DEFORMATION TUNER DESIGN FOR A DOUBLE SPOKE CAVITY

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Abstract

IPN Orsay is developing the low-beta double Spoke cavities cryomodule for the ESS. Based on previous successfully tested prototypes, a fast/slow tuner has been studied to compensate resonance frequency variations of the cavity during operation. The typical perturbations are coming from LHe saturated bath pressure variations as well as microphonics and Lorentz force detuning (LFD). Two tuners are being built in order to validate both expected performances and series production feasibility. In this paper, the tuner design of the double Spoke cavity is presented.

INTRODUCTION

Design of the cold tuning system (CTS) described here is an evolution of several other tuners [1, 2] which are all based on the same kinematic concept. The idea is to fit a mechanism on the LHe tank side (see Fig. 1) which will pull the cavity beam tube flange. The mechanism consists in a main frame which is the slow tuner, plus two integrated piezo actuators which represent the fast tuner. Parameters related to the cold tuning system are presented in Table 1.

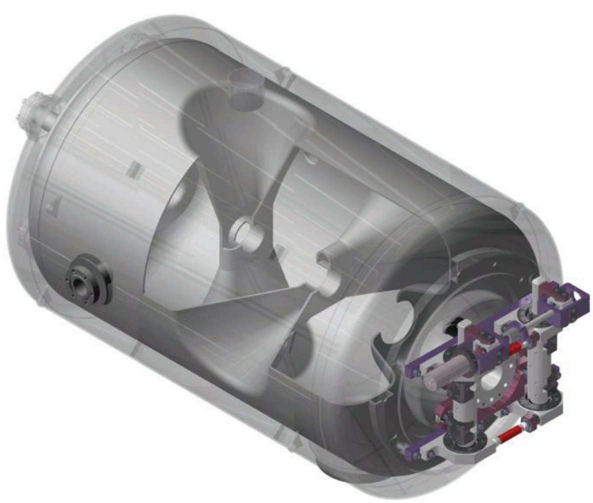

Figure 1: Localization of the CTS fitted on the LHe tank (shown with transparency) of the double Spoke cavity.

SLOW TUNER

Kinematics

A ball screw system driven by a stepper motor acts on a double lever arm mechanism to provide a significantly reduced displacement along the beam axis (see Fig. 2). This principle enables to apply high forces with a fine precision over a large stroke.

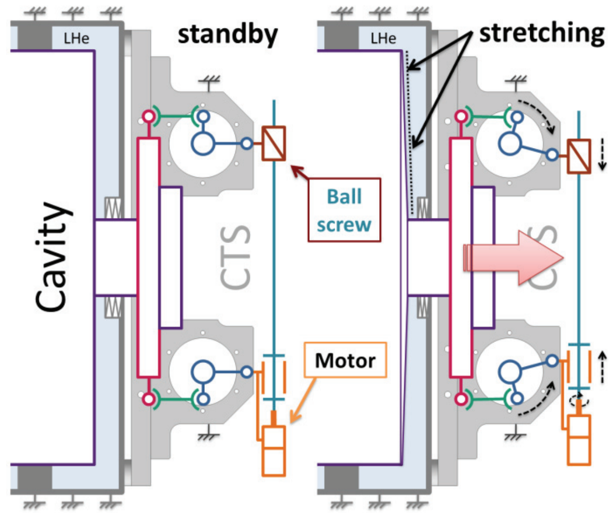

Figure 2: Kinematic model which shows how the cavity is deformed (right) from its initial state (left).

Table 1: CTS Summary Data Table

Parameter	Unit	Value
Cavity Sensitivity	kHz/mm	110
Cavity RF Bandwidth	Hz	1,355
Cavity Stiffness	kN/mm	20
Max. Cavity Deformation	mm	1.0
Max. Strength	kN	20
Resolution	Hz/step	< 1.0 Hz
LFD	Hz	400

Bearings

The stainless steel ball screw is provided with molybdenum disulphide (MoS_2) coating as dry lubricant, and the balls are made of zircone (ZrO_2). Zircone is a ceramic material that exhibits a good friction behavior even when lubrication conditions are severe and has a coefficient of thermal expansion (CTE) close to the stainless steel that is quite interesting in such cryogenics application.

