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Instability Experimental Design of Magnetic Bearing in KAIST Micro Modular Reactor

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1. Introduction

The newly released IMO regulation forces the diesel engine on the container ship to be replaced to reduce CO_2 emission. Since the ship has limited space, the alternative engine should also be compact enough to be stored in the ship. To satisfy the requirements above, a concept of fully modularized fast reactor with supercritical CO_2 (S-CO_2) cooled direct Brayton cycle, namely Micro Modular Reactor (MMR), can be used. [1]

In case of MMR with 10MWe capacity, the magnetic bearing can be a good choice for the turbomachinery. This conclusion can be readily supported by the previous research, which is also partially shown in fig 1. It is noted that an oil lubricated bearing can bear larger load than other bearings, but because oil and S-CO_2 interaction is unknown and the CO_2's purity would be problematic for MMR, it is not selected. The magnetic bearing is appropriate for the MMR to support the rotor mass while no purity problem is expected.

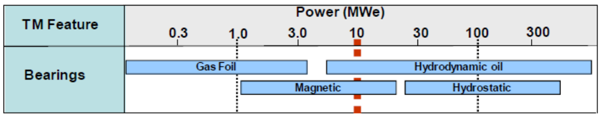

Figure 1. Bearing options for S-CO_2 Brayton Cycles with various power scales [2]

There were several studies related to the magnetic bearing for S-CO_2 Brayton cycle application [4], [5]. However, from these studies, the instability issue was repeatedly mentioned under high pressure operating conditions. The instability induces the eccentricity of the rotor to grow until the clearance between rotor and stator is not enough to operate under the cycle condition. This instability issue was observed to be related to the fluid conditions including pressure and density.

In this paper, the magnetic bearing experiment is designed to find the cause of instability and a method to resolve it. The layout of the experiment loop is suggested to achieve the experimental objectives.

2. Methods and Results

2.1 Magnetic bearing description

The magnetic bearing uses 8 electromagnets to apply the magnetic force to the rotor. The symmetrically located 8 electromagnets make possible to consider two axis of rotor separately. This is described in fig 2. To satisfy its purpose, the inductive displacement sensor detect the clearance of the bearing. From the detected signal, the controller manipulates the current to control the magnetic force.

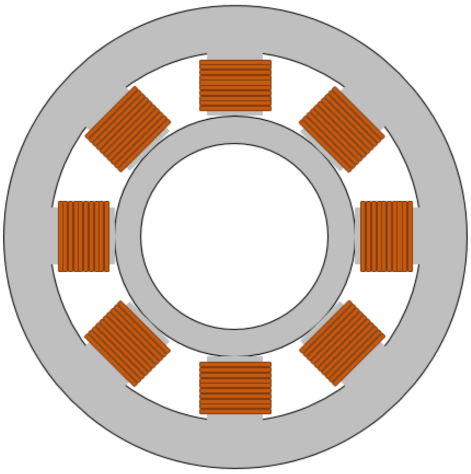

Figure 2. Cross Section of Radial Magnetic Bearing

The empty space is filled with the working fluid. In case of the Brayton cycle, the leaked fluid from the labyrinth seal cools the rotor as well.

In this experiment, the bearing and rotor is operated without impellers or dummy disks to isolate the rotor from other issues. By doing this the authors think that evaluating the instability issue of the rotor can be more easily done. This would keep the working fluid from circulation so that there is no leaked fluid to cool the system. Because the frictional energy loss from the rotation is huge, the water jacket type of cooling without inner cooling would not be enough to keep the system's temperature. From this reason, pump will be added in the loop for the circulation.

2.2 Instability tendency evaluation

The rotor is initially balanced so that the center of the rotor is almost overlapped. However, during the rotation under the cycle operating conditions, the instability starts to develop which results in rotational speed to be lower than the design speed.

Since the rotor eccentricity should not be the same or larger than the clearance so that rotor does not hit the bearing, the instability's dimension is related to the length or force. Since the controller uses displacement sensor, the instability can be evaluated by measuring the eccentricity.

It was previously observed that the instability magnitude varies with the working fluid's properties [4]. One of the potential instability inducing factor can be the working fluid properties in the bearing gap. These properties could be pressure, density, viscosity or others. This conditions will be controlled during the experiment with a pump and a chiller.

2.3 Cooling for frictional energy loss

The major loss of the rotor motion is the windage loss which is due to the friction between rotor and working fluid. The amount of the windage loss is predicted from [3]. This experiment requires a chiller whose capacity should be larger than the windage loss.

As mentioned in 2.1, this amount of the loss cannot be absorbed only by the water jacket cooling since the system temperature can become too high. Therefore, the chiller should have parallel structure so that chiller can absorb heat from both working fluid and the shielding of the system.

2.4 Layout of the experiment loop

Based on the above discussion, the layout of the experiment loop is determined while considering the bearing structure and to investigate the instability issue. It is shown in fig 3.

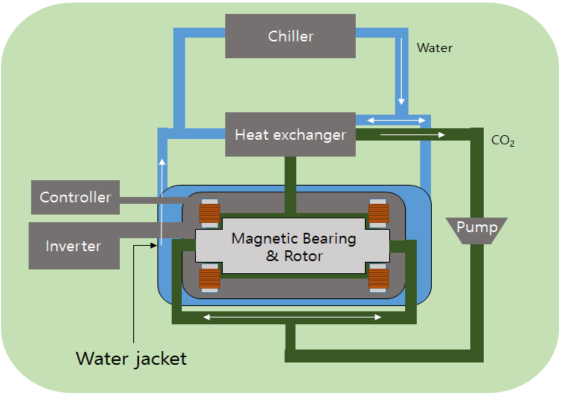

Figure 3. Layout of the Bearing Instability Experiment

In this experiment layout, the CO_2 axial mass flux is assumed negligible compared to the radial mass flux because the rotor rotates rapidly while labyrinth seal blocks the CO_2.

From this figure, the water flux from the chiller is separated to manipulate the chilling ratio between heat exchanger and water jacket. The heat exchanger is the preparation for the shortage of the water jacket's heat transfer ratio. The other reason is that, with heat exchanger and pump, the temperature distribution around the rotor can describe the real cycle condition in detail. From these reasons, the mass flux between heat exchanger and water jacket should be controlled throughout the experiment.

2.5 Process of the experiment

The displacement of the rotor has its magnitude and frequency. Its magnitude is regarded as having some relations with the working fluid properties and the rotational velocity.

To understand the relations of fluid's properties and instability, the displacements for various fluid properties and rotational velocities should be measured and compared. From the comparison, the tendencies between instability and the variables will become apparent.

3. Conclusions

The experimental facility is being prepared, and the instability from expected external forces are being evaluated. The expected forces affecting the instability are fluid friction, rotor unbalance, rotor bending and so forth. The calculation results will be helpful to evaluate the experimental results.

After the experiment, the control method of magnetic bearing under S-CO_2 power cycle conditions with reduced instability can be suggested.

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