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THE APPLICATION OF MICROCOMPUTER IN OPTIMUM DESIGN AND PERFORMANCE FORECAST OF SCREW COMPRESSOR

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Abstract

This paper has introduced the measurement and analysis of all space curved surface errors of screw machinery (including single screw and twin screw) and the setting of functional spacefigure, thus optimizing the design parameters and forecasting the performance index.

The measuring method designed is an ingenious combination of the mechanism and grid with microcomputer technique, and the measurement results of the corresponding framework joints of space curved surface have been described in this paper. The optimum design has been obtained by theoretic derivation and experiment. The machinery has good efficiency and has yielded remarkable economic benefits.

Introduction

In rotary machinery, the rotor and gate rotor of a single screw compressor and the rotor pairs of a twin-screw compressor are conjugate parts. By the engagement of curved surfaces of these parts, elementary capacity is enlarged or reduced. The surfaces also support gas pressure, and the space between the curved-surfaces is sprayed with lubrication oil. Finally, the pattern and place of the discharge vent are related with the concrete curved surfaces. Therefore, the engaging tolerance in single screw and twin-screw compressors , which have been discussed in this paper, is essential to the performance index of these machines.

This paper has given measuring methods of engaging tolerance (on single screw and twin-screw compressors), which were not accomplished by predecessors, such as the analysis of errors, the process of processing the errors with a micro-computer, and final influence on performance index.

Measurement and Analysis for Engagement Error of Twin-Screw Compressor Rotor Pairs

We have experimented on a screw refrigerator, the nominal diameter of which is 200 mm. When the average engaging tolerance is reduced from 0.1 mm to 0.07 mm, the volume efficiency increases 3%, and the adiabatic efficiency increases 0.5% or so ; With an ammonia refrigerator whose nominal diameter is 160 mm, when the average engaging tolerance is reduced from 0.07 mm to 0.04 mm, volumetric efficiency increases 4.5% under nominal working conditions.

Figure 1 gives the error curves of the screw rotor (200 mm in nominal diameter) measured with two methods in a factory of our country. One uses magneto-railing techniques, and the other uses " Dynamic Conjugators-engaging

Measuring Device " which we have made by ourselves. The figure shows that the results got with these two methods correspond basically.

Why do the four teeth of the same positive rotor have such different screw-curve errors ? A clear answer has been got by measuring the tolerance of drive chain of the machine.

Fig. 2 gives the arranged picture of magnetic-railing measuring elements, which has been applied in measuring transmission-chain errors of a typical miller of our country. In Fig. 2, magnetic-disc 1 and 2 show the errors of graduated worm-gear pairs, Magnetic-disc 3 and magneto-scale make transmission error of leading screw-nut known, and magnetic-disc 2 and 3 reflect total errors. As Fig. 3 shows, the error of graduated worm-gear pairs is considerable in total errors. Fig 4(a) shows the greatest graduation errors when the four teeth are in the initial position, while the errors are the smallest when the four teeth are in the position shown in Fig.4(b) ($\Delta_{graduated} = 0.707 \Delta F_{\Sigma}$).

The Principle and Method for Measuring Gate Rotor and Rotor Errors in Single Screw Compressors

The fundamentals of measuring engaging tolerance of single screw-rotor pairs is introduced as follows. Fig. 5 shows the arrangement of magnetic measuring elements. The results obtained are shown in Fig. 6 . As is shown in Fig.6, eccentricity results in Δ_1, Δ_2 is tooth form errors, and Δ_3 results from vibration. Fig.6(a) shows the total error, Fig.6(b) is gate rotor error (got from point measure through curve-fitting) and Fig.6(c) is the rotor error.

Realization of Error Modification and On-line Control in the Measurement by use of a Microcomputer

To show the total error state of a couple of rotors, $C_m^1 \times C_n^1$ times measurements are to be made. By using a micro-computer, only m (when $m > n$) or n (when $n > m$) times are required, so the calculating time is greatly saved.

As the surfaces of the rotors are curved ones and the sphere is not a partical, the measurement must be modified. The calculation frame figure is as Fig. 7. In this figure, t_1^0 is the end surface parameter of contact point of sphere with the female sample plate, (and t_2^0 with the male one). Using the iteration method, t_1 and τ_1 , the parameter of contact point of the sphere with the rotor can be calculated. Taking t_{20} as the aim function, t_2^0 the beginning value, calculation is carried on until $|t_2 - t_{20}| \leq \varepsilon$, then the value t_2^* of the last cycle is the end surface parameter of the contact point of the sample plate curve.

In the process of measurement, the modification is on line. As the signal is stagnant, it must be forecast. This is solved by the computer control system on line. The control frame figure is shown as Fig. 8.

