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"SPHERE" - - PROGRAM FOR MINIMUM WEIGHT DESIGN OF ISOGRID-STIFFENED SPHERICAL SHELLS UNDER UNIFORM EXTERNAL PRESSURE

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ABSTRACT

A system of programs called SPHERE has been developed for optimization of stiffened spherical shells under uniform external pressure. The stiffeners are assumed to be blades and are arranged in an isogrid pattern in order to maintain isotropy of the stiffened wall. In this way formulas and tables applicable to buckling of monocoque isotropic spherical shells can be applied, with proper definition of effective modulus and thickness, to buckling of stiffened spherical shells. Both the skin of the shell and the stiffeners are assumed to be of isotropic material, with different material properties in skin and stiffeners. Only membrane prebuckling states are considered. The theory used follows, for the most part, that given in Ref. 1, with the exception that skin and stiffeners may be of different material. The effect of transverse shear deformation is ignored. The effect of initial imperfections is included. An example is provided.

SUMMARY OF THEORY

The geometry pertaining to the subject of this paper is illustrated in Figs. 1 and 2. Decision variables for the determination of minimum weight design are the dimensions d, h, t, and ts (named SPACNG, HEIGHT, TSKIN, and TSTIFF, respectively, in SPHERE).

The following phenomena (behaviors) constrain the design:

1. general instability of the stiffened shell	(Refs. 1,2,3)
2. local buckling between stiffeners	(Refs. 1,3,4)
(a) buckling of shallow spherical cap	(Ref. 3)
(b) buckling of triangular plate	(Refs. 1,4)
3. buckling of stiffeners	(Refs. 5,6)
4. stress in the skin	(Ref. 1)
5. stress in the stiffeners	(Ref. 1)

The spherical cap mentioned in Item 2(a) has a radius that lies between r1 and r2 in Fig. 2. The effect of initial imperfections is accounted for by means of "knockdown" factors provided in tabular form by the user of SPHERE. Figures 3 shows the "knockdown" factor KGEN vs normalized imperfection amplitude DELBAR for general buckling of a complete spherical shell, and Figure 4 shows the "knockdown" factor KLOC vs. a geometrical "shallowness" parameter

LAMBDA for local buckling of a spherical cap.

More details on the theory used in SPHERE are given in Appendices C and D.

The optimizer used in SPHERE is called ADS, developed by Vanderplaats (Refs [8], [9]). SPHERE uses the subset of ADS identified as "the method of feasible directions".

"SPHERE" IS PRODUCED VIA "GENOPT"

A system of programs, BEGIN, DECIDE, MAINSETUP, OPTIMIZE, CHANGE, CHOOSEPLOT, DIPLOT, (collectively called "SPHERE") for the minimum-weight design of isogrid-blade-stiffened spherical shells under uniform external pressure, was written with the use of GENOPT (Ref. 7).

In the GENOPT literature [7] two kinds of user are identified:

1. the GENOPT user, that is, the person who uses GENOPT in order to create a system of user-friendly programs for optimizing a class of objects;

2 the "end" user, that is, the person who uses the program system created by the GENOPT user in order to optimize specific members of the class of objects encompassed by the GENOPT-user-created system of programs.

In this case the GENOPT user is the writer and the "end" user is the reader.

The user of GENOPT (the writer in this case) is asked by GENOPT in an interactive mode to provide:

1. Text that describes the problem at hand and its method of solution.

2. names, definitions, and "help" text for input data required for complete characterization of the object being optimized (elastic, isogrid-stiffened spherical shell in this case).

3. names, definitions, and "help" text for input data that defines the environment (uniform static external pressure in this case).

4. names, definitions, and "help" text for all phenomena that may affect the design (general buckling, local skin buckling, stiffener buckling, skin stress, stiffener stress in this case).

5. names, definitions, and "help" text for an allowable and a factor of safety corresponding to each phenomenon named and defined in 4.

6. the name, definition, and supporting "help" of the objective of the optimization (weight in this case).

7. algorithms for the prediction of all phenomena that may affect the design, written in terms of the data names provided in Items 2 - 5. In this case the five phenomena (called "behaviors") are listed above. The algorithms are listed in SUBROUTINES BEHXi, i=1,5, which appear in APPENDIX D.

8. an algorithm written in terms of the names provided in Items 2 - 6 for calculation of the objective of the optimization (weight in this case). The algorithm is very simple in this case:

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WEIGHT = RHOSKN*TSKIN + 3.*RHOSTIF*TSTIFF*HEIGHT/SPACNG
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and occurs in SUBROUTINE OBJECT, which appears in APPENDIX D.

Input data supplied to GENOPT by the GENOPT user (the writer in this case) are listed in APPENDIX A. Directions for the use of GENOPT and information about the files that GENOPT produces are given in APPENDIX B included here, and in the files GENOPTST.ORY and GENOPT.HLP, two of the many files that constitute the GENOPT system [7].

