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CONTAINMENT OF COMPOSITE FAN BLADES

Quarterly Progress Report No. 4

April 1 Through June 30, 1977

by

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GENERAL ELECTRIC COMPANY

Prepared For

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NASA Lewis Research Center
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FOREWORD

This program, dealing with the development and evaluation of various concepts for the Containment of Composite Fan Blades, is currently being conducted by the General Electric Company, Aircraft Engine Group, under NASA Lewis Contract NAS3-20118. The program is being performed under the direction of Mr. G.T. Smith, the NASA Program Manager.

This report presents the results of the fourth quarter of Technical effort on this program, covering the period of April 1 through June 30, 1977. The overall program is being performed under the direction of Mr. A.J. Wilson, Program Manager; and Mr. C.L. Stotler, Technical Project Manager. The effect on analysis and sub-component testing is being directed by Mr. A.P. Coppa of General Electric's Space Sciences Laboratory at the Valley Forge Space Center.

SECTION 1.0

INTRODUCTION

The objective of this program is to develop containment concepts for use with large composite fan blades, taking into account the frangible nature of composite blades. The containment systems developed will be evaluated using metal blades and superhybrid blades as well as composite blades. A fourteen-month technical program exclusive of reporting, is planned to accomplish this objective.

An initial analysis will predict the interaction between a failed fan blade and the blade containment structure. Scaling factors will then be established to allow impact testing using subscale containment rings and simulated blades. This subscale testing will provide the basis for the design and fabrication of containment systems for further evaluation in a rotating rig test facility where actual blades can be released to impact the containment. This testing will include the effect of subsequent blades in the fan stage. The test data will be evaluated against the analytically predicted results and any appropriate modifications made to the analytical procedures. Based on these data, overall systems weights and design characteristics of a composite fan stage installation will be determined and compared to the requriements of an equivalent titanium fan blade system.

In order to perform the program in an orderly manner, the effort has been divided into five technical tasks and a reporting task. The technical tasks are as follows:

Task I - Analytical Determination of Blade Impact Conditions

Task II - Blade Impact Penetration Tests

Task III - Design and Fabrication of Blade Containment Systems

Task IV - Test Evaluation of Blade Containment Systems

Task V - Formulation of Blade Containment Systems Requirements

SECTION 2.0

TECHNICAL PROGRESS

Task II - Blade Impact Penetration Tests

The official test plan for the conduct of the sub-scale testing to be conducted under this task was finalized and submitted to NASA. The test parameters and general sequence were previously discussed in the third Quarterly Progress Report.

The behavior and performance of the containment structures to be tested under Task II will be assessed by the following means:

a. High Speed Photography

Fastex motion pictures (12000-15000 frames/sec) will be analyzed to determine or estimate:

(1) Containment structure dynamic deflection

(2) Blade motion, engagement arc

(3) Times of important events (blade arrest, perforation of containment ring, nesting motion, lateral exit)

(4) Exit velocity of large blade fragment(s)

(5) Blade fragmentation process.

b. Post-Test Examination of Targets

Previous experience has shown that post-test examination is very useful for assessing target behavior. Observed failure modes of material and structural elements aid estimation of containment resistance values. Examples of data that can be obtained are:

(1) Containment structure overall deformation and damage.

(2) Pin bending, buckling modes.

(3) Nesting displacements.

(4) Dimensions and character of material slicing.

(5) Tracking control features.

(6) Weight loss of target specimen.

c. Fragment Trap Panels

Blade (projectile) fragments that exit through the containment structure will be captured by special energy absorption paneling suitably placed to intercept them. Several types of such panels have been used successfully by GE to capture fragments initially traveling at speeds up to 1000 fps. Change in panel weight before and after a test will reveal the weight of fragments captured as a result of the test.

d. Support Spoke Extensions

Measurement of permanent support spoke extensions permits determination of the distribution of local reactions due to adjacent casing attachments. Such data also permit estimation of casing energy absorption. Casing support can be varied from zero to heavy values by varying spoke diameter and material.

e. End Shock Absorber Reactions

The specially designed shock absorbers permit measurement of end reaction forces and displacements. These values are relatable to the remote casing support reactions and the inertia of the absent 180° portion of the containment structure.

