ILC COAXIAL BLADE TUNER*

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Abstract

A coaxial (blade) tuner solution has been developed for the compensation of the Lorentz force detuning of the superconducting cavities under the high gradient pulsed operation foreseen for ILC operation. The device is based on prototypes successfully tested at DESY in 2002 both on CHECHIA and on the superstructures inserted in the TTF string. During both tests the blade tuner performed as expected in terms of stiffness, frequency sensitivity and tuning capabilities. An improvement of the tuner characteristics has been designed by the integration of fast tuning capabilities by means of piezo-ceramic elements. Two prototypes of the new INFN coaxial piezo blade tuner have been manufactured and will be tested in the near future at DESY and BESSY after integration with the cavities. In this paper the blade tuner design and its main characteristics are presented, together with the perspectives of a sensible cost reduction from the prototypes, in view of the large scale production foreseen for the ILC.

INTRODUCTION

The coaxial blade tuner was originally developed [1] for the need of a cold tuning system for the tests of the TTF superstructures concept [2], because the longitudinal clearance required by the standard TTF tuning system was incompatible with the superstructure design.

Similarly, for the case of the International Linear Collider, the minimization of inter-cavity distance is one of the critical points in order to reduce the accelerator footprint. Therefore, the ILC reference layout assumes a coaxial tuner solution. The original blade tuner design tested both in CHECHIA and on the TTF linac has fulfilled its requirements in term of slow cold tuning capabilities, but did not include the fast tuning action required at the high gradients (> 30 MV/m) envisaged for the ILC operation.

FAST PIEZO BASED TUNING ACTION

Recently, a fast, piezo-based, tuning action has been added to the blade tuner concept and it has been described in references [3-5]. Two existing blade tuner assemblies have been equipped with a revised leverage system and two modified Helium tank systems have been manufactured in order to include the piezo active elements (see Figure 1). Tests were initially foreseen at DESY and BESSY after the final tuner integration with two existing TTF cavities before this Conference, but higher priorities for the Module 6 assembly operation at DESY lead to a delay in the testing program.

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The piezo-blade tuner system is composed of three main components: the ring-blade assembly, the leverage system needed to actuate the slow tuning and the piezo system needed for the fast tuning action. Figure 2 shows these components in the final tuner system: in particular one can see the piezoelectric elements acting between the ring-blade assembly and the outer ring to the left of the picture (welded on the He tank). The four threaded bars, parallel to the piezo elements accomplish two different tasks: first of all they are needed during transportation, handling and assembly phases to avoid inelastic deformations of the bellow. In this case they are tightly bolted at both ends to provide stiffness to the system. Furthermore, in the operating condition, the inner bolts are properly loosened and the bars act as safety devices in case of piezo mechanical failure or overpressure conditions inside the Helium tank.

With respect to the original system used for the TTF superstructures, the leverage system has been rotated to one side, in order to avoid the mechanical interferences with the Invar rod providing the cavity longitudinal alignment in the TTF CRY3 design.

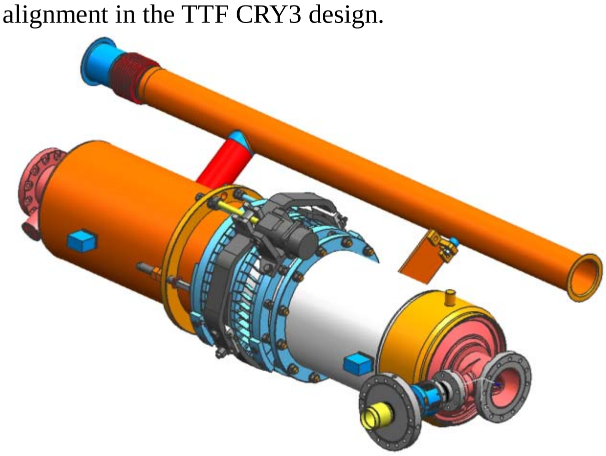

Figure 1: The cavity dressed with the modified helium tank and piezo blade tuner.

Moreover, a revised cavity pre-tuning procedure has been devised in order to guarantee a correct range of preload values on the piezoelectric elements along the entire slow tuning range. This procedure allows also avoiding the “neutral” point of the leverage system and requires that the tuner operation always acts stretching the cavity (thus compressing the piezoelectric elements).

Figure 2 shows the tuner components, color-coded by part material: blue denotes Ti, gray stainless steel, yellow CuBe and red brass. The piezo elements are the dark gray rectangular bars acting on the left Ti ring. The whole weight of the mechanism is approximately 20.5 kg. Each half blade-ring assembly has an array of 23 “packs” of 2 blades on each side, for a total of 184 flexural elements (blades). The blade packs for the two halves of the blade-ring assembly are electron beam welded in a single pass with a special tooling device, in order to limit any unnecessary loading/unloading procedures of the electron beam welding machine, which lead to an increase in costs and longer manufacturing times.

