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VOLUME II
MATERIALS FOR ADVANCED TURBINE ENGINES (MATE) PROJECT 3
DESIGN, FABRICATION AND EVALUATION OF AN OXIDE DISPERSION STRENGTHENED SHEET ALLOY COMBUSTOR LINER

By

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1.0 SUMMARY

Experimental land based engine tests were conducted to evaluate the performance of ODS sheet alloy MA956 as a burner liner. A louvered configuration was used. The flight cycle consisted of 4.5 minutes idle, 1.5 minutes takeoff and intermediate conditions in a PW2037 engine with average uncorrected combustor exit temperature of 1527°C (2780°F). After 500 cycles the burner was dismantled for post-test evaluation which consisted of visual observation and fluorescent penetrant inspections. The results of the inspection indicated no loss of integrity of the burner liner and no material degradation of the louver and the attachments.

2.0 INTRODUCTION

Background

Advanced aircraft turbine engines expected to enter commercial service in the 1990's will have performance, cost and weight requirements that will necessitate the use of advanced materials technologies in their construction. In order to accelerate the development of these materials technologies to a point where they can be engine verified, a cooperative Government/Industry effort, "Materials in Advanced Turbine Engine", MATE, was initiated under NASA sponsorship. The MATE Project 3 consisted of eight tasks. The results of tasks one through six have been reported in Volume I of the Final report (NASA CR-174691, February, 1984).

This volume presents the FEDD category 2 technical effort accomplished under Project 3. This report includes an engine test program and post test evaluation of the ODS sheet alloy MS956 burner liner under Tasks VII and VIII.

Efficient engine performance demands higher gas temperatures with consequent negative impact on combustor durability. Hastelloy X burners designed for 870°C (1600°F) metal temperatures experience much hotter streaks with heavy penalties to operating life. Improvement in durability to meet future aircraft turbine engine operation and maintenance goals requires improved burner materials and design.

Oxide Dispersion Strengthened (ODS) alloy sheet materials with creep strength and oxidation resistance superior to those of Hastelloy X have the potential to significantly improve the burner durability and reduce distortion induced damages. These, in turn, would result in a decrease in engine maintenance cost.

Two ODS alloys were initially selected: Incoloy MA956 which is a FeCrAl based alloy and Haynes HDA8077 which is a austenitic, NiCrAl based alloy. Both of these alloys are strengthened with a submicron dispersion of yttria. Initial property comparison with Hastelloy X indicated that the ODS alloys have a +167°C (+300°F) advantage both in creep strength and cyclic oxidation resistance. Based on manufacturing reproducibility, MA956 was selected over HDA8077.

A hybrid PW2037 inner burner liner containing MA956 and Hastelloy X components was designed and constructed. A louvered configuration was selected for the component because of greater field experience with such configuration and its compatibility with the bill-of-material PW2037 design. To accommodate the limited thermal fatigue capability of the ODS alloy, a segmentation approach was used, the segments being held by brazing and riveting.

To meet the objectives of the program, the following tasks were performed :

- o Task VII - Engine Test - Task VII was designed to provide engine testing of the hybrid burner in a cyclic test environment in a ground based PW2037 engine for a target duration of 150 hours. The test was intended to demonstrate structural integrity of the burner and to assure continued safe engine operation.

- o Task VIII - Post-Test Evaluation - Task VIII was to assess the performance of the ODS alloy hybrid burner in the engine test in terms of 1) its capability to extend the life of the current combustor liners, 2) decrease in maintenance cost achievable with ODS, 3) effects on direct operating costs and 4) overall benefits of incorporating ODS alloy liners in advanced turbine engines.

3.0 TASK VII ENGINE TEST

Test Conditions

The engine test program consisted of 4.5 minutes idle, 1.5 minutes takeoff and intermediate power conditions in an experimental ground based PW2037 test engine with the average uncorrected combustor exit temperature of 1527°C (2780°F). The schematic of the test cycle is shown in Figure 1. Five hundred endurance test cycles were completed with the total engine time of 108 hours of which 87.6 hours was on endurance.

