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MODE ANALYSIS OF SINGLE SPOKE RESONATOR TYPE-2 (SSR2) FOR RISP *

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ABTRACT

Rare Isotope Science Project (RISP) in the Institute of Basic Science (IBS), Daejeon, South Korea, is developing the high-energy superconducting (SC) linac composed of two types of superconducting cavities, single spoke resonator type-1 (SSR1) and type-2 (SSR2) [1]. Both cavities have same RF frequency of 325MHz, but different beta, 0.3 for SSR1 and 0.51 for SSR2. For operating SC cavity within the target frequency, all external disturbances must be removed or avoided. From a view of mechanical vibration, comparably low frequency up to 20kHz always happens as a consequence of combination between outer disturbance and resonant frequency of SC cavity. In this paper, we will show the design layout and the specifications. Also, the mechanical resonance analysis for both bare and dressed cavity will be conducted with a numerical analysis program.

SSR2 SC CAVITY

SSR2 SC cavity prototyping was started from 2018, and its design concept was balloon-variant which came from the research collaboration with TRIUMF, the national laboratory of Canada [2]. For suppressing multipacting, the balloon-variant design is applied to both SSR1 and SSR2 of RISP. Table 1. shows the comparison result of SSR1 and SSR2 specifications [3].

Table 1: Specifications of SSR1 and SSR2

Spec.	SSR1	SSR2
Operating Frequency	325MHz	
Beta	0.3	0.51
Epeak	35MV/m	
Vacc	> 2.4MV	> 4.1MV
Q0	>3.2E9	>5E9
df/dP	<10Hz/mbar	
Aperture	50mm	
Pressure Envelope @ 300K	2 bars	
Pressure Envelope @ 2K	5 bars	

Figure 1 shows the layout of SSR2 SC cavity. RISP is now making six SSR2 SC cavities for prototyping [4]. Until now, 4 cavities are fabricated as a bare cavity and ready for cryogenic test, and 2 cavities are now on the electron beam welding (EBW) stage. Figure 2 shows the EBW finished SSR2 bare cavity.

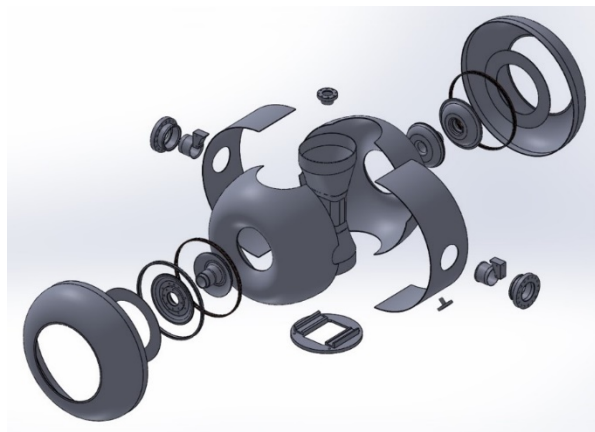

Figure 1: Layout of SSR2 Dressed Cavity.

Figure 2: Fabricated SSR2 Bare Cavity.

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SSR2 MODE ANALYSIS

Same as SSR1 [5], the finite element method (FEM) simulation was proceeded for evaluating the mechanical characteristics of SSR2 SC cavity such as Von Mises stress and deformation/strain. Also, mode analysis and harmonic response were calculated for defining its structural characteristics. However, unlikely to SSR1, SSR2 SC cavity fabrication process is not finished yet, thus the vibration test of SSR2 SC cavity is not proceeded.

Nonetheless of the absence of vibration test for SSR2 SC cavity, mode analysis of this paper make it possible to estimate the mechanical resonance of SSR2 SC cavity. Because during the previous studies and experiments [5,6], current numerical analysis method and code is verified for predicting mechanical resonance of other systems such as quarter wave resonator (QWR) or single spoke resonator type-1 (SSR1) precisely. Therefore, in this paper we will discuss only with numerical analysis with commercial code, ANSYS ver.18 [7].

MODEL SETUP AND ANALYSIS

Figure 3 shows the meshed shape of dressed SSR2 SC cavity. SSR2 SC cavity is mainly composed with two materials, pure niobium for bare cavity and 316L stainless steel for liquid helium jacket. Table 2 shows the material properties of pure niobium and 316L stainless steel [8].

