Some Technical Concepts on the Exchanging or Regenerating System with Ice Bearing as an Example

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Synopsis

Some concepts of exchanging elements in order to maintain a life of total system is discussed here and the many problems arising from this theme will also be mentioned in this paper.

Especially concerning the theoretical study of ice thrust bearing as one example of the restitution or exchanging systems being treated, the author report of the results obtained.

There seems to be a trend toward many wide applications and developments about this technology in the future.

1 Introduction

Recently, the life design of circuits or control system has become more complicated, though its estimation for a life maintenance of mechanical elements is primitive even now.

If a part of such complicated high cost system was damaged, its total system should stop itself or be equal to nothing for its functional value.

It would lead to a great disadvantage and finally the life of the organization would not only die, but also suffer from a disaster.

In this paper, the statistical characteristics and the reliability of the group are not dealt with, but only the life continuity to estimate properly how to burn its boats.

Here, I will propose a few of the problems as follows ;

2 Exchanging Pattern

The old organization or the element used during the prearranged period should be exchanged to a new one instead of continuing its functions.

The exchanging pattern can be considered as follows;

a) Forcing Type

This is a open loop type with new elements as shown in Fig. 1−I. The exchanging element flows down from the one side into the other accidented position to be exchanged and discharged as their elements die step by step. The functional signal into the system should be gone through the exchanged part without changing it.

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The weak point of this type is that it cannot use the element twice.

Then, in the case of emergency and continuous or impatient necessities, we can not keep it safe in functions. In the exchanging response, as the flow shows the on-off pulse, life should be endured during the off-period. Particularly, the number of fresh elements is limited to continuous use.

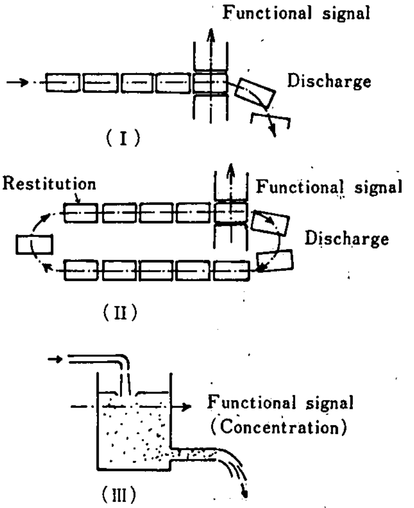


Fig. 1−1 Exchanging Pattern

b) Restitution or Regeneration Type (Nagashino gun type system which was used by the Nobunaga in the famous Nagashino battle)

This is a closed loop flow of the exchanging element. (Fig. 1−II)

The same used element which is able to be recovered or regenerated in the reclamation period can be used many times. In the case of necessarily taking time of reclamation, this type is very useful except that there is no spare.

First of all, in this case, it may call into question, the fact that, first, the fatigue due to recycles might happen to integrate for the long time, and secondly, the over design might limit the other parts by means of that design.

c) Diffusitive Type

The case of exchanging dirty water for clean water by inlet and outlet pipe as shown in Fig. 1−III belongs to this type here.

The quantity of functions are not digital, but continuous media.

d) Recrystalization Type

The same used element become new themselves, the so-called recrystalization in metallurgy.

e) Batch Type

f) Assembly Type and Part Type

As Mentioned above, it will be considered that it is only possible to analize and synthesize the lives of the complicated total system by the estimation of which method is best for the exchange of each element.

We should designate the life control or the flow chart of the above mentioned in order to at least continue the life.

Next, the effects on the total mass for group by the exchanging or failing of one cell or part is considered as an important project. If the multiplication is perfect in that growth process, a total body or machine is derived from the equation as follows

$$y_n = a\sum_{s=1}^{s} m^{s-1}\cdot\left\{1(n-st)-1(n-st-k)\right\} \tag{1}$$

But, if any variables fail anywhere, decisive change of the body might occur.

