ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-TUP032

MODAL ANALYSIS AND VIBRATION TEST FOR QUARTER WAVE RESONATOR FOR RAON*

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Abstract

The Rare Isotope Science Project (RISP) in the Institute of Basic Science (IBS), Korea, is developing and constructing the multi-purpose linear accelerator at the north side of Daejeon, South Korea. RISP accelerator (RAON) is composed of low-energy region (SCL3) and high-energy region (SCL2) [1]. Low-energy region is made with quarter-wave resonator (QWR) and half-wave resonator (HWR) while high-energy region is made with single spoke resonator type-1 (SSR1) and type-2 (SSR2). This paper presents the initial resonance issues of QWR superconducting (SC) cavity occurred during cold test and disturbance measurement in the Munji SRF test facility. Also, this paper shows the modal analysis and vibration test of QWR SC cavity.

INTRODUCTION

Since 2018, RISP enters the pre-production stage for SCL3 so that QWR and HWR SC cavities [2], RF couplers, tuners, and cryomodules [3] are prepared with entire assembly. For the mass-production, first we should evaluate the QWR and HWR entire assembly. We prepared for the first pre-production QWR cryomodule test with fully-assembled QWR cryomodule. Figure 1 shows the installed QWR cryomodule in the horizontal test bunker at the Munji SRF test facility.

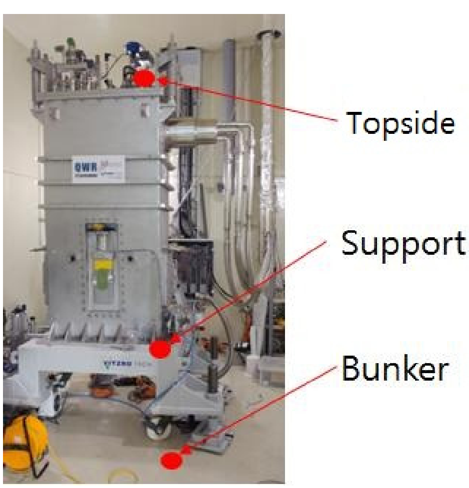

Figure 1: Installed QWR SC Cryomodule.

*This work was supported by the Rare Isotope Science Project (RISP) of Institute for Basic Science (IBS) funded by Ministry of Science and ICT and NRF of South Korea (2013M7A1A1075764)
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RESONANCE OF QWR SC CAVITYDURING COLD TEST

During cold test, there were some failures for RF phase control of QWR cavity due to unexpected disturbances. After finishing cold test, we measured the vibration level on the several points of Munji SRF test facility. By repeating turn-on and turn-off of all devices including general utilities, we found that there were two main outer disturbances, one came from the cold box of cryogenic system and the other came from the water circulation pump connected to the utility water supply line. Figures 2 and 3 show the disturbances from both vibration sources corresponding to the device on and off.

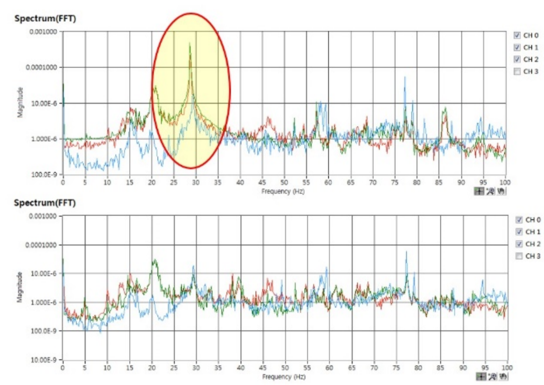

Figure 2: Disturbance from Cold-Box (upper – turn-on, lower – turn-off).

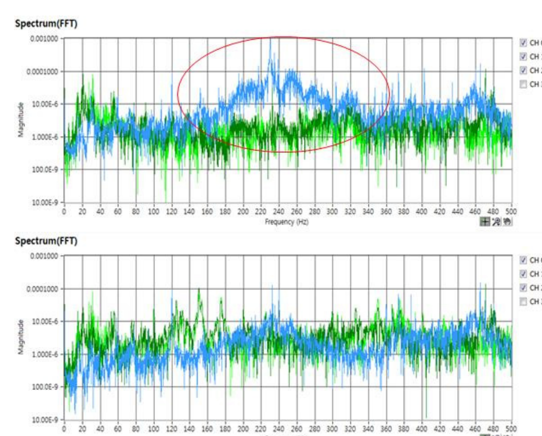

Figure 3: Disturbance from Circulation Pump (upper - turn-on, lower - turn-off).

