Boundary Elements VII

Volume 1

Editors:
C. A. Brebbia
G. Maier

Boundary Elements VII

Proceedings of the 7th International Conference, Villa Olmo, Lake Como, Italy, September 1985

Volume I

Editors:
C.A. Brebbia
G. Maier

A Computational Mechanics Publication

Springer-Verlag
Berlin Heidelberg New York Tokyo

C.A. BREBBIA

Computational Mechanics Institute
52 Henstead Road,
Southampton SO1 2DD
England

G. MAIER

Istituto di Scienza delle Costruzioni
Department of Structural Engineering
Politecnico di Milano
Milano
Italy

British Library Cataloguing in Publication Data

Boundary elements VII : proceedings of the 7th international conference, Villa Olmo, Lake Como, Italy, September 1985.——(A Computational mechanics publication)
1. Engineering mathematics 2. Boundary value problems
I. Brebbia, C.A. II. Maier, G. III. Series
620'.001'515353 TA347.B69

ISBN 0-905451-36-8

ISBN 0-905451-36-8 Computational Mechanics Centre, Southampton
ISBN 3-540-15729-8 Springer-Verlag Berlin Heidelberg New York Tokyo
ISBN 0-387-15729-8 Springer-Verlag New York Heidelberg Berlin Tokyo

PREFACE

Boundary Elements has in recent years developed from a theoretical method into a practical tool for engineering analysis. Its growth has coincided with the search for techniques which are simpler to use and better adapted to the design process. Boundary element theoreticians have met this challenge by producing a method which although mathematically more complex than finite elements is more accurate and easy to use. The price to pay in terms of extra mathematical and computational work has been amply justified by the results but it is the function of research and development to produce the best possible tools. Users should not as far as possible, be required to carry out work which is not of direct relevance to their immediate design. In this regard the solution's accuracy, the results' reliability, convergence when using different meshes, complex discretization and other problems should be solved by the software developers rather than the designer.

There is a growing feeling that engineers are dissatisfied with many of the finite element codes now in existence. Questions frequently arise regarding their accuracy and reliability. How can the results be trusted when so much has been done to obscure the errors? How can the engineer quickly verify equilibrium, when stresses have been averaged or smoothed? Can you trust the technique when two different codes give different results? These questions were less pressing during the last decade when designers were happy to obtain any computer results, but now all this has produced a demand for more accurate solutions.

It is important for us and essential for the future of the Boundary Element Method that we address these problems at this early stage. The Boundary Element Method is a relatively complex technique which requires a better mathematical and numerical knowledge than finite elements. Integration problems for instance, can produce numerical inaccuracies which are not only easy to detect but detract from the true value of the technique. Methods of solving systems of equations also need to be improved. Not all programs are as user friendly as could be desired and may require a theoretical knowledge that is unwarranted for the designer. Some have no checks on error or equilibrium, few if any advise the user or have a comprehensive set of diagnostic messages.

The development of the boundary element method into an effective engineering tool must entail the solution of these problems. We can learn from the mistakes of others, as Bismarck said "Only fools learn by experience. I learn from other people's experiences".

Como

September 1985

CONTENTS

VOLUME 1

3. TIME DEPENDENT PROBLEMS

14. APPLICATIONS

SESSION 1 POTENTIAL PROBLEMS

Computation of Dielectric Permittivity from Experimental Measurements

G. T. SYMM
Division of Information Technology and Computing, National Physical Laboratory, Teddington, England

ABSTRACT

When an open-ended coaxial line radiates into a homogeneous dielectric medium, the reflection factors within the line depend upon the permittivity of the medium. This dependence is analysed here by a form of boundary element collocation technique involving series and integrals. Whilst the analysis essentially yields equations for the reflection factors in terms of prescribed permittivity, it also enables us to solve the inverse problem of computing the permittivity of the dielectric from (measured values of) the reflection factors.

INTRODUCTION

In recent years microwave reflection techniques have become very popular for the nondestructive measurement of material properties, as required for example in biomedical diagnosis. Here we describe one such technique, for obtaining the complex permittivity of a dielectric medium from the reflection factors (which are also complex) in an open-ended coaxial line which terminates on its surface.

We first consider solution of the direct problem, of determining the reflection factors for a prescribed permittivity, by the method of Mosig et al. (1981). We then proceed to solve the inverse problem of determining the permittivity from the reflection factors, in particular from the dominant reflection factor, which can be measured experimentally.

THE DIRECT PROBLEM

Consider a coaxial line, with inner and outer radii a and b, respectively, filled with a (lossless) homogeneous dielectric of relative permittivity ϵ_c and terminated in the plane $z = 0$

in a flat metallic flange extending to infinity (in theory) in the transverse direction (Fig.1). The material to be tested occupies the half-space $z > 0$ and is assumed to be homogeneous, isotropic, linear and non-magnetic, and to have complex relative permittivity

$$\epsilon_m = \epsilon' - i\epsilon'' \quad (1)$$

where ϵ' and ϵ'' are both non-negative.

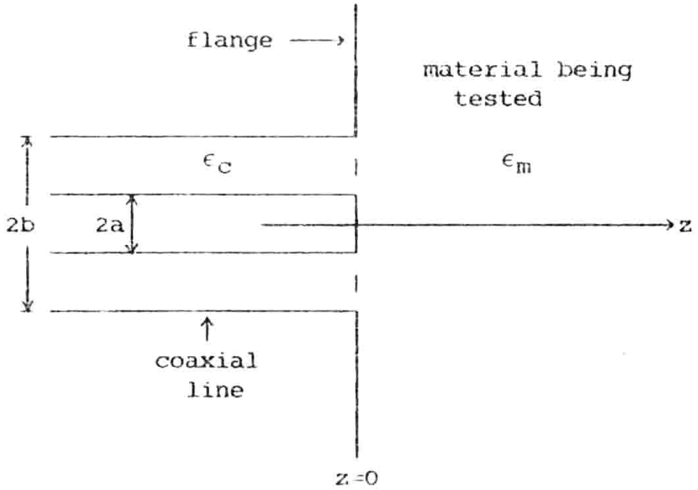

Fig.1. Open-ended coaxial line radiating into a homogeneous medium

The dimensions of the line and the upper frequency of operation are selected so as to permit propagation of the dominant TEM mode only, i.e. the wave mode in which the axial components of the electric and magnetic intensity vanish, i.e.

$$E_z = 0, \; H_z = 0, \quad (2)$$

and (assuming unit relative permeability) the transverse components take the form (Jones, 1979)

$$\mathbf{E}_t = \exp(-ikz)\text{grad}\psi \quad (3)$$

and

$$\mathbf{H}_t = (k/\omega\mu_0)\exp(-ikz)\mathbf{k}\wedge\text{grad}\psi \quad (4)$$

where ψ satisfies Laplace's equation

$$\nabla^2\psi = 0 \quad (5)$$