ABSTRACT

The effect of applying a vaned recessed casing treatment to a single stage axial flow fan has been investigated. The influence of the axial position of the recess relative to the rotor leading edge and other geometrical modifications of the vane passage have been examined. Significant improvements in stall margin were observed without (in some builds) loss in peak efficiency.

Slow and fast frequency response yawmeter probes have been used in the study to examine both the steady flow conditions and the unsteady flow caused by rotating stall.

NOMENCLATURE

Ca	axial chord of rotor tip
U	mid span blade speed
Va	axial component of velocity
X	distance between rotor leading edge and the rearward end of the treatment
ϕ	flow coefficient, Va/U
ϕ_{rs1}	stall flow for the solid casing build
ϕ_{rs2}	stall flow for the treated build
ρ	density of air
ψ_{TS}	(P (exit static) -P (inlet total))/ρU^2
ψ_{TS1}	stall pressure rise coefficient for the solid casing build
ψ_{TS2}	stall pressure rise coefficient for the treated build
η	efficiency
ΔH	Work input
$\Delta\phi_1$	$1 - \phi_{rs2}/\phi_{rs1}$
$\Delta\phi_2$	$\phi_{rs1}/\phi_{rs2} * \psi_{TS}{}^{1}/\psi_{TS2} - 1$

1. INTRODUCTION

Extension of the fan stable flow range will provide a more flexible engine as its operating range is often limited by the surge (stall) line of the fan. Increasing the surge margin of the fan, therefore, is of high priority in any engine development programme.

During recent years there have been many attempts to increase fan and compressor stall margin using various techniques such as variable inlet guide vanes (1), bleed or blow off valves (2), small scale casing treatments (axial, skewed and circumferential slots, tapered or straight holes, honeycombs etc.) (3,4,5,6,7,8,9). Although these have useful applications they also have disadvantages. The low pressure axial fan industry, which suffers similar range problems, have developed an alternative large scale or 'recess vaned' casing treatment. Such a casing treatment is shown in Fig. 1 and involves the application of a large vaned recess in the outer casing of the fan which extends partly over but mainly upstream of the rotor blades, (10,11,12,13,14,15,16). The operating principle appears to be that as the fan operation moves towards the stall line some radially unbalanced flow (or in more severe cases some radially unbalanced reversed flow) is transported from the blade tips into the treatment, turned (by means of cambered vanes inside the recess) and re-introduced to the main flow upstream of the rotor. By proper arrangement of the outer recess, significant improvements in flow range can be obtained often with minimal loss of unstalled efficiency. These results have all been achieved on industrial low speed fans and the purpose of the present work was to investigate the ability of such devices to improve the stall margin of a low speed axial flow fan rotor with aerospace type loadings.

In the authors' previous paper (16) the application of a large scale type casing treatment to an axial flow rotor-stator (stage) compressor was reported. In that paper the level of flow improvement was about 50% which was achieved without loss of efficiency. Further studies indicated that stall was precipitated by stall at the hub of the stator blade. To avoid this limitation a fuller investigation of the isolated rotor has been made, the results of which are reviewed here.