Research on condition monitoring failure in axial piston pumps

ZHOU WEN, LU SHIXIN, WU GANG, ZHOU JIANKUN
Department of Mechanical Engineering
Taiyuan University of Technology
Taiyuan, Shanxi, P. R. China

ABSTRACT

In this paper the condition monitoring and fault diagnosing of slipper looseness failure in swash plate axial piston pumps are investigated analytically and experimentally. The paper first describes mathematical models of loose slipper failure. Then normal power spectrums and fault power spectrums are experimentally discussed. Through contrast between theoretical models and experimental models we can approximately judge quantity of loose slippers. Finally, a corresponding criterion of slipper looseness fault diagnosing is discussed.

KEYWORDS

Pump, Slipper, Failure, Monitoring, Diagnosing

INTRODUCTION

The general failures of swash plate axial piston pumps contain a very high ratio (≥ 80%) of loose slipper's faults by statistical data in China. Therefore, identify and diagnosing of slipper looseness failure are very significant.

The axial piston pumps are hydraulic power sources with many complex movements and greater power in unit weight. Many vibration excitable sources exist in the pump. Hence vibration frequency spectrums on the pump-housing are very complex and it is very difficult how the fault signals are identified from the general vibration frequency spectrums.

Through the theoretical analysis and the much experiment we have discovered that three characters exist in the auto power spectrums of loose slipper's failure.

a. Change of high frequency spectrums.

b. Increase of general energy in logarithm auto power spectrums.

c. Change of fundamental harmonic and harmonics in auto power spectrums.

On these grounds we shall discuss the problems of identify and diagnosing slippers looseness failures.

* The project supported by natural science foundation of Shanxi province China

THEORETICAL ANALYSIS

In this paper, it is discussed that clearance, quantity and distribution of loose slippers have influence on their auto power spectrums.

A phenomenon of the loose slipper in slipper pumps arise often from contamination-wear. The clearance ε between piston and slipper is greatest in the low pressure range and least in the high pressure range, when slipper is loose. Therefore an impulse force appear at the moment passing interface between the low pressure and the high pressure range. This impulse force is carried through pump's plate into pump housing. Consequently informations about the loose slipper failure are included in the pump's housing vibration spectrums.

In the paper, the study is a axial piston pump of 63 CY-14-1B type. The distribution of its seven slippers is shown in Figure 1.

Deduced mathematical models of loose slippers failure partially arranged in table 1.

A part of the corresponce power spectrums is expressed in Figure 2 (τ = 0.1T). Figure 2 shows calculated auto power spectrums of one, three (No. 1, No. 2 and No. 3) and four (No. 1, No. 2, No. 3 and No. 4) loose slippers.

From Figure 2 we can see that the auto power spectrums of impulse force are dependent on quantity and distribution of loose slippers.

At the impulse moment high frequency vibration is produced naturally. But its mathematical analytic describing is very difficult. The theoretical analysis make known that vibration's energy increased simultaneously too.

EXPERIMENTAL STUDY

The test works are made on the testing bed for measuring reliability of directional valve.

Where test pressure is 31.5 MPa; flow is 72 L/min; oil temperature is 50 ± 4°C; directional frequency is 0.95 Hz.

The condition monitoring is carried out on four monitored spots on the pump-housing (see Figure 3). The measured signals are vibration accelerating of the pump-housing. The measured signals by accelerometers are recorded on the magnetic tape and analysed on the signal analyser (HP 3562A.) after pretreatment. Through correlation integral analysis random interference may be attenuated.

Figure 4 is a part of the test data on the monitored spot 1. The spot 1 is sensitivest for the loose slipper failure.

From Figure 4 a) and b) we can find out the change of high frequency spectrums (2.15—3.125KHz). Its appearance is effect of high frequency vibration at impulse moment. Figure 4 a) — d) show also the change of amplitudes of fundamental harmonic and harmonics in linear auto power spectrums. Figure 4 e) and f) express the increase of general energy in logarithm auto power spectrums.

