An accurate checking hole method used in hydraulic manifold CAD

Senior Engineer Song Jin-Qi
Fang Yong-Hong, Huang Yuan-Chao
Beijing Research Institute of Automation for
Machine Building Industry
No.1 Jiaochangkou Dewai, 100011 Beijing, CHINA

ABSTRACT

An accurate checking hole method is presented in developed hydraulic manifold CAD. The method is to discretized the hole surface and get finite point set, then the point set are calculated by Boolean algebra. Besides, an optimum calculation process is developed to save the CPU working time while checking hole program is running.

KEYWORDS

Checking Hole Method, Manifold CAD

INTRODUCTION

There are some defects in checking holes program which is used in manifold design. For example, some program can only check holes which are parallel or perpendicular to the faces of manifold[1], others simplify cone as column or ball in the mathematical model of checking holes program[2]. All this could not decide whether the holes connection satisfied our demanded design. These defects would cause faults or failures in hydraulic system design and manufacture.

In this paper, an accurate checking hole method is presented, the calculation method is as following.

First, HOL_1 and HOL_2 , which are demanded to check, are established in surface point set $HOLS_1(d_1, h_1, w)$ and 3D point set $HOLV_1$

(d_2, h_2) separately. The d , h and w are diameter, length and wall of the hole separately. Second, $HOLS_1(d_1, h_1, w)$ is discretized to become finite point set $\{point(x, y, z)\}$. The (x, y, z) is the point value. Third, we decide whether the following formula is content

$$\begin{aligned} point(x, y, z) \in HOLS_1(d_1, h_1, w) \quad \& \\ point(x, y, z) \in HOLV_2(d_2, h_2) \end{aligned}$$

If content, HOL_1 and HOL_2 are connected.

Using this method to check all holes in the manifold will spend longer running time. So an optimum calculation process is adopted. The process is to calculate shortest distance between two holes axis, and decide

whether to use the accurate method. When the accurate method is adopted, it calculates just in a small dangerous area and gives the minute wall between two holes.

MATHEMATICAL EXPRESSIONS OF HOLES IN HYDRAULIC MANIFOLD

Any two holes in manifold can be expressed by d , h , h_c . (Fig. 1) Usually, the minimum wall between two holes is demanded. So, balls are made on the hole surface (Fig. 2) we take one hole as HOL_1 and another as HOL_2 , make balls on HOL_1 surface. If the top of hole has cone, the mathematical model is:

$$\begin{aligned} d_1' &= d_1 + 2w \\ hc_1' &= 0.5d_1' \tan 30^\circ \\ h_1' &= h_1 + w \tan 30^\circ \end{aligned}$$

Fig. 1 Expression of hole

Fig. 2 make balls on the hole surface

If the hole is only a column, the model is

$$\begin{aligned} d_1' &= d_1 + 2w \\ h_1' &= h_1 + w \end{aligned}$$

ESTABLISH FINITE POINT SET ON HOLE SURFACE

Finite point set on HOL_1 surface will be set up in the coordinate system which HOL_1 is located (Fig. 3). The crossing point on column is:

$$\begin{aligned} x_1 &= 0.5d_1' \cos \theta \\ y_1 &= 0.5d_1' \sin \theta \\ z_1 &= z_t \\ (0 < \theta &\leq 360^\circ) \\ (0 &\leq z_t \leq h_1') \end{aligned}$$

The crossing point on cone is:

$$\begin{aligned} x_1 &= \frac{d_1' z_t \cos \theta}{2hc_1'} \\ y_1 &= \frac{d_1' z_t \sin \theta}{2hc_1'} \\ z_1 &= h_1' + hc_1' - z_t \\ (0 < \theta &\leq 360^\circ) \\ (0 &\leq z_t \leq hc_1') \end{aligned}$$

Fig. 3 The description of crossing point

COORDINATE TRANSFORMATION

Because the status values of HOL_i ($a_i, b_i, c_i, \alpha_i, \beta_i, \gamma_i$) and HOL_j ($a_j, b_j, c_j, \alpha_j, \beta_j, \gamma_j$) are described in the world coordinate system (WCS), all point set in which HOL_i located (ICS) should be transformed to HOL_j located (JCS) through the WCS in order to simplify checking hole mathematical model. The formula we used is as following:

$$\begin{aligned} X &= x_{in} \cos \alpha - y_{in} \sin \alpha \\ Y &= y_{in} \cos \alpha + x_{in} \sin \alpha \\ Y' &= Y \cos \beta - Z_{in} \sin \beta \\ Z &= Z_{in} \cos \beta + Y \sin \beta \\ Z' &= Z \cos \gamma - X \sin \gamma \\ X' &= X \cos \gamma + Z \sin \gamma \\ x_{out} &= X' + a \\ y_{out} &= Y' + b \\ z_{out} &= Z' + c \end{aligned}$$

in the formulas:

x_{in}, y_{in}, z_{in} are the values in old coordinate.

$x_{out}, y_{out}, z_{out}$ are the values in new coordinate.

α, β, γ are the angles rotated around Z, X, Y axis separately.

a, b, c are the original point values of old coordinate in new one.

Replaced above parameters ($x_{in}, y_{in}, z_{in}, \alpha, \beta, \gamma, a, b, c$) by point values in ICS and status values in WCS, and the point values in WCS can be obtained.

