CHARACTERISTICS OF A FAST PIEZO-TUNING MECHANISM FOR SUPERCONDUCTING CAVITIES

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Abstract

A fast piezoelectric tuner has been proposed for dynamic Lorentz force compensation for the TESLA linear collider [1]. Initial experiments with the tuner have demonstrated the successful control of the cavity resonance during pulsed operation at high gradients. So far no extensive experience exists for piezos actuators operated in pulsed operation at cryogenic temperatures in presence of radiation. A series of tests has been initiated at DESY to demonstrate that piezo elements are adequate for TESLA operation in terms of gradient as well as lifetime. The paper addresses various issues including coupling to mechanical resonances, and lifetime testing exposing the piezos to gamma radiation.

1 INTRODUCTION

The objective of the active Lorentz force compensation is achieved if the cavity detuning can be maintained constant and close to zero (<< 1 bandwidth) during the whole RF pulsed or at least during the flat-top duration of 950 us.

In contrast to the Lorentz force the piezo actuator acts only locally on the cavity walls which results in a different coupling factor to the various mechanical modes as compared to the Lorentz force. Therefore it is important to measure the transfer function from piezo control input to the resonance frequency of the cavity. The transfer function allows to determine model parameters including the resonance frequencies, quality factor, and the coupling coefficients to the mechanical modes. This information can be used to study the controllability of the Lorentz force and possibly microphonics in feedforward and feedback control configuration.

Measurement of the expected lifetime of the piezo actuators are essential for the selection of the model to be used since pulsed operation at cryogenic temperatures and in a radiation environment has not yet been explored in detail.

2 TRANSFERFUNCTION

2.1 Setup

The purpose of this experiment is to study the piezoelectric actuator to SRF cavity transfer function. It consists of measuring the amplitude and phase of the transmitted RF signal (through the mixer) as function of the frequency of the mechanical vibration of the structure generated by the piezoelectric actuator. The measurements were performed at Room Temperature (R.T) on the cavity S35 with its LHe tank.

The instrumentation block diagram and the photographs of the experimental set-up are presented in figure 1-3.

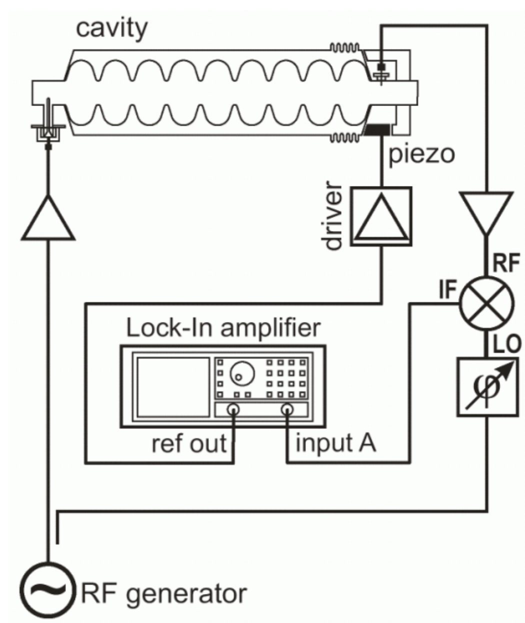

Figure 1: Block diagram of the measurement setup.

Figure 2: Experimental setup. The cavity is equipped with He tank and mechanical frequency tuner.

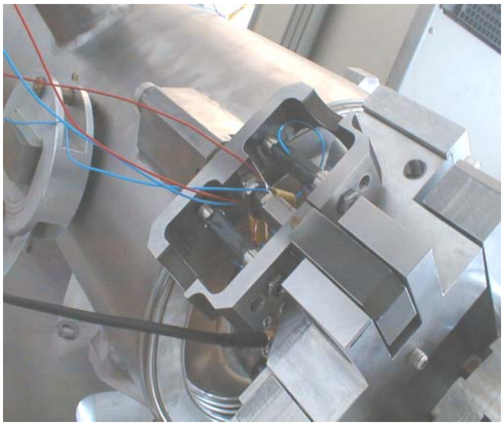

Figure 3: Close view to piezoelectric actuators in the mechanical frequency tuner.

2.2 Measurement results

Precise measurements were performed at room temperature (Fig.4). More than 25 resonance peaks are observed in the frequency range studied (0-1000 Hz). Notice that both longitudinal and transverse mode of mechanical vibration of the cavity could be excited by the piezoelectric actuator. The experimental spectrum shows more resonances than predicted by numerical simulation and further theoretical investigation is needed for a better understanding.

Moreover, the quality factors Q_m of several different observed modes were deduced from the data leading to values in the range 5 to 230. These quality factors correspond to damping coefficients between 2,98 s^{-1} and 68,5 s^{-1}.

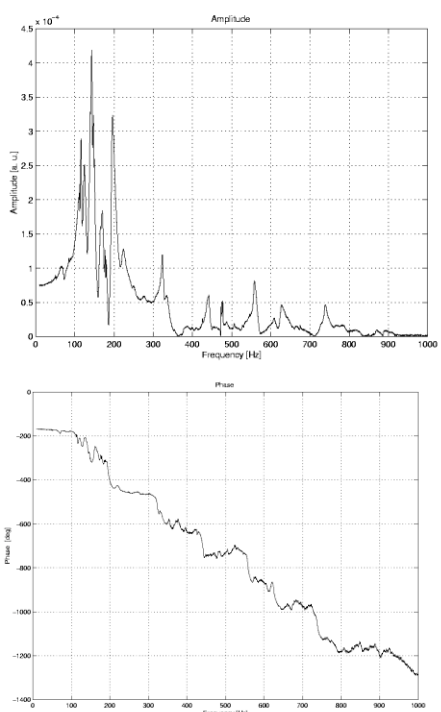

Figure 4: Amplitude and phase signal of the transfer function. Several resonances can be seen.

