Stabilization studies from LAPP/ESIA

Ch.Boulais[1], V.Cozma[2], L.DiCiaccio[1], F.Formosa[3], V.Fournier[1], S.Géneté[1], C.Girard[1], A.Jeremie[1], Y.Karyotakis[1], J.Lottin[2]

1) Laboratoire d'Annecy-le-Vieux de Physique des Particules (LAPP), IN2P3-CNRS, 9, chemin de Bellevue, BP 110, F-74941 Annecy-le-Vieux CEDEX, France
2) Laboratoire d'Informatique, Systèmes, Traitement de l'Information et de la Connaissance (LISTIC-ESIA) - Université de Savoie, 5, chemin de Bellevue, BP 806, F-74016 Annecy-le-Vieux CEDEX, France
3) Laboratoire de Mécanique Appliquée (LMECA-ESIA) - Université de Savoie, 5, chemin de Bellevue, BP 806, F-74016 Annecy-le-Vieux CEDEX, France

Abstract

The LAPP/ESIA group presents the status of the work done in Annecy, France. Finite-element simulations of the final focus stabilization study are presented, as well as the latest measurements on the recently installed test benches.

Introduction

The laboratories from LAPP and ESIA have recently started a collaboration with the CERN group working on the stabilization of the final focus magnet destined for a future linear collider. Some test facilities have been installed at LAPP and ESIA, and this note describes the work done on these test stations. The work is centered around three main research activities : vibration measurements, feedback loop and mechanical vibration simulations.

Vibration measurements

The new test stand at LAPP is comprised of 2 triaxial velocity VE-23 sensors from Geosig. They have a full scale of ±1mm/s (±10V) and a frequency range from 4.5 to 315Hz. In addition, a Güralp geophone has been added to the set-up with a frequency range from 0.003 to 50Hz. These sensors have been purchased to be compatible with the existing stabilization set-up at CERN. This will make comparisons and combined measurements possible.
Before making sensitive ground motion measurements or nanometer size measurements, it is important to become familiar with the new sensors. For this purpose, an aluminum bar has been fixed at each end to readily available supports. The sensors have been fixed on the bar to record the response of the bar to a hammer hit. Figure 1 shows the set-up.

Figure 1 : Photo of the initial sensor set-up for the hammer test.

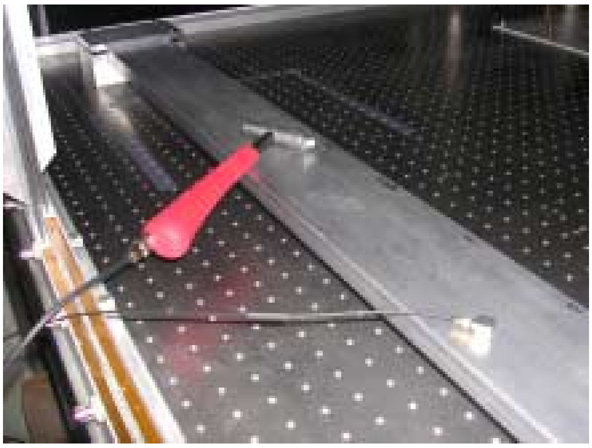

Figure 2 : Photo of the current set-up for the hammer test.

The hammer impact has generated some intrinsic vibration modes in the bar. The bar has also been drawn in the CAO program CATIA. Intrinsic modes have been calculated with this program. The results have been compared to the measurements. Additional peaks are observed in the measurements. They are probably due to modes coming from the supports, which have not been simulated with CATIA. The next step is to replace the blue supports by more stable ones and redo the measurements. We have used a vibration measurement system from Brüel & Kjaer with a calibrated hammer and accelerometers. The new set-up is shown in figure 2. This will enable us to suppress the additional peaks and to understand better the origin of the peaks observed in the measured power density spectrum. First measurements show agreement of measurement and calculation to within a few percent shown in figure 3.

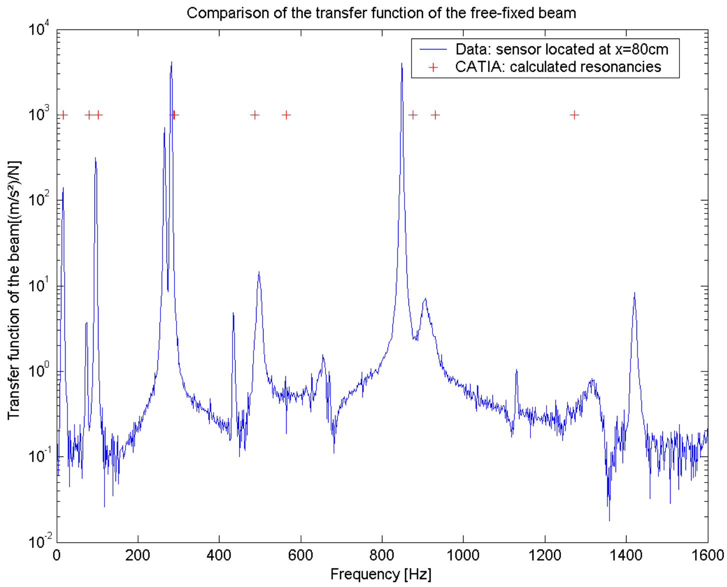

Figure 3 : Comparison of the measurements done on the new set-up and the calculations done with CATIA.

