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4.3 LIGHTWEIGHT/LOW CONDUCTIVITY PARTS

INTRODUCTION

Several Lightweight/Low conductivity components for the Stratified Charge Rotary Engine were identified during the NASA Phase III sixth month program review. The Lightweight/ Low Conductivity engine components, proposed for the rotary engine critical technology enablement program, were anticipated to provide improved engine performance. The components identified were:

a. Lightweight Rotor - Titanium

b. Composite Structural Material End Housing

Subsequently, due to the restructuring of the Phase III contract only the Lightweight Rotor was continued into final design, hardware procurement and parts readied for testing. The Composite Structural Material End Housing effort was terminated after completion of a conceptual design layout. A brief discussion of the Composite End Housing design and benefits is provided.

LIGHTWEIGHT ROTOR

OBJECTIVE

Conduct a candidate material screening study and select the best applicable material to provide the lightest rotor assembly configuration while operating at the NASA Enablement Rig Engine design conditions.

TECHNICAL APPROACH

A wide variety of rotor designs and rotor constructions were considered in selecting the best Lightweight Rotor design candidate. The search included a review of three decades of rotor design and a review of recently developed material technologies.

Primary considerations in selecting the Lightweight Rotor design were the capability to withstand the NASA rig engine design operating conditions, the potential for maximum weight reduction, and the probability of successful fabrication.

The design operating conditions anticipated for the stratified charge rotary engine are shown in Figure 1. Figure 1 is an estimated indicator card for engine operations at 160 bhp (120kw)

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and 8000 rpm. The indicator card depicts a peak combustion pressure of 1110 psi (7.65 mPa) and a peak combustion chamber temperature of 3500° R (1671° C).

Candidate rotor materials and design configurations which were considered are listed in Figure 2.

Selection of the most promising Lightweight Rotor candidate material and design is described in detail in JDTI Rotary Engine Division Report "Lightweight Rotor Candidate Material Screening Study" 25 March 88, NAS3-24628.

The selection report recommended a titanium material rotor as the lightest rotor configuration having a relatively high probability for successful fabrication of a prototype rotor. The report's recommendation was approved by the NASA Project Manager for design and fabrication.

Rotor design layout effort was initiated and was supported by design analysis which drew on the successful experience of JDTI Series 70 engine rotor design, analysis, fabrication and test experience. Finite element stress analysis utilizing ANSYS method code was employed to examine temperature distributions, resulting thermal stresses, inertial loading, and pressure loading. The maximum stress range throughout the rotor structure was determined for all rotor positions and predicted engine operating conditions. Design considerations included rotor fabrication, assembly, bearing retention, and thermal conductivity amongst others.

RESULTS

The Lightweight Rotor design effort resulted in the release of detail design drawings for a Titanium Rotor. The following drawings describe the complete rotor design:

TITLE	DRAWING NO.
Rotor & Bearing Assembly, ADE	NR10252
Rotor, Titanium, Gear & Adapter Assembly, ADE	NR10251
Rotor, Titanium, ADE	NJ12479
Rotor & Bearing Assembly, DE	NR10447
Rotor, Titanium, Gear & Adapter Assembly, DE	NR10446
Rotor, Titanium, DE	NJ12870

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As discussed in Section V of the referenced report, the Howmet Ti-Cast Division was selected to provide investment rotor castings. The casting material selection was titanium 6-2-4-2 (Ti-6Al-2Sn-4Zr-2Mo). This decision was based on additional material studies (after the screening report) that revealed the 6-2-4-2 has a higher strength/density ratio for elevated temperature applications than the titanium 6-4 material. Howmet proceeded to develop investment patterns for both ADE and DE rotor castings.

Trial machining of the cast titanium 6-2-4-2 alloy material was initiated concurrent with the rotor pattern development so that the methods of machining the rotor casting material were developed when castings became available.

Both ADE and DE rotor assemblies have been completed and are available for testing in either the NASA 1007R Enablement Rig Engine or the NASA 2013R Rig Engine.

Figure 3 illustrates the rotor assembly cross-section and major components. Also provided are actual weight savings when compared to the original 17-4PH material workhorse rotor assembly designed for the NASA 1007R Enablement Rig Engine. Figure 4 lists the advantages of lightweight rotor assemblies when incorporated into the rotary engine power section.

Figure 5 shows the rotor casting and completed rotor assembly. The surface of the casting is the final chemical-milled surface. The completed rotor assembly includes the bolted-in rotor gear and oil seal adapter (not visible).

An additional benefit of the titanium Rotor design is the low thermal conductivity of the titanium. The thermal conductivity of the titanium 6-2-4-2 material is only 30% of the thermal conductivity of the 17-4PH material. The selection of titanium as the rotor material provides a means to examine reduction of heat transfer to the rotor cooling oil.

The titanium 6-2-4-2 material has several drawbacks which must be taken into account. The investment castings of titanium are expensive, and the as-cast parts require chemical milling. The chemical milling is required to remove an approximate 0.030 inch (0.762mm) thick case of alpha-phase titanium to ensure the desired metallurgical properties are obtained. Titanium is difficult to machine. The titanium rotors also require NiBron plating of the apex seal slots and rotor gear mating surfaces to prevent galling.

