impact of turbulence. The maximum pressure around the burr is $2.07 \times 10^7$ Pa and pressure at the root of the burr is larger than pressure at the head, so it can be ensured that deburring can be realised in a better way.

Based on the velocity nephogram in Figure 3(c), when hydraulic oil enters into a relatively thin intersecting bore from the cross bore, speed of hydraulic oil increases suddenly, which facilitates removal of cross-bore burrs at the intersecting bore. It can be known based on the figure that the maximum speed appears at the intersection of the cross bore and the main bore on the brake master cylinder.

Based on the turbulence intensity nephogram in Figure 3(d), turbulence intensity at the cross bore of brake master cylinder is the largest and increase of turbulence intensity at the intersecting bore is obvious, for which activity of hydraulic oil at the intersecting bore is instantaneously enhanced. Therefore, hydraulic oil at this segment has the most intense movement, which can ensure effective deburring.
4.2 Modal analysis

Burrs at the internal intersection are mainly uniform burrs with a height of 1–2 mm and thickness of 0.1–0.2 mm. A specific burr can be simplified as a cantilever and its cross section is a rectangle with a width of 0.2 mm, a thickness of 0.1 mm and a height of 1 mm.

Material and properties of the brake master cylinder researched in this paper is as shown in Table 2.

Table 2 Material and properties of the brake master cylinder in this paper

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (kg/m³)</th>
<th>Elastic modulus (MPa)</th>
<th>Poisson’s ratio</th>
<th>Fatigue limit strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast aluminium alloy (ZL107)</td>
<td>2.7 × 10³</td>
<td>7.2 × 10⁴</td>
<td>0.33</td>
<td>32</td>
</tr>
</tbody>
</table>

For the purpose of making resonant frequency reach the inherent frequency under the effect of alternating load, model analysis on a burr is conducted. A burr should be imported into the model and a fixed constraint should be imposed at its left side, after which its inherent frequency and corresponding mode of vibration are calculated through ANSYS workbench finite element simulation, based on which law of change is analysed. Based on the actual working condition of the burr and subsequent requirements, the first four orders of modes are extracted for analysis in this paper. Modal frequency of the first four orders is indicated in Table 3 and mode of vibration is as shown in Figure 6.

Table 3 Modal frequency of the first four orders

<table>
<thead>
<tr>
<th>Order</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>81,983</td>
</tr>
<tr>
<td>2</td>
<td>1.59 × 10⁵</td>
</tr>
<tr>
<td>3</td>
<td>4.91 × 10⁵</td>
</tr>
<tr>
<td>4</td>
<td>5.87 × 10⁵</td>
</tr>
</tbody>
</table>

It can be known based on the table that the first-order and third-order mode show bending deflection of the burr at the direction of vertical width; the second-order mode shows bending deflection at the direction of vertical thickness and the fourth-order mode shows first-order torsional deflection of the burr. Result of the above modal analysis lays a theoretical foundation for the following harmonic response analysis.

4.3 Harmonic response analysis

Harmonic response analysis, also known as frequency response analysis or frequency sweeping analysis, is used to determine steady-state response of a structure under the effect of a sinusoidal load with known frequency and amplitude (Jia and Chen, 2016). Harmonic response analysis is often used to analyse structures under the influence of turbulence, for which the burr is analysed through harmonic response analysis.

In ANSYS workbench, harmonic response module and model module should be connected. The force calculated by Fluent should be loaded on the burr (in the direction of Z) and magnitude of such force is 2.07 × 10⁷ Pa, namely 4.14 N. Frequency range, number of iterations and interval are set as 0–846,000 Hz, 300 times and 2,820 Hz respectively. Frequency response curves of stress in the directions of X, Y and Z on the upper surface are extracted to determine change of the burr. The results of the analysis are shown in Figure 4.
Figure 4  Stress frequency response diagram, (a) frequency response curves of stress in the directions of X (b) frequency response curves of stress in the directions of Y (c) frequency response curves of stress in the directions of Z (see online version for colours)
Figure 4 indicates that the largest stress amplitudes in the directions of X, Y and Z all appear at frequencies near 81,780 Hz, based on which it can be determined that obvious resonance occurs in the burr near 81,780 Hz. Stress frequency response in the direction of X is far larger than stress frequency responses in the directions of Y and Z, indicating that variation of stress mainly occurs in the direction of X. It can be known from result of modal analysis that first-order inherent frequency of the burr is 81,983 Hz and resonance occurs in the burr easily when frequency reaches a point near 81,780 Hz. At this moment, change of the burr reaches the maximum degree. Figure 4 indicates that vibration frequency of the burr stimulated under alternating load is 81780 Hz. Situation of such burr at the frequency of 81,780 Hz is analysed.