The gun facility that is used to perform this sub-scale testing had to be relocated from its previous site due to a general reorganization of laboratory spaces. Subsequent to this relocation a facility check-out test was performed. The principal objective of the test was to run through the firing procedure and to observe the performance of all systems operations such as diaphragm rupture initiation, vacuum maintenance and balance, Fastax camera sequencing and photography, and the projectile mounting and separation, as well as to obtain sabout velocity and deceleration characteristics.

The test featured a titanium blade projectile that was mounted on the sabot by means of a rigid aluminum sting which held the projectile in an orientation that is representative of the heavy interaction phase of the containment process. This orientation is illustrated in Figure 1.

The test was very successful and informative. The principal objective of achieving control of the projectile orientation and position was satisfied. Examination of the high speed motion photographs of the projectile flight showed that the projectile moved throughout the test field with its initial mounting orientation and position. The projectile velocity was measured at close to 850 ft/sec.

The photographic frame rate was measured to be somewhat greater than 11,000 frames/sec. and the quality of the pictures was good, signifing that reasonably accurate measurements of the photographic record can be obtained. There was no clouding or obscuration of the field of view, an important consequence of operation with our unique tapered tube decelerator. This device contains all propellant gases within the gun tube, until after the test is completed. In conventional gun test operations, these gases rapidly engulf the test field and seriously limit observability of significant events. The photographs also showed that the test field was absolutely free of debris. This is not surprising in view of the simplicity of the blade mounting scheme which utilizes only hard mounted components. This is a significant achievement for testing of this type at the high velocities utilized.

The decelerator tube in this initial test removed more than 99% of the maximum kenetic energy of the sabot system. The sabot, therefore emerged from the decelerator tube with a small, but not negligible velocity. Decelerator tube performance, in ths present state-of-the-art, requires test calibration and verification. This is due to the imperfect characterization of the process variables, and only partial understanding of the mechanics. The decelerator for the present program was designed with a much smaller taper compared to our past practice in order to obtain as large an exit area as possible. This was desired in order to permit maximum freedom of setting blade projectile orientation and adequate exit clearance margin. Since the range of angle settings and the observed control of projectile position permit a reduction of the exit area, a new decelerator tube section with a smaller exit diameter will be fabricated prior to performance of the Task II final tests. This section should provide adequate stopping capability with in the range of test velocities planned.

The first Task II test was performed on June 21. This test differed from the preliminary test described previously in that the containment test apparatus with a containment structure mounted in it was employed. The test was very successful. All test systems and operations performed well. In order to provide for complete deceleration of the sabot, the firing pressure was reduced by 5 psi from the 300 psi value employed in the preliminary test. This slight reduction in pressure effected stopping of the sabot within the deceleration tube without any perceptible change in the resulting blade projectile velocity.

Examination of the high speed motion pictures showed that the blade projectile speed prior to striking the containment structure was close to 850 ft/sec. The orientation and position of the projectile relative to the containment structure was excellent. Photographic quality was good, and the blade was clearly observable throughout the process. This will yield valuable data about the containment process. The resulting containment ring motion and gross deformation were also clearly observable. The photographic record will be analyzed in detail later.

The containment structure utilized in the test was a stainless steel (type 321) of simple sheet construction, and having a unit weight of 3 $lb/ft.^2$. This scales to approximately 6 & 12 $lb/ft.^2$ for the TF 34 and CF-6 engine sizes respectively. The material and construction of the structure is representative of oonventional, present day fan containment practice. This test should be regarded as corresponding to test No. 3 of the Task II Test Plan as described in Quarterly Progress Report No. 3 of this program with the exception of the higher test velocity and performance index obtained in the actual test.

The structure is shown in its post-test condition and still mounted in the test apparatus in Figures 2 and 3. Figure 2 presents an overall view of the structure as viewed approximately normal to the engine cross section plane. Figure 3 shows a more detailed view of the path of the blade along the inner surface of the containment structure. A brief description of the containment interaction follows.

