Unpublished report

USE OF GENOPT AND BIGBOSOR4 TO OBTAIN OPTIMUM DESIGNS OF A DEEP SUBMERGENCE TANK

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David Bushnell, Retired

(This is an abridged version. See the full-length report for more:

genopt.papers/2009.sub.vol1.pdf and genopt.papers/2009.sub.vol2.pdf)

ABSTRACT

The GENOPT/BIGBOSOR4 capability [1-3] is used to obtain an optimum design of a titanium cylindrical tank with hemispherical ends. The tank is subjected to 15000 psi uniform external pressure. The objective of the optimization is to minimize the weight of the tank subject to stress and buckling design constraints. The decision variables establish the distribution of the shell wall material in a wide neighborhood of the junction between the hemispherical and cylindrical segments of the tank. The titanium is assumed to remain elastic. Creep is not included. The maximum allowable effective stress is assumed to be 120000 psi. A factor of safety of 1.3 is used for buckling and a factor of safety of 1.0 is used for stress. Enough detail is given so that an engineer or researcher other than the writer will be able to optimize similar shell structures with GENOPT/BIGBOSOR4.

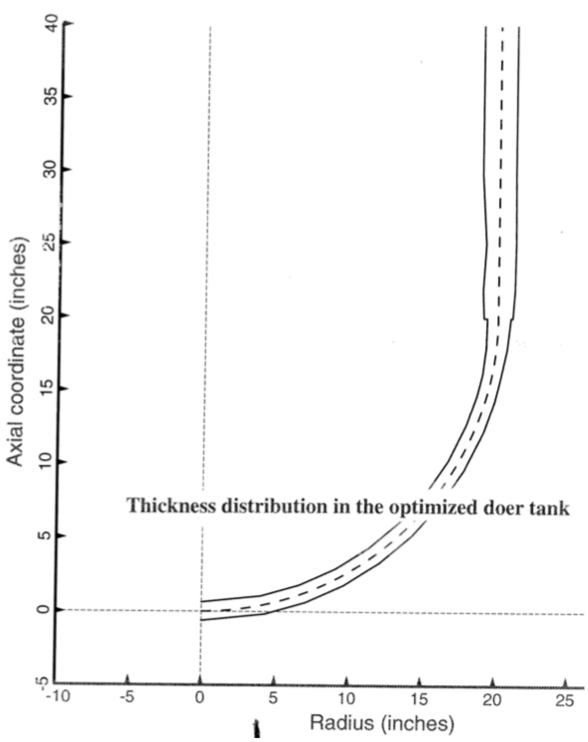

Figure used on the cover of the unpublished report.

INTRODUCTION:

The GENOPT/BIGBOSOR4 capability [1-3] is used to obtain an optimum design of a titanium cylindrical tank with hemispherical ends. The tank is subjected to 15000 psi uniform external pressure. The objective of the optimization is to minimize the weight of the tank subject to stress and buckling design constraints. The decision variables establish the distribution of the shell wall material in a wide neighborhood of the junction between the hemispherical and cylindrical segments of the tank. The titanium is assumed to remain elastic. Creep is not included. The maximum allowable effective stress is assumed to be 120000 psi. A factor of safety of 1.3 is used for buckling and a factor of safety of 1.0 is used for stress.

The GENERIC case described in this report is called "submarine". The SPECIFIC case is called "doer".

Some references are listed in Table 1. The work in this paper was motivated by Grant Cutler of the DOER Company in Alameda, California. The DOER Company wants to build a deep submergence vehicle for operation anywhere in the ocean. This vehicle will include several different geometries of shells that must withstand the high pressure that exists in the deepest parts of the ocean. The example presented here might represent a shell that protects a battery. However, no dimensions or material properties were obtained from the DOER Company during the generation of the results presented here. This is merely an example that the reader can use as a guide for producing analogous results for configurations of particular interest to him or her.

Another, perhaps stronger, motivation to do this work is the desire to encourage engineers and researchers at NASA and elsewhere to use GENOPT at their own facilities. The results presented and the discussion in this "submarine" report provide yet another example that will, it is hoped, make it easier for others to learn how to set up GENOPT cases.

