EXPERIMENTAL RESULTS WITH LIFT ENGINE EXHAUST NOZZLES

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ABSTRACT

Selected exhaust nozzle problems considered by Allison in the development of lift engines are discussed. Special emphasis is made of those problems which can be investigated with cold flow model tests. Data from test programs conducted in the Fluidyne test facilities are used to illustrate nozzle performance trends caused by geometric constraints. Simulations of ground proximity and cross flow were made. Tests with swirling nozzle inlet flow were designed to investigate penalties posed by deletion of turbine exit straightening vanes. Different approaches to the simulation of swirl distribution are presented.

Introduction

The coming age of the lift engine presents several new problems to the exhaust nozzle designer. Since few of the traditional requirements are relaxed, the task of designing an optimum nozzle is a difficult one.

The possession of high efficiency and low weight has always been required of aircraft engine components. And so it continues: a lift engine must have a very high thrust-to-weight ratio simply to justify its own existence. A one percent reduction in exhaust nozzle efficiency would necessitate all of the engine components being built one percent larger in size if the desired thrust is to be developed. The importance of nozzle efficiency is thus readily seen.

The physical size of an aircraft component is also very important, especially when it

causes the aircraft frontal area to increase. Since a lift engine will be mounted essentially vertical, its length contributes directly to the frontal area. It therefore becomes clear that the length of the exhaust nozzle joins weight and efficiency as measures of excellence.

As part of an overall program to develop turbine engine components for V/STOL applications, the Allison Division of General Motors Corporation has conducted a scale model test program under sponsorship of ASD and BuWeps. The program included several nozzle types. One of these, the concave-base nozzle, is the main theme of this paper.

Facility Description

Nozzle performance data presented in this paper were obtained from scale model tests in the Fluidyne Engineering Corporation Elk River test facilities. Most of the tests were performed in the static nozzle test stand which is shown schematically in Figure 1. The test nozzle is attached to a strain-gage force balance which measures the axial load, vertical load and pitching moment. The model is isolated from the air supply piping by a flexible rubber seal. Mass flow through the model is measured by a standard ASME choked long-radius flow nozzle. The test chamber enclosing the model may be either back-pressured by an exit valve or pumped to less than atmospheric pressure by the model flow. A steam ejector may be used to augment the ejector action of the test nozzle when high nozzle pressure ratios are required.

The nozzle models were approximately one-eighth scale. Testing was conducted with cold air and at pressure levels giving Reynolds numbers of approximately one million, which is within the range typical of a full size engine. A nozzle pressure ratio range of 1.5 to 2.5, typical for a lift engine, was investigated.

Data Analysis Method

Propulsion nozzles for airbreathing engines are analyzed and compared in terms of gross