Analysis of Orifice Area and Area Gradient of Assembled Shape Orifice

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Abstract. The calculation method and formula of orifice area and area gradient of double triangular groove and U shaped groove assembled shape orifice is analyzed, the calculating program of valve orifice area is established in MATLAB software. It uses polynomial segmentation to fit the combination valve orifice area curve, the valve orifice area $A(x)$ and area gradient $w(x)$ expressions are obtained.

Introduction

Hydraulic valve has many forms of valve port, typically there are two kinds of forms that the whole circumference opening and non-circular opening. Hydraulic valve has a structure which is non-circular opening spool valve, various shapes throttling groove uniformly is distributed on the spool valve shoulder circumference, so as to obtain different flow control characteristics. The references [1 ~ 3] and references [4] analyzed orifice area of some non-circular opening spool valves, and the polynomial fitting method is adopted to derive the calculation formula. According to calculation formula, orifice area of the servo valve is calculated; a mathematical model of variable-displacement pump negative flow control mechanism is established; the effect of servo valve structure parameters on dynamic characteristics of variable-displacement pump is obtained.

Deduction of calculation of flow area

The research objection is a assembled valve for double triangle and U type groove combination valve, the valve orifice area calculation diagram as shown in Fig. 1. Now, servo valve flow area is analyzed as following.

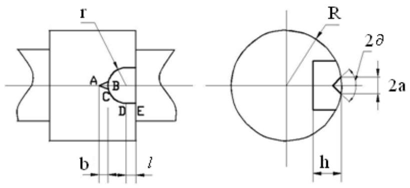

Fig. 1 Calculation sketch of the servo valve orifice area

If $x_B = b, z_B = a, x_D = b + r, z_D = r,\ x_E = b + r + l$, when at the point C:

$$z_c = \frac{-2m(R-kx) + 2\sqrt{m^2R^2 - k^2x^2 + 2kRx}}{2(1+m^2)} \tag{1}$$

$$x_C - b = r - \sqrt{r^2 - {z_C}^2} \tag{2}$$

In the formula: h is the of depth throttling groove; r is U shaped groove port radius; R is the max diameter of spool valve; x is Valve opening; n is the number of throttling grooves; a is double triangle groove for a opening in the axis z; b is double triangle groove for a opening in the axis x.

$z=\sqrt{r^2-(x-r)^2}$, mm ; $y=\sqrt{R^2-r^2+(x-r)^2}$, mm ; $k=\frac{R+a\cdot ctga-\sqrt{R^2-a^2}}{b}$, $m=ctga$

Through formulas (1) and (2) , the value of z_C and x_C are obtained.

Area A_2 and infinitesimal element area dA_2 are:

If $x_1<x_C$,

$$z=\frac{-2m(R-kx)+2\sqrt{m^2R^2-k^2x^2+2kRx}}{2(1+m^2)} \quad (3)$$

$$A_2=2n\int_0^{x1}R\cdot\arcsin\frac{z}{R}dx \quad (4)$$

$$dA_2=R\left(2\arcsin\frac{z}{R}\right)dx \quad (5)$$

If $x_1<x_D$,

$$A_2=A_{2C}+2n\int_{x_C}^{x1}R\cdot\arcsin\frac{z}{R}dx \quad (6)$$

Here , $z=\sqrt{r^2-(x-(b+r))^2}$, A_{2C} has the value of A_2 in formula (7) while $x_1=x_C$.

If $x_1<x_E$,

$$A_2=A_{2D}+n(x_1-(b+r))\times 2R\arcsin\frac{r}{R} \quad (7)$$

A_{2D} has the value of A_2 in formula (7) , while $x_1=x_D$

Area A_1 is:

If $x_1<x_B$,

$$A_1=n\left(2\times\frac{1}{2}\arcsin\frac{z}{R}\cdot R^2-z\cdot y_v\right) \quad (8)$$

Here $y_v=R-kx$, $z=\frac{-2m(R-kx)+2\sqrt{m^2R^2-k^2x^2+2kRx}}{2(1+m^2)}$.

If $x_B<x_1<x_C$,

A_1 as the Fig.2 shown,

$A_1=A_{ACEFDB}=n(A_{AOB}-A_{COD}+A_{CDEF})$.

$$A_1=n\left(2\times\frac{1}{2}\arcsin\frac{z}{R}\cdot R^2-z\cdot y_v\right)-ctg\partial\cdot z_2{}^2+2z_2\cdot(y_v+ctg\partial\cdot z_2-(R-h)) \quad (9)$$

Here, $z_2=\sqrt{r^2-(x-(b+r))^2}$.

