K Y O K A I . 3 D

AN INTERACTIVE THREE-DIMENSIONAL BEM SOLVER

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SYNOPSIS

A small boundary element computer program, KYOKAI.3D, is presented. The program package is dedicated to the numerical solution of linear potential problems and elasticity in three dimensions. Boundary element mesh is automatically generated by preprocessor via an interactive standard graphic terminal. Constant boundary elements are used for the discretization of boundary integral equations. Calculated equipotential lines and traction contours are plotted on arbitrary solid surfaces of the model by postprocessor. The KYOKAI.3D aimes at providing engineers who have little knowledge about both three-dimensional modelling and boundary element method. The user is conducted by easily comprehensive, interrogative commands. Typical examples are demonstrated to access the versatility of this turn-key system.

1. INTRODUCTION

Boundary element method (BEM, for example, Banerjee and Butterfield [1979, 1981], Banerjee and Show [1982], Brebbia [1981, 1982], Crouch and Starfield [1983]) is said an alternative of the excellent numerical methods in computational continuum mechanics in science and engineering. Being compared to domain-type methods such as finite differences and finite elements, BEM has many side advantages. Among them, it is directly applicable to domains extending to infinity, gives better accuracy near singularities, higher order of stability and convergence, economy of computer memory, and portable structure in writing the computer program.

On the other hand, BEM has several disadvantages. Because of its singularity in weighting function, appropriate numerical integrations must be carefully chosen to obtain good results. Applications to nonlinear problems are rather limited due to the characteristic nature of the fundamental solutions. The c.p.u. time in the computer implementation is not necessarily small.

Computer programmes ever published are so few that BEM has not been fully acknowledged as a powerfull numerical tool for engineers. The computer program BEASY developed by Danson et al.[1982] and CA.ST.OR-3D by Afzali and Chaudouet [1982] for application purposes are now commercially available. The state-of-the-art is summarized in Brebbia [1982].

In this short paper, we introduce a small turn-key system portable on mini-computers. The system is a boundary element solver together with pre-post processors. In the preprocessing stage, input data are automatically generated in a conversational mode on a graphic display. In the postprocessing stage, calculated numerical results are automatically plotted on the surface of the solid model.

The computer program is the aggregate of three excellent programmes developed individually. The preprocessor is the translation of the 3/D mesh generator KUBIK developed by Pissanetzky[1981]. The 3/D BEM solver is the tranlation originally developed by Ikeuchi[1982]. The postprocessor is the translation of interactive computer graphic system MOVIE.BYU developed by Christiansen and Stephenson[1981].

2. KYOKAI.3D - AN INTERACTIVE 3/D BEM SOLVER

2.1 Outline of KYOKAI.3D

KYOKAI.3D is a new augumented version evolved from the old KCM (after KUBIK-CAL-MOVIE.BYU) computer program. The KCM was a three-dimensional potential problem solver using BEM with the pre-post processor. Elastic problem solver was added to the KCM, and some modifications were made to it into an integrated boundary solver. The computer program KYOKAI.3D consists of five categorical blocks of activities. The activities are initiated by its peculiar set of key commands. The specification in each block is made by the set of subcommands.

Mesh of solid elements is generated in the first block by using KUBIK system which was given in favor of Dr.Sergio Pissanetzky. User has to input the data of outline, which is defined by corner nodes and the numbers of meshes in local three directions of the model. This block has also subcommands and automatically performs numbering of nodes, counting element connectivity, determination of coordinates of all nodes. The outline of the model and the fine mesh with or without hidden line elimination can be plotted to check the validity of the model construction.

Boundary conditions of the problem to be solved are introduced in the second block. The data thus augumented become the complete input data for the next third block. The selective change of the input data just created is possible by a specially purposed change subcommand.

Three-dimensional problems are analyzed in the third block. Numerical solution is sought by the boundary element method. Constant elements are used. Calculated temperatures are applicable to the thermal load in the elasticity analysis followed through internal data conversion.

Calculated results are transformed in the fourth block in order to make the data formats prepared for plotting. One can clip the model with arbitrary planes in the space. When the user wants to display the interior, he must clip the model prior to the next block.

Equipotential and traction contour lines are depicted in the fifth block. Contour lines are presented on the surface of the model. In case of displaying interior configulation, one has to separate the model into parts with clipping planes and rotate by parts. Deformation is also plotted in three-dimensional perspectives. Stress ellipsoids are to be included in this block.

Blocks are mutually independent. They have individual input and output files and perform reading and writing on every execution. Therefore re-start capability is guaranteed. If input data to any block are generated, one can start immediately with the block.

2.2 KYOKAI.3D Commands

KYOKAI.3D system has six key commands. Five commands one-to-one correspond to five blocks of activities. The additional STOP command terminates execution of the KYOKAI.3D system, returning the control to the operating system. Blocks for pre- and postprocessor have some mnemonic subcommands. The tree structure of commands is shown in Fig.1.

```
KYOKAI.3D ----- M E S H ---- KUBIK subcommands
             |
             |-- I N F  ( for formatting interface )
             |
             |-- C A L
             |
             |-- S E C T  ( for section of the model )
             |
             |-- D I S P ---- MOVIE.BYU subcommands
             |
             |-- S T O P
```

Figure 1. Command structure of KYOKAI.3D.