Simulation experiment indicates that the rightmost end of the burr has the largest displacement and the maximum value is 88.903 mm, so free end of the burr will have bending fracture under the effect of an alternating load generated by 30 MPa hydraulic oil. Simulation experiment indicates that external surface at the leftmost end of the burr sees the largest stress and the maximum value is 1.4459 × 10^6 MPa. The minimum value in stress area of the small middle section is 43.712 MPa, which is larger than the fatigue limit 32 MPa of the burr of cast aluminium alloy. Therefore, the fixed end of the burr will have fatigue fracture under the alternating load generated by 30 MPa hydraulic oil.

According to the above methods, the inlet pressure 30 MPa, 10 MPa, 5 MPa, 1 MPa are used in the simulation experiment, get the relationship between inlet pressure and maximum/minimum stress in Table 4.
The relationship between inlet pressure and maximum/minimum stress:

<table>
<thead>
<tr>
<th>Inlet pressure (MPa)</th>
<th>Maximum stress (MPa)</th>
<th>Minimum stress (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>$1.4459 \times 10^6$</td>
<td>43.712</td>
</tr>
<tr>
<td>10</td>
<td>$6.3122 \times 10^5$</td>
<td>27.956</td>
</tr>
<tr>
<td>5</td>
<td>$2.6968 \times 10^4$</td>
<td>11.377</td>
</tr>
<tr>
<td>1</td>
<td>$6.3937 \times 10^2$</td>
<td>2.6721</td>
</tr>
</tbody>
</table>

Therefore, the fixed end of the burr will have fatigue fracture under the alternating load generated by 30 MPa hydraulic oil.

5 Experimental analysis

The samples were selected randomly and the deburring experiment was carried out by the method proposed in this paper. Experimental result depicted in Table 5.

The relationship between location of bur and machining result (inlet pressure = 30 MPa):

<table>
<thead>
<tr>
<th>Width of burr (mm) (default height: 1 mm)</th>
<th>Location of bur</th>
<th>Machining Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 mm</td>
<td>Inside the automotive brake master cylinder</td>
<td>The residual burr height &lt; 0.2 mm</td>
</tr>
<tr>
<td></td>
<td>On the cross bore</td>
<td>The residual burr height &lt; 0.05 mm</td>
</tr>
<tr>
<td>1 mm</td>
<td>Inside the automotive brake master cylinder</td>
<td>The residual burr height &lt; 0.1 mm</td>
</tr>
<tr>
<td></td>
<td>On the cross bore</td>
<td>The residual burr height &lt; 0.05 mm</td>
</tr>
</tbody>
</table>

From the experimental data in Table 5, we can see that the simulation results are basically consistent with the experimental results and the effect of deburring on the cross hole is better than that in the master cylinder and 30 MPa inlet pressure can basically remove burrs.

Figure 5  The deburring machine tool of automobile brake master cylinder cross hole (see online version for colours)
The deburring machine of automobile brake master cylinder cross hole based on fatigue fracture method is designed in this paper, the deburring machine tool is shown in Figure 5. Automobile brake master cylinder cross hole before and after deburring, respectively, cut and contrast analysis, transverse incision of automobile brake master cylinder cross hole is shown in Figure 6. Through the high power microscope observation, before deburring, you can see the intersection hole obvious burr exists, as shown in Figure 7(a). After deburring, you can see no burrs exist at the intersection, as shown in Figure 7(b).

It can be seen from Figure 7 that effect of deburring for orifices is very satisfactory after machining.

6 Optimisation of machining technology

If only single pressure is used in processing, it is difficult to give consideration to efficiency and processing quality. Due to the consideration of processing efficiency and machining quality, machining process cannot and should not be kept at a constant pressure all the time, but there may be many kinds of pressure appearing in the process. At this time, we need to distinguish whether the flow under this pressure is normal or whether it needs downtime. Through experiments, we can find out the flow relation under
Research on deburring technology

different pressure during the single processing in a certain range of accuracy. In the process of machining, the equivalent flow is used as the basis for judging the machining process.

