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A Study on The Stability of the Rotor of the Cryogenic Centrifugal Pump

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The stability of the rotor of the centrifugal pump operating at a cryogenic temperature (-196°C) with/without an inducer shall be ensured. This paper describes the analysis process of determining the stability of the rotor for a cryogenic centrifugal pump in the design step using ARMD, a commercial program for rotor analysis. First, the accuracy of a finite element model of the rotor through comparative analysis of ANSYS and ARMD at convential and cryogenic circuimstances is verified, Second, ARMD is used to analyze the critical speed of the rotor with/without an inducer in a cryogenic situation. Finally, the stability of the seal gap is confirmed by an unbalanced response analysis under cryogenic conditions.

1. Introduction

In recent years, as cryogenic liquid industries such a s LNG increase, the use of centrifugal pumps required f or transporting cryogenic liquids is required. Figure 1 sh ows the 3D model of the centrifugal pump. For the sta bility of the cryogenic centrifugal pump, a stable operati on of the rotating body in the cryogenic state is require d. Therefore, in this paper, we want to confirm the stab ility of the rotating body. First, interpretation accuracy i s verified through comparison between ANSYS and AR MD. Second, the Critical speed Analysis of rotor with/ without inducer in a cryogenic state. Finally, the stabilit y of the seal gap is confirmed through unbalanced resp onse analysis in a cryogenic environment.

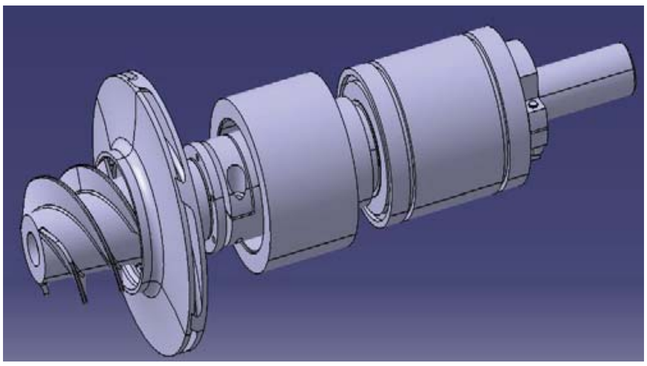

Fig. 1 Rotor 3D Model

2. Verifying Analysis Accuracy

Analysis was conducted through ANSYS, a commercial program for finite element analysis. First, we proceed with modeling of cross-sectional information to be applied to the line. The cross-section was circular to simplify the model, and the same diameter as the actual rotation axis was input and modeled. The physical properties of the axis at room temperature required for analysis are stainless steel, as shown in Table 1. Second, the impeller modeling is conducted. For simplification, the impeller was modeled as a simple circular disk shape to have the same mass as the existing shape, and was designated as a point mass during analysis and applied to the axis. Table 2 shows the components of the point mass. The position of the bearings was applied the same as the actual one, and a total of four bearings were applied. The Stiffness value of the bearing was 10^8 N/m and the Damping value was 0 Ns/m. Finally, set the RPM range you want to check. Since the actual rotational speed of the rotor is 3600 RPM, set the range to 0 to 6000 RPM and with the analysis. Through ARMD, a commercial program for rotor analysis, finite element modeling was performed with 45 elements and 46 mass points as shown in Figure 2. The impeller was applied to mass point 6, and the bearings were applied to mass point 10, 12, 31, and 37. Analysis proceeds by applying the same analysis conditions and rotational speed as ANSYS analysis. Table 3 shows the analysis results of ANSYS and ARMD. As a result of the analysis, it can be confirmed that the natural frequencies of the same model are almost identical. Therefore, the accuracy of the ARMD results has been verified.

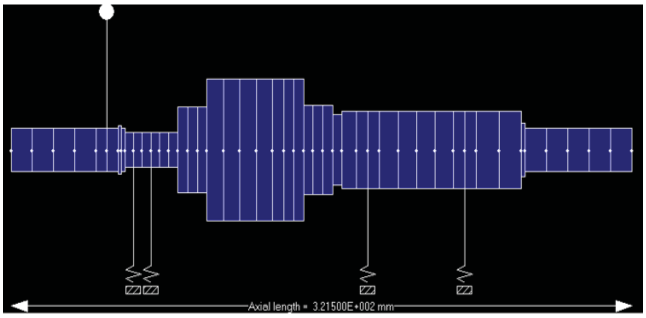

Fig. 2 Without Inducer Model

Table 1 Physical properties of the axis at room temperat ure

Young's Modulus	193	[GPa]
Shear Modulus	74.23	[GPa]
Density	7980	[Kg/m^3]

