WATER FLOW VIBRATION EFFECT ON THE NLC RF STRUCTURE-GIRDER SYSTEM*

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Abstract

As part of the vibration budget study for the NLC Main Linac components, the vibration sources in the NLC modules (Girder) are under investigation. The activity is focused on the effect of cooling water flow on the structures (FXB type) stability, the transmission of vibrations to the adjacent components, and the effect of different materials of construction used for the supports. Experimental data and ANSYS simulations have been compared. This paper reports on the ongoing work.

INTRODUCTION

The stringent requirements on the alignment of the components of the main linac for the Next Linear Collider (NLC) resulted in an extensive program studying the effects induced by cooling water flow on: the RF accelerating structures, their supports (girders), and the adjacent quadrupoles.

The acceptable tolerance for the accelerating structure itself is rather loose, on the order of 10 μm. The major concern is related to the stability of the adjacent quadrupoles that must be kept within a 10 nm tolerance.

The quadrupoles are positioned on separate supports with respect to the RF structures, but a considerable amount of vibrations can still couple through the beam pipe.

Previous analyses of this problem [1, 2] were focused on 1.8 m long RDDS style RF structures supported by strongbacks bolted on a concrete block. The work here is a follow up on this subject, documenting and describing a more up to date setup based on 0.6 m long structures supported by strongbacks made of different materials and with different connections to the floor.

WATER COOLING SYSTEM

In order to generate the accelerating field of 65 MV/m, the present FXC [3] design RF structures need a peak input power of ~56 MW, which, given the working parameters, results in a heat load of 3.5 kW/m to be adsorbed by the cooling system [4]. The requirements for the water cooling system are: the temperature of the RF wall of the accelerating structure that should be kept around 45 C [5] to maintain the copper within its best electrical properties, the temperature of the water in the cooling towers that should be kept above 28 C in order to maximize the heat exchange to cost ratio, and the pressure drop in the system that should be balanced with respect to the pumping costs.

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These parameters fix the temperature rise and the flow rate of the cooling water in the RF structures. For the present design of the cooling pipes in a counterflow configuration with 2 inputs and 2 outputs, a flow rate of ~0.14 liters/s with a temperature rise of 6 C is necessary to keep the RF structures at the optimal operating conditions [6, 7].

EXPERIMENTAL SETUP

The measurements were performed in a quiet tunnel in the Fermilab fixed target area (MP8) where the low conductivity water (LCW) circuit was available.

Two different setups were considered: the first one, shown in Fig. 1, consisted of two 0.6 m long RF structures connected in series with a bellow and supported by a standard NLCTA strongback. During the measurements, strongbacks constructed of aluminum and stainless steel were used. The strongbacks were bolted to the floor for simplicity.

In the second, more realistic setup, in order to simulate the supports of a NLC-girder, the strongbacks were modified and the number of RF structures was increased from two to three. Since the final design girders will apply a beam based alignment, the support system shown in Fig. 2 was utilized to simulate the contact between the girder beam and the mover. The strongback was touching the floor through 5 points as it will be in the NLC-girder in order to allow for five independent degrees of freedom. This support system permits the strongback to move freely along the beam direction

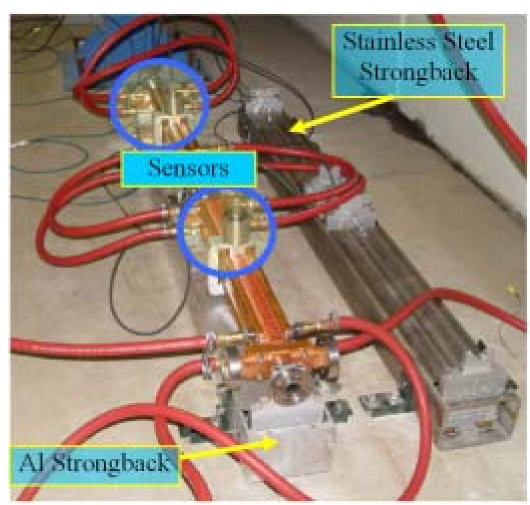

Fig. 1 Experimental setup: (on the left) two RF structures instrumented on an Al strongback bolted to the floor; (on the right) a Stainless steel strongback

Fig. 2 Mover Mock up supports used to simulate a more realistic connection to the tunnel floor

In the second setup a permanent magnet (PM) was also connected to the system through a bellow in order to evaluate the vibration coupling through the beam pipe.