The processing pressure is 1 MPa, 5 MPa, 10 Mpa, 15 MPa, 20 MPa, 25 MPa, 30 MPa respectively, so that the calibrated flow rate is the same, that is to say, the flow coefficient of each sample is the same. After a certain amount of experiments, effective experimental data as can be seen in Table 6 are obtained.

Table 6  Relationship between processing flow and calibrated flow at different pressures

<table>
<thead>
<tr>
<th>Pressure (MPa)</th>
<th>1</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow (L/min)</td>
<td>0.997</td>
<td>1.726</td>
<td>2.232</td>
<td>2.983</td>
<td>3.803</td>
<td>4.511</td>
<td>5.442</td>
</tr>
</tbody>
</table>

Fitting curve of flow rate and pressure is shown in Figure 8.

The fitting equation is equation (2):

\[ F = 0.876 \times P^{0.487} \]  \hspace{1cm} (2)

Equivalent flow conversion equation is equation (3):

\[ F_{equ} = \left( \frac{P_2}{P_1} \right)^{k_b} \times F_1 \]  \hspace{1cm} (3)

In this equation, \( F_{equ} \) represents equivalent flow at downtime pressure; \( F_1 \) represents actual measured flow under current pressure; \( k_b \) represents constant coefficient; \( P_1 \) represents real-time pressure; \( P_2 \) represents scheduled downtime pressure.

In order to improve efficiency and quality of machining, it is necessary to control pressure. A reasonable machining plan was discussed in this paper based on the following two machining technologies:

For plan A, a higher machining pressure should be adopted at the early stage of machining, while a lower machining pressure should be adopted in the late stage of machining, for which linear variation of pressure is required. For plan B, a lower machining pressure should be adopted at the early stage of machining, while a higher
machining pressure should be adopted at the late stage of machining. For the purpose of conducting a comparison between result of machining under this condition and that under the condition of a fixed pressure, the following three experiments were conducted in this paper: For plan C, machining was conducted under a fixed pressure of 5 MPa; for plan D, machining was conducted under a fixed pressure of 15 MPa; for plan E, machining was conducted under a fixed pressure of 30 MPa.

In plan A, the initial pressure was 30 MPa and decreased progressively at a speed of 1 MPa/s. When the pressure reached 1 MPa, it was maintained and no longer decreased. In plan B, the initial pressure was 1 MPa and increased progressively at a speed of 1 MPa/s. When the pressure reached 30 MPa, it was maintained and no longer increased. Result of machining is indicated in Table 7.

It can be seen from the analysis in Table 7 that plan B has the largest flow scattering difference, while plan A has the smallest flow scattering difference. However, among these plans, plan A has a higher machining efficiency. Flow scattering differences and machining efficiencies of plan C, plan D and plan E range between those of plan A and plan B. When a comparison among plan C, plan D and plan E was conducted, it could be seen that flow scattering difference of plan D was better, while machining efficiency of plan E was better. Therefore, plan A was selected as the plan machining technology, namely that a higher pressure should be adopted at the early stage of machining, while a lower pressure should be adopted at the late stage machining.

<table>
<thead>
<tr>
<th>Plan</th>
<th>Mean flow (L/min)</th>
<th>Upward deviation of flow coefficient</th>
<th>Downward of flow coefficient</th>
<th>The average processing time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan A</td>
<td>2.428</td>
<td>1.14%</td>
<td>-1.09%</td>
<td>11</td>
</tr>
<tr>
<td>Plan B</td>
<td>2.833</td>
<td>2.10%</td>
<td>-2.27%</td>
<td>31</td>
</tr>
<tr>
<td>Plan C</td>
<td>2.081</td>
<td>1.48%</td>
<td>-1.59%</td>
<td>36</td>
</tr>
<tr>
<td>Plan D</td>
<td>2.453</td>
<td>1.49%</td>
<td>-1.31%</td>
<td>30</td>
</tr>
<tr>
<td>Plan E</td>
<td>2.650</td>
<td>1.14%</td>
<td>-1.42%</td>
<td>24</td>
</tr>
</tbody>
</table>

In order to train the processing model, the input variable is set as \( X = [x_1, x_2, x_3, x_4] \). The meaning of each component: \( x_1 \)-parameter, \( x_2 \)-flow difference of turning point of flow growth rate curve \( x_3 \)-processing time at the minimum constant pressure, \( x_4 \)-shutdown pressure. The Gaussian function is taken as the membership function in the fuzzy layer. The input variable is \( x_i \) fuzzified into \( m_j \) language variables according to the actual situation. The outputs are flow dispersion and the average processing time respectively.

