BEAM PIPE HOM ABSORBER FOR 750 MHz RF CAVITIES*

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Abstract

Superconducting HOM-damped (higher-order-mode-damped) RF systems are needed for present and future storage ring and linac applications. Superconducting RF (SRF) systems typically contain unwanted frequencies or higher order modes (HOM) that must be absorbed by ferrite and other lossy ceramic-like materials that are brazed to substrates mechanically attached to the drift tubes adjacent to the SRF cavity. These HOM loads must be thermally and mechanically robust and must have the required broadband microwave loss characteristics, but the ferrites and their attachments are weak under tensile stresses and thermal stresses and tend to crack. A HOM absorber with improved materials and design will be developed for high-gradient 750 MHz superconducting cavity systems. RF system designs will be numerically modeled to determine the optimum ferrite load required to meet the broadband loss specifications. Several techniques for attaching ferrites to the metal substrates will be studied, including full compression rings and nearly-stress-free ferrite assemblies. Prototype structures will be fabricated and tested for mechanical strength.

INTRODUCTION

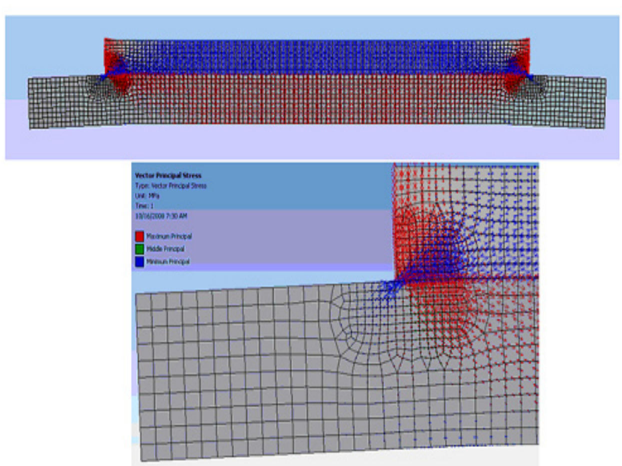

Figure 1. ANSYS calculation of a ferrite material brazed to copper. Maximum Principle stress is shown in red, the tensile stress. The minimum principle stress, compression, is shown in blue. .

HOM load designs for SRF cavity applications are complicated due to the processes used to attach brittle ferrites to metallic substrates and the buildup of unwanted stresses. The stresses at assembly are further increased, because the different thermal expansion coefficients of the ferrite, the braze material, and the substrate [1] cause additional stresses during cool down from the brazing temperature to operating temperature. Typically, the HOM load designs are fabricated from ferrite slabs and brazed to form a circle of lossy material inside the drift tube [2.3.4].

When ferrites are brazed or soldered to substrates, there will be stress build up at the edges of the ferrite as shown in an ANSYS example of ferrite on copper in Figure 1, where the difference between attachment temperature and operating temperature is 500Cº.

CONCEPT

Based on the HOM load techniques developed for 500 MHz superconducting RF systems for high current storage rings and 1300 MHz systems for the ERL injector, a HOM absorber with improved materials and design will be developed for high-gradient 750 MHz superconducting cavity systems for storage ring and linac radiation sources. This work will build on novel construction techniques developed earlier at the SLAC B-factory.

The fundamental ideas for the fabrication of HOM loads using ferrites in compression are similar to the concept used in the design of compressed windows [5]. For stress-free designs the ideas are similar to those used in building HOM loads for PEP-II [6].

Microwave design principles will be based on the utilization of fabrication techniques in order to allow the microwave design to dominate the overall effectiveness of the HOM load as opposed to the limitation of construction techniques.

TECHNICAL APPROACHES

Stress-Free Design

For a stress free slab design, buffer layers and posts are proposed. Buffer layers have proven to be an effective means to minimize the formation of tensile stresses between dissimilar materials as discussed in references [5] and [6]. However, buffer layers must be carefully designed, processed, and tested, to assure their performance under operating conditions. In reference [5], for example, the copper buffer layer was allowed to stress relieve at 440C, during the cool-down of a braze cycle. In reference [6], the design of posts was optimized to provide the necessary stress relief along with providing adequate surface area to conduct the heat away generated by the microwave losses in tiles. The ANSYS model in Figure 2, shows the concept of the post design used to relieve tensile stress in the buffer layer, as opposed to transmit the tensile stresses into the ferrite. Once the buffer layer is designed into a novel assembly such that no tensile stress are transmitted to the ferrite, then an SRF

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HOM load can be fabricated with slabs in a profile that is optimized for microwave performance.

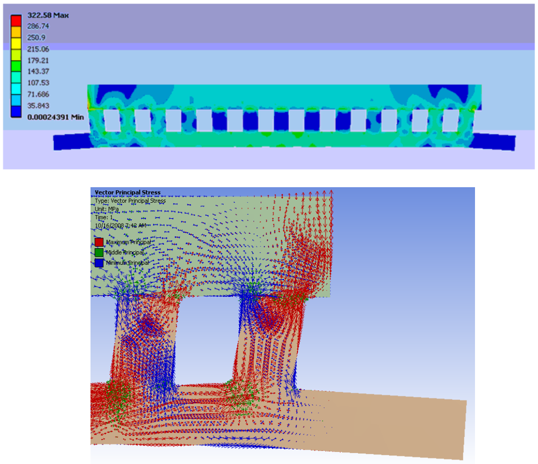

Figure 2. ANSYS calculation showing conceptually how the displacement of posts isolates the difference in thermal expansion of the copper and ferrite, thereby reducing the tensile stresses in the ferrite. .