In the figure. Y_n --- reference input or set value

e_n --- error

m_n --- control variable

d_n --- external disturbance

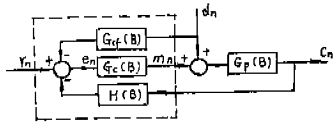
C_n --- output or response of the system

$G_p(B)$ --- dynamic or static characteristio of the controlled processing

$H_c(B)$ ---algorithm of the feedback controller

$G_c(B)$ --- control algorithm

$G_{cf}(B)$--- algorithm of forward controller



computer

Fig. 8

The steps for the computer to realize the processing control are as follows:

1) Sampling: At the required moment, the computer samples the output of the measurement processing.

2) Calculating : To calculate the error $e_n = Y_n - C_n$. and the control variable m_n according to the control algorithm and error e_n .

3) Controlling : To output the control variable m_n to the controlled part so as to control the processing.

The composition of the control system modifying all kinds of errors to the measurement process is shown in Fig.9. The control performance of the system above is perfect and control algorithm is easy to modify. By using time- share, the control of the multiloop can be realized , so as to improve the accuracy of the measurement and get good results.

The applications of a microcomputer in this paper are as follows: the frequent manual analysis and flyback calculation of lead error, the average engagement gap, the leakage area, the maximum engagement gap, the minimum engagement gap and its address, the engagement accuracy (the maximum change value of engagement gap), graduation error, graduation accumulation error, point arrangement measurement of molded line, and the optimum engagement of a couple of rotors. The drawing of figures on CRT is realized and results are obtained both qualitatively and quantitatively.

Frequency analysis in frequency domain and time domain is done with magnetic tape recorder and real time analysis meter.

Error modification includes : the modification of the system errors of every part of the installation, such as the installation error of the sample plate and corresponding engagement point, the modification of the error when the sphere is not a particle, and the modification of the lead error and graduation error, etc.

Conclusions

Volume efficiency is an important index for judging the performance of screw compressors. It also shows gas leakage throught engaging clearance and the leakage results in the change of gas mass in elementary capacity. Thus, the compression process is a mass-changing process. The following gives a mathematical discription when leakage, spray and heat transfer are considered.

$$\frac{dT_g}{d\varphi_1} = -T_g \left(\frac{\partial p}{\partial T}\right)_v \frac{1}{m_g c_v} \left(\frac{dV}{d\varphi_1} - \frac{dV_l}{d\varphi_1}\right) + \left\{ h_{z+1,g} - u_g \right.$$

$$\left. + \left[T_g \left(\frac{\partial p}{\partial T}\right)_v - p \frac{V - V_l}{m_g}\right] \right\} \cdot \frac{1}{m_g c_v \omega_1} \cdot \frac{1}{\rho_l \omega_1}$$

$$\cdot \frac{dm_{z+1,l}}{dt} - \frac{aV}{m_g c_v \omega_1} \left(T_g - T_l \right)$$

$$\frac{dT_l}{d\varphi_1} = \frac{(T_{z+1,l} - T_l)}{m_l \omega_1} \frac{dm_{z+1,l}}{dt} + \frac{aV}{m_l c_l \omega_1} \left(T_g - T_l \right)$$

$$\left(\frac{dm}{dt}\right)_{g \text{ or } l} = \left(\frac{dm_{z+1}}{dt} - \frac{dm_{z-1}}{dt} - \frac{dm_s}{dt}\right)_{g \text{ or } l}$$

For an ideal gas, it can be simplified as

$$\frac{dT_g}{d\varphi_1} = -\frac{(k-1)T_g}{V - V_l} \left(\frac{dV}{d\varphi_1} - \frac{dV_l}{d\varphi_1}\right) + \frac{(KT_{z+1,g} - T_g)}{m_g \varphi_1} \cdot \frac{dm_{z+1,g}}{dt}$$

$$- \frac{(k-1)T_g}{m_g \omega_1} \left(\frac{dm_{z-1,g}}{dt} + \frac{dm_{s,g}}{dt}\right) + \frac{p_{z+1} - p}{m_g c_v} \cdot \frac{1}{\rho_l \omega_1} \cdot \frac{dm_{z+1,l}}{dt}$$

$$- \frac{aV(T_g - T_l)}{m_g c_v \omega_1}$$

The verified test is shown above.

When engaging clearance is magnified, outer leakage increases and volume efficiency decreases. Especially, under cryogenic working conditions, the magnification of engaging clearance of refrigerators results in the decrease of inter-discharge pressure and enlarges the loss of iso-volumetric compression process, and also results in further reduction of idiabatic efficiency. Therefore, how machining-level of screw rotors is developed is one of the essential ways to improve performance and this can be guaranteed by the measurement and verification device.