Table 2 Point Mass Ingredient

Mass	Moment of Inertia	Polar Moment of Inertia
0.799 [Kg]	5.48e-004 [Kg · m^2]	1.097e-003 [Kg · m^2]

Table 3 First Frequency Mode

RPM	ANSYS Freq. [Hz]	ARMD Freq. [Hz]
1000	993.78	997
4000	975.48	978.73
6000	963.42	966.61

3. Critical Speed Analysis of Rotor with/without Indu cer in Cryogenic Environment

Analysis at cryogenic conditions is conducted by cha nging only physical properties during analysis at room t emperature. The Figure 2 shows a without inducer mo del.with inducer model is shown in Figure 3. The mater ials, characteristics, inducer, and impeller values at cryo genic temperatures are as shown in Table 4, and the be aring values are analyzed by applying the same stiffness and attenuation values. Next, like the analysis at room t emperature, set the range to 0 to 6000 RPM and with t he analysis. Table 5 shows the results with/without indu cer in a cryogenic environment. As a result of the anal ysis, it was confirmed that the primary eigenfrequency o fthe model equipped with the inductor was at least 744. 23 Hz and at most 767.5 Hz. In addition, models witho ut inductors showed a minimum of 993.95 Hz and a m aximum of 1032.18 Hz. This value significantly exceeds the rotor's rated operating RPM of 3600 RPM (60 Hz) and therefore has no resonance hazard.

Table 4 Cryogenic Environment STS316L Material Prop erties

Young's Modulus	212.25	[GPa]
Shear Modulus	81.9	[GPa]
Density	7926.5	[Kg/m^3]

Table 5 Cryogenic Environment First Frequency Mode

RPM [Speed]	With Inducer Freq. [H z]	Without Inducer Freq. [Hz]
1000	763.66	1026.13
4000	751.98	1006.8
6000	744.23	993.95

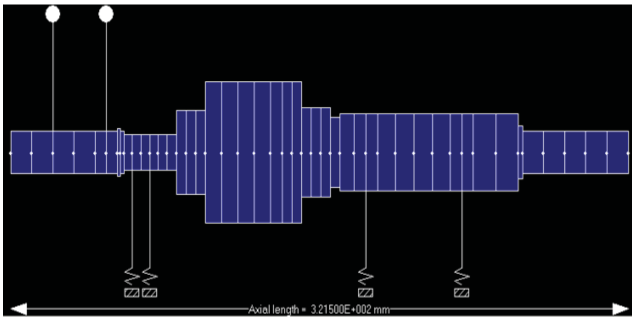

Fig. 3 With Inducer Model

4. Confirmation of seal clearance stability through unbal anced response analysis in cryogenic environment

To calculate the unbalance load to be applied to the connections of the axes, obtain the value using the unba lance load diagram. If you look for an intersection of36 00 RPM and G1.0, can find an eccentricity of 2.65 µm. If the value is obtained using the Unbalance load formu la, the Unbalance load value of 1.6N can be obtained. The unbalance load value is applied to the 20th mass p oint to conduct an unbalanced response analysis to confi rm the stability of the seal gap. As a result of the anal ysis, all models including/not including an inducer in a cryogenic environment showed values within the range o f 9E-06 mm to 1E-05 mm. These fine values are consi dered difficult to affect the gap between the seal and th e axis. Therefore, it is judged that the stability of the s eal gap has also been secured.

5. Resulfs

This paper verifies the accuracy of analysis through the comparison between ANSYS and ARMD, first to co nfirm the stability of the cryogenic centrifugal pump. Se cond, the critical speed of the rotating body according t o the presence or absence of an inducer in a cryogenic environment was analyzed. Since the result value accord ing to the presence or absence of an inducer significantl y exceeds the actual rated operating RPM value of the rotor, it is judged that there is no resonance risk. Finall y, the stability of the seal gap was confirmed through a n unbalance response analysis in a cryogenic environme nt. As a result of obtaining the value using the Unbalan ce load diagram and performing an unbalanced response analysis, all models with/without an inducer showed val ues in the range of 9E-06mm to 1E-05mm. Since thesef ine values are considered difficult to influence the sealg ap, the stability of the seal gap is also secured It is jud ged that stable operation of the rotating body is possibl e at cryogenic temperatures.

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