Effect of Combustor Casing Deformation on the Air Flow at Annulus

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ABSTRACT- ***This paper describes an experimental analysis of the flow inside a real part of a can combustor used in Babylon/Iraq gas turbine power station. The combustor which has been studied contains deformation in the outer air casing due to the high temperature within the liner. Flow quality through annulus is crucial as it feeds air to the primary, secondary and dilution holes. One of the most important criterions of combustion chamber design is to have uniformity of pressure in the annulus region as early as possible which ensures flow split through various liner holes and minimum combustor length .This can be achieved by sufficient as well as efficient diffusion of air from compressor. Used pitot static tube to measure the velocity profile at ten stations in the outer annuls. The performance of the system was also assessed in terms of total pressure loss and static pressure recovery between the first and last measurement stations. It was observed that the deformation effected on the flow uniformity and penetration of air through the holes, thus effected on the performance of the combustor.***

Key wards -Can combustor, annulus flow, velocity profile, pitot static tube.

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1. INTRODUCTION

Combustor is an integral part of the gas turbine power unit. It receives air form a compressor and delivers it to the turbine at an elevated temperature; it is highly desirable to have this done with better overall efficiency and smoke free combustion. In general the combustor has three main components i) diffuser, ii) casing-liner annulus, and iii) liner. The flow pattern in the dump and annulus has substantial effect on the liner flow pattern and influences the level and distribution off liner wall temperature.

Fishenden and Stevens [1] initially investigated the overall performance of annular combustor dump Diffuser system by varying several parameters, including the mass flow split to each feed annulus pre-diffuser area ratio and the dump gap (DG). They concluded that the principal determinants of stagnation pressure loss in stagnation pressure loss in such systems are the amount of diffusion being attempted and the radius of curvature undertaken by the flow as it passes around the flame tube. This latter effect was found to be a function of the size and shape of the flame tube and the dump gap (DG). Mean flow fields in axisymmetric combustor geometries with different swirl intensities have been investigated by Rhode et al, [2] for dump and gradual expansion confinements. They observed that increasing the swirl intensity produces a short ended corner recirculation region and a central recirculation bubble. Samimy and Langenfeld [3] measured the mean and r.m.s velocities in a dump combustor with and without swirling inlet flow. They found that for swirling flows, Reynolds stress showed values up to20 times higher than those of non-swirling flow. McGuirk and Palma [4] carried out experiments in a realistic can–combustor to understand the interaction between two rows of radically opposed jets penetrating across flowing stream with and without swirl. They concluded that a staggered arrangement of dilution holes blocks the upstream flow near the wall and forces the flow to mix with the central core. An experimental investigation carried by carrotte et al. [5] to determine the flow characteristics and aerodynamic performance of modern gas turbine combustor dump diffuser has shown that the major contribution to the stagnation pressure loss was generated around the flame tube head whereas most of the static pressure recovery occurs within the pre-diffuser. The annulus flow characteristics of a can–combustor model for different liner dome shapes have been experimentally established under isothermal flow conditions for both non-swirling and swirling flow carried by A Rahim at al. [6]. They found that swirling flow with a hemispherical dome liner gives better flow characteristics in the annulus region. Rizk and Mongia [7] formulated a numerical approach to combustor design. The approach combines the capabilities of analytical tools with well-established empirical correlations. Diffuser combustor flow interaction analysis for simplified axisymmetric simulation and a full three-dimensional simulation has been done numerically by Karki et al.

[8]. Dhirgham and A.Rahim [9] investigated the design of can-combustor with non-swirling and swirling flows at inlet is considered for the analysis under isothermal environment, through CFD study. They shows that numerical results are validated against experimental results a reasonable matching.

This study aimed to analysis the flow inside annulus can combustor in two cases, smooth combustor casing and casing have deformation, and durability of using this deformation combustor in the power station unit. Also analysis the static pressure loss and static pressure recovery and effect this deformation on the combustor performance.

NOMENCLATURE

Cp static pressure recovery coefficient

Cp_L stagnation pressure loss coefficient

R radius of combustor (mm)

r local radius (mm)

Pt total pressure (Pascal)

Ps static pressure (Pascal)

DG damp gap (mm)

X/Dc axial distance is normalized with the diameter of the casing as the origin.

