1994

Measuring Friction Losses Using Accelerometer

W. Oh
GoldStar Company

H. Lee
GoldStar Company

I. Lee
GoldStar Company

Follow this and additional works at: http://docs.lib.purdue.edu/icec
MEASURING FRICTION LOSSES USING ACCELEROMETER

Won-sik Oh*, Hyeong-kook Lee*, In-seop Lee*

* Living System Laboratory, GoldStar Co., Ltd.,
327-23 Garibong-Dong, Guro-Gu, Seoul, 152-020, Korea

ABSTRACT

This study presents a technique of measuring the friction losses of a compressor. The basic idea is that the kinetic energy of compressor mechanism is dissipated by the friction when compressor is turned off. So, the viscous friction losses can be calculated from measured acceleration. This method has the advantage that losses of a compressor are measured by placing the accelerometer on proper position of compressor without modifying the shaft or another parts of compressor.

INTRODUCTION

Estimation of friction losses is very important in the compressor design. Theoretical calculation is simple, but experimental measurement has the following two difficulties.

1. Test compressor must be modified to attach the transducers.
2. Transducer attachment itself is very difficult.

This paper describes simple measurement method without above difficulties.

IDEA

After power off, the kinetic energy of the moving parts will be dissipated by friction. So, If we can measure variation of the kinetic energy (hereafter K.E.), then we can estimate the friction.
PRACTICAL CONSIDERATION

1. Most of K.E. is stored in the rotational motion of the rotor of electric motor.
2. Let's assume friction as viscous damping.

CALCULATION

Equation of the rotor rotational motion after power off

\[ J \ddot{\theta} + C \dot{\theta} = 0 \]  

(1)

\( J \): Inertia of the rotor  
\( C \): Equivalent damping coefficient of friction

After integration,

\[ \theta(t) = \omega_0 \times \frac{J}{C} \times \left[ 1 - e^{-Ct/J} \right] \]  

(2)

\( \omega_0 \): Rotational speed before power-off

For simplicity, let's assume as

\[ e^{-Ct/J} = 1 - \frac{Ct}{J} + \frac{1}{2}(Ct/J)^2 \]

then

\[ \theta(t) = \omega_0 \times \left[ t - \frac{(1/2)(C/J)x t^2} \right] \]  

(3)

Finally, the friction loss estimation is as follows.

Friction Loss = Friction Torque \( \times \omega_0 = C \omega_0^2 \)

From eq.(3)

\[ \text{Friction Loss} = 2J\omega_0^2 \left( 1/t^2 \right) \left( t - \theta(t)/\omega_0 \right) \]  

(4)
TO BE MEASURED

From eq.(4), the values which must be measured to estimate the friction loss are as follows.

<table>
<thead>
<tr>
<th>parameter</th>
<th>explanation</th>
<th>measurement method</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>inertia of moving parts</td>
<td>Calculation: rotor inertia + equivalent value of others</td>
</tr>
<tr>
<td>$\omega_0$</td>
<td>rotational speed before power off</td>
<td>rpm measurement using stroboscope during compressor running</td>
</tr>
<tr>
<td>$\theta(t)$</td>
<td>rotated angle of rotor from power-off ($t=0$) to certain time ($t$)</td>
<td>counting number of rotation using accelerometer or other transducers + start/stop angle correction</td>
</tr>
</tbody>
</table>

MEASUREMENT SET UP

Fig.1 shows the schematic diagram for understanding of the measurement technique. The Acceleration signal is measured by placing the accelerometer on proper position of mechanism.

![Fig.1 Experimental Set Up](image-url)
RESULTS AND DISCUSSION

We compare the measured friction losses with the calculated for average oil temperature of 82°C and viscosity of 32cst in Table 1. The calculated friction losses for the journal and thrust bearing is estimated lowly as compared with the measured friction losses because the friction losses is calculated on condition that all of mechanism have the oil temperature of 82°C. But the oil temperature of the journal and thrust bearing is lower than the other part. So, it is reasonable that the measured friction losses is estimated highly than the calculated for the journal and thrust bearing.

Fig.4 shows effects of temperature on friction losses.

<table>
<thead>
<tr>
<th>Friction loss location</th>
<th>Calculated</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Journal Bearing [w]</td>
<td>10.94 (44.7%)</td>
<td>18.93 (64.3%)</td>
</tr>
<tr>
<td>Thrust Bearing [w]</td>
<td>2.46 (10.1%)</td>
<td></td>
</tr>
<tr>
<td>Cylinder/Piston [w]</td>
<td>6.99 (28.5%)</td>
<td></td>
</tr>
<tr>
<td>Slider [w]</td>
<td>1.82 (7.4%)</td>
<td>10.5 (35.7%)</td>
</tr>
<tr>
<td>Crank Pin [w]</td>
<td>2.27 (9.3%)</td>
<td></td>
</tr>
<tr>
<td>Total [w]</td>
<td>24.48</td>
<td>29.43</td>
</tr>
</tbody>
</table>
ERROR ANALYSIS

Possible sources of the error in measurement of the friction loss are as follows.

<table>
<thead>
<tr>
<th>possible error source</th>
<th>corrections / considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>approximation in eq.(3)</td>
<td>- select t &lt;&lt; 1</td>
</tr>
<tr>
<td></td>
<td>- use eq.(2) and solve it by numerical iteration</td>
</tr>
<tr>
<td>measurement error in $\theta_0$</td>
<td>- If there is some error, then it will be amplified by the order of square.</td>
</tr>
<tr>
<td>measurement of $\Theta(t)$, $t$</td>
<td>- no problem</td>
</tr>
<tr>
<td></td>
<td>- practically simple and accurate</td>
</tr>
<tr>
<td>assumption of viscous damping</td>
<td>- no idea but practically no problem</td>
</tr>
<tr>
<td>power of oil pumping</td>
<td></td>
</tr>
</tbody>
</table>

SUMMARY

1. Simple technique for measuring friction losses are developed.
2. Its accuracy is sufficient for practical applications.

REFERENCES