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ABSTRACT

Based on the value dynamic response simulation fast and accurately, the finite element method is used to solve the two-dimension thin plate vibration model by some skill. In this paper the optimum model of the part shape of the valve is set up, the variable permissible error method is selected to seek the optimum valves, then by means of its program the value shape of the smallest part stress concentration is gained, it makes the valve of design get high reliability and long life-time.

1. INTRODUCTION

Reed valve is one of the key part of reciprocating micro-compressor. Because of its bad working condition, the valve breaks frequently, which affects the economic performance and reliability of micro-compressor directly. It is clear that the valve failure is important obstruction to get the high reliability machine.

In recent years, people have done a lot of work on reed valve, such as its design theory, machine performance, strength of technology and so on. However the theory of reed valve is still imperfective and the valve technic performance is often unsteady.

The life-time of the valve relies on its amplitude of stress, times of circle, distribution of stress ect. In the opinion of design, the decisive factor is the shape of the valve. So it is necessary to design the valve which has a good movement and even distribution stress.

The two-dimension finite element equations of reed valve is handled by the skill of vibration shape superpostion to solve the valve movement simultaneous equations which couple the dynamic equations with the flow equation.The dynamic respond simulation of the valve can be achieved fast and accurately. In this paper this method is used to optimize the valve shape then the valve of the smallest part stress concentration is gained to improve the reliability of the valve.

II. MATHEMATICAL MODEL

Because the relationship between the function of reed valve shape and the function of stress distribution is implicit and nonlinear. It is impossible to obtain the functional extreme values to get the optimum shape of reed valve by the analytic method. This paper disperses the valve shape to gain a series of plots coordinate instead of the valve shape function. The stress numerical solution of the valve whose shape is link a series of outside nodes can be gained by using the finite element method, then the optimum model of the value shape is as follow :

hypothesis : the set of all the finite element nodes coordinate which are divided up by the valve shape is B^n . the optimum design parameter A_1 , A_2 ..., A_n are selected in B^n . then

$$\min \quad \Delta\sigma [A_1, A_2, \ldots, A_n, T] \tag{2-1}$$

$$\text{s.t.} \quad A_1 - A_1^{o1} \leq 0 \; ; \; -A_1 + A_1^{o2} \leq 0$$

$$\vdots \qquad\qquad \vdots$$

$$A_n - A_n^{o1} \leq 0 \; ; \; -A_n + A_n^{o2} \leq 0$$

$$\sigma_{max} [A_1, A_2, \ldots, A_n, T] \leq \sigma_o$$

where

$\Delta\sigma$ - the minimization object. here it is the mark of the stress concentration

A_1^{o1} , A_1^{o2} -- the upper or lower limit of the optimum design parameter. It depends on the fix size of the valve

σ_{max} -- maximum dynamic stress of the valve

σ_o -- the allowable intensity of the valve material

Formula (2 - 1) is the optimum model of the part shape of reed valve.

III. MAKE OF THE STRESS CONCENTRATION

The reed valve stress is a function of the valve X,Y coordinates and time T. In order to achieve the valve even distribution stress, it is necessary to consider the stress multiple-effect on X, Y, T coordinates, so the hypothesis is given as follows to reduce the cost of calculation and to make the results of optimum problem convergence fast.

At the moment T of the valve movement, the stress of each finite element is even inside the element and it equals arithmetic mean of four Gauss points stress of the element. (I,T) expresses even stress of the 1th element.

On the basis of the hypothesis, Mark of the stress concentration can be defined as follows :

In the time space of the valve movement, Mark of the stress concentration is the maximum of a element even stress minus the minimum of a element even stress at the same time in the elements set, where the elements set is belong to the elements of optimum of the part shape.

$$\Delta_2 \sigma = \max [\bar{\sigma}_{max} (I,T) - \bar{\sigma}_{min} (J,T)]$$

where

I,J ---- The element number of maximum even stress or minimum even stress in the elements set.

T --- the moment of the valve movement

IV. OPTIMUM METHOD AND PROGRAM

The relation between the stress and the valve shape, other parameters of structure is complicated. It's optimum problem is a restrained optimum problem . There is no analytic results can be gained. In this paper a minimum restrained method --- the variable permissible error method is selected, it is a suitable method, to seek the optimum shape of reed valve.

The variable permissible error method is one of the searching method. It is widely used in a large field. One of the superiorities is that the restrained position is satisfied relaxedly at initial stage and it is satisfied at close hand , when the searching valves approach the results of optimum problem , so the great amount of calculation is reduced.

The method of design program is divided it in groups then to design them and to fix all of them altogether, so the structure of program is simple. Each part of the program is independent and changeable. Fig.(1) shows the total structure of the optimum program.

V. APPLIED EXAMPLE

Fig.(2) shows the fixed chart of the insult reed valve which is used in a mini-compressor. Fig.(3) shows the finite element grid of the reed valve. The results of the valve dynamic analysis indicate as follows :

1. The damage plot of the valve stress is at the eight element.
2. The outline size valve get great change at the sixth, seventh, eighth element, the stress concentration of this part is serious, and it is necessary to optimize this part shape of the valve.

The mark of the stress concentration of the part which is the sixth, seventh, eighth element is selected for object function and optimum parameters of design is coordinates of this part valve shape by the valve dynamic analysis.