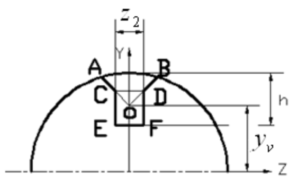

Fig. 2 Calculation sketch of A_1 area in the BC section

If $x_C < x_1 < x_D$,

$$A_1 = n\left[\frac{1}{2}R^2\left(2\arcsin\frac{z}{R}\right) + 2\times\frac{1}{2}yz - 2z(R-h)\right] \tag{10}$$

Here , $z = \sqrt{r^2 - (x-(b+r))^2}$, $y = \sqrt{R^2 - r^2 + (x-(b+r))^2}$.

If $x_D < x_1 < x_E$,

$A_1 = A_{10}$ (Constant)

$$A_{10} = n[\frac{1}{2}(2\arcsin\frac{r}{R})\times R^2 + 2\times\frac{1}{2}r\times\sqrt{R^2 - r^2} - 2r\times(R-r)] \tag{11}$$

Calculation results and analysis

The table 1 shows calculation data for a valve.

Table 1 Valve port parameter of a valve

R	r	a	b	l	h	n	∂
6mm	0.5mm	0.15mm	0.6mm	0.9mm	1mm	2	45

MATLAB program can be compiled, sectional fitting of the flow area of the combined valve orifice through a polynomial, approximate expression of valve port area $A(x)$ can be obtained, and then $w(x)$ can be obtained according to $A = wx$.

The flow area curve $A(x)$ can be calculated as shown in Fig. 3, the dotted line is area A_2, and the solid line is area A_1. As shown in Fig. 6, valve opening with two special valve opening x_1、 x_2, while $x = x_1$ and $x = x_2$, two area curves intersect that is $A_1 = A_2$; If $x < x_1$, minimum flow area of valve port is A_1; If $x_1 < x < x_2$, minimum flow area of valve port is A_2; If $x > x_2$, minimum flow area of valve port is A_1, $A_1 = A_{10}$ is constant. In a wide range of valve opening, the valve port area $A(x)$ is approximate gradient. We can obtain intersection B = (0.602 , 0.182) and intersection C =(1.607 , 1.986).

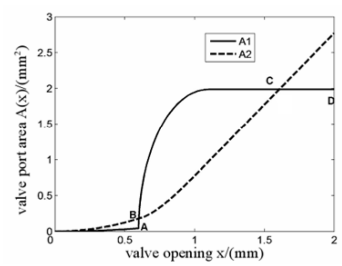

Fig. 3 Valve orifice area calculation curve

Valve orifice flow area $A(x)$ polynomial:

$$\begin{cases} A = -0.0017x^3 + 0.1281x^2 & (0 < x < 0.6) \\ A = 1\times10^{11}(-0.5692x^4 + 1.3681x^3 - 1.2332x^2 + 0.4940x - 0.0742) & (0.6 < x < 0.602) \\ A = 1.3962x^4 - 7.0322x^3 + 13.1451x^2 - 8.8081x + 2.0710 & (0.602 < x < 1.607) \\ A = A_{10} = 1.9861 & (1.607 < x < 2) \end{cases}$$

Flow area gradient $w(x)$ of valve orifice:

$$\begin{cases} w = -0.0052x^2 + 0.2562x & (0 < x < 0.6) \\ w = 1\times10^{11}(-2.2767x^3 + 4.1044x^2 - 2.4664x + 0.4940) & (0.6 < x < 0.602) \\ w = 5.5850x^3 - 21.0966x^2 + 26.2902x - 8.8081 & (0.602 < x < 1.607) \\ w = 1.2362 & (1.607 < x < 2) \end{cases}$$

In the section AB, the flow area of the gradient of double triangle - U combined grooves increases suddenly, valve opening (x) in the transitional zone between the double triangle and the U groove, the section area A_1 of the valve port is obviously increased, and the flow area gradient $w(x)$ is also increasing. In the section CD, that is $1.607 < x < 2$, the valve opening has reached the section U shaped groove at this point, the flow area A_1 is taken as a constant.

Conclusion

This paper uses polynomial segmentation to fit the combination valve orifice area curve, the valve orifice area $A(x)$ and area gradient $w(x)$ expressions are obtained. It provides a reference for the calculation of the flow characteristics of the combined valve port.

Acknowledgment

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