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MODAL ANALYSIS AND VIBRATION TEST OF SINGLE SPOKE RESONATOR TYPE-1 (SSR1) FOR RAON*

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Abstract

Rare Isotope Science Project (RISP) is developing the single spoke resonator type-1 (SSR1) and type-2 (SSR2) for making superconducting linear accelerator 2 (SCL2). For optimizing of SSR1 and SSR2, we should research every aspects of superconducting cavity including RF performances and mechanical properties. This paper explains about modal analysis of SSR1 using FEM (finite element method) applying material properties of RRR300 niobium for bare cavity and STS316L for liquid helium jacket. Also, this paper shows the vibration test results with modal analysis.

INTRODUCTION

RISP SCL is divided with two sections, SCL3 from ISOL/ECR to low-energy experimental area and SCL2 from the end of SCL3 to high-energy experimental area [1]. Through prototyping, RISP also investigated the resonant frequency characteristics of SSR1 SC cavity due to outer disturbance. This paper explains about modal and harmonic response simulation of SSR1 SC cavity using ANSYS ver.2018, and compares analysis result with the vibration test of dressed SSR1 cavity done by lateral vibration machine.

SSR1 MECHANICAL DESIGN AND MANUFACTURED SC CAVITY

RF Design of SSR1 SC cavity was proceeded based on the contract with TRIUMF. After contract, SSR1 engineering drawing was released by 2016 [2–5] and prototype test was finished by 2019 [6]. Figure 1 shows the first prototype of SSR1 SC cavity, and Table 1 shows the SSR1 cavity design parameters. Based on this design, RISP modified RF shape and fabrication process, and the modified SSR1 SC cavity was fabricated and tested at the RISP Sindong SRF. Currently four dressed cavity has been made, one of them has finished the cold test and satisfied target Eacc and Q factor, and three cavities is now preparing for the cold test.

Figure 1: SSR1 SC Cavity Design.

Table 1: SSR1 Cavity Design Parameters

Parameters	Values	Units
Operating Frequency	325	MHz
Beta	0.3	-
Operating Temperature	2	K
Epeak/Eacc	<4.5	-
Bpeak/Eacc	<7	mT/(MV/m)
Vacc	2.5	MV
df/dP	<10	Hz/mbar
Beam Aperture	50	mm
Pressure Envelop 300 K	>2	bar
Pressure Envelop 5 K	>5	bar

SSR1 MODAL ANALYSIS

For the operation of SC cavity, the natural/resonant frequency should be clearly defined for analyzing the sensitivity of microphonics and LFD according to its resonant frequency. Defining the resonant frequency, the modal and harmonic response analysis of SSR1 SC cavity was proceeded with commercial program ANSYS 18.0 [7]. Figure 2 shows the mesh shape of SSR1 SC cavity. Automated tetrahedral mesh, which is approximately 520,000 elements, was used for FEM analysis. Materials of bare cavity and liquid helium jacket were applied high purity niobium and stainless steel 316L [8], and ANSYS workbench solvers were connected with structural, modal, and harmonic response. Modal analysis checked resonant frequency modes up to 25, and harmonic response drew the bode plot up to 1000 Hz

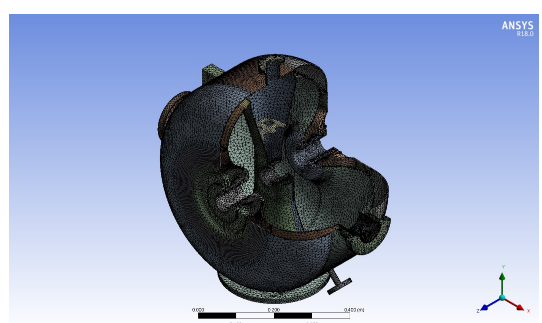

Figure 2: Mesh Shape of SSR1 Dressed Cavity.

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with 5 Hz resolution. Checking the response difference, the response was calculated at three points, spoke center, fixed and free cover. Consequently, three response results were shown in the FigureS 3–5, and common resonant frequency peaks were appeared near 40, 240, 350, 580, and 710 Hz. Commonly appeared frequency modes of above figures are shown in the Figure 6–10.