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The disturbance from the cold-box is around 27 Hz and the other disturbance from circulation pump is between 200 Hz and 280 Hz. Vibration from any source can be reduced by applying proper damping system, but cannot be removed. Furthermore, any disturbance can affect the RF control. Therefore, we focused on the analysis of low frequency effect to the QWR SC cavity including modal analysis and vibration experiments.

MODAL ANALYSIS OF QWR SC CAVITY

Figure 4 shows the modelling of unjacketed QWR SC cavity with ANSYS Mechanical ver.18.0. Initially QWR SC cavity has a weakness with mechanical vibration because of inner conductor which behaves as a pendulum.

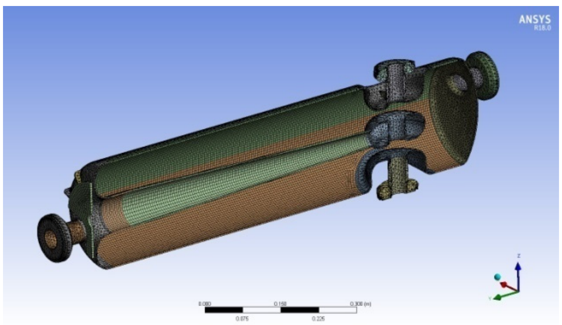

Figure 4: Modelling of unjacketed QWR SC Cavity.

For the modal analysis, beam port flange was fixed as boundary condition with applying gravity which could make a weight force to the whole body. We found two modes of QWR SC cavity corresponding of the outer disturbances. Figure 5 shows the first bending mode of inner conductor which have a 35 Hz and 42 Hz frequency which we have found at first prototyping [4]. Figure 6 shows the second bending mode of inner conductor at 246 Hz. Applying harmonic analysis, we can make a bode plot of unjacketed QWR SC cavity as shown in Fig. 7.

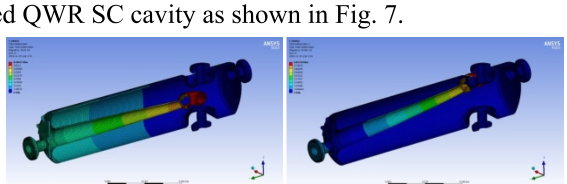

Figure 5: Inner Conductor 1st Bending Mode (left - In-phase bending, right - Pure bending).

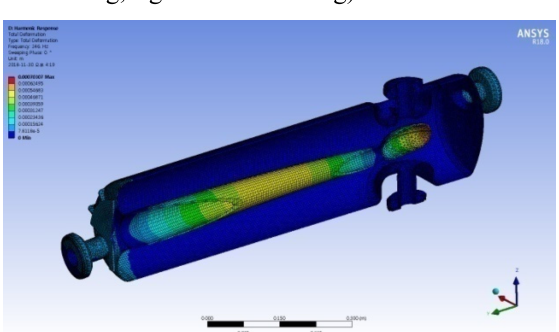

Figure 6: Inner Conductor 2nd Bending Mode.

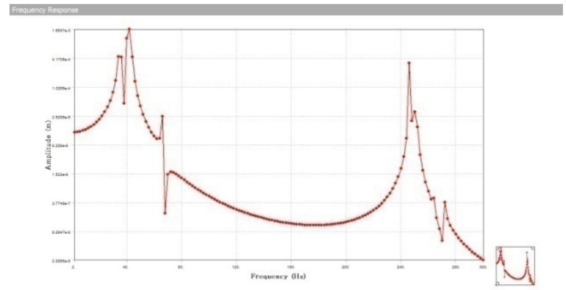

Figure 7: Bode Plot of Unjacketed QWR SC Cavity.

Through the FEM analysis we calculated the lower modes of QWR SC cavity which could make RF power uncontrollable. Proving this analysis, we proceeded the vibration test of unjacketed QWR SC cavity with vibration test system.

VIBRATION TEST OF QWR SC CAVITY

Figure 8 shows the setup for the vibration test at the Korea Institute of Machinery and Materials (KIMM), the one of the official certification institute of mechanical test in South Korea. Figure 9 shows the fixture for the vibration test of QWR SC cavity.

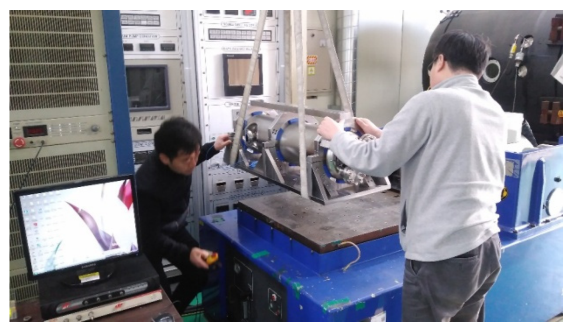

Figure 8: Vibration Test Setup.