Ball bearings of the main frame are made with stainless steel and are slightly oversized regarding the maximum static load capacity to ensure an optimal lifetime.

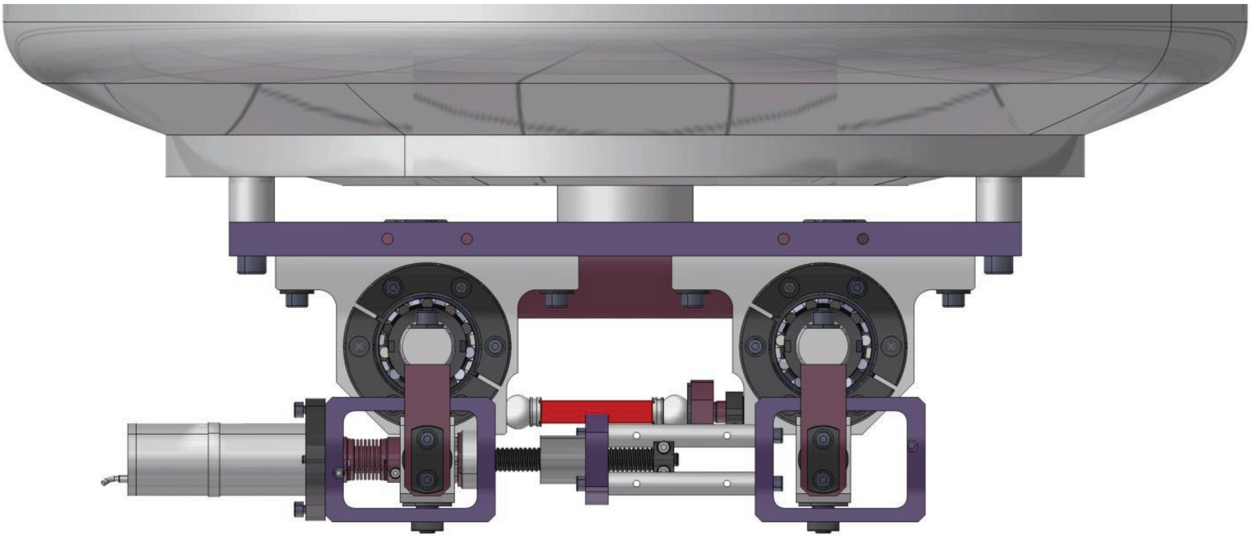

Figure 3: Lateral view of the CTS assembled on the double Spoke cavity side.

Mechanical Stiffness

In order to stretch efficiently the cavity, the tuner must be much stiffer than the cavity. When applying a force on the cavity, part of the motion produced is lost because the tuner deforms itself. While this can be easily overcome for the slow tuner by achieving additional motor revolutions, this is not as simple for the fast tuner which has a very limited stroke. The most stressed parts during the tuning process have been designed to grant an overall stiffness of about 110 kN / mm.

Cryomodule Mechanical Integration

Since the tuner is located on the side of the cavity (see Fig. 3), a particular attention has been paid to minimize the impact on the length of the cryomodule. Another important point was to make accessible the most critical elements: the ball screw, the piezo actuators and the stepper motor.

FAST TUNER

Rigid Lever Arm

For many tuning systems [3, 4], piezo actuators are connected between the cavity and the tuner. In the present one, each piezo is inserted into a rigid lever arm part (see Fig. 4) of the CTS because it would not sustain the whole maximum expected force applied on the cavity. The rigid lever arm permits to share the force applied on the cavity by the slow tuner mechanism in order to reduce the pressure exerted on the piezo actuators. In addition, this configuration allows an easy access for maintenance and does not require disconnecting the cavity from the CTS when removing temporary one or both actuators. The side effect is that only 38% of the dual piezos displacement is transmitted to the cavity.

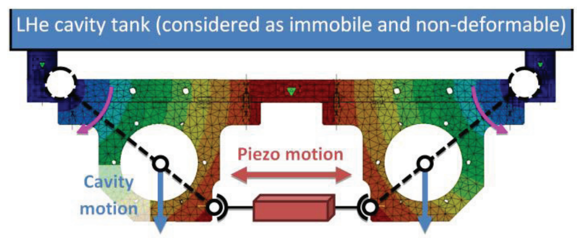

Figure 4: Displacement vector simulation result when the piezo actuators are solicited: red field points the highest value while blue field means no motion.