4.0 TASK VIII POST-TEST EVALUATION

Visual Observation

The combustor exposed in the test engine did not show any loss of structural integrity. It was dismantled by grinding off selected rivets to expose the 24 louver segments around the circumference of the combustor (Figure 2), each segment covering an arc of 15°. Visual observations revealed the absence of any gross distortion and oxidation. There were no detectable changes in the the dimensions of the louvers: circumferential length 8.25 cms, slot length 2.5 cms and axial length about 3.8 cms. No noticeable change in the interlouver gap was detected either. The close-up of a slotted louver is shown in Figure 3. The end of a typical rivet head is shown in Figure 4.

Fluorescent Penetrant Inspection

All the MA956 louver panels were wire brush cleaned at the rivet heads and panel slots and the fluorescent penetrant was applied following standard procedure. Subsequent inspection of the panels under ultraviolet light exposure showed no indications of sharply defined cracks and no defects other than pre-existing benign machining marks in the rivets (Figure 4). It is therefore concluded that the burner withstood the engine test without any material distortion or cracking to the louver segments and the attachment rivets.

Performance Evaluation

The selection of the combustor design was based on its impact on operating life, maintenance cost, direct operating cost (DOC) and an analysis of the risk factor involved. The DOC is derived from initial combustor fabrication cost, overall weight of the combustor and maintenance cost, the latter being a combination of material and labor cost. The risk factor is a composite of fabricability and design/structure risks. Fabrication and assembly of the combustor test article described in volume I (Reference 1) clearly demonstrates that the material is fabricable using reasonable precautions to avoid deformation below the ductile-brittle transition (≃100-150°F). Design analysis calculations, also discussed in Reference 1 show that for the selected design, the operating life would be 6.5 x that of the base line, the maintenance cost 75 percent lower, the DOC reduced by 1.48 percent and the risk moderate compared with high risk for the base line design.

While the test reported in this volume did not offer the opportunity to cycle the bill-of-material or the ODS combustor configuration to destruction, the virtually pristine condition of the ODS segments and attachments after 500 cycles endurance at relatively high CET attests to the basic soundness of the ODS material and louver design and is not inconsistent with meeting the calculated durability and associated DOC benefits.

5.0 CONCLUSIONS

Based on the engine test and post-test evaluation of the sheet alloy louvers of the burner liner, the following conclusions can be made:

- O.D. sheet alloy MA956 is a viable candidate for gas turbine engine combustor application.
- Riveting is a viable method for attachment of ODS combustor components.
- Segmentation is a promising combustor design approach to accommodate the limited thermal fatigue capability of ODS alloys.
- The selected design is capable of minimizing maintenance cost, direct operating cost and the risk factor while extending life.

Reference

1. Henricks, R. J. and Sheffler, K. D., "Materials for advanced turbine Engines (MATE)-Project 3; Design, Fabrication and Evaluation of an Oxide Dispersion strengthened sheet alloy combustor liner", Volume 1, Final Report, (NASA CR-174691), United Technologies Corporation, February 1984.