Feedback loop

A little mock-up has been developed at ESIA in order to test a numerical-experimental approach to the stabilization problem of a beam-like structure. Figure 4 gives a global view of the experimental setup.

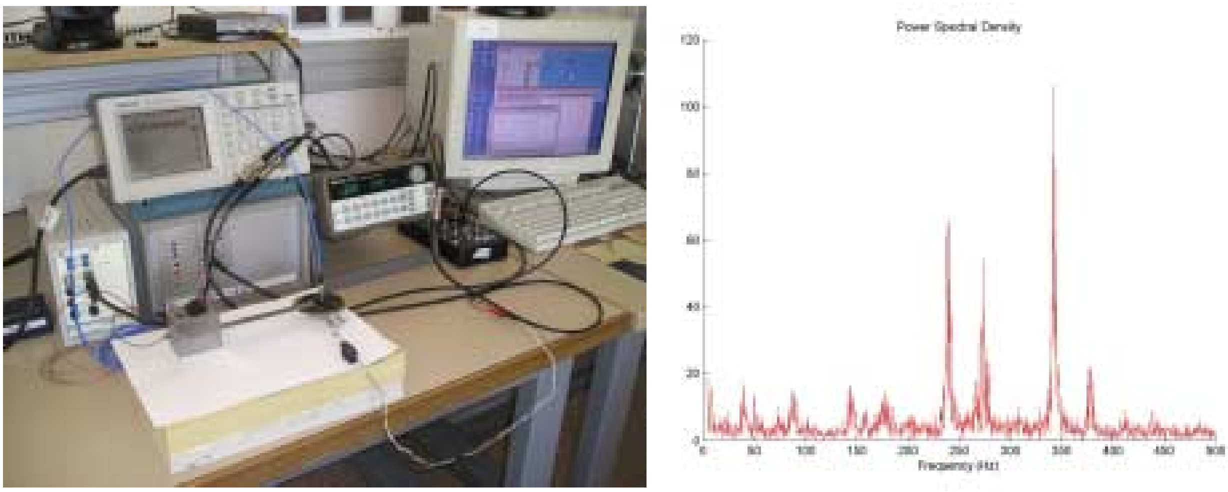

Figure 4 : Global view of the experimental set-up and frequency response of the steel beam to a hammer impact.

Since the frequency range of the structure response is about 10 to 1000 Hz (Figure 4), the aim of this mock-up is to define a methodology, both from a theoretical and application point of view. The structure is based on a 12.7x150x1 mm steel beam clamped in a support assumed to be fixed. The beam is instrumented with a glued ceramic PZT 10x10x0.8 mm patch used as an actuator whereas an accelerometer is fixed at the free end of the beam. The set-up is shown in figure 5.

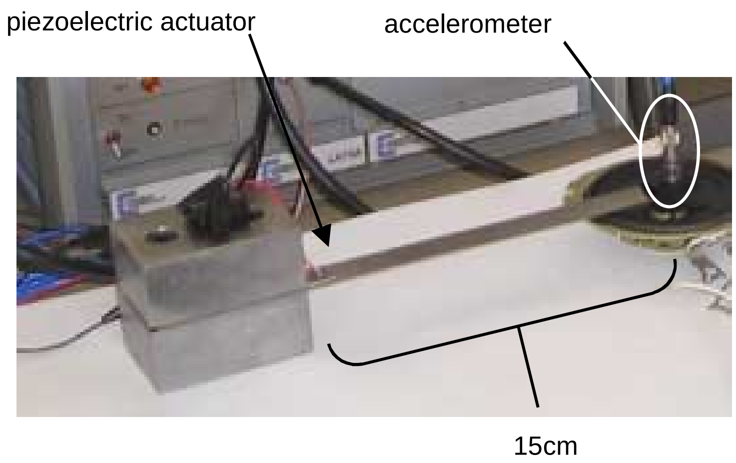

Figure 5 : Close-up of the instrumented structure.

A finite coupled element model of the instrumented structure has been performed. This model allows an optimum location analysis for both the actuator and sensor.

