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Modeling, Fabrication, and Optimization of Niobium Cavities – Phase I: Quarterly Progress Report May 15, 2001 - August 15, 2001

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Modeling, Fabrication, and Optimization of Niobium Cavities – Phase I

Quarterly Progress Report
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UNLV-AAA University Participation
Program

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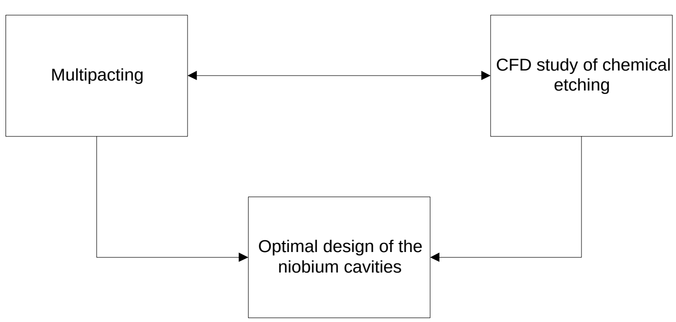
Principle Investigators

Purpose and Problem Statement

Multipacting is one of the major loss mechanisms in rf superconductivity cavities for accelerators. This loss mechanism limits the maximum amount of energy/power supported by the cavities. Optimal designs have been identified in others' studies. In practice, these designs are not easily manufactured. Chemical etching processes used to polish the cavity walls result in a nonuniform surface etch compromising the optimal geometrical design. Past multipacting studies have not examined the impact of wall perturbations.

It is the purpose of this study to examine the chemical etching process in the design of niobium cavities so to maximize the surface quality of the cavity walls while minimizing the multipacting losses. Single and multiple cavity cell geometries are to be investigated. Optimization techniques will be applied in search of the chemical etching processes, which will lead to cavity walls with near ideal properties. Figure 1 depicts a block diagram of the optimization procedure, which is intended to be fully automated among a variety of existing codes.



Personnel

Principal Investigators:

- Dr. Robert A. Schill, Jr. (Electrical Engineering)
- Dr. Mohamed B. Trabia (Mechanical Engineering)

Research Investigator:

- Dr. Yi-Tung Chen (Mechanical Engineering)

Students (Summer 2001):

1. Ms. Myong Holl, Undergraduate Student, (Mechanical Engineering)
2. Mr. Greg Lull, Undergraduate Student, (Electrical Engineering)
3. Ms. Qin Xue, M.S. Graduate Student, (Mechanical Engineering).

National Laboratory Contact:

- Dr. Dominic Chan, Project Leader for Superconducting RF Engineering Development and Demonstration AAA Technology Project Office at Los Alamos National Laboratory

Notes:

1. Mr. Sathishkumar Subramanian, Graduate Student in Mechanical Engineering, has just joined our group.
2. Mr. Greg Lull will be leaving the project at the end of August of 2001. A student is currently being sought to replace Mr. Greg Lull.

Management Progress

Budget Issues:

- Purchase of software codes (Field Precision, MATLAB, and FEMLAB).
- Purchase of two complete computer systems (Gateway. A third computer system has been ordered.

Notes:

1. Most of the major equipment budget has been spent.
2. Salary expenditures are on target.

Management Problems

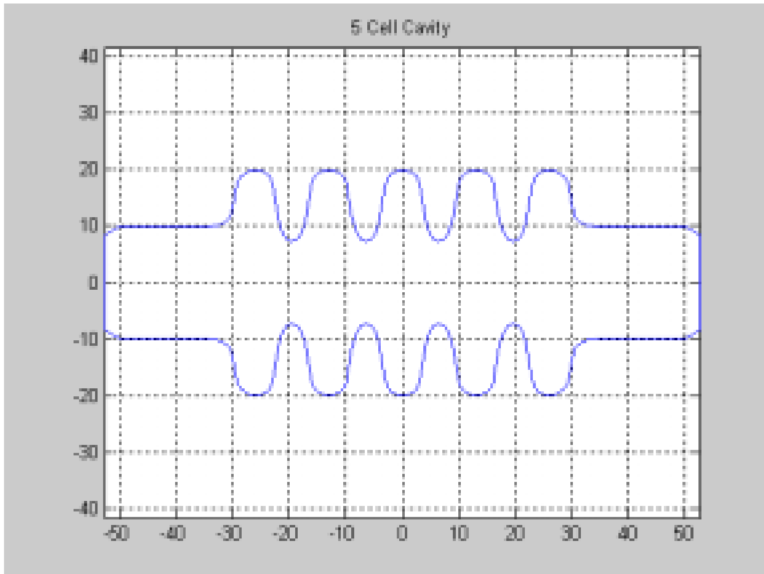
Several software difficulties have been identified and are currently being addressed as can be seen in the remainder of this report. Some of these issues has taken longer than expected and has slowed the progress of the current research in some areas.