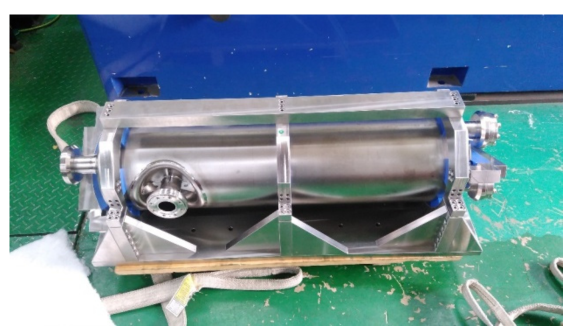

Figure 9: Fixture for QWR Cavity for Vibration Test.

Vibration test was performed by the lateral vibration machine, FAMTECH EDS-4000LS, and test conditions followed the KS B ISO10055 and JIS D 1602 code. For a precise measurement, we attached the accelerometer to the inner conductor as Fig. 10. By sweeping sinusoidal wave up to 1000 Hz with 0.5 G, we could find the similar resonance shape of unjacketed QWR SC cavity by comparing with ANSYS FEM analysis as shown in Fig. 11.

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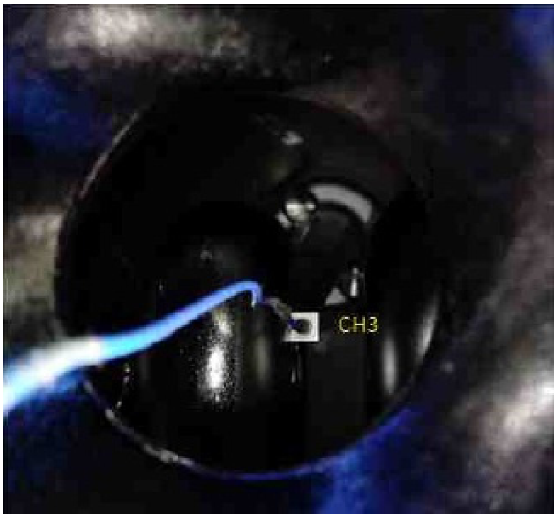

Figure 10: Inner Conductor Attachment.

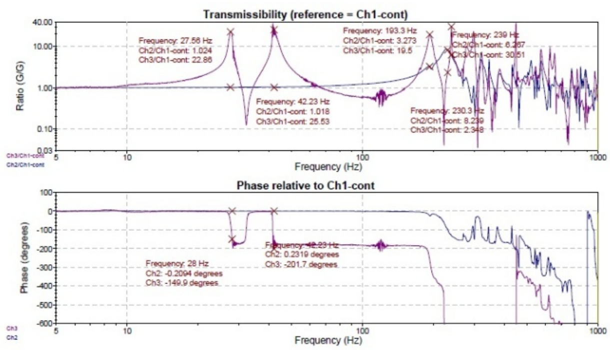

Figure 11: Vibration Test Results.

From the vibration test results, we could find the resonant frequency of unjacketed QWR SC cavity, 27.56 Hz, 42.23 Hz, 193.3 Hz and 239 Hz. We thought that 27.56 Hz was from the inner conductor 1st bending mode (in-phase with outer) and 42.23 Hz was from the inner conductor 1st bending mode (pure bending). Also, we could assume that the resonance of 193.3 Hz was from the fixture and 239 Hz was from the inner conductor 2nd bending mode. Comparing with previous FEM analysis by ANSYS, we concluded that clear resonant frequencies existed between 27 Hz and 42 Hz, and also around 240 Hz which is already measured during the QWR cryomodule cold test.

CONCLUSION

From the cold test of QWR cryomodule and the vibration test of unjacketed QWR SC cavity, we could find a clear resonance issue of QWR cavity due to the outer disturbances which could be generated by surrounding devices such as cold-box, circulation pump, other motors or generators. Our SRF utilities at the Munji site is a little unstable without clear root causes, so we requested to our cryogenic system team for reducing liquid helium pressure fluctuation below 1 mbar. Also, we requested to RF engineer for increasing control bandwidth for better RF power input. We will also check the background vibration level of our main SRF site, Sindong, for avoiding disturbance problems.

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