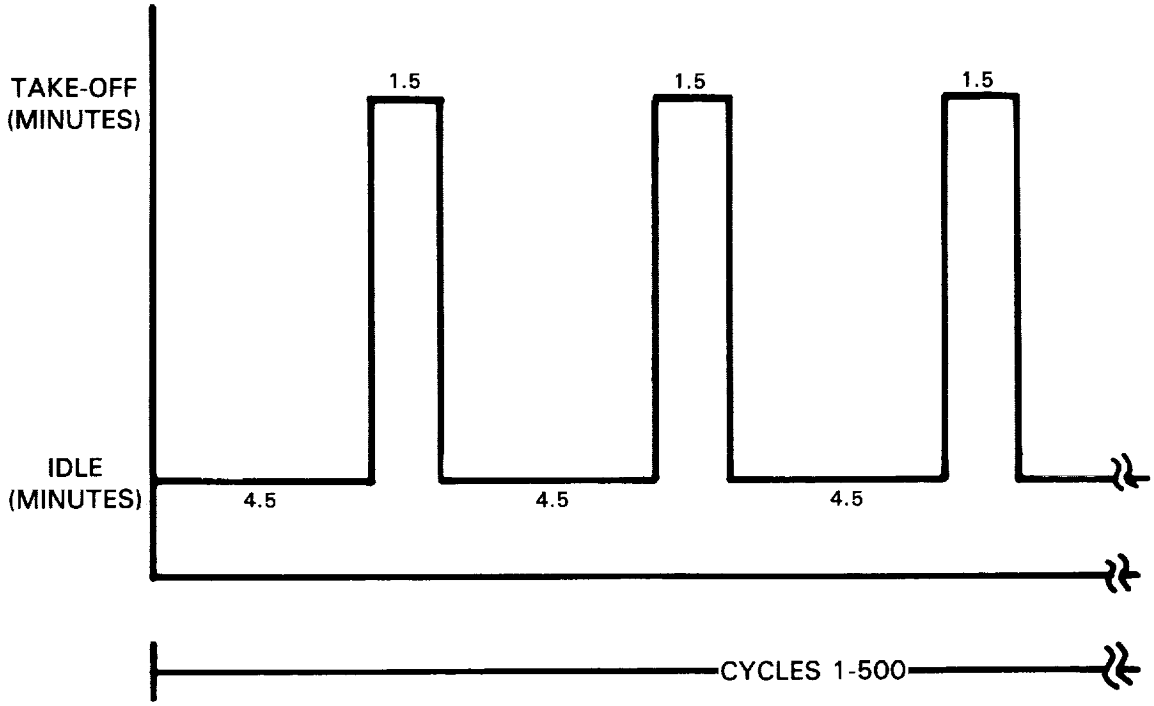

Figure 1: Schematic of PW2037 Experimental Test Engine Cycle Showing Endurance Test Cycles.

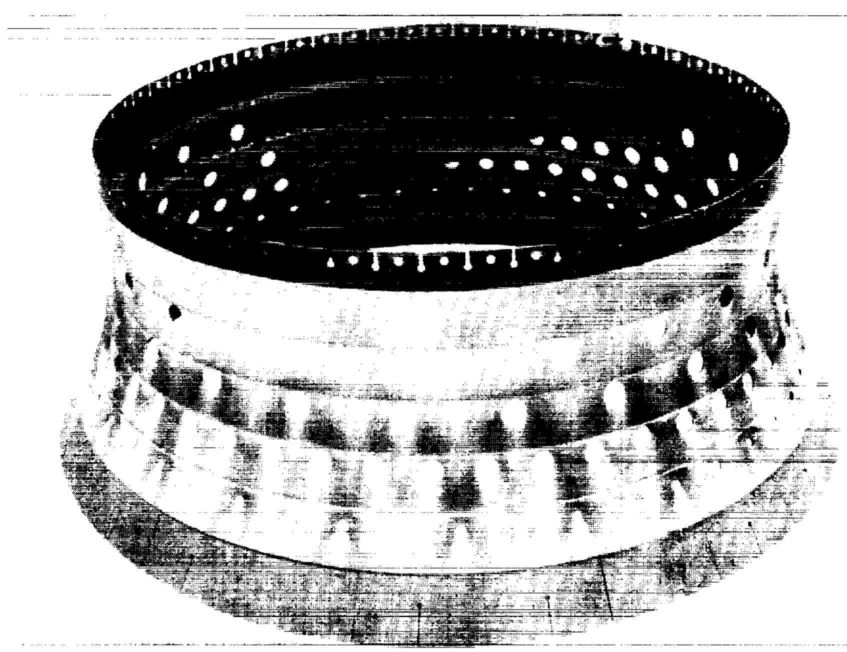

Figure 2: Dismantled Combustor with MA956 Louvers at Bottom.

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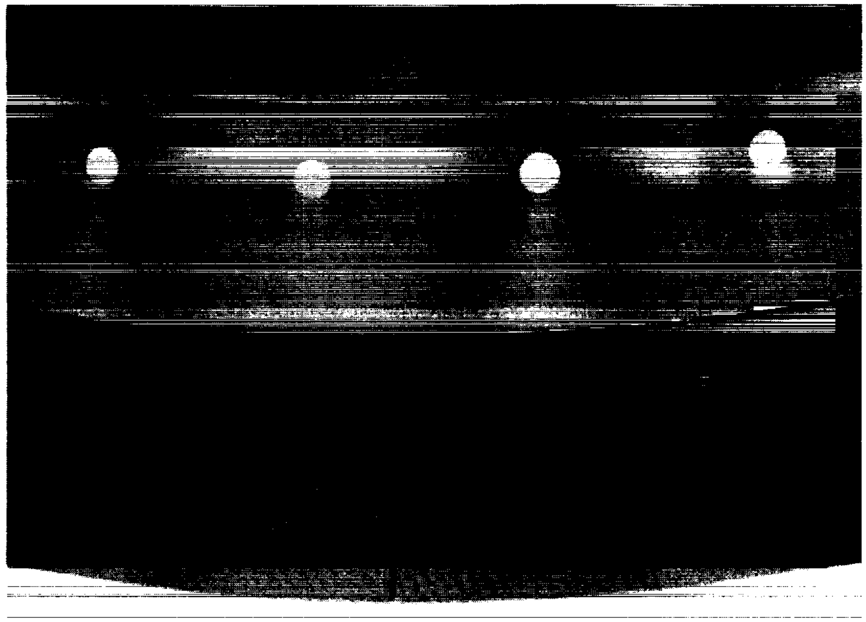