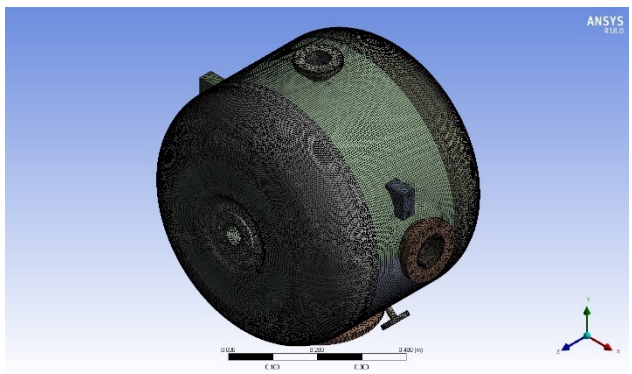

Figure 3: Mesh Shape of SSR2 SC cavity.

Table 2: Material Properties

Spec.	RRR300 Niobium	Stainless Steel 316L
Young's Modulus	107 GPa	193GPa
Poisson's Ratio	0.36	0.25
Yield Strength	51MPa	170MPa
Maximum Tensile Sterngth	134MPa	483MPa

Figure 4 shows the boundary conditions for numerical analysis. We applied fixed support condition to jacket support block – bottom side, gravitational force condition for its own weight, and 0.2 MPa pressure condition at the outer surface of bare cavity and inner surface of liquid helium jacket.

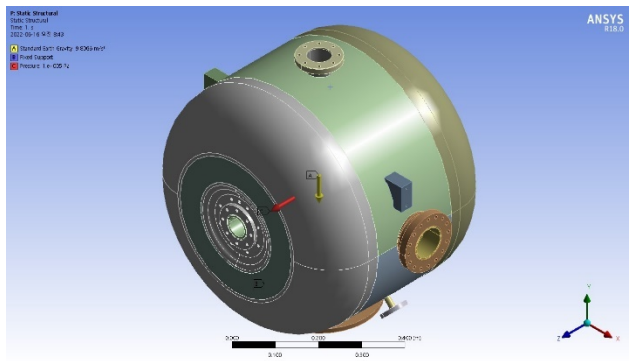

Figure 4 : Boundary conditions.

After finishing structural analysis, we proceeded modal and harmonic response analysis. Same as SSR1 simulation, harmonic response was calculated at three points, spoke centre, free cover and fixed cover. Free cover means no connection between cavity stiffener ring and jacket, and fixed cover means TIG weldment between cavity stiffener ring and jacket. Figure 5 to 8 show the four harmonic response analysis results, spoke centre, free cover, fixed cover and three-points combined. At figure 5, the four highest and dominant peaks are shown around 585, 420, 220, 40 Hz. We can define other peaks at different points from figure 6 to 8 as same as figure 5.

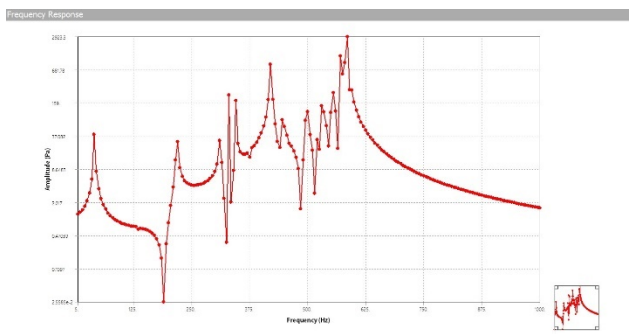

Figure 5 : Harmonic Response – Spoke Centre.

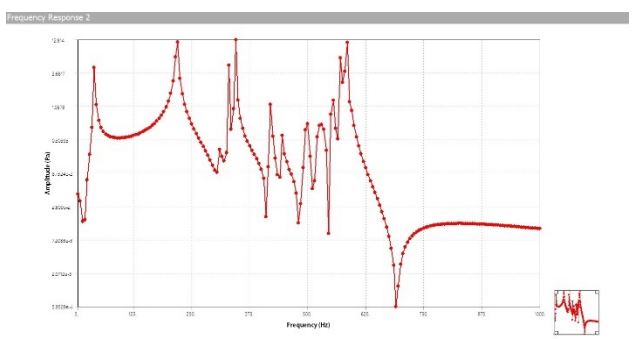

Figure 6 : Harmonic Response – Free Cover.