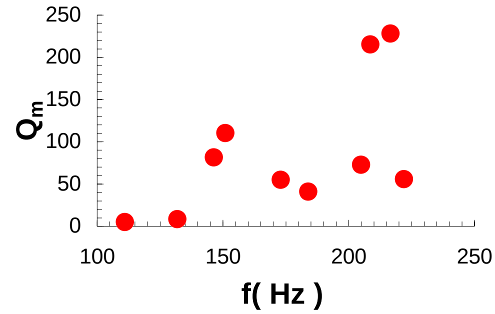

Figure 5: Quality factors for the first 10 dominant mechanical modes of the cavity.

The phase signal of the transfer function changes over several hundred degrees in the frequency range from 10 to 1000 Hz.

Reproducibility tests were also performed showing less than 10 % relative variation between two experimental runs. Furthermore the piezoelectric actuator amplitude was varied and the resulting spectra compared: as no significant difference was observed between the corresponding results, the linear behavior of the system is confirmed.

Figure 6: Setup of the cryostat with the Co60 source.

3 LIFETIME TEST IN RADIATION ENVIRONMENT

The piezotranslators is an integral part of the cavity tuning mechanism and will therefore be exposed to the gamma-radiation generated by field emission in the cavities (dark currents) and occasional beam loss in the accelerator. The upper limit for the average dose rate for TESLA is dictated by the capacity of the cryogenics which can handle an additional heat load of 0.1W/m corresponding to a dose rate of 10 Gy/h. Assuming a lifetime of the accelerator of 20 years this correspond to a maximum total dose of 2 MGy.

3.1 Setup

Currently the performance of the piezotranslator is evaluated in a radiation environment (Co60 source, 1.4 kGy/h) during pulsed operation (at 100 Hz) at 77K (liquid nitrogen dewar). The fixture contains 2 piezo elements in series were one element is pulsed at 100 Hz with a pulse structure consisting of a 300 µs ramp from -40 to +140 V, 1 ms flat-top duration followed by a 300 µs ramp from +140V to -40V. The second element is used as a sensor to detect the force created by the first element.

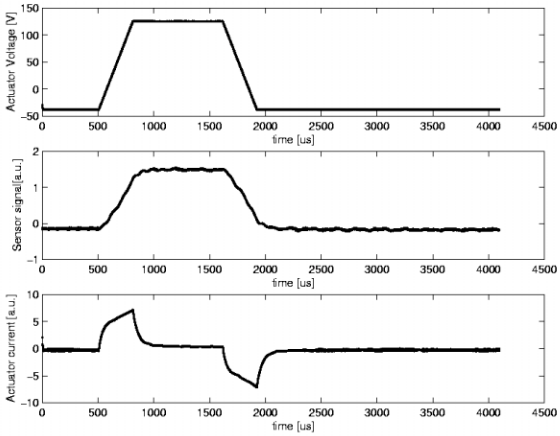

Figure 7: Applied voltage to actuator (top), sensor voltage (middle) and actuator current (bottom).

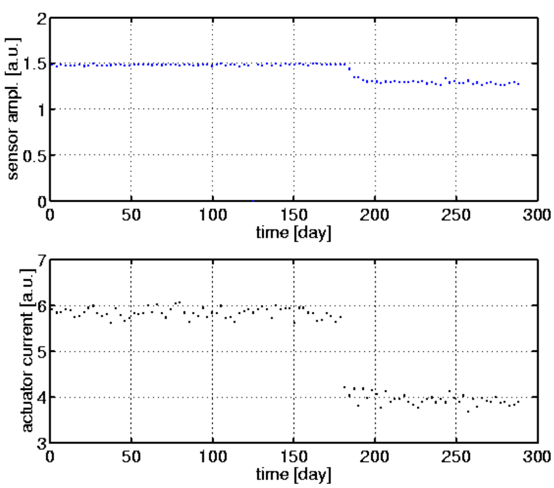

Figure 8 Sensor voltage (top) and actuator current (bottom). The change of the actuator current is due to the use of a different mechanical setup and different control electronics.

3.2 Measurement results

During 9 months of testing no appreciable detoriation of performance has been observed while the piezos have been exposed to a total dose of 2 MGy (last 4 month of operation).

4 FUTURE PLANS

Further measurements on mechanical resonances will include the identification of the mechanical modes and a comparison with simulation results. Also an optimal configuration of the frequency tuner with integrated piezo actuator and sensor with respect to controllability, redundancy and lifetime needs to be developed. Lifetime tests of various actuators will be conducted including exposure to neutron and operation at 2 K.

5 CONCLUSION

The transfer function measurements show a large number of modes between 100 Hz and 3 kHz with the dominating modes up to 500 Hz. The large phase shift over this frequency range makes it clear that feedback for microphonics control using the RF signal will not be possible with the piezo actuator. However the high mode density will allow excellent feed forward control for the repetitive detuning caused by the Lorentz force. The lifetime test in presence of radiation has demonstrated that the requirements for 20 years of operation can be fulfilled.

6 REFERENCES

[1] 'Dynamic Lorentz Force Compensation with a Fast Piezoelectric Tuner', M. Liepe, W.D.-Moeller, S.N. Simrock, PAC 2001