Before obtaining above auto power spectrums test data are pretreated with a computer (for example, mean in time domain etc.).
TABLE 1
Mathematical models of the loose slippers failure

<table>
<thead>
<tr>
<th>Quantity of loose slipper Zf</th>
<th>Impulse distribution</th>
<th>Accelerometer power frequency spectrums</th>
</tr>
</thead>
<tbody>
<tr>
<td>one loose slipper</td>
<td></td>
<td>$\left( \frac{A_{an}}{E} \right)^2 = \left[ \frac{2}{n\pi} \sin \frac{n\pi T}{T} \right]^2$ $(n=1, 2, 3\ldots)$</td>
</tr>
<tr>
<td>No. 1 and No. 2</td>
<td><img src="image" alt="Impulse distribution" /></td>
<td>$\left( \frac{A_{an}}{E} \right)^2 = \left[ \frac{4}{n\pi} \cos \frac{n\pi T}{T} \right]^2$ $(n=1, 2, 3\ldots)$</td>
</tr>
<tr>
<td>No. 1 and No. 3</td>
<td><img src="image" alt="Impulse distribution" /></td>
<td>$\left( \frac{A_{an}}{E} \right)^2 = \left[ \frac{4}{n\pi} \cos \frac{3n\pi T}{T} \right]^2$ $(n=1, 2, 3\ldots)$</td>
</tr>
<tr>
<td>No. 1 and No. 4</td>
<td><img src="image" alt="Impulse distribution" /></td>
<td>$\left( \frac{A_{an}}{E} \right)^2 = \left[ \frac{4}{n\pi} \cos \frac{3n\pi T}{T} \right]^2$ $(n=1, 2, 3\ldots)$</td>
</tr>
<tr>
<td>No. 1, No. 2, and No. 3</td>
<td><img src="image" alt="Impulse distribution" /></td>
<td>$\left( \frac{A_{an}}{E} \right)^2 = \left[ \frac{2}{n\pi} (1+2\cos \frac{2n\pi T}{T}) \sin \frac{n\pi T}{T} \right]^2$ $(n=1, 2, 3\ldots)$</td>
</tr>
<tr>
<td>No. 1, No. 2, and No. 3</td>
<td><img src="image" alt="Impulse distribution" /></td>
<td>$\left( \frac{A_{an}}{E} \right)^2 = \left[ \frac{4}{n\pi} (\cos \frac{n\pi T}{T} + \cos \frac{3n\pi T}{T}) \sin \frac{n\pi T}{T} \right]^2$ $(n=1, 2, 3\ldots)$</td>
</tr>
<tr>
<td>No. 1, No. 2, and No. 3</td>
<td><img src="image" alt="Impulse distribution" /></td>
<td>$\left( \frac{A_{an}}{E} \right)^2 = \left[ \frac{4}{n\pi} (1+2\cos \frac{2n\pi T}{T} + 2\cos \frac{4n\pi T}{T}) \sin \frac{n\pi T}{T} \right]^2$ $(n=1, 2, 3\ldots)$</td>
</tr>
</tbody>
</table>

Zf — quantity of loose slipper; $\omega$ — radian frequency of pump; $A_{an}$ — accelerating amplitude of harmonics of impulse force; $E(=f(\frac{\epsilon}{n^2\pi}))$ — amplitude of impulse force; $n$ — harmonic number; $\tau$ — impulse breadth; $T(=\frac{2\pi}{\omega} = \frac{1}{f} = 0.04S)$ — period
IDENTIFICATION AND DIAGNOSING

The differential spectrum between normal spectrums and fault spectrums $\Delta G_i$ is shown in Figure 5.

$$\Delta G_i = \frac{1}{k} \sum_{j=1}^{k} G_{fij} - \frac{1}{m} \sum_{j=1}^{m} G_{nij}$$

($i = 1, 2, 3, \ldots$)

Where

$G_{nij}$ — amplitude of $i$-st harmonic in the normal spectrums by $j$-st measurement.

$G_{fij}$ — amplitude of $i$-st harmonic in the fault spectrums by $j$-st measurement.

Figure 2. Calculating auto power spectrums of loose slippers

Figure 3. Distribution of monitoring spots
Figure 4. (a) and (b) show linear auto power spectrums; (c) and (d) show zoom FFT auto power spectrums; (e) and (f) show logarithm auto power spectrums (vibration accelerating on the monitored spot 1)
Threshold value $K_t$ of loose slipper failure may be determined in accordance with the above formula and by the corresponding fault power spectrums for permissive limit clearance $\epsilon_l$ (for example, $\epsilon_l = 0.15\text{mm}$). $K_t(Z_f) = 0.778$, when four slippers are loose. The pump must be repaired, if $K_m > K_t$.

CONCLUSION

Through comparison between the differential and the calculating spectrums the quantity $Z_f$ of loose slippers may be rough determined. The definition of threshold value $K_t$ is difficult. But it may be determined through much experiment with statistic method.

REFERENCES

1. Qiu Zhelin, Chen Zaoneng, Lu Yuanzang,: Research on diagnosing failure of axial piston pump with pump-housing' s vibration signals. hydraulics and pneumatics (China), 1988