The PM, developed at Fermilab [8], does not require cooling and was sitting on a separate support with respect to the structures.

The water system was completely instrumented in order to measure, temperature, flow, and pressure at both input and output of the setup. The water flow in the structures was adjusted using valves at the input of the system.

The reported measurements were performed with the RF structures fed by the cooling water in two configurations: in the first case, two counterflow circuits, while in the second case, four independent pipes in parallel to maximize the flow rate were used. The vibrations were measured using 4 different types of sensors: piezo-accelerometers, geophones, dual coil seismometers and a tri-axial precise seismometer.

RESULTS AND DISCUSSION

Strongback materials

A number of tests were performed on the setup consisting of two structures on a strongback bolted to the tunnel floor, by raising the water flow from zero to 0.6 liters/s.

In order to check the effect of the pressure fluctuation in the water line, tests with the output valve closed and the input valve either open or closed were performed and showed no appreciable difference. Additional tests were performed to understand the effect of vacuum on the transmitted vibrations especially through the bellows. The results were in agreement with previous studies [2], no appreciable difference was observed.

Fig. 3 shows the results of the average integrated displacement for frequencies above 10 Hz on the aluminum strongback at different flow rates. The resultant displacement is not strongly dependent on the flow rates in this range. The flow is in fully developed turbulent conditions (Re >> 2100) for all the cases. Some of the development of the fully turbulent flow in the cooling water pipes can be attributed to the partial opening of the input valves to adjust the flow rate.

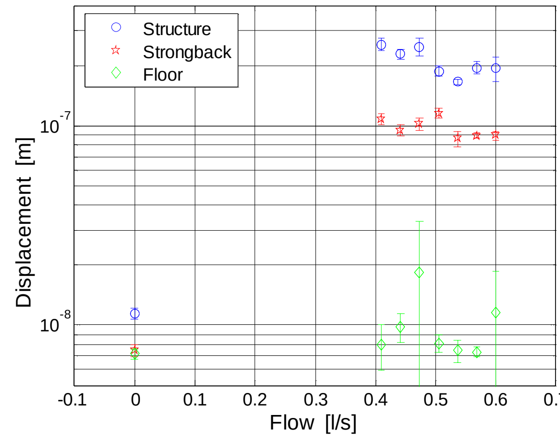

Fig. 3 Average integrated displacement above 10Hz of the structure (blue), the strongback (red) and the floor (green) at different flow rates and with no flow.

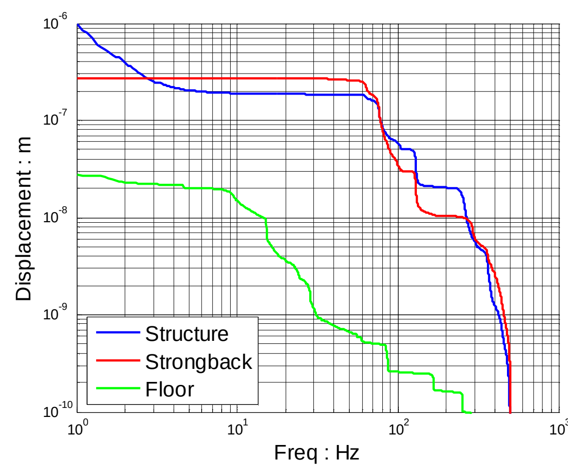

Fig. 4 Integrated displacement spectrum of the structure (blue), Aluminum strongback (red) and floor (green) with 0.41 water flow.

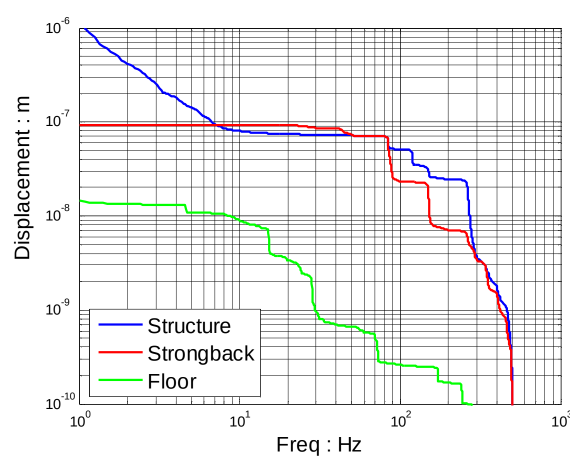

Fig. 5 Integrated displacement spectrum of the structure (blue), Stainless Steel strongback (red), and floor (green) with 0.41 liters/s water flow.