In order to reduce the number of the optimum parameters and to ensure seeking the reasonable optimum valve shape sucessfully, the optimum parameters of design x(1), x(2) select the Y-coordinate of 31 and 37 nodes. Fig.(4) shows the location of optimum parameters. The optimum problem is

$$\min \quad \Delta_2\sigma\,(\,x(1)\,,\,x(2)\,,\,T\,)$$

$$\text{s.t} \quad \begin{array}{l} 0.018 \leq x(1) \leq 0.037 \\ 0.018 \leq x(2) \leq 0.037 \\ \sigma_{max} \leq 390 \times 10^6 \end{array}$$

By means of the program, the optimum results are,

$\Delta_2\sigma = 4.918 \times 10^7 (N/m^2)$, $x(1) = 0.0293$ (m) , $x(2) = 0.0290$ (m)

Before optimization, make of the part stress concentration at same place is , $\Delta_2 \sigma = 5.263 \times 10^7$ (N/m^2). It is known that the mark of the part stress concentration drops 6.6% after optimization.

Fig. (5) shows the different valve shape between optimization and non-optimization. It is easy to see that comparing optimization to non-optimization the outline size change of the seventh element link up with the eighth element is much large and the outline size change of the sixth element link up with the seventh element is not. Obviously, the outline size of the sixth element link up with the seventh element is reasonable. But the outline size of the seventh element link up with the eight element is not.

V. CONCLUSION

1. Relying on the part shape optimum model of reed valve and its program, in this paper it will be realized to optimize the part shape of reed valve and to obtain the minimum part stress concentration.
2. By means of the model and the program, this paper optimized one reed valve of a mini-compressor. The results indicate that after optimum the shape of reed valve, the mark of the part stress concentration drops 6.6%. It proves that the model and the program is useful and reliable.

VI. REFERENCES

(1) R.Cohen , " Valve Stress Analysis - for Fatigue Problems " Proceedings 1972 Purdue Compressor Technology Conference.

(2) Dr. Werner Soedel, " Design and Mechanics of Compressor Valves", 1984.

(3) Edward J. Haug Jasbir S. Arora "Applied Optimal design -- Mechanical and Structural Systems" John Wiley and Sons, 1979.

(4) D.M. Himmelbau "Applied Nonlinear Programming " McGraw - Hill Book Company, 1972.

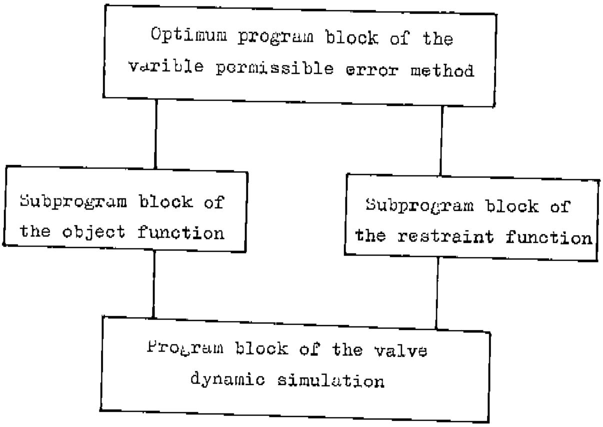

Fig.1. The total structure of optimum programming

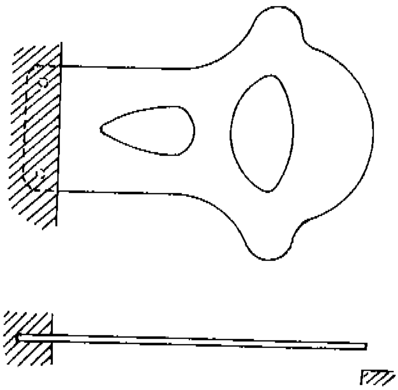

Fig.2. The scheme of fixing valve

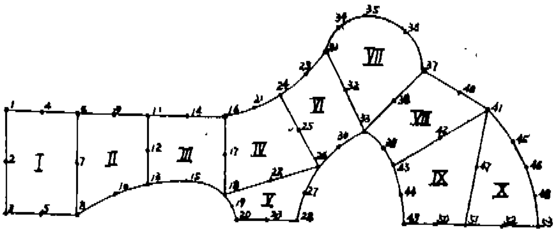

Fig.3. Finite element grid of reed valve

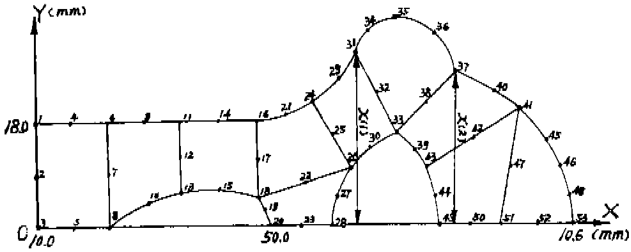

Fig. [illegible]. Location of the optimization of parameters

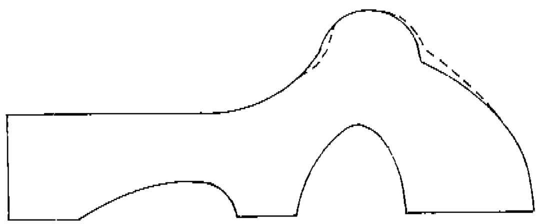

Fig.5. Optimized and unoptimized reed valve shape
solid line — unoptimized
dashed line — optimized