References

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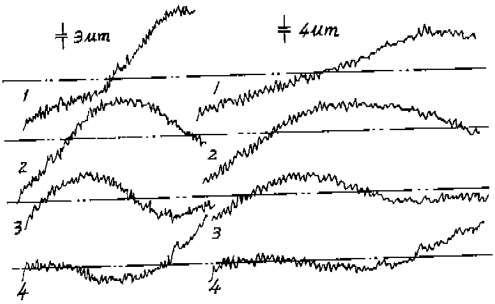

Fig. 1 Error measurement comparison of male rotor with two method

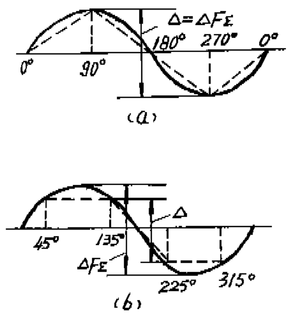

Fig. 4 Δ -- graduation error

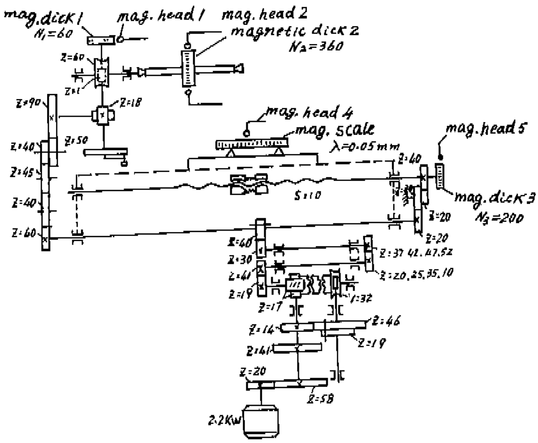

Fig.2 Arrangement for measuring rotor working machine transmission error

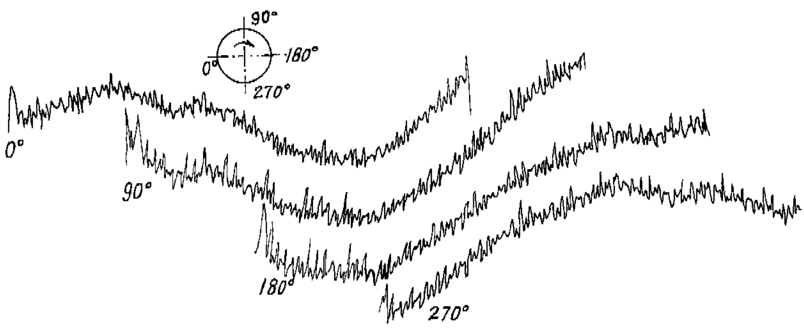

Fig. 3

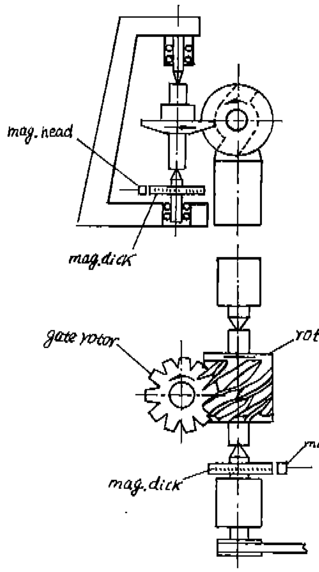

Fig. 5 Photo and principle for rotor and gate rotor of single screw

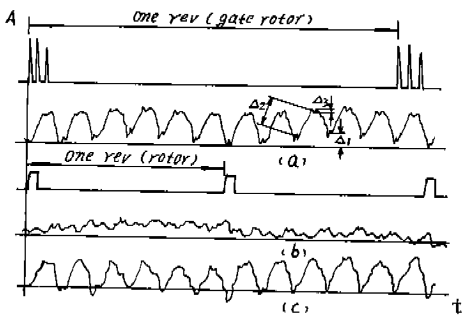

Fig. 6

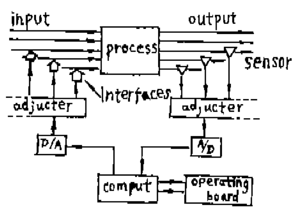

Fig. 9

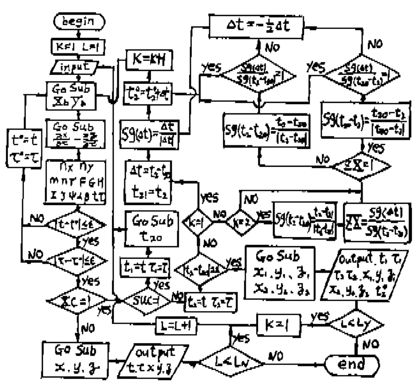

Fig.7 Compute programe block