We intend to overcome some of the software difficulties. A purchase of a chemical engineering toolbox will aid in the study of azimuthally symmetric geometries is anticipated in the second quarter. If the electromagnetic codes are shown to be incompatible with the TRAK_RF code, a different particle tracking code written by Dr. H. Padamsee will be sought.

Technical Progress

Parametric Design of the Niobium Cavity

A model for single-cell as well as multi-cell niobium cavity was created in MATLAB. All dimensions are considered as parameters that can be varied later by the optimization programs.



Multipacting Study

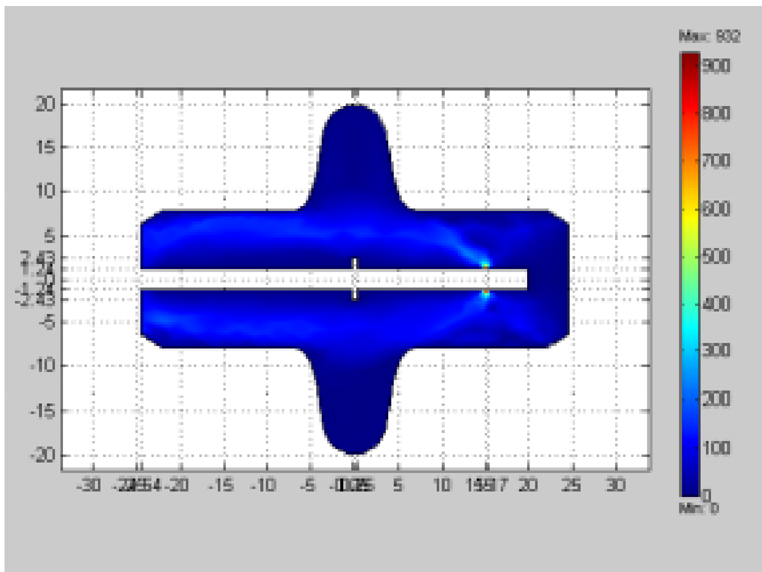
A set of codes has been in part purchased from Field Precision Inc. to investigate multipacting in a niobium cavity. TRAK_RF, a two-dimensional research particle tracking code, has been provided to us at no cost. A significant amount of time has been spent in learning these codes and examining the accuracy and consistency of the codes. Some versions of the purchased codes have not been compatible with TRAK_RF resulting in inconsistent results. Further investigations are underway to either correct or work around the inconsistency.

Three script codes (makemesh.m, callwsim.m, and run_rtf.m) have been developed to automate the calling and running of the Field Precision software in a MATLAB environment. The resonant frequency of neighboring modes is determined. The file findmaxfield.m has been written to find the maximum normalized primary field in the cavity structure. A correction factor is determined and used to renormalize the computed fields so to treat all geometry perturbations on an equal footing. The normalization constant is based on the fields supported by a cylindrical cavity whose wall geometry is best fits the cavity geometry under test. The file partplot.m has been written to provide a visual plot of the trajectory of a charged particle. Two other batch files have been written to aid in the study of the codes.

CFD Study of Chemical Etching

Surface finish of the niobium cavity plays an important role of achieving the best performance. Perturbation of the geometry of the cavity inner surface can seriously affect its performance due to rf heating or electron field emission. Therefore, fabrication of the cavity is followed by a surface finish treatment using chemical etching. A baffle is inserted inside the cavity and an etching fluid is circulated to improve surface finish. The following steps were taken toward understanding and modeling of this problem:

1. Attempting to understand the particular of the chemical etching process as it is now through intensive discussions with Dr. D. Chan, LANL.
2. Started developing a finite element model for the process using FEMLAB software. FEMLAB was used since is an integrated part of MATLAB, which makes it easier to create parametric designs. The following figure shows the results of a preliminary simulation of the etching fluid flow within a single-cell niobium cavity. We are still in the process of tuning this model.



3. We are in the process of extending the analysis of the previous step to a five-cell niobium cavity.
4. We plan to purchase a FEMLAB Chemical Engineering Module that will be helpful in producing more accurate model of the problem.

Optimization Study

Due to the elliptical geometry of the cavity, current etching techniques do not produce a uniform surface finish. The project starts with modeling a single-cell cavity. Results will be verified using data from LANL. The project will be extended to multiple-cell cavities. Results will be also verified using data from LANL. Our immediate objectives are

- Producing accurate models of multipacting and chemical etching.
- Verify modeling results using experimental data of LANL.
- Integrate modeling tools with optimization techniques.

We are having ongoing discussions with LANL personnel regarding these issues.