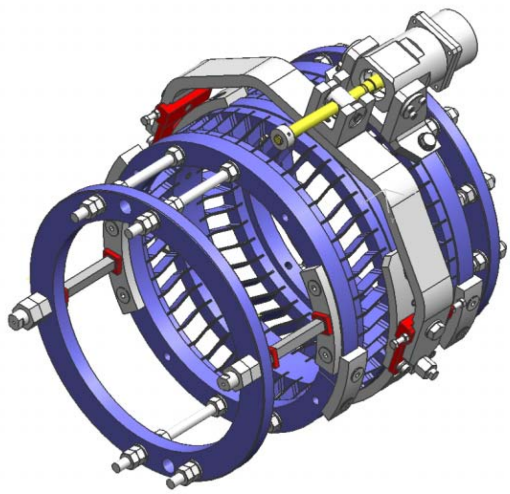

Figure 2: The piezo blade tuner (the cavity He tank is not shown for simplicity.

Titanium has been chosen as the main tuner material both for thermal shrinkage compatibilities with the materials used for the He tank and cavity (respectively, Ti and Nb), but also for its elastic and strength properties, which allow to reduce the stresses in the flexural elements with respect to the case of cheaper structural materials, as stainless steel.

The present ring-blade mechanism is extremely stiff (~100 kN/mm when fixing the central ring rotation) [4-5]. The overall combined tuner stiffness (as provided to the cavity) is essentially limited by the leverage mechanism, especially in terms of slacks and allowances, which reduce its value to the experimental one of 25 kN/mm [1]. In addition to that, the forces exerted from the tuner during the fast and slow actions are directly transferred to the helium tank and, from there, to the cavity by means of the Nb-Ti conical end plates, which have a limited stiffness [5]. The contribution of these end plates further reduces the stiffness of the overall cavity length constraining system, which opposes to the longitudinal cavity shrinkage driven by the Lorentz force action at high fields.

DESIGN CHANGES IN VIEW OF LARGE SCALE ILC PRODUCTION

For the long term feasibility of the ILC proposal [6], all components should be properly engineered and costed, having in mind the perspectives of the large scale production foreseen for the collider (> 16,000 components for the baseline 500 GeV design).

This consideration led us to begin exploring possible simplifications and cost reduction efforts for an industrial scale blade tuner. By lowering the requirements on the ring-blade stiffness (on the basis of the considerations expressed before) a “lighter” version was devised, which reduces the needed material and the number of machining and weld procedures. The preliminary result of this study is shown in Figure 3, using the same material color-coding as Figure 2.

The width of the Ti rings has been reduced, as well as the number of blade elements. Now the system has an array of 14 “packs” of 2 blades on each side, for a total of 112 flexural elements (blades), with a 40% reduction in the number of blade packs, and a consequent reduction of the assembling time and number of EBW welds. This leads to a corresponding decrease of the nominal stiffness of the ring-blade mechanism that is anyway consistent with the overall stiffness requirement dominated by the other system components (see above). The blade length and width have also been adjusted to improve the tuning range in order to relax the pre-tuning requirements.

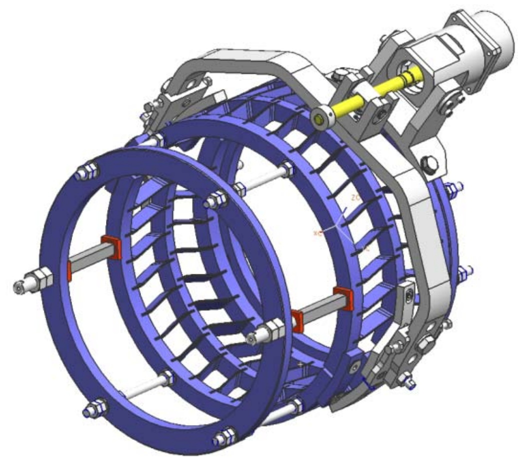

Figure 3: “Light” version of the piezo blade tuner, with an achieved 40% weight reduction and simplified manufacturing procedures.

Furthermore, the blade position at the central ring is no longer collinear on the two opposing sides, but is assembled in an alternated pattern, allowing welding the two opposite blade packs in a single EBW seam. Figure 4 shows the details of the blade packing into the tuner rings in the two designs.

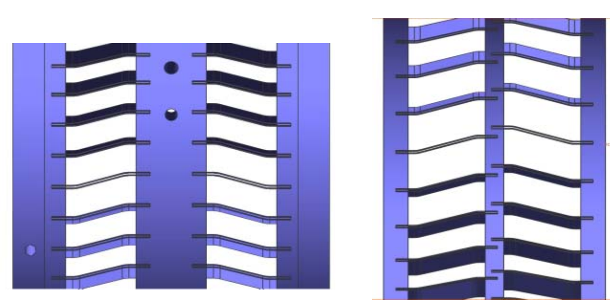

Figure 4: Detail showing the drastic reduction in the thickness of the rings from the original design (left) to the “light” version (right) and the simplification in the electron beam welding pattern for the assembly of the flexural elements. For numerical values refer to Table 1.