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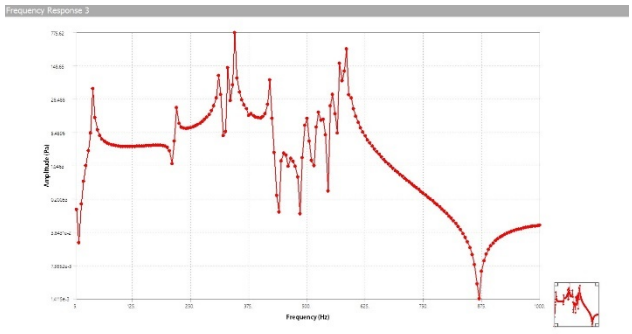

Figure 7 : Harmonic Response – Fixed Cover.

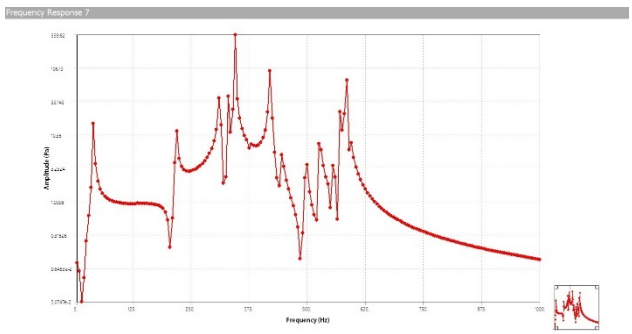

Figure 8 : Harmonic Response – Combined.

Table 3 shows the summary of highest and dominant peaks of three points each and combined. With this summary, we can observe five main dominant peaks. Figure 9 to 13 show the mode summary of each peak.

Table 3: Mode Summary

Points	First (Hz)	Second (Hz)	Third (Hz)	Fourth (Hz)	Fifth (Hz)
Spoke Centre	40	220		420	585
Free Cover	40	220	345		585
Fixed Cover	40		345	420	585
Combined	40	220	345	420	585

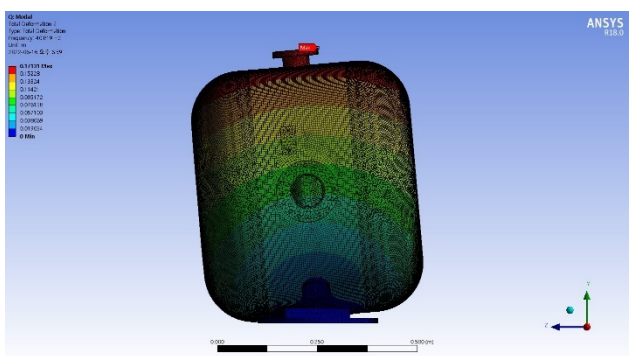

Figure 9 : 1st Mode – Simply Bending (pitching).

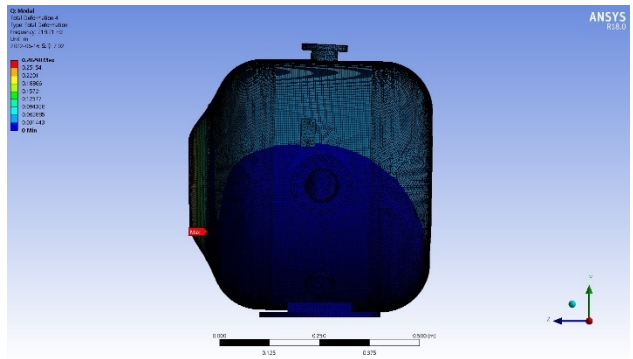

Figure 10 : 2nd Mode – Free Cover Fluctuation.