Figure 3: Post-test 500 Cycles 2780°F CFT MA956 Louver

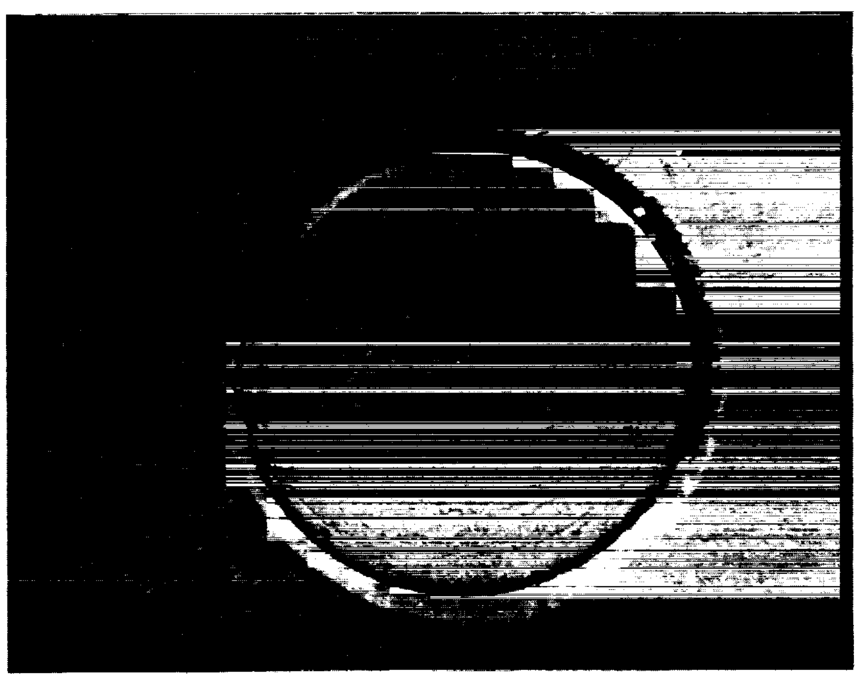

Figure 4: Louver Rivet at 10X after 500 Cycles 2780°CFT.

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16. ABSTRACT
The objective of this program was to evaluate the suitability of wrought oxide dispersion strengthened (ODS) superalloy sheet for gas turbine engine combustor applications. Two yttria (Y_2O_3) dispersion strengthened alloys were evaluated; Incoloy MA956 and Haynes Developmental Alloy (HDA) 8077 (NiCrAl base). Preliminary tests showed both alloys to be potentially viable combustor materials, with neither alloy exhibiting a significant advantage over the other. MA956 was selected as the final alloy based on manufacturing reproducibility for evaluation as a burner liner.

A hybrid PW2037 inner burner liner containing MA956 and Hastelloy X components and using a louvered configuration was designed and constructed. The louvered configuration was chosen because of field experience and compatibility with the bill-of-material PW2037 design.

The simulated flight cycle for the ground based engine tests consisted of 4.5 minutes idle, 1.5 minutes takeoff and intermediate conditions in a PW2037 engine with average uncorrected combustor exit temperature of 1527°C (2780°F). Post test evaluation consisting of visual observations and fluorescent penetrant inspections was conducted after 500 cycles of testing. Test results showed no loss of integrity in the burner liner and no material degradation in the louver and attachments.

17. KEY WORDS (SUGGESTED BY AUTHOR(S))
Oxide Dispersion Strengthened Alloys, Nickel Alloys, Iron Alloys, Gas Turbine Engines, Burners, Combustors, Creep, Oxidation, Thermal Fatigue

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