Vibration System Analysis of Radial Magnetic Bearing for MMR Condition

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Introduction & Background

- **KAIST-MMR (MMR, Micro modular Reactor)’s Advantages**
  - MMR (fully modulated fast reactor with super critical CO2) has high power density with moderate heat source temperature.
  - MMR can replace the diesel engine to avoid violating the newly released IMO regulation.

- **Appropriate bearing selection**
  From the power scale of the MMR, magnetic bearing is well applicable. Oil lubricated bearing is excluded because oil supply and sealing system harms its compactness and independence.

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  - Shaft breakaways from the revolution orbit
  - Leaked working fluid cools the rotor
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- **Configuration of MMR**
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- **Experimental study of magnetic bearing instability**
  - **Layout of the experiment loop**
    The pump, chiller and heat exchanger are derived from the SCO2PE which is S-CO2 pressurizing loop constructed in KAIST to control the thermal condition
  - **Force analysis**
    The shaft trajectory data is inserted to the developed fluid force analysis model. From this, the fluid force exerted on the shaft during the experiments are estimated. The calculated results are used to verify the model.

- **Modified fluid force analysis model**
  - Lubrication in magnetic bearing with inner coated geometry
    Magnetic bearing’s electromagnet is exposed to the working fluid leaked through the labyrinth seal. Because the complex geometry is difficult to model, smooth geometry is analyzed with model at first.
  - Fluid force model with Reynolds equation
    - Thin film fluid dynamics equation
    - Velocity profile from Navier & Stokes equation
    - Substituting to the continuity equation
    - Negligible axial direction & Quasi steady (perfect revolution)
    - Purpose : Pressure distribution & force exerted to the shaft
  - Fluid force model results for 30,000 RPM and $e$ (Eccentricity ratio) = 0.08
  - Bearing modeling coordinate description
  - Bearing options for S-CO2 Brayton cycles with various power scales

- **Conclusions & Future work**
  - ***Insability source***
    High density of S-CO2 can be the instability source of the magnetic bearing levitation
    This analysis cannot define the effect of the rapid angle change near pseudo-critical line
  - ***State Space Analysis***
    $\dot{X} = AX + Bu $, $X = \begin{bmatrix} \frac{C_r}{m} & 0 & 0 & 0 \\ 0 & \frac{C_r}{m} & 0 & 0 \\ 0 & 0 & \frac{K_m}{m} & 0 \\ 0 & 0 & 0 & \frac{K_m}{m} \end{bmatrix}, \quad A = \begin{bmatrix} a & b & 0 & 0 \\ 0 & a & 0 & 0 \\ 0 & 0 & a & b \\ 0 & 0 & 0 & a \end{bmatrix}$
    - With A’s eigenvalue, the vibration system’s convergence can be predicted.
    - AMB's control strategy can be designed with desired eigenvalue.
    - The effectiveness of it is planned to be tested with several control strategy