MECHANICAL STUDY ON THE CAVITY PACKAGE OF 1.3 GHz SUPERCONDUCTING ACCELERATING UNIT AT IHEP

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Abstract

In this paper, mechanical study on the cavity package of 1.3 GHz superconducting accelerating unit is reported. Several cases have been analysed via ANSYS Workbench for safety consideration such as self-gravity effects, the tuning distance and the support structure for the thin-wall bellow. The safety requirement for tuning distance at room temperature is suggested in the paper.

INTRODUCTION

The program of 1.3 GHz Superconducting Accelerating Unit is under study at IHEP. A scheme of the unit structure is shown as fig. 1. In the unit, a 9-cell SRF cavity, tuner and a liquid helium (LHe) vessel including a section of 50 mm long, 0.3 mm thick bellows will be welded and assembled together to form a relatively independent component called cavity package. In the study, mechanical analyses are carried out focusing on the package to assure its safety in the fabrications or other room temperature measurements. A commercial program of ANSYS Workbench [1] is used.

Since the yield strength of the two materials of Nb and Ti at room temperature less than that at low temperature, if the design is safe at room temperature, it can also meet the requirement at low temperature. Thus our simulation is mainly carried out for the package at room temperature. The properties of the material are shown as in table 1 [2, 3].

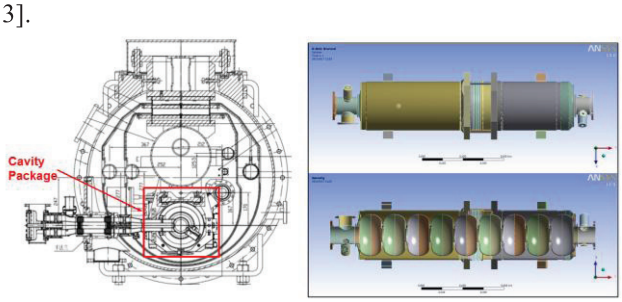

Figure 1: Schematic view of the cryomodule cross-section at IHEP (left) and the cavity package for simulation (right).

Table 1: Properties of Nb and Ti at room temperature used in simulation [2, 3].

Material	Density [kg/m^3]	Modulus [kg/m^3]	Poisson's ratio	Yield [MPa]
Nb	8570	105	0.38	38
Ti	4510	106	0.34	275

STRESS DISTRIBUTION DUE TO SELF-GRAVITY

In this part, we considered two different supporting cases. One is that the cavity package is supported by the four brackets which are specially fabricated for fixing the package to the outside barrel of the cryomodule. The other case is that two flanges at two ends of cavity beam tube are supposed as the supporting points.

Supported by the Four Brackets

Four brackets are specially fabricated for support of the cavity package to the outside iron barrel as shown in fig. 2. Besides the components shown in the fig.2, the tuner setup will also be assembled to the package. So, a weight of 36 kg was added on the middle flanges. The stress distributions on the LHe vessel and the cavity are shown as upper picture and lower picture of fig.2, respectively. As we can see, the maximum stress is about 14 MPa. This value is much lower than the Nb yield strength of 38 MPa. That meant that this design of the four brackets is safe enough for support the weight of whole package.

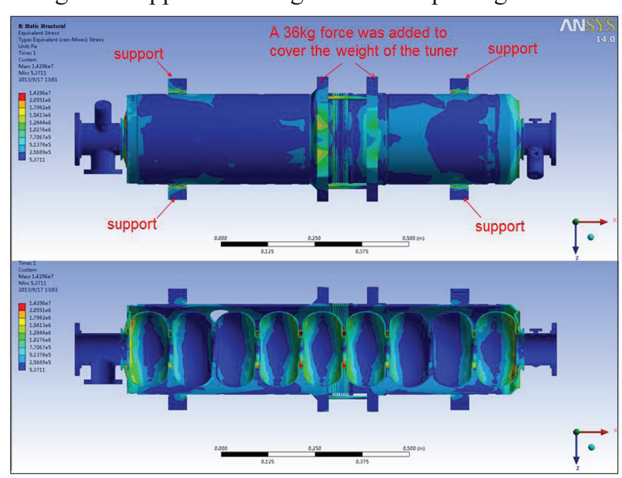

Figure 2: Stress distribution due to the self-gravity. Package supported with four supporting blocks.

Supported by the Beam Tube Flanges

In the fabrication, assembly and other processes, the package is usually moved by holding the two places if there is no special requirements for those operations. Thus the analysis was carried out to verify the safety of this supporting method. Like above, a 36 kg force also added to the middle flanges to compensate the weight of the tuner.

The stress distribution is shown as fig.3. As we can see, the stress is mainly on the beam tube and the four supporting bars between the two middle flanges. The maximum stress is about 15.7 MPa. It is also much below the yield strength 38 MPa, which respects that the supporting method also meets the safety requirement. However, comparing the two cases, we would better like the first supporting method mentioned above since it makes the stress distribution more uniform and smaller.