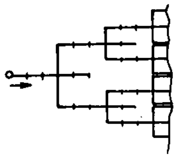


Fig. 1－2 A Example of Multiplication
$a=1,\ t=3,\ m=2,\ k=5$

where a : a number of ancester
k : life period
m : a number of multiplication
n : one step or unit with respect to time
s : a number of generation
y_n : population of cell at the time
$1(\ )$: step function
t : time lag of multiplication $t=1, 2, \cdots$

In this paper, first of all, the case of ice thrust bearing as an example is discussed from the view point of the theoretical design.

Fig. 2 shows the schematic mechanism of the ice thrust bearing.

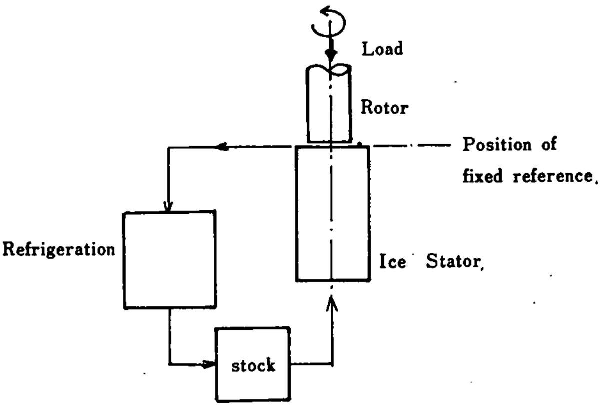


Fig. 2 Schematic of Ice Bearing System

Notice that only a part of this bearing of rotor and stator between these walls is taken up in Fig. 3 .

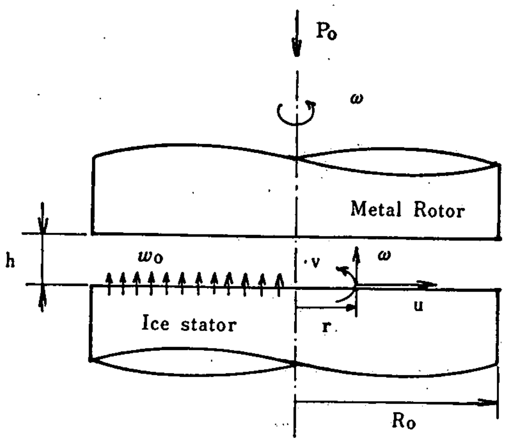


Fig. 3 Ice Hydrostatic Thrust Bearing and its nomenclatures

This bearing geometry as shown Fig. 3 consists of a rotor made of metal and an ice stator which is pushed upward due to melt.

At once, the melting phenomenon is assumed to be an injection from the ice surface as a porous media.

Navier-Stokes equation in circular co-ordinates is used in order to describe the flow motion between two the walls.

3 Nomencluture

h : clearance between walls
p : static pressure
$\boldsymbol{P}$: load capacity of bearing
P_o : $\boldsymbol{P}-(P_{atm}\times\pi R_0^2)$
r : radial distance
R : outer radius of bearing rotor
T : frictional torque of rotor
u : radial velocity component
v : circumferential velocity component
w : axial velocity component
w_o : injection velocity (melting speed)
z : axial distance
μ : fluid viscosity
ρ : fluid density
ω : angular speed of rotor

4 Fundamental Equations and Their Solutions

From their mechanism, we will consider the steady and so-called hydrodynamic lubricating conditions.

Navier-Stokes equation[3] becomes to

$$\begin{cases} -\rho\dfrac{v^2}{r} = -\dfrac{\partial p}{\partial r} + \mu\dfrac{\partial^2 u}{\partial z^2} & (2) \\ 0 = \mu\dfrac{\partial^2 v}{\partial z^2} & (3) \\ 0 = \mu\dfrac{\partial^2 w}{\partial z^2} & (4) \end{cases}$$

and the assumptions of these boundary conditions for each velocities u, v, w are

$$u = w = 0,\quad v = \omega r \quad \text{at } z = h$$
$$u = v = 0,\quad w = w_o \quad \text{at } z = 0$$

where, w_o (melting velocities studied by Wakahama[4] have a tendency to be in proportion to the load pressure.) is injection velocity.

