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PIV MEASUREMENTS OF THE FLOW IN A ROTATING CAVITY WITH A RADIAL INFLOW

Yu Xiao*, Luo X, Xu G Q, Sun J N
National Key Lab. on Aero-Engines, School of Jet Propulsion,
BUAA, Beijing, 100191, China
(* Corresponding author: yx-mail@sohu.com)

INTRODUCTION

In modern aero engines air required for cooling purposes is bled from the compressor and it was called as internal cooling system.A rotating cylindrical cavity provides a simple model to study the flow between co-rotating compressor discs. The flow in a rotating cavity with a radial inflow was called as source-sink flow by Hide in 1968 [e.g., Hide R. 1968], and then, the most importance of this study is perhaps that of Owen, Chew, Pincombe and Rogers Rogers R.H. [1985] ,[Pincombe J.R. 1984],[Rogers. 1985]

The early visualization experiments by Firouzian et al [Rogers. 1986]had shown the flow structure and measured velocity profiles by laser-doppler anemometry(LDA), the flow visualization confirm the expected flow structure: a source reginon near the shroud. Ekman layer on the discs,a sink layer near the centre of the cavity, and an interior core of rotating fluid; and experimental datas of the tangential component velocity in the interior core were, in the main, in good agreement with the nonlinear laminar and turbulent Ekman-layer theory. In this paper particle Image Velocimetry (PIV) was applied to study the flow in a rotating cavity with radial inflow and provided the spatial distribution of the instantaneous velocity field.

EXPERIMENTAL APPARATUS

1 Test rig

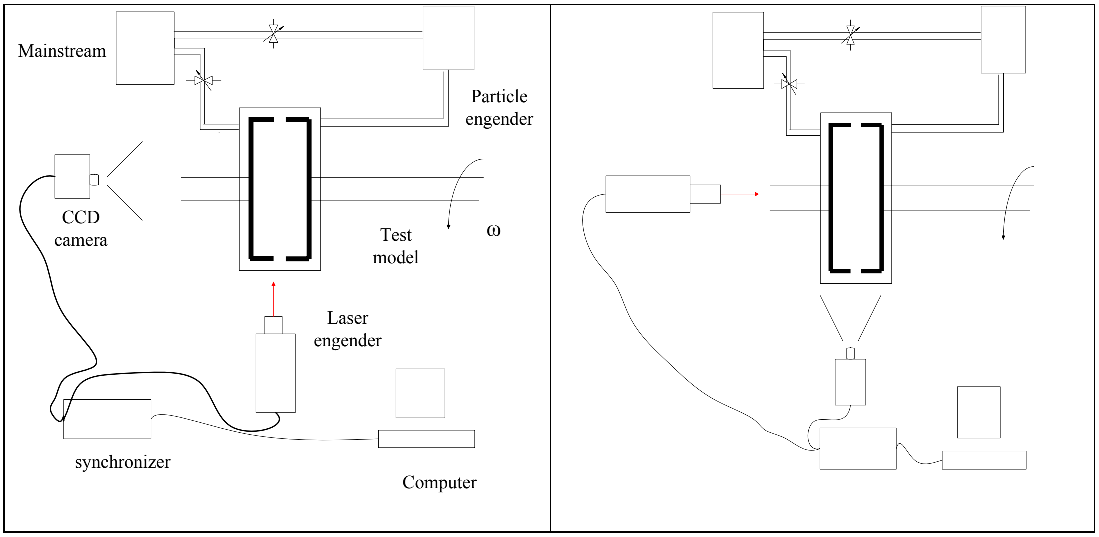
The experiment was finished on the multifunctional rotating facility in National Key Laboratory on Aero-engines of BUAA.
The cavity comprised two polycarbonate discs of 670mm diameter and a peripheral shroud of 10mm thickness. The distance between the two corotating discs is 60mm and the inflow gap is 11mm.

2 PIV system:

Double-pulsed Nd:Yag asers(with a maxium energy output of 150 mJ/pulse, and a repetition rate of 30Hz) was used to supply pulsed laser sheets. A professional CCD camera whose shutter is capable of being triggered by an electronic signal was used to capture the PIV images. The twin Nd:Yag lasers and the camera were control by a synchronizer (TSI Model 6300). The ash particles with approximate diameter of 2-5μm was used as the PIV tracers. .The post process software is TSI INSIGHT.

3 Experimental methodologies

In order to visualize the flow structure in the rotating cavity, the characteristic of the cross-stream flow (r-z) and the inter-disk mid plane flow(r-ω) were acquired. At the same time, the light sheet and the camera must be at perpendicular and the position was shown in figure 1.