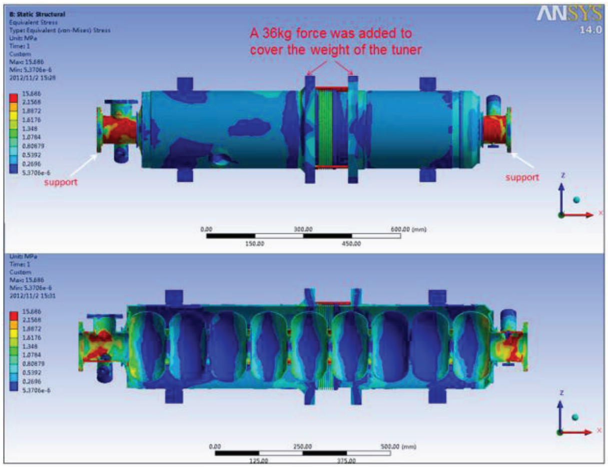

Figure 3: Stress distribution due to the self-gravity. Package supported with four supporting blocks.

EFFECTS OF TUNING ON THE PACKAGE

Cavity tuning is a process to stretch the length of the package. So, effects of stretch distance on the package are simulated. The stretch distance used in the simulation is 3mm as the real design, and the room temperature material properties are used for the same reason as talked in former introduction part. In the study, we will shows the stress distribution in the LHe vessel and the 9-cell cavity, respectively. Besides, the force to stretch the package is also simulated. It is about 3500 N for stretching 1 mm.

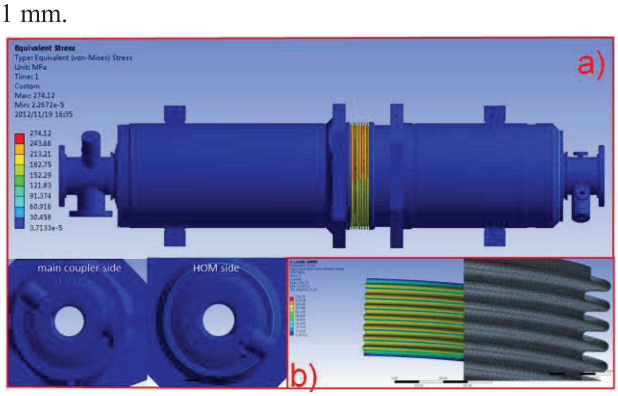

Figure 4: The effect of tuning distance on the LHe vessel(a) and the bellows(b).

The Stress Distribution on the LHe Vessel

Fig. 4 shows the stress distribution on the LHe vessel after 3mm stretch. As shown in fig. 4a), the stress was mainly distributed on the 0.3 mm thick bellows as designed. Stress at other parts including the main body of LHe vessel as well as two ends are no higher than 60 MPa. Comparing with the Ti yield strength 275 MPa, it is a safe value.

However, since the thickness of bellows is only 0.3mm which is much smaller that the LHe vessel thickness of 5mm, the meshing process may cause the errors of stress in the bellows. In terms of the above simulation result that the deformation occurs mainly on the bellow, we separate the bellows from the whole LHe vessel and suppose that the bellow will be stretched to 3mm.The the simulation was done again specially for the bellows. Fig. 4b) shows the mesh and results. After 3mm stretch distance, the maximum stress is under 137 MPa, which also under the Ti yield strength requirement.

The Stress Distribution on the 9-cell Cavity

The same simulation as above is also carried out for the 9-cell cavity. The result shows as in fig. 5a). However, we find that if the cavity is stretched 3mm at room temperature, the stress in the many parts will be beyond the Nb yield strength. The violet colour in fig. 5a) respects those parts.

Thus, the effects of stretch distance have to be studied. The relationship between the stretch distance and maximum stress is shown as in fig. 5b). We find that at room temperature, the stretch distance should be under 0.76 mm to insure the safe requirement of yield strength of Nb.

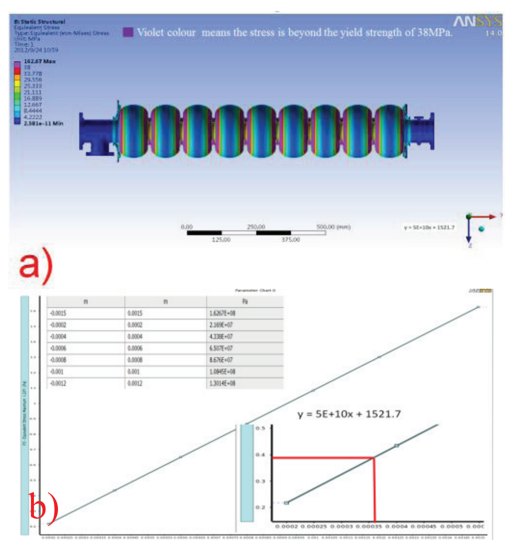

Figure 5: The effect of tuning distance of 3mm on the SRF cavity 5a). Effect of stretch distance on stress shown in fig. 5b).

SUMMARY

Mechanical study on the cavity package of 1.3 GHz superconducting accelerating unit at IHEP is carried out. The simulation results show that the current design meets stress requirements of self-gravity. For the tuning distance of 3 mm, the LHe vessel will be safe at room temperature; however, the maximum stress will be beyond the Nb yield

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strength requirement. At room temperature the stretch distance should be under 0.76 mm for safety consideration.

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