COMPOSITE DRIVE END HOUSING

Restructuring of the NASA Phase III contract eliminated the final design, hardware procurement and testing of the composite drive end housing. Figure 6 illustrates the end housing conceptual design configuration and Figure 7 presents comparative material data. An approximate 27% weight saving was estimated for this lightweight end housing design.

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CONCLUSIONS

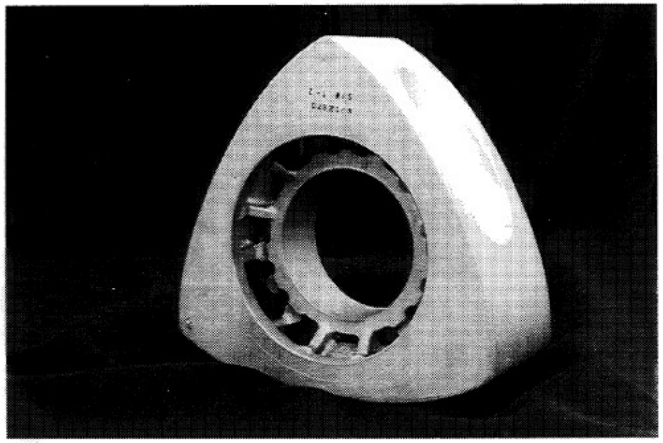
1. A lightweight, Titanium 6-2-4-2, Rotor has been successfully designed, investment cast and machined to provide finished rotor assemblies ready for engine testing. The Titanium 6-2-4-2 rotor provided a 35% rotor assembly weight reduction relative to the 17-4PH stainless steel rotor previously used.

2. Composite construction methods for the rotary engine End Housing application may provide substantial weight savings.

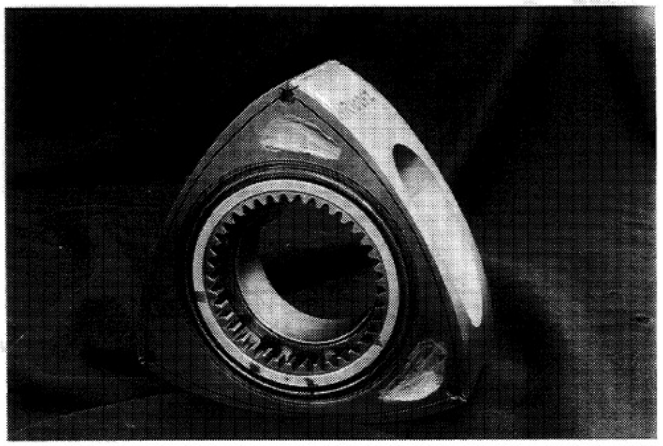
RECOMMENDATIONS

Engine test the titanium rotor assemblies to determine their performance and mechanical capabilities.

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TITANIUM ROTOR CASTING



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COMPOSITE DRIVE END HOUSING

PRESENT WT. 14.4 Lbs. (6.53kg) **COMPOSITE WT. 10.5 Lbs. (4.76kg)**

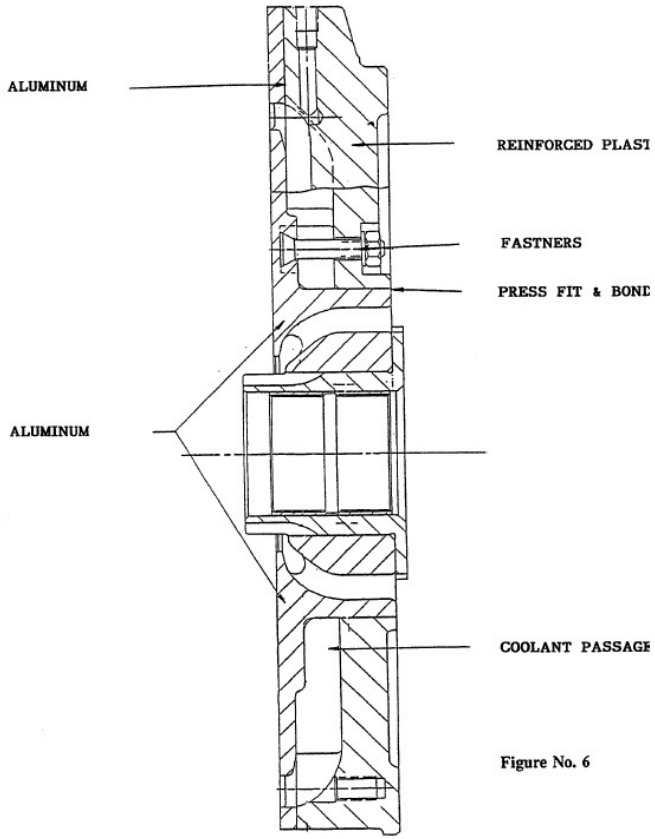


Figure No. 6