These solution w and v from equation (4), (3) according to their boundary conditions are

$$w = -\frac{\omega}{h}z + w_o \tag{5}$$

$$v = \frac{\omega}{h}r \cdot z \tag{6}$$

By substituting these w, v into an equation (2), and by solving it, we can obtain

$$u = \frac{1}{\mu}\left(\frac{\partial p}{\partial r}\right)\frac{z^2}{2} - \left(\frac{\rho\omega^2 r}{\mu h^2}\right)\frac{z^4}{12} + \left\{\frac{\rho\omega^2 r h}{12\mu} - \frac{1}{2\mu}\left(\frac{\partial p}{\partial r}\right)h\right\}z \tag{7}$$

whereas, the law of continuity is

$$2\pi r\int_0^h u\,dz = \int_0^h 2\pi r w_o dr = \pi r^2 w_o \tag{8}$$

By substituting u of the equation (7) into the above equation, then p is shown as follows ;

$$p = p_{atm} + \left(3\frac{\mu w_o R^2}{h^3}\right)\left(1 - \frac{r^2}{R^2}\right) - \left(\frac{3}{20}\rho\omega^2 R^2\right)\left(1 - \frac{r^2}{R^2}\right) \tag{9}$$

where, $p = p_{atm}$ at $r = R$

If we put w_o equal αp based on Wakahama's relation[4], p satisfies the following equation

$$\left(\frac{\partial p}{\partial r}\right) + \left(\frac{6\mu r\alpha}{h^3}\right)p = \left(\frac{3\rho\omega^2}{10}\right)r \tag{10}$$

Hence, if we put $p = p_{atm}$ at $r = R$, the equation becomes as follows :

$$p' = K\left[1.0 - \left(1.0 - \frac{1.0}{K}\right)\exp\left\{-U(r'^2 - 1)\right\}\right] \tag{11}$$

where $K \equiv \dfrac{1}{20}\dfrac{h^3 P_{atm}}{\alpha\mu\rho R_o^4\omega^2}$, $U \equiv \dfrac{3\alpha\mu R^2}{h^3}$, $p' \equiv \dfrac{p}{p_{atm}}$, $r' \equiv \dfrac{r}{R}$

Then, the load capacity can be obtained by the following equation,

$$\boldsymbol{P} = \int_0^R 2\pi r p\,dr \tag{12}$$

According to the above equation (11),

$$P' = K - \left(\frac{1.0 - K}{U}\right)(1.0 - \exp U)$$

where $P' \equiv P/(\pi R^2 p_{atm})$

Also, in the case of the equation (9), P' is reduced as follows

$$P' = 1.0 + \frac{R^2}{2}\left\{\frac{3\mu w_o}{h^3 p_{atm}} - \frac{3\rho\omega^2}{20 p_{atm}}\right\} \tag{13}$$

Therefore, using the above equation (13), the clearance between their walls becomes

$$h = \left\{\frac{\frac{4}{3}\mu w_o R^4}{\frac{P - \pi R^2 p_{atm}}{2\pi} + \frac{3}{80}\rho\omega^2 R^4}\right\}^{1/3} \tag{14}$$

As a result, the total frictional torque on the rotor can be computed from

$$T = \int_0^R \left(\frac{\partial v}{\partial z}\right)_{z=h} 2\pi\mu r^2 dr \tag{15}$$

Using the equations (6), (14), (15), the torque T becomes

$$T = \frac{1}{2}\pi\mu\omega R^4 \left\{\frac{P - \pi R^2 p_{atm} + \frac{3}{40}\pi\rho\omega^2 R^4}{\frac{3}{2}\pi\mu w_o R^4}\right\}^{1/3} \tag{16}$$

5 Numerical Examples and Discussion

According to equation (9), the pressure distribution between plates has comparatively a tendency to be more flat than to the equation (11) as shown in Fig. 4.