Substantial deformation of the structure resulted. This is characterized by heavy local bulging of the structure in the region where the deviation of the flight trajectory of the projectile was most abrupt. Large out - of - roundness occurred in the vicinity of the local bulging as shown in Figure 2 and this propagates with diminishing magnitude to remote regions of the structure. Twisting deformation of the structure was minor, this being a consequence of the projectiles trajectory remaining rather centered relative to the width of the structure throughout its movement. Another contributing factor to the low resultant twist is the relative large ratio of structure width to blade projectile width of about 3 as compared to the value of 2 employed in the previous GE-AEG/SSL containment technology program.

As is consistent with the blade orientation and position relative to the containment structure, the rear corner (corresponds to the tip, leading edge corner of the blade in an actual engine situation) struck the structure first. This produced a crease in the steel surface, as indicated by the arrow labelled 1 in Figure 3. Shortly thereafter, the forward (base) edge of the blade struck and the blade rapidly became reoriented to a flat attitude relative to the surface of the structure. Throughout its subsequent motion the blade remained in the flat orientation and did not experience any appreciable yaw component. The visible track of the blade along the containment structure has a width close to the width dimension of the blade.

The velocity of the blade did not diminish substantially as it moved along the containment structure. It had a large velocity, to be measured later, when it reached the 180° opposite and of the structure. A comparison with Watertown Arsnel data for the impact energy involved showed that the containment thickness was marginal for an obliquity angle of 60°. The fact that the actual obliquity angle was approximately 75° resulted in the successful containment of the projectile.

The next six containment targets, for finned designs, one Kevlar cloth design, and one transverse honeycomb design have been completed and are being sent to the Space Science Laboratory for testing. These targets are shown in Figures 4 and 5. The final two target configurations will be based on the test results obtained from these designs.

Task III - Design and Fabrication of Blade Containment Systems

Quotes have been received from several sources for the machining of the TF34 titanium span configuration required for the TICOM blades. Fiberglass "shoes", to be used in the blade manufacture have been made and the titanium blades are being sent to the selected vendor for machining.

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FIG. 1 Blade projectile and mounting arrangement on sabot.

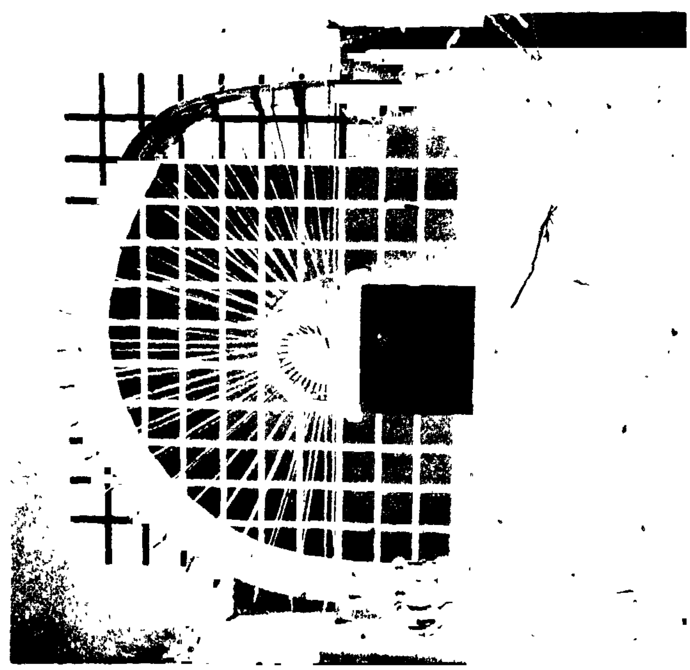

FIG 2 Post-Test condition of type 321 stainless steel containment structure, showing overall out-of-roundness deformation. Blade impact velocity ~850 FPS.

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FIG. 3 View of inner surface of type 321 stainless steel containment structure after impact at a velocity of ~850 FPS, showing large local deformation and track of blade projectile.