GENOPT produces a number of processors, BEGIN, DECIDE, MAINSETUP, etc. that a designer may use to find minimum weight designs. Definitions of these processors and directions for using the system of programs, written partly by GENOPT and augmented by the "behavior" algorithms mentioned in Items 7 and 8 above, are given in APPENDIX E. The "behavior" algorithms supplied by the GENOPT user are listed in APPENDIX D (SUBROUTINES BEHX1, BEHX2, BEHX3, BEHX4, BEHX5, and OBJECT).

For more information about GENOPT the reader should consult Ref. [7].

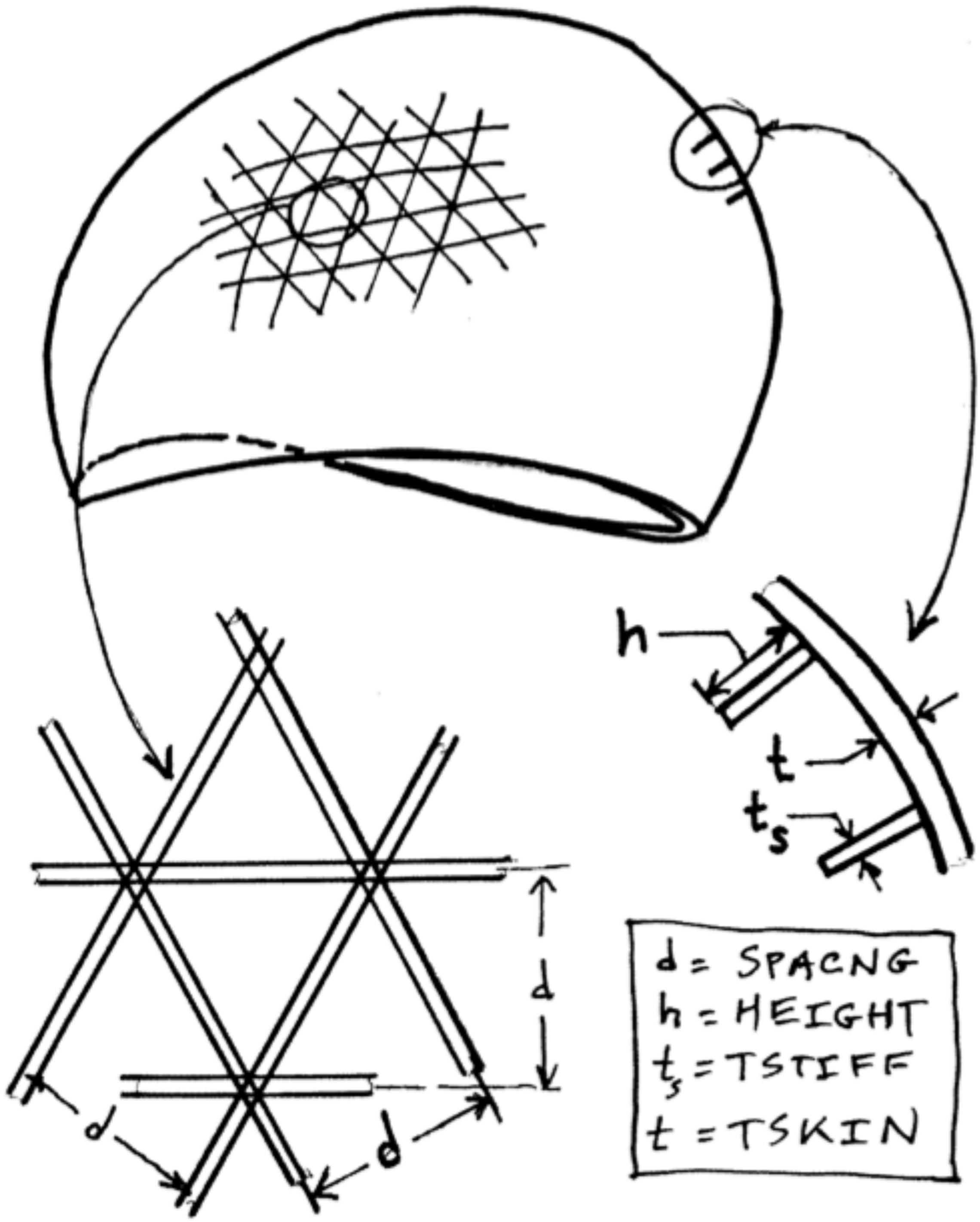

Fig. a Spherical shell with internal isogrid stiffening. The decision variables are d, h, t_s, and t. (from the report, “SPHERE – Program for minimum weight design of isogrid-stiffened spherical shells under uniform external pressure”, David Bushnell, Lockheed Palo Alto Research Laboratory, January, 1990)