While most of CTS parts are made in AISI 316 L stainless steel, the rigid lever arm is made in Ti-6Al-4V titanium alloy which has a lower CTE. This will reduce the pressure due to the thermal shrinkage of the rigid lever arm on the actuators.

Piezo Actuators

Two manufacturers, Noliac and Physic Instrument, have been chosen for providing piezo actuators in order to compare their performances and lifetime.

It is widely known that the piezo actuators stroke is strongly reduced at low temperature. In order to partially compensate this effect, zircone ceramic balls (see Fig. 5) have been used as slight thermal barriers that would raise a little bit the temperature of the actuators which will basically self-heat. Another trick is to operate the actuators in bipolar voltage excitation which is possible at low temperatures to double the available stroke.

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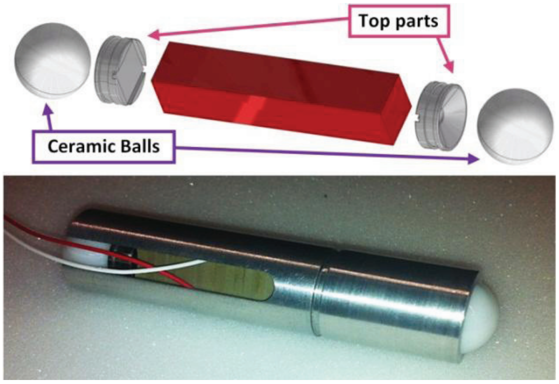

Figure 5: the piezo assembly CAD view (top) and picture with the protection tube encapsulation (bottom).

Preload System

In order to run piezo actuators in dynamics operations for the LFD and/or microphonics compensation, it is necessary to preload them around 20 MPa. In the present design, this value is reached by adding three effects:

- The differential thermal shrinkage between the rigid lever arm and the actuators.
- A part of the pressure applied on the cavity by the slow tuner action.
- A manual preload during assembly at room temperature which permits to balance the two other effects and reach the final desirable value.

The magnitude of each effect has been roughly estimated but depends on a lot of different parameters and computations. Experimental data are thus required in nominal operation conditions to ensure that piezo are properly preloaded before starting any dynamic operations.

CONCLUSIVE PERSPECTIVES

A double Spoke cavity tuner has been studied and two prototypes are being manufactured (see Fig. 6).

Figure 6: Picture of the CTS partially assembled on a triple Spoke cavity.

Preliminary room temperature tests will be achieved by the end of the year at IPN Orsay on a triple Spoke cavity [5] which has similar mechanical specifications while the double Spoke cavity is currently still in fabrication.

Extensive cryogenic tests are scheduled in 2014 at IPN Orsay in order to qualify properly both the performances of the CTS and the lifetime of many critical components such as ball bearings, ball screw and piezo actuators.

REFERENCES

[1] M. Fouaidy, N. Hammoudi, N. Gandolfo, S. Rousselot, M. Nicolas, P. Szott, S. Blivet, H. Saugnac and S. Bousson, "Cold Tuning System Dedicated to 700 MHz Superconducting Elliptical Cavity for Protons Linac," in *Proceedings of SRF*, Ithaca, New York, USA, 2005.

[2] S. Bousson, J. Biarrotte, J. Dufour, N. Gandolfo, T. Junquera, J. Lesrel, L. Lukovac and F. Lutton, "Spoke Cavity Developments for the EURISOL Driver," in *Proceedings of LINAC*, Knoxville, Tennessee USA, 2006.

[3] C. Pagani, A. Bosotti, P. Michelato, N.Panzeri, R. Paparella and P. Pierini, "The Fast Piezo-Blade Tuner for SCRF Resonators," in *Proceedings of SRF*, Ithaca, New York, USA, 2005.

[4] G. Devanz, P. Bosland, M. Desmons, E. Jacques, M. Luong and B. Visentin, "Compensation of Lorentz Force Detuning of a TTF 9-cell Cavity with a New Integrated Piezo Tuner," in *Proceedings of EPAC*, Edinburgh, Scotland, 2006.

[5] H. Gassot, G. Olry, S. Rousselot and S.Bousson, "Mechanical Design of Triple Spoke Cavity for EURISOL," in *proceedings of SRF*, Chicago, USA, 2011.