The total weight of the tuner is now slightly less than 12 kg, thus allowing a direct 40% decrease in Ti material costs. Table 1 lists the main dimensional changes for the ring-blade assembly for the two designs.

Table 1: Characteristics of the ring-tuner assemblies.

	TTF	**Light ILC**
End Ring width	30 mm	16 mm
End Ring height	25 mm	16 mm
Central Ring width	40 mm	12 mm
Central Ring height	17 mm	16 mm
Blade packing	2	2
N of packs / whole tuner	4x23	4x14

Changes were also performed on the leverage mechanism, where the brass plate transferring the leverage force to the ring has been replaced by a steel piece, thus stiffening an important point in the driving mechanism.

This improvement required a redesign of the pin, that in the original concept was cylindrical, originating a detrimental interference during the movement as illustrated in Figure 5. Moreover, erosion of the brass part due to friction in operation was observed after the disassembly of the tuners [7]. The new pin profile has been obtained by imposing a tangential contact between the pin and the new stainless steel plate (see Figure 6). This modification is intended also to improve the reliability of the mechanism against wear out of the mechanical components. A proper treatment for reducing friction is foreseen on the pin surface.

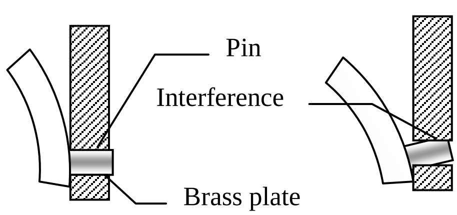

Figure 5: Detail showing the interference for the cylindrical pin case in the original design.

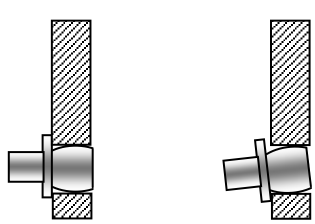

Figure 6: Detail showing the new pin geometry.

The light version of the blade tuner has been designed to accommodate different piezoelectric elements up to a length of 70 mm. In such a case the foreseen range of compensation performances are reported in Table 2, considering the possible use of only one actuator or two actuators. These values have been estimated assuming a conservative residual piezo stroke capability at 2 K of 10% of the room temperature measured values, and a factor of 2 of margin needed for the dynamic effect (with respect to the static LFD case) [8]. One should also note that for stiffness reasons, only 73% of the axial stroke of the piezo is transmitted to the cavity [5], the rest being absorbed by other elastic elements in the system.

Table 2: Fast tuning capabilities of 70 mm piezo.

n. of piezo	Cavity dv/dz (kHz/mm) [9]	Warm piezo stroke (μm)	$\Delta\nu$ (Hz)
1	315	100	575
2	315	100	1150

With these conservative assumptions on the stroke at 2 K the use of two piezo actuators is needed for the ILC operation, while the failure of one still enable to provide nearly 60% of the nominal required action (1 kHz).

CONCLUSIONS

We have started to analyze design modifications to the coaxial blade tuner concept in order to reduce manufacturing costs and simplify the manufacturing process, in view of a possible industrialization for the ILC. Other possible modifications (e.g. changes in the leverage system, other blade packing factors, …) are under study and will be critically compared in terms of perspectives of cost-reduction while meeting the design specifications and the high reliability goals of such a critical ancillary component of the superconducting radiofrequency accelerator. After the validation of our modeling with the measurements of the two existing (old design) prototypes we will proceed to fabrication of one prototype of the light tuner.

REFERENCES

[1] D. Barni, A. Bosotti, C. Pagani, R. Lange, H.B. Peters, "A New Tuner For TESLA", Proceedings of EPAC2002, Paris, France, p. 2205.
[2] J. Sekutowickz et al., "Test of Two Nb Superstructure Prototypes", in Phys. Rev. ST - AB, **7**, 012002 (2004).
[3] C. Pagani, A. Bosotti, P. Michelato, N. Panzeri, P. Pierini, "Improvement of the Blade Tuner Design for Superconducting RF Cavities", Proceedings of PAC2005, Knoxville, TX, USA, p. 3456.
[4] C. Pagani, A. Bosotti, P. Michelato, N. Panzeri, R. Paparella, P. Pierini, "The Fast Piezo-Blade Tuner for SCRF Resonators", in Workshop on Superconducting RF, Cornell, USA, 2005.
[5] C. Pagani, A. Bosotti, P. Michelato, R. Paparella, N. Panzeri, P. Pierini, F. Puricelli, G. Corniani, CARE-Note-2005-021-SRF.
[6] See www.linearcollider.org.
[7] R. Lange and K. Jensch, private communication.
[8] M. Liepe, contributions to the ILC BCD, in [6].
[9] B. Aune et al, "Superconducting TESLA cavities", Phys. Rev. ST - AB, **3**, 092001 (2000).