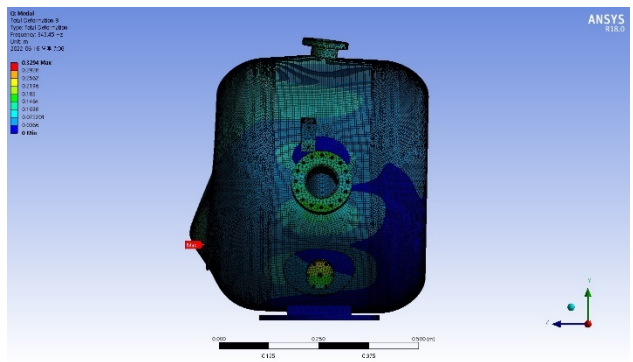

Figure 11 : 3rd Mode – Complex Mode.

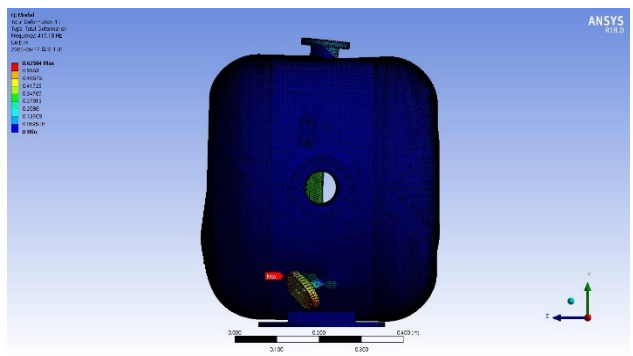

Figure 12 : 4th Mode – Helium Inlet Bending.

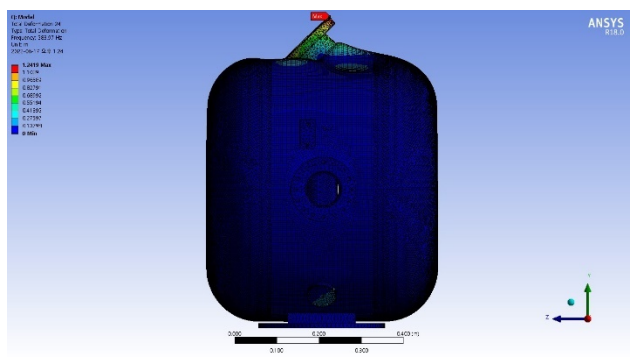

Figure 13 : 5th Mode – Helium Outlet Bending.

ANALYSIS COMPARISON

Comparing with SSR1 mode analysis results, we found that there was a similarity between SSR1 and SSR2 mode shape. Table 4 shows the comparison of SSR1 and SSR2 mode analysis results.

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Table 4: Comparison of SSR1 and SSR2 Modes

Num.	SSR2 Mode (Hz)	Mode Def.	SSR1 Mode (Hz)	Mode Def.
1st	40.82	Bending	46.73	Bending
2nd	218.2	Fluctuate	240.8	Fluctuate
3rd	-	-	265.5	He Inlet
4th	345.5	Torsion	349.4	Torsion
5th	419.2	He Inlet	-	-
6th	584.0	He Outlet	579.6	He Outlet
7th	-	-	710.1	Complex

From the table 4, SSR1 and SSR2 mode analysis results are very similar. The first mode of both cavities exists near 40Hz, 46.73Hz for SSR1 and 40.82Hz for SSR2. The second and the fourth modes of both cavities are also so close each other, 240.8Hz for SSR1 and 218.2Hz for SSR2 in the free cover fluctuation mode, 349.4Hz for SSR1 and 345.5Hz for SSR2 in the free cover torsional mode. Through this comparison, it can be assumed that shape similarity between two cavities makes structural similarity and mechanical resonances appear very similar to the outer disturbance. Nonetheless, there is a slight difference between the mode analysis of two cavities. It might come from the weight(mass) difference. SSR2 is heavier than SSR1, so the resonant frequency of SSR1 can be smaller than that of SSR1, because the frequency of system is directly proportional to the stiffness and is inversely proportional to the mass.

We will proceed the vibration test of dressed SSR2 SC cavity after finishing our cryogenic test.

CONCLUSION

Through analysis, we can find that SSR2 mode is very similar to SSR1. RISP are now preparing for the next stage, pre-production of SCL2 which has a plan for fabrication of modified SSR1 and SSR2 model. For activating next stage, RISP will finish the current SSR1 and SSR2 prototyping stage within this year.

ACKNOWLEDGEMENTS

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