This set-up is connected to a PC via ADC cards, and Matlab software is used to build and test control schemes in order to reduce vibration amplitudes. Some tests have been carried out to reject specific modes that are amplified by the mechanical structure. Figure 6 right shows evolution of sensor output and control signal when the control scheme becomes active at t=1s. The schematics of the control loop is shown on the left side of figure 6.

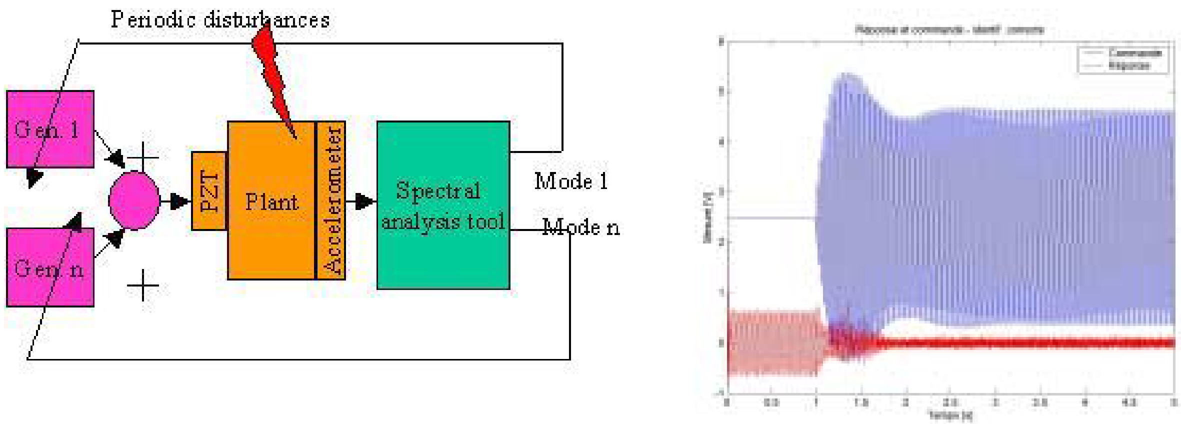

Figure 6 : Description of the control scheme to reduce vibrations at specific frequencies.

Mechanical simulations

Another aspect of our work consists of mechanical simulations. The idea is to simulate a final focus quadrupole, as closely as possible. The first step is to calculate the intrinsic modes of the quadrupole, and to refine the concept to reduce the number of vibration modes at low frequency. This will be done, by changing the design and by adjusting the position of the supports. In a second step, this conception work will become the basis for the design of a large scale mock-up on which sensors and actuators will be placed. This will help validate the feedback loop described previously.

The starting point of this work is the article by M.Aleksa and R.Russenschuck [Ale02] about possible designs for the final focus quadrupole. The details of the design are given in reference [Ale02]. The permanent magnet model has been introduced into CATIA and calculations for the intrinsic vibration modes have been done. The results are presented in table 1.

		Tubular		
		free	embedded at both ends	embedded on one side
Frequency in Hz	1st	23	23,7	3,7
	2nd	63,4	65	23
	3rd	123,4	126,3	64,2
	4th	202,3	206,5	124,9
		Conical		
		free	embedded at both ends	embedded on one side
Frequency in Hz	1st	41,1	39,5	10,6
	2nd	109,6	107,9	46,4
	3rd	210,2	208,9	115,1
	4th	341,2	340	215,3

Table 1 : Intrinsic vibration modes for different support designs of the final focus quadrupole.

In the first stage of the work, different support positions have been considered : a free floating quadrupole, one embedded at both ends, and one embedded on one side. The latter solution is considered in the case of a quadrupole slightly inserted in the detector. What can be seen in table 1, is that a free quadrupole and one embedded at both ends have the same intrinsic vibration modes. However, when only one end is embedded, an extra low frequency mode appears. Another case has been considered. The constraints on the quadrupole size are very stringent near the interaction point. However, as the distance to the interaction point increases, the size constraints can be slightly loosened. The magnet envelope can have increasing thickness with increasing distance to interaction point. Table 1 shows that the rigidity of such a system increases, since the intrinsic vibration modes increase to higher frequencies. However, the same conclusion can be given for the supports as for the constant thickness design with an extra vibration mode appearing in the case of a quadrupole fixed only at one end.

Conclusion

The test benches at LAPP and ESIA will be used to continue the stabilization study. First, the feedback loop should be validated by comparing Matlab simulations with measurements done on the "little mock-up". The mechanical simulations will be used to design the large scale Mock-up. In parallel, it will be essential to find adapted sensors and actuators, characterize Annecy ground motion, and finally validate the feedback loop on the "large scale mock-up".

References

[Ale02] M.Aleksa and S.Russenschuck CLIC Note 506, Study of some options for the CLIC Final Focusing Quadrupole , CERN-OPEN-2002-009.

Acknowledgements

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