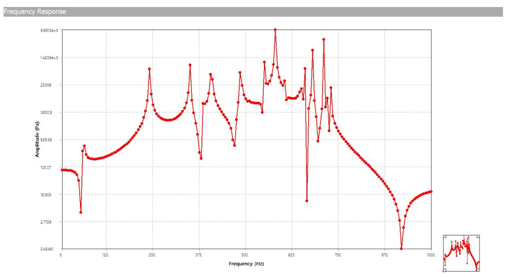

Figure 3: Harmonic Response of Spoke Center.

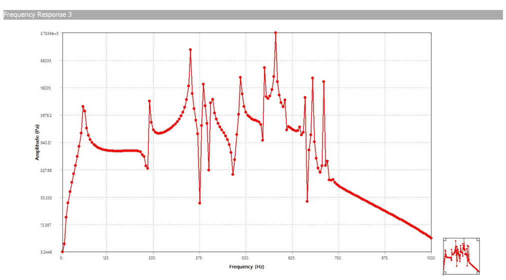

Figure 4: Harmonic Response of Fixed Cover.

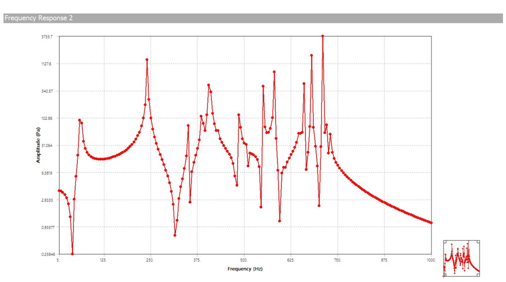

Figure 5: Harmonic Response of Free Cover.

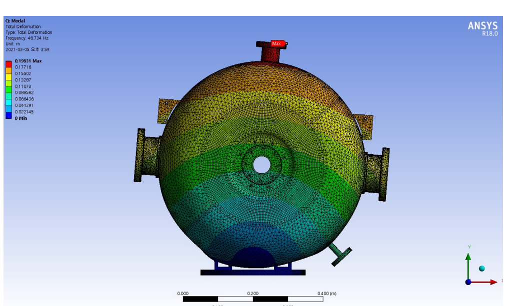

Figure 6: 1st Mode - 46.73 Hz.

SSR1 VIBRATION TEST

After analyzing resonant frequency peaks of SSR1 SC cavity with ANSYS code, the actual resonant frequency

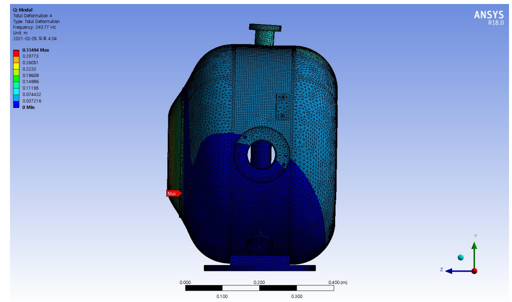

Figure 7: 4th Mode - 240.77 Hz.

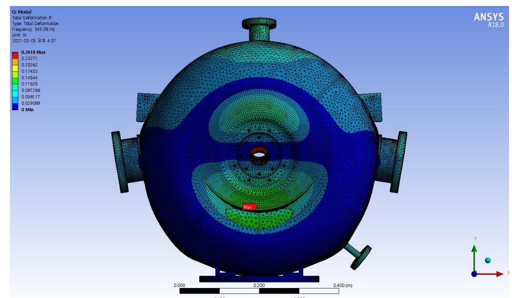

Figure 8: 8th Mode - 349.38 Hz.

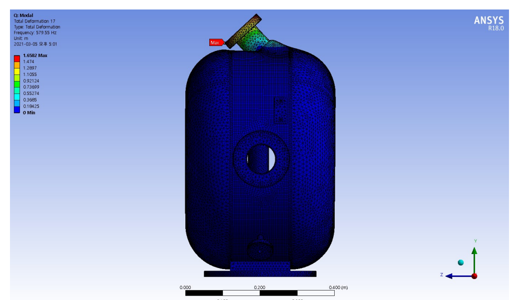

Figure 9: 17th Mode - 579.55 Hz.