The optimisation of automobile master cylinder deburring processing parameters is not only to ensure that the flow dispersion is as small as possible, but also to make the processing time acceptable. Flow dispersion and processing time is a pair of mutually restricted evaluation indexes. It is difficult to ensure flow dispersion with too short processing time, but the flow dispersion may also not meet requirements when the processing time is too long. The optimisation to two indexes at the same time is a multi-objective optimisation. In the ideal state, assuming that \( \left( x_1^*, x_2^*, \ldots, x_4^* \right) \) is the best solution point of the system, the target function of the overall optimisation is set as \( G(x_1, x_2, \ldots, x_4) \). According to the situation where the target function of flow dispersion
optimisation is \( g_d(x_1, x_2, \cdots, x_n) \) and the target function of the average processing time optimisation is \( g_t(x_1, x_2, \cdots, x_n) \), then
\[
G(x_1, x_2, \cdots, x_n) = \left[ g_d(x_1, x_2, \cdots, x_n), g_t(x_1, x_2, \cdots, x_n) \right].
\]

Namely, \( \left( x_1, x_2, \cdots, x_n \right) \) cannot only enable \( g_d(x_1, x_2, \cdots, x_n) \) to achieve the optimisation, but also enable the \( g_t(x_1, x_2, \cdots, x_n) \) to achieve the optimisation. This point is difficult to find and it does not exist in general.

The optimisation algorithm used in this paper is the particle swarm optimisation. In the case of single-objective optimisation, the optimal solution or the solution close to the optimal solution can be found usually. While in the case of multi-objective optimisation, it is difficult to compare solutions and the multi-objective optimisation is done to get only a ‘compromise’ solution for multiple single-objective problems. Namely, some sacrifices and concessions have been made by each optimisation object, thus obtaining a non-inferior solution of the overall evaluation index. In order to obtain the non-inferior solutions of flow dispersion and average processing time, in this system, it is required to get the optimal solution or a relatively good solution of flow dispersion and average processing time and then a weighting factor is introduced to convert the multi-objective limiting value finding into single-objective limiting value. The fitness function is equation (4):
\[
\min G(X) = \min \left[ w_u \left( g_d(X) - g_d(X_d^*) \right)^2 + w_t \left( g_t(X) - g_t(X_t^*) \right)^2 \right]
\]
where \( w_u \) and \( w_t \) are weights of flow dispersion and average processing time respectively; \( g_d(X) \) and \( g_t(X) \) are flow dispersion and average processing time in each iteration. \( X_d^* \) and \( X_t^* \) are the optimal points of optimising flow dispersion and average processing time individually; \( g_d(X_d^*) \) and \( g_t(X_t^*) \) are the optimal flow dispersion and average processing time in individual optimisation. Because the flow dispersion is more important than processing time, after attempts, the weighing factor of flow dispersion \( w_u = 0.7 \) and the weighing factor of processing time \( w_t = 0.3 \). In processing, when the flow difference is small, the flow growth rate should not be too large or too small.

7 Conclusions

In this paper, against the background of fluid impact-based fatigue fracture technology, deburring with the fatigue fracture method was used as the object of research. A deburring machining platform was established, based on which feasibility and process plan of this method was studied. Based on the result of experimental comparative analysis, the deburring method based on fatigue fracture of burr caused by fluid impact is an effective deburring method, for which its efficiency is far greater than those traditional manual deburring methods. In addition, a new process plan was applied on the platform and a great effect of machining was realised. This equipment was used by an automobile company in Jilin Province, which achieved a good result of application. After application, the qualification rate of automobile brakes increased obviously. After inspection by some manufacturers, such effect of deburring meets their requirement on products completely. Therefore, research in this paper is of great significance in improving efficiency and quality of processing of automobile brake master cylinder and reducing traffic safety.
hazard. Due to the variety of cross hole parts, each type has hundreds of models and the same type of flow requirements may not be the same, there are a variety of processing medium types, classification, sorting and processing of data to establish a reasonable, a complete database, knowledge base, from the perspective of big data to further study the unknown characteristics of the processing and processing parameters in the future.

Acknowledgements

The authors gratefully acknowledge the funding of this study by science and technology development plan of Jilin Province (20120354 and 20130204024GX), venture fund project for personnel studying abroad of Jilin Province (2010273) and talent development project of Jilin Province (20091328).

References