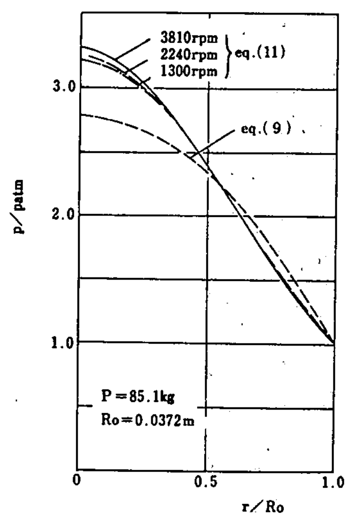


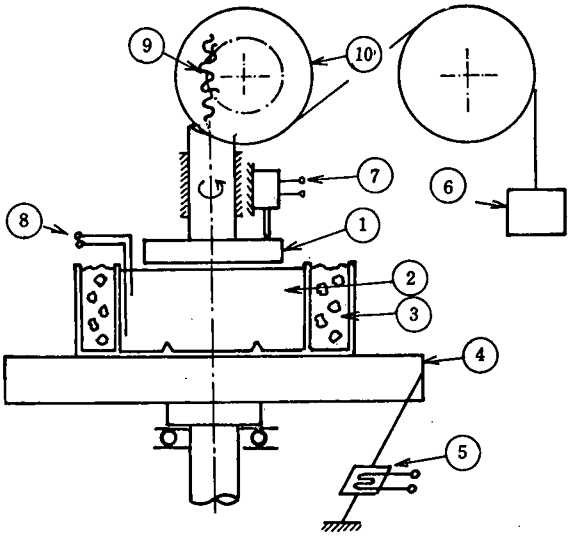
Fig. 4 Pressure Distributions between the Rotor and Stator

In a small P, the latter case of equation (11) has a limit or threshold value of cavitation occurence which has a negative pressure.

Torque increases rapidly with the radius and revolution of the rotor according to the equation (16) except for the small scale and low speed.

6 The Melting Velocity or Injection Speed of Ice Measured Experimentally

As the results of experiments shown in Fig. 5, the author obtained the melting velocity of the ice stator to be about 0.25~0.75mm/s as shown in Fig. 6.



① Rotor ② Ice ③ Cooling Material ④ Base ⑤ Wire Strain Gauge ⑥ Load
⑦ Potentio Meter ⑧ Thermo Couples ⑨ Rack & Pinion ⑩ Pulley & Belt

Fig. 5 Aparatus of the Tested Ice Thrust Bearing

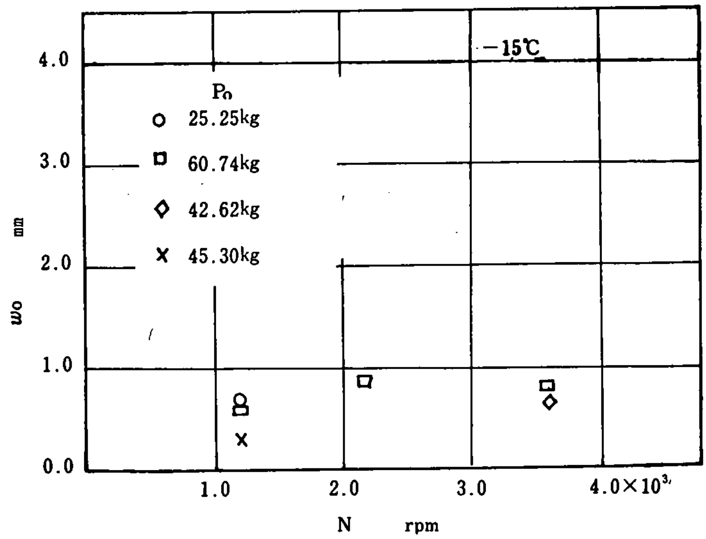


Fig. 6 Injection (melting) Velocity in the tested Ice Thrust Bearing

This value could be estimated as the satisfactory low velocity of the industrial ice bearing with the regenerating system.

7 Conclusion

In order to find out the melting and seizure mechanism of melting bearing and of the first step techniques of the development as an example of regenerating systems, the author tried one simple experiment. Then, it was concluded that the ice bearing system can be useful for industrial application which is necessary to continue the designate life forever.

In the future, step by step, we should study the analysis of biomechanical regenerating system.

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