OPTIMUM DESIGN OF MECHANICAL COMPONENTS UNDER STRESS USING FINITE ELEMENT ANALYSIS AND NONLINEAR PROGRAMMING

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TO THE MEMORY

of

MY FATHER

CERTIFICATE

This is to certify that the thesis entitled 'Optimum Design of Mechanical Components Under Stress Using Finite Element Analysis and Nonlinear Programming' being submitted by Shankar S. Bhavikatti to the Indian Institute of Technology, Delhi, India, for the award of the degree of Doctor of Philosophy in Applied Mechanics is a record of bonafide research work carried out by him under my supervision and guidance. The thesis work, in my opinion has reached the standard fullfilling the requirements for the Doctor of Philosophy Degree. The research report and results presented in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

This study is concerned with the development of a suitable structural synthesis procedure for mechanical components under stress and its application to a few problems. The emphasis is mainly on the optimum design of shapes of the mechanical components, the objective being a better performance without violating constraints on stress, deflection and other design requirements. The geometries of such structures are very complicated and hence simple closed form solutions are not possible for stress analysis. Finite element method is considered to be ideally suited on account of its versatality in handling arbitrary boundary conditions, accuracy when used with superior elements and adaptability for different problems.

In the shape optimization of the continua the number of design variables is usually small but ehe number of constraints is large. The computing time required for each stress analysis is large. For such cases sequential linear programming is suited well. Three improvements are suggested in the conventional move limit method of sequential linear programming. The efficiency of the improved method is demonstrated in context of six test problems.

A general purpose optimization program SLPF is developed for the optimum shape design of mechanical components under stress. For stress analysis quadratic isoparametric elements are used and for optimization improved move limit

method of sequential linear programming is used. The stress derivatives are assembled by an efficient method. The program SLPF consists of a main program, 21 standard subroutines and six problem dependent subrountines. Five problem dependent subroutines are very small and need very little effort from the user.

This program has been used to investigate optimum shapes of the following five mechanical components (i) Fillets in flat and round tension bars (ii) Shoulder fillets in tension bars and T-heads; (iii) Cross section of rotating disk (iv) Flanged and flued expansion joints and (v) Transition profile of a spherical pressure vessel and nozzle junction. In last two problems multiple loadings are considered. In each problem the mathematical formulation, finite element idealization and progress of optimization are explained. For each problem, studies have been conducted by varying certain design parameters and the results are presented in detail. Due to limitations on computing time no attempt is made to prepare complete design charts. The capability of the program to handle various problems is clearly demonstrated. Useful design curves are given for each problem.

The efficiency of the improved method is compared with conventional method in the context of the structural problems. All the three suggested improvements are found to be very useful in structural problems and they have made the method more efficient and reliable.

TABLE OF CONTENTS