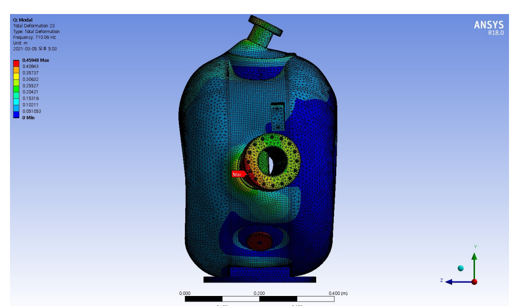

Figure 10: 23th Mode - 710.06 Hz.

should be checked for the evaluation of FEM code. Previous QWR SC cavity FEM analysis was also evaluated by actual vibration test [9], and we can make a acceptable FEM analysis procedure when we applied same vibration test to SSR1 SC cavity. Figure 11 shows the vibration test preparation of SSR1 SC cavity by the Korea Institute of Machinery and Materials (KIMM). At Fig. 11, four vibration sensors were used. CH1 is a baseline sensor, CH2 is spoke-center, CH3 is fixed-cover, and CH4 is free-cover. Figure 12 shows a simple

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fixture for installation vibration sensor at the spoke center and used vibration sensor. Vibration machine is FAMTECH EDS-4000LS which is same as used for previous QWR SC cavity test, and vibration test codes are KS B ISO 10055 and JIS D 1601. Vibration was applied up to 1000 Hz, and acceleration value was initially 0.5G and changed to 0.3G due to higher vibration response. Vibration mode was shown in Fig. 13 [10], and resonant frequency mode of SSR1 SC cavity appeared very similar to the FEM analysis results. First resonant peak – simply bending mode - is around 48 Hz and near to 46 Hz by FEM code. Next peak is around 234.6 Hz and near to 240.77 Hz, and fourth peak is around 349.2 Hz and near to 349.38 Hz by FEM code. Fifth peak is around 580.8 Hz and near to 579.55 Hz, and sixth peak is around 737.3 Hz and near to 710.06 Hz. Table 2 shows the comparison summary between FEM analysis and vibration test.

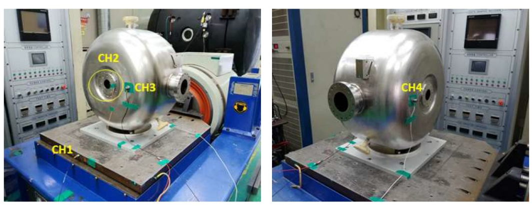

Figure 11: SSR1 SC Cavity Vibration Test Setup.

Figure 12: Sensor Fixture and Vibration Sensor.

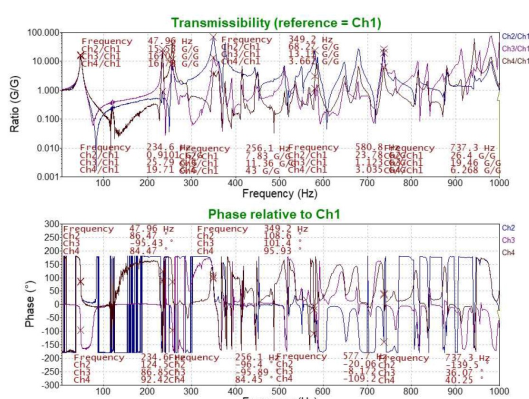

Figure 13: Vibration Test Results.

CONCLUSIONS AND FUTURE WORKS

Through this paper, we can see that ANSYS FEM code for modal analysis of SSR1 SC cavity can estimate its resonant frequency quite precisely. Same as QWR, frequency map of SSR1 SC cavity is plotted and used for avoiding resonant frequency caused by outer disturbance. And, undoubtedly, I expect that resonant frequency of SSR2 SC cavity is calculated and estimated using same ANSYS code. RISP will proceed this numerical analysis after fabrication and cold test of SSR2 SC cavity.

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Table 2: FEM Simulation and Vibration Test Comparison

Simulation	Vibration Test	Modes
46.73 Hz	47.96 Hz	Simply Bending
240.77 Hz	234.6 Hz	Free Cover Fluctuating
265.54 Hz	256.1 Hz	LHe Inlet Bending
349.38 Hz	349.2 Hz	Free Cover Torsion
579.55 Hz	580.8 Hz	Lhe Outlet Bending
710.06 Hz	737.3 Hz	Complex

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