1. Introduction
This paper analyzes i) the static characteristics of thermally induced levitation (TIL) forces caused by thermal creep flow, which occur only in regions where the Knudsen number is not negligible and a temperature gradient exists, and ii) the static lubrication characteristics of a plane inclined slider over a running boundary wall [1]. Using the molecular gas-film lubrication (MGL) equation with consideration of thermal creep flow, we investigated the basic characteristics both theoretically and numerically, especially when the boundary wall has an inverse V-shaped temperature distribution.

2. Analysis
2-1 Thermal creep flow and thermal induced levitation
When the Knudsen number, \( K_n \), is not negligible (or where the molecular mean free path is not negligible compared with the spacing) and temperature gradients exist along the boundary walls, a special flow referred to as “thermal creep flow” is induced from the colder to hotter regions. When the boundary temperature has an inverse V-shaped distribution, levitation pressure (force) occurs under the slider (Fig. 1).

2-2 MGL equation with thermal creep flow
The molecular gas-film lubrication (MGL) equation can be extended to lubrication problems with a temperature gradient [1, 2]

\[
\frac{d}{dx} \left( \frac{\bar{Q}_f}{H^1} \right) = \frac{d}{dx} \left( \frac{\bar{Q}_f}{H^1} \right) - \frac{A}{1 + \tau_f} \frac{PH^1}{H^1} = 0
\]

where \( H = \frac{h}{h_0} \), \( \bar{Q}_f(D) \) (\( = \frac{Q_f}{Q_{pcw}} \)) and \( \bar{Q}_f(D) \) (\( = \frac{Q_f}{Q_{pcw}} \)) are the pressure flow rate and thermal creep flow rate respectively and both are given in look-up tables.

2-3 Analytical method
Using Eq. (1), numerical calculations and a linearized solution for small a center temperature \( T_{BC} \), are obtained.

3. Numerical results
3-1 Pressure generation for stationary disk (\( A = 0 \))
When \( A = 0 \), the linearized equation for \( \tau_f \ll 1 \) gives the following solution:

\[
P = 1 + 2 \tau_f \left( \frac{\bar{Q}_f}{\bar{Q}_0} \right) X \quad (0 \leq X \leq 0.5)
\]

Figure 2 compares numerical results and a linearized solution for the spacing \( h_0 = 0.1 \mu m \). For small \( \tau_{BC} \), two results coincide with each other. For large \( \tau_{BC} \), the pressure \( P \) increases.

3-2 Pressure generation for running disk (\( A \neq 0 \))
Figure 3 shows pressure distributions for \( h_0 = 0.1 \mu m \) and \( U = 0.1 \) m/s with \( \tau_{BC} \) as a parameter. When \( \tau_{BC} \) is small, the numerical results and linearized solution coincide with each other. Considering the disk speed, the pressure peaks shift to the left. Even when thermal creep flow is neglected, pressure occurs for \( U = 0 \). Figure 4 shows pressure distributions for \( h_0 = 0.1 \mu m \) and \( U = 1 \) m/s with \( \tau_{BC} \) as a parameter. For large disk speeds, and therefore a large bearing number, the numerical solutions approach to \( P \mid_{\infty} (1 + \tau_{f}) \), respectively.

4. Conclusion
Molecular gas-film lubrication (MGL) characteristics are clarified with consideration of the boundary temperature distribution using the generalized MGL equation including thermal creep flow.

References

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**Fig. 1 Thermally induced levitation**

**Fig. 2 Pressure distribution (\( U = 0 \) m/s)**

**Fig. 3 Pressure distribution (\( U = 0.1 \) m/s)**

**Fig. 4 Pressure distribution (\( U = 1 \) m/s)**