A, B… and L station of measurement and Investigated locations.

u local axial velocity

U mass average axial velocity at inlet

WOB without bloating

WB with bloating

2. EXPERIMENTAL FACILITY

The can combustor that has been studied was a real part of Babylon gas turbine power station - Iraq, which happen raise in temperature in liner leads to deformation in air casing. This part was brought to the laboratory and connected it to subsonic wind tunnel. Figure (1) shows the experimental set-up in the lab.

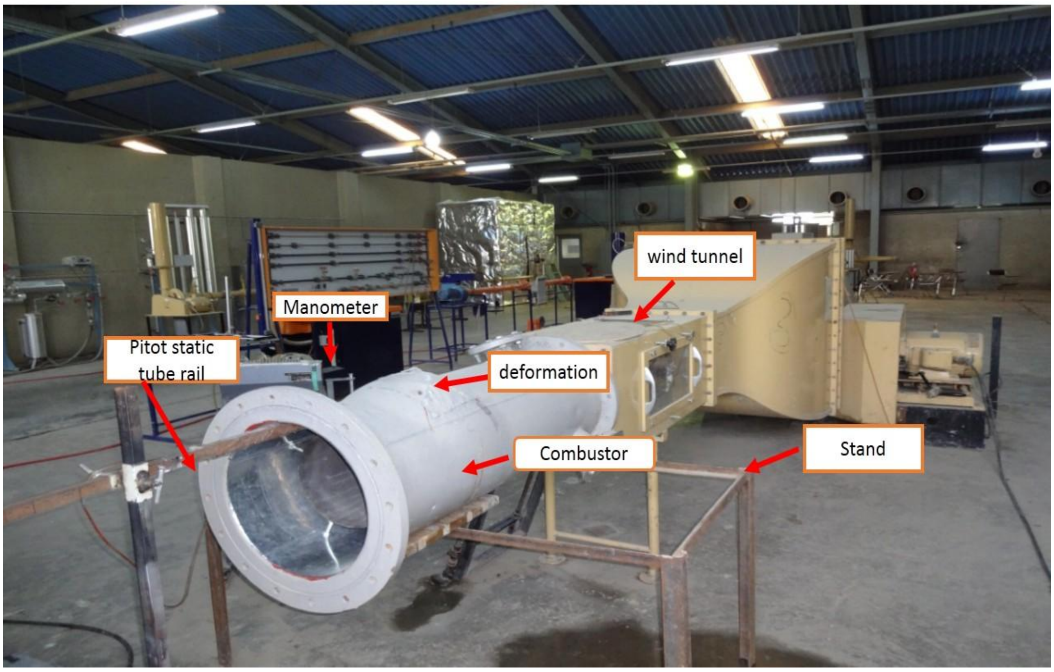


Figure 1 Experimental setup

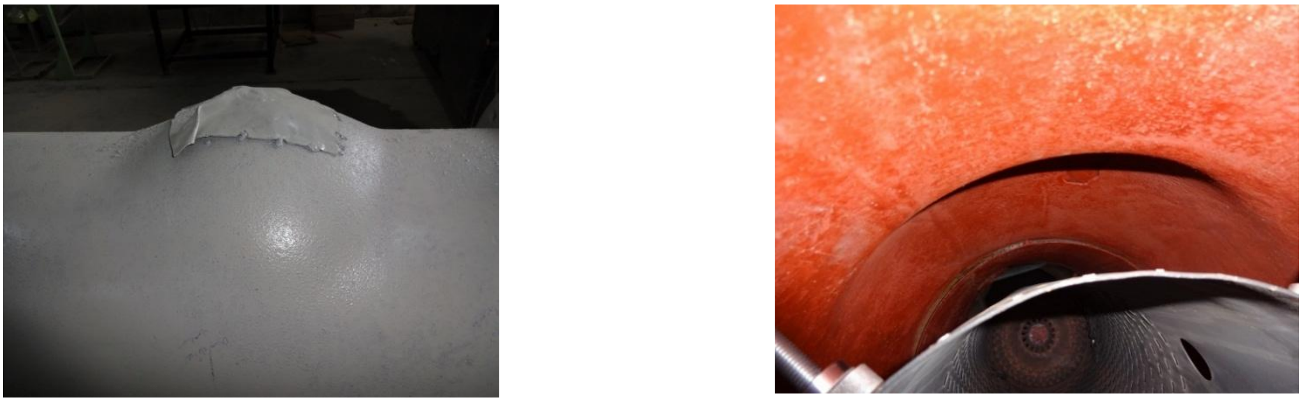


Figure 2flipchart shows the measurement location in smooth casing and deformation casing