Figure 4. Finned Containment Targets.

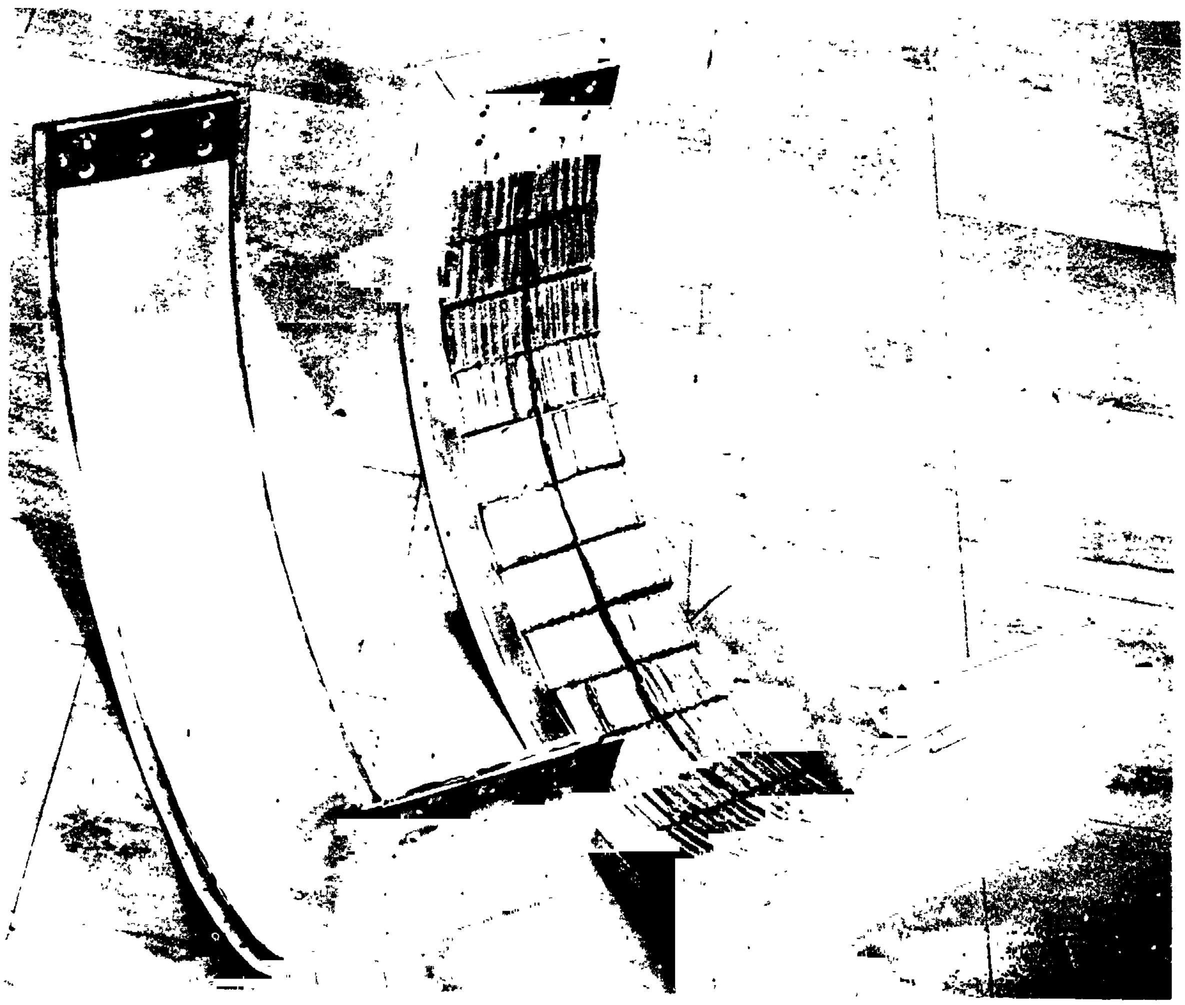

Figure 5. Containment Targets.