Fig. 4 shows the vibration spectrum of the setup with the aluminum strongback at 0.41 l/s water flow. Results for the stainless steel strongback are shown in Fig. 5. It can be noted that the spectrum is quite different and correlated to the different properties of the materials of the supports. The stainless steel strongback allows for lower vibration amplitude in the RF structures.

The experimental results have been compared to finite elements simulations performed on 3D models generated in ANSYS as shown in Fig. 6. The experiments and the simulations are in good agreement. The first mode predicted by the simulation is at 69 Hz compared to an observed peak at 67 Hz; the second mode predicted at 78 Hz corresponds to an observed peak at 75 Hz and at higher frequencies also the third and fourth modes have consistent correspondence. These results give us confidence in the simulation process to be performed for the final NLC main linac girder design.

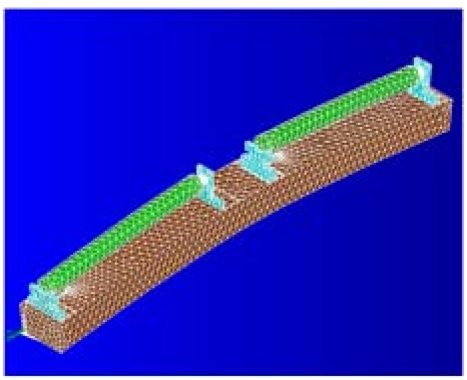

Fig. 6 ANSYS model of the strongback with two RF structures, first mode.

Supports effect and coupling to a quadrupole magnet

Additional tests have been performed on the aluminum strongback with three RF structures using the supports shown in Fig 2 and connected through bellows to the PM.

Results shown in Fig. 7 demonstrate that the vibration level at 0.6 liters/s is still acceptable. The coupling of vibrations to the magnet is small and will not affect its tight stabilization.

In Fig. 7 the red solid line represents the amplitude of vibrations on the magnet when the cooling water is on, while the red dashed line shows the condition without water cooling. The effect of the water flow can be quantified as 3 nm above the background. The strong peak at 70Hz coupled to the PM is related to the way the magnet was supported during the test. The confirmation of this assumption was verified by changing the supports spacing and observing a shift of the peak. The water flow rates explored cover the range of possible configurations of the accelerator and demonstrate that the vibration level is acceptable. Additional work can be done in order to better simulate the NLC-like conditions by adding the real motors, wave guides to the RF ports of the structures and by extending the strongbacks to support four structures, consistent with the present conceptual design for an NLC girder.

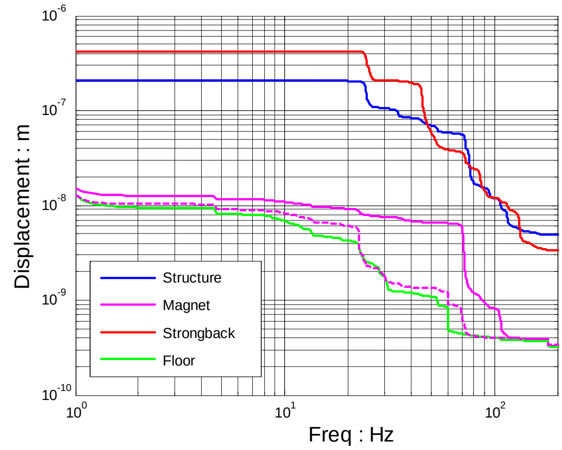

Fig. 7 Integrated displacement spectrum of the structure (blue solid), Al strongback (red solid), magnet (magenta solid) and floor (green solid) with 0.6 liters/s water flow. The magenta dashed line represents the spectrum for the magnet when no cooling is present.

CONCLUSION

The cooling water system plays a predominant role in the vibration budget of the RF structure – girder system. Several setups leading to a more precise simulation of the final girder design have been tested showing that the vibrations induced are within tolerances. The coupling to the adjacent PM has also been proven to be within specifications. Additional tests performed adding wave guides and adopting optimized supports for the RF structures are part of the ongoing activities.

ACKNOWLEDGMENTS

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