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RECOMMENDATIONS FOR FUTURE WORK

Recommendations for future work to be presented arise out of observations and problems encountered in carrying out the subject independent research and development program and, in particular, in analyzing and designing structures using the Convair Aerospace flanged isogrid. None or little of the recommended work has been addressed in the development of unflanged isogrid (Reference 5-2) because: (1) unflanged isogrid primarily reacts loads by unbuckled skins and (2) unflanged isogrid design approaches are not tailored to discrete grid properties.

Although unflanged isogrid has been successfully developed by the McDonnell Douglas Astronautics Company, and used on the Thor Delta launch vehicle and the Sky Labs, flanged isogrid has not yet seen comparable development and use.

Unflanged isogrid has generally been used as a pseudo-homogeneous skin. That is, cutouts have been made and reenforced after basic isogrid machining is complete. Also, welded longitudinal joints in cylindrical structures have not efficiently provided for isogrid structural continuity and the avoidance of hard spots when reacting axial loads. Such does not appear feasible or desirable in flanged isogrid applications in which structural continuity can be maintained across joints and cutouts, and in which integral transition sections are used to avoid flange hard spots to uniformly distribute load into the isogrid structure.

Because of this and other considerations which exists as state of the art for unflanged isogrid technology is generally not applicable to the Convair Aerospace flanged isogrid.

The following isogrid technology study outlines are written in a work statement form. They are based on and extend the Convair Aerospace flanged isogrid technology.

7.1 FLANGED ISOGRID INTERNAL LOAD DISTRIBUTIONS

The purpose of this study is to perform photoelastic experiments coupled with analytical investigations to evaluate:

a. The effects of isogrid node flexibility on load distribution between in-line and diagonal grid members.

b. Elastic buckling and tension fields in skin members.

c. Load beaming in transition sections.

d. Load transfer by skin shear in corners of isogrid pockets.

7.2 ISOGRID DESIGN FABRICATION TECHNIQUES

This study is aimed at evaluating design and fabrication techniques for:

a. Integrally machined and formed structurally integrated doors in cylindrical and conical isogrid adapter structures (see Section 6.2).

b. Bolted field joint flanges which are formed after being mated in the flat (see Section 6.4).

c. Avoidance of anticlastic curvature in formed cylindrical and conical isogrid structures by use of tapered brake dies, skimming, and shot peening.

d. Reduction in skin gages and minimizing fabrication tolerances by selective or total chemical milling of formed isogrid panels.

e. Stretch, age, and creep forming of compound curvatures in isogrid.

f. Three dimensional machining of preformed shapes to produce extra deep lattice type isogrid structures (see Section 6.1).

g. Joining of isogrid and non-isogrid bulkheads to isogrid cylindrical sections of tank structures (see Section 6.4).

h. Using a thermally conductive bond to hold plate on a chuck during isogrid machining in place of a vacuum chuck.

i. Employing extra thick material with skin side facing off as a last operation to avoid use of any holding fixture during machining.

j. Machining and chemical milling isogrid in metals such as titanium and stainless steel.

7.3 ISOGRID REPAIR TECHNIQUES

The objective of this study is to evaluate and demonstrate the repairability of all parts of isogrid structures damaged by fabrication errors or operational use. Items to be repairable are cracked or incorrectly machined grid members, nodes, and skins.

7.4 ISOGRID OPTIMIZATION STUDIES

The aim of this study is to evaluate and demonstrate potentials for improving isogrid structural efficiency by:

a. Tapering the grid structural properties between nodes.

b. Varying skin thicknesses over individual pockets.

c. Upsetting (i.e., dimpling) skins.

d. Varying node stiffnesses with respect to longitudinal and diagonal grid members.

e. Varying grid cross-sectional properties along cylindrical and conical structures to maximize structural performance (i.e., using heavier section at the center of the structure).

f. Modifying grid cross-section along cylinder length to bow the neutral forming plane to compensate for or avoid anticlastic curvature. A cylindrical adapter like the General Dynamics 10-foot diameter by 37-inch long adapter (being tested at MSFC) is to be fabricated and tested. The existing NC machining program is to be modified to include the design optimizations and all existing tooling and test fixtures will be reused. Analysis will include use of discrete element model computer programs - such as NASTRAN.

7.5 TECHNIQUES FOR PREDICTING GENERAL INSTABILITY LOADS

The method for generating topographical representations of radial deflections on cylindrical structures (as described in Appendix C, Section C.4) is to be extended to other shell structures (such as conical, spherical, and typical tank bulkhead structures). Studies are to be performed using the data developed on the cylindrical adapter (Appendix C) to establish a theoretical basis for relating topographical characteristics or signatures to general elastic instability loads. Particular attention will be given to the study of topographic increments resulting from load increments when yield stress are being developed in the grid structure.

7.6 PHOTO ELASTIC MODELING

General stability and relative local stress distributions are to be studied by fabricating polycarbonate (Lexan), or equivalent, scaled models of flanged isogrid cylindrical and conical structures. Stress distributions are to be examined by polarized light defraction techniques. Correlation with full scale structures are to be established based on analytical and experimental data.

7.7 AUTOMATIC INSPECTION OF MACHINED ISOGRID

Develop techniques for use of a tracer or stylus to replace the cutting tool of the milling machine to perform programmed inspection of all machined isogrid surfaces. The techniques are to be evaluated in terms of basic measurement accuracy and means for cost effective implementation. Adaptive machining inspection sequences are to be investigated as means for reducing tolerances by machining program modification based on automatically developed inspection data.

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