3. NUMERICAL EXAMPLES

Heat Conduction in Quarter-Cylinder

A quarter of a cylindrical revolution is modelled by the MESH command. The 3/D perspectives are shown in Fig. 3.1. The uniform temperature of 60° C is maintained inside, while the uniform temperature of 0° C on the wall outside. Other side walls are kept adiabatic.

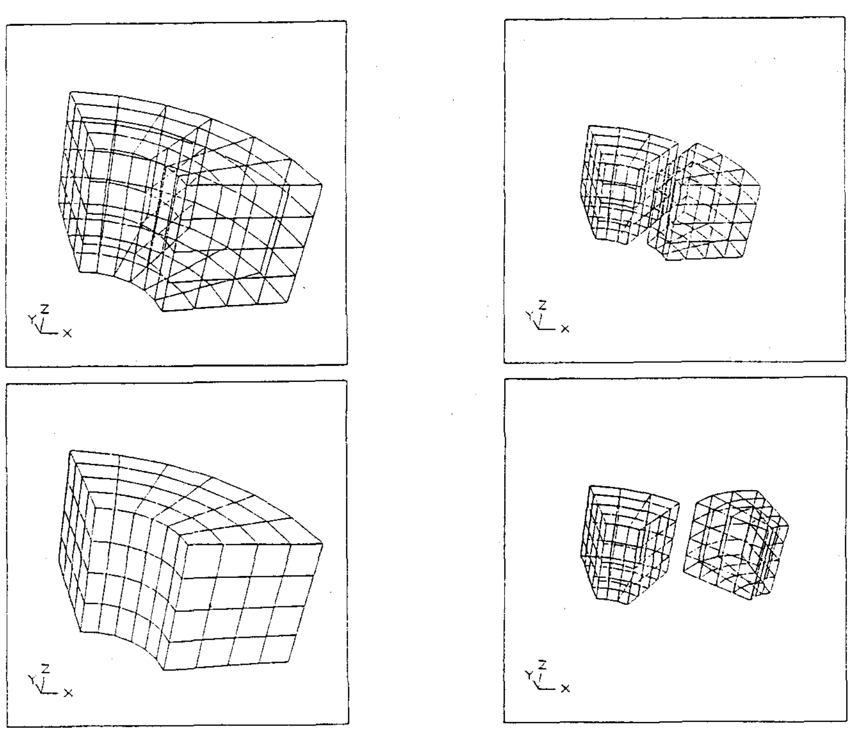

Figure 3.1. 3/D model

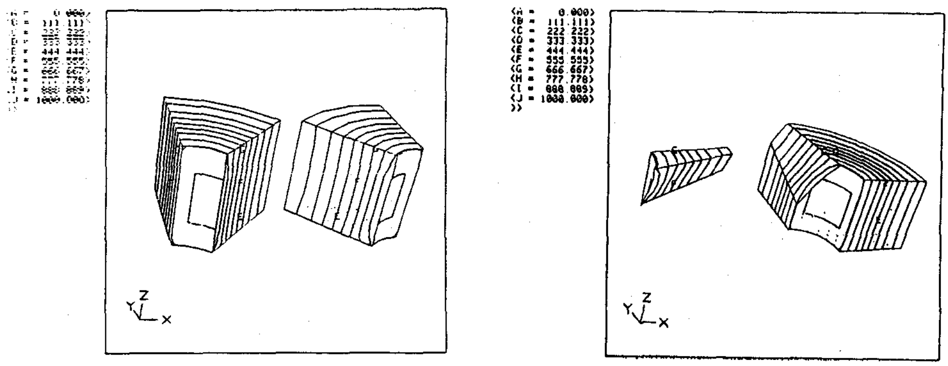

Figure 3.2. Isotherms

4. CONCLUDING REMARKS

In this resume, our endeavour was described on the development of a small turn-key three-dimensional boundary element solver for non-profitable educational users. The program structure and the interactive pre-post procedures were briefly discussed. The usefulness of the program was illustrated by the boundary element analysis in thermoelasticity.

Our program aimes at providing an easy-to-use environment of combined numerical techniques for researchers and students to solve applied mechanical problems on mini-mainframe computers within a few hour. The system is designed to some extent to be machine independent and modular to facilitate the maintenance and to include new developments quickly and easily. Each subprogram is coded in FORTRAN IV. Therefore the minimum difficulties are met in the installation operations except the maker supplied graphic routines.

The majer design constraint on the KYOKAI.3D arises from a requirement for interactive computer graphics environment. If this could not be maintained, there would be some difficulties in model definition, result examination, and post-processing. Without graphic capability, the data check would be error prone.

The KYOKAI.3D was developed on a PRIME 450 under the PRIMOS operating system with 512 kilobytes central memory, 96 megabytes peripheral disk storage, and a TEKTRONIX 4010 graphic display terminal. The minimum architecture required can be much smaller. The KYOKAI.3D will run successfully on smaller mini-mainframe computers. The installation of the system on other IBM-type computer systems has been tested. Multi-user simulation is possible.

A portion of the program package and the user's guide described in this document is available from: Applied Mathematics Department, Fukuoka University, Fukuoka 814-01, Phone: 092-871-6631. The Department does not make any warranty, or it does not assume any responsibility for computer programs and the document. The Department prohibits secondary distribution of any part of this system without written permission of Assistant Professor K. Onishi of the Department. The usage should be confined to non-commercial purpose.