Compression Ring Design

Next, we discuss the compression ring design. Such an idea was implemented in reference [5]. In this novel approach to SRF HOM load designs, the idea is to make use of the mechanical strength of the ferrite material, as opposed to staying away from its weakness. In compression, the ferrite material is 10 times stronger than in tension. A mechanical assembly such that the ferrite is always in compression, 50% below its limits, and never in tensile, will never crack. Such an idea was implemented in reference [5] for ceramic windows. However, for the ferrite ring, it will not be necessary to make a vacuum tight and mechanically rigid braze, since the ferrite will be mechanically held by the compressive forces established by the assembly process.

At room temperature to operating temperature, the compression ring and ferrite ring are designed to have an interference fit. During the assembly process, the ferrite ring is lowered in temperature, and the compression ring heated by resistive heating, such that the compression ring is larger than the ferrite and slips over the ferrite ring using an assembly fixture.

This novel HOM load design maximizes the transfer of heat generated by the microwave losses, since the ferrite ring is in direct contact with the compression ring which is attached to the heat sink. This novel assembly relies on an RF design that works with rings of lossy materials

RF Design

The codes used to design HOM loads must be able to incorporate the real and imaginary parts of the material characteristics of dielectric and permeability. Codes such as CLANS and COSMOL achieve this goal.

The novel HOM load design proposed in this proposal will be to incorporate rings of material such as those already studied in reference [1] in mechanical configurations such as those in Figure 3. Many of these materials have been measured for RF performance as documented in reference [9].

SUMMARY

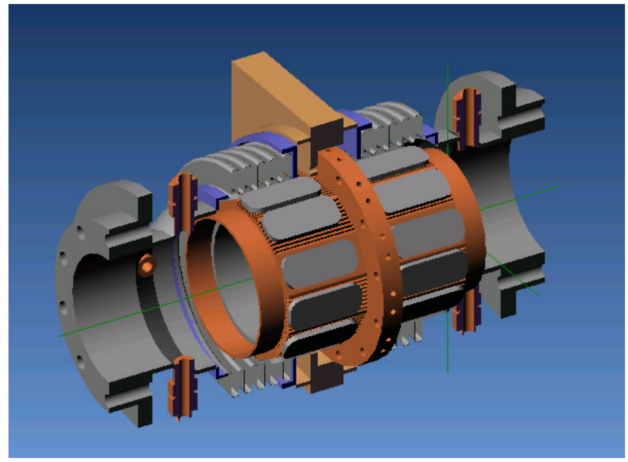

Figure 3. One example of the improved HOM load in the existing bellows assembly.

The current design includes 48 tiles with individual brazes to flat surfaces. In one example of the proposed improvements, the outside tiles remain, however they are brazed to stress relieving posts. The inside tiles are replaced by a cylinder of ferrite material in compression. This assembly can possibly be built in a single braze with a braze fixture that holds the outside ferrites in place during the braze. At temperature the copper shell is extruded, such that during cool down from braze temperatures it puts the ferrite cylinder in compression.

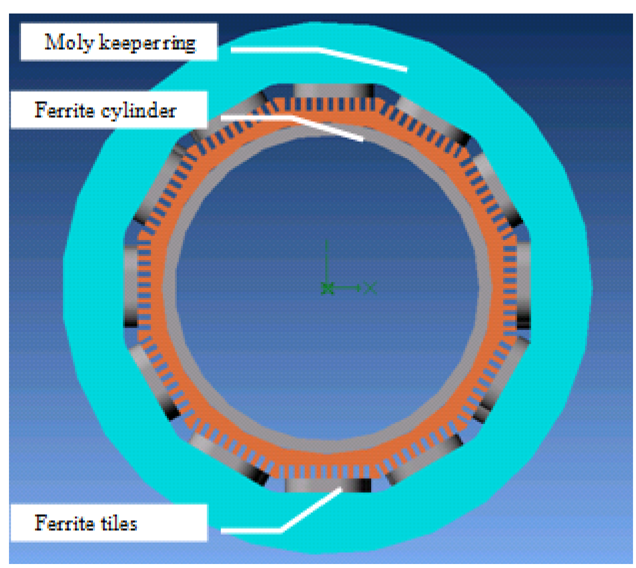

Figure 4. Top view of fixturing for a single braze cycle. The process brazes the outer ferrite tiles and places the inner ferrite cylinder in compression without braze material.

An alternate HOM load assembly may be accomplished with cylinders only and no tiles. The outer tiles are replaced with a cylinder that is brazed to the posts with a keeper ring assembly as shown in Figure 5.

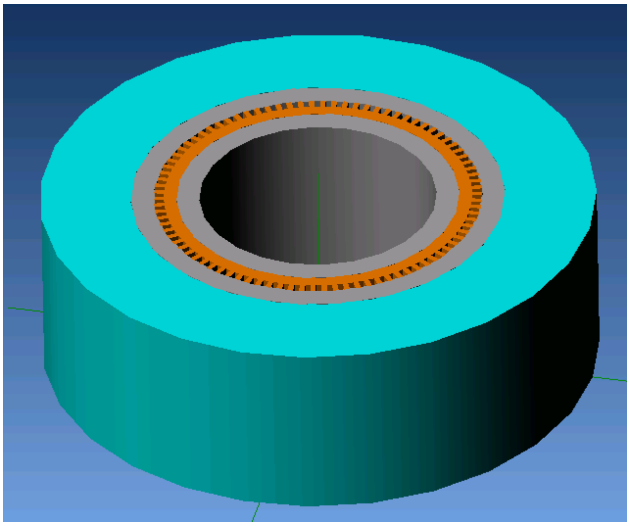

Figure 5. View of brazing assembly fixturing for inner and outer cylinders of ferrite using a suitable keeper ring to prevent the outer ferrite from being in tensile during the brazing process. After cool down, the inner ring is not brazed but held in compression by the extruded copper inner core.

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