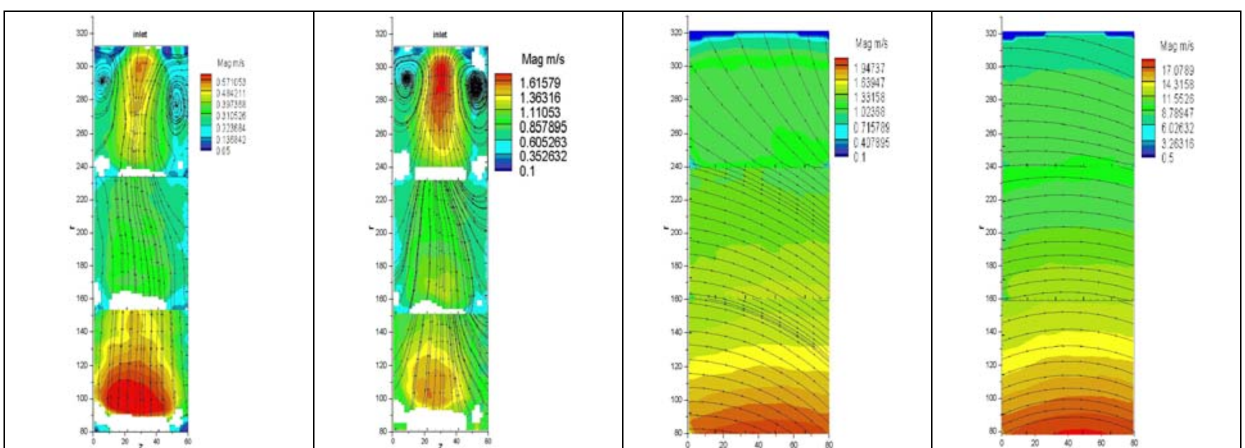
a r-z b r-ω

figure 1 position of PIV test

4 Results and discussion

The extent of the different regions in source-sink flow depends on the rotational speed, mass flow rate and swirl of the fluid at inlet. At the relatively high flow rates the source region will fill most of the cavity. Figure 2 a shows the flow structure in different rotational speed on the r-z plane(using PIV).Figure 2 b shows the streamline at r-ω plane.

Radial distributions of the tangential velocity show the influence of nondimensional mass flowrate and rotating Reynolds number (Figure 3).



m =200(kg/h) ω=100rpm	m =200(kg/h) ω=500rpm	m =200(kg/h) ω=100rpm	m =200(kg/h) ω=500rpm

r-z plan r-ω plane

Figure 2 streamline

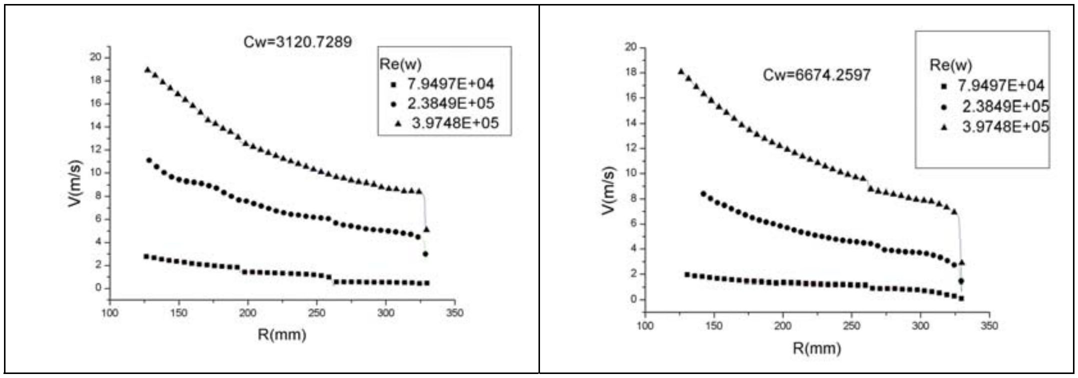
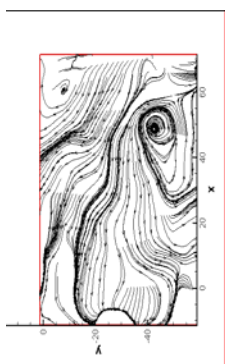


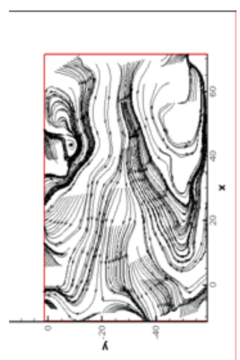
Figure 3 Radial distributions of the tangential velocity

The tangential velocity is increased with the increase of rotating Reynolds number($Re_{\omega} = \omega R^2 / \nu$) and decrease of nondimensional mass flowrate ($C_w = m / \mu R$).

Figure 4 shows the instantaneous absolute velocity and ensemble-average velocity at same position in the rotating cavity. At the flow rate(C_w =3.12×10^3, Re_{ω} =7.95×10^4 or the higher flow rate) ,the flow structure was found to be unstable.

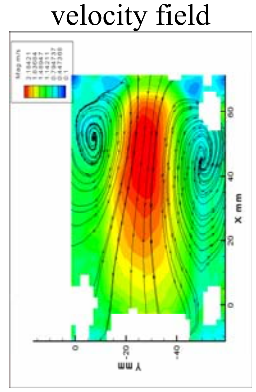


instantaneous velocity field



instantaneous velocity field

instantaneous velocity field



ensemble-average velocity field

Figure 4 instantaneous velocity field and ensemble-average velocity field

CONCLUSION

This study has further shown the major conclusions

1) PIV is a suitable and efficient method to investigate the flow and could give a spatial distribution of the instantaneous velocity.

2) The main parameters influencing the flow in a rotating cavity with a radial inflow are nondimensional mass flowrate and rotating Reynolds number. The increase of C_w and the decrease of Re_ω is accompanied by an increase in the size of the source region.
The tangential velocity is increased with the increase of rotating Reynolds number and decrease of nondimensional mass flowrate.

3) For the most case(=3.12×10^3, Re_ω =7.95×10^4 or the higher flow rate) where the source region fill all of the cavity , the tangential component of velocity could be overestimated by a free vortes theory , the angular momentum of the inflowing fluid is assumed to be conserved.

4) The control of light reflection and the dispersion of tracer particles are the key factors of the PIV measurement. It is necessary to design a special air system to control the dispersion of the tracer in the rotating cavity.

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