In WCS, replaced by point values and status values multiply by -1, the point values in the JCS can be obtained.

CHECKING HOLE RULER

In JCS, the following formulas are used to decide whether the two holes are connected or not.

The discriminants for the column hole are:

$$\begin{aligned} X_{out1}^2 + Y_{out1}^2 &< 0.25d_j^2 \\ 0 &< Z_{out1} < h_j \end{aligned}$$

The discriminants for hole with a cone are:

$$\begin{aligned} X_{out1}^2 + Y_{out1}^2 &< \frac{d_j^2}{4hc_j^2} (hc_j + h_j - Z_{out1})^2 \\ h_j &< Z_{out1} < h_j + hc_j \end{aligned}$$

The discriminants for the holes which are in the same side and $d_i > d_j$ are:

$$\begin{aligned} \alpha_i - \alpha_j &= \beta_i - \beta_j = \gamma_i - \gamma_j = 0 \\ (a_i - a_j)^2 + (b_i - b_j)^2 + (c_i - c_j)^2 &\leq 0.25(d_i + d_j)^2 \end{aligned}$$

If one of the above formulas is content and $w=0$, HOL_i and HOL_j is connected.

If none of the formulas is content and $w=w_d$ is our demanded, HOL_i and HOL_j is not connect.

If $w=0$ and none of the formulas is content and $w < w_d$ and one of the three formulas is content, the wall is less than our demanded wall (w_d), the two holes are dangerous. If we increase w from 0 step by step, we could get the real minute wall.

OPTIMUM PROCESS

Usually, most of holes which connected or not is obviously. If all holes in manifold are calculated by accurate method, it will spend a long time. An optimum method is developed in the course of checking. The optimum method is as following.

First, dangerous holes can be selected by calculating the shortest distance (dis_{ij}) between two center line segments ($\overline{s_i e_i}$ & $\overline{s_j e_j}$) of two holes (Fig. 4). That is:

$$dis_{ij} = \text{dis}(p_k, \overline{s_j e_j}) = \min(\text{dis}(p_i, \overline{s_j e_j}))$$

in the formula:

p_i ($i=1,2,\dots$) is any point on segment line($\overline{s_i e_i}$).

Fig. 4 The shortest distance between two line segments

If $\text{dis}_{-ij} > 0.5(d_i + d_j) + w$, then HOL_i and HOL_j is not connected and the demanded wall is content.

If $\text{dis}_{-ij} < \min(0.5d_i, 0.5d_j)$, then HOL_i and HOL_j is connected.

Otherwise, the accurate checking hole method must be adopted to determine the holes connection.

When we search the $\min(\text{dis}(p_i, \overline{s_j e_j}))$, the method of half segment $\overline{s_i e_i}$ divided internally is adopted to make p_i converge to p_k fast[3]. The value of $\text{dis}(p_i, \overline{s_j e_j})$ is calculated with analytic method shown in Fig. 5.

If $\sqrt{p_i s_j^2 - p_i o^2} + \sqrt{p_i e_j^2 - p_i o^2} > \overline{s_j e_j}$
 then $\text{dis}(p_i, \overline{s_j e_j}) = \min(p_i s_j, p_i e_j)$
 else $\text{dis}(p_i, \overline{s_j e_j}) = p_i o$

Second, after roughly selected and getting p_k , dangerous area between two holes can be decided and an accurate checking will be adopted only around the small area of p_k . It will decrease the working time as short as possible.

Besides, for the connected HOL_i and HOL_j , the value of dis_{-ij} can be as a basis to determine whether the flow area is enough.

Figure 6 gives the simple diagram of procedure of the accurate checking hole method.

EXAMPLE

Fig.7 is one cross-section of a manifold, table 1 is the part of information that the program outputed. It shows that hole one connect hole two; the minimum wall between hole one and hole three is 2.6mm, this is the dangerous wall if the demanded wall is 4mm; hole two connect hole four, but the shortest distance between two center line segments of two holes is just 7.2mm, so the flow area of these two holes is not enough.

User can use these information to verify his drawing until get a satisfied result.

Fig. 5 The calculation of the $\text{dis}(p_i, \overline{s_j e_j})$

Fig. 6 Simplified flowchart of the program

CONCLUSION

The calculating method has been applied to manifold design program, and has been widely used in many factories in China successfully. The users reflect that: mastering is simple, operating is convenient, providing of information is comprehensive, the checking-result is precise.

TABLE 1
Information of the program outputed

i_No	j_No	Wall_dang	Hol_Cnt	Dist
1	2	----	Y	0.5
1	3	2.60	N	7.5
1	4	----	N	24.5
2	3	----	N	21.5
2	4	----	Y	7.2
3	4	----	N	35.8

i_No, j_No--hole number;

Wall_dang--dangerous wall;

Hol_Cnt--connected holes;

Dist--shortest distance between
two holes's center line segments.

REFERENCES

- [1] Dalian University of Technology, Dalian, China, Research Report on Assembly Hydraulic System Design, Nov., 1990.
- [2] Shanghai Jiao Tong University, Shanghai, China, Research Report on Manifold Design for Cartridge Valves, July, 1990.
- [3] Beijing University and Qinhua University "Computational Method" Editorial Group, Computational Method, Science Press, Beijing, 1977.

Fig. 7 One cross-section of a manifold