BIGBOSOR4:

BIGBOSOR4 is executed multiple times inside the optimization loop. As is described in [2], the originally "stand alone" version of BOSOR4 [8] has been divided into subroutines: B4READ (the preprocessor), B4MAIN (the mainprocessor), and B4POST (the postprocessor) for execution in an optimization context. The capability of BOSOR4 [8] has been expanded to handle many more shell segments [2]. This expanded version is called "BIGBOSOR4" here and in other reports. BIGBOSOR4 can now handle up to 295 shell segments [5]. There now exists a "stand alone" version of BIGBOSOR4 as well as the version of BIGBOSOR4 designed to be used in connection with GENOPT. This "stand alone" version of BIGBOSOR4 is used to produce plots such as those shown in Figs. 1 - 4.

The models used here are BIGBOSOR4 models. Therefore, the discretization is one-dimensional, which causes solution times on the computer to be much less than for the usual two-dimensionally discretized models such as those used in connection with the STAGS computer program [9 - 11].

SUPEROPT:

SUPEROPT is a script by means of which GENOPT attempts to find a "global" optimum design. A SUPEROPT execution generates about 470 design iterations. SUPEROPT is described in [12]. A SUPEROPT run consists of many optimizations starting from different points in design space. Each new "starting" design in a single SUPEROPT execution is generated randomly but consistent with upper and lower bounds and equality and inequality constraints. The results of a single SUPEROPT execution are displayed in Fig. 5. Each major "spike" in that plot represents a new, randomly obtained, "starting" design.

ABOUT GENOPT:

GENOPT [1 - 5] is a system by means of which one can convert any analysis into a user-friendly analysis and into an optimization capability. GENOPT is not limited to the field of structural mechanics.

In the GENOPT "universe" there are considered to be two types of user: 1. the "GENOPT user", and 2. the "end user". The GENOPT user creates the user-friendly analysis and optimization capability for a class of problems, and the end user uses that capability to find optimum designs for a member of that class. (In this "submarine" case the GENOPT user and the end user are the same person: the writer).

GENOPT user:

It is the duty of the GENOPT user to create user-friendly names, one-line definitions, and "help" paragraphs for the variables to be used in the analysis or analyses [1]. The GENOPT user must also supply software (subroutines and/or FORTRAN statements) that perform the analysis or analyses [1-5]. The GENOPT user must decide what behaviors will constrain the design during optimization cycles, behaviors such as general buckling, local buckling, stress, vibration, etc. While establishing problem variables, the GENOPT user must decide which of 7 roles each of these variables plays [1]. The 7 possible roles are:

1. decision variable candidate (such as a structural dimension)
2. parameter that is not a decision variable candidate (such as a material property)
3. environmental variable (such as a load)
4. behavioral variable (such as a stress)
5. allowable variable (such as a maximum allowable effective stress)
6. factor of safety (such as a factor of safety for stress)
7. objective (such as weight)

End user:

It is the duty of the end user to provide a starting design, loads, and material properties, to choose decision variables, lower and upper bounds, equality constraints, and inequality constraints, and to choose whether to optimize or simply to analyze an existing design or both.

Some advice:

Please read [1] first, followed by the first part of [3], which contains many details about how to use GENOPT. Tables 2 and 3 (taken from [4]) contain some information on the use of GENOPT. In Table 3 a generic name, "cylinder" frequently appears. In [4] the generic name specified by the writer is "weldland". In this report the generic name specified by the writer is "submarine". When studying Table 3 and setting up the proper files at his or her facility, the reader should substitute the generic name, "submarine" for the generic name, "cylinder" used in Table 3. The "setting up" operation in this case called "submarine" is completely analogous to that described for the generic cases called "weldland" in [4] and "trusscomp" in [5].

The optimizer tool:

GENOPT uses the optimizer, ADS, created by Vanderplaats and his colleagues many years ago [6,7]. In GENOPT the ADS software is "hard-wired" in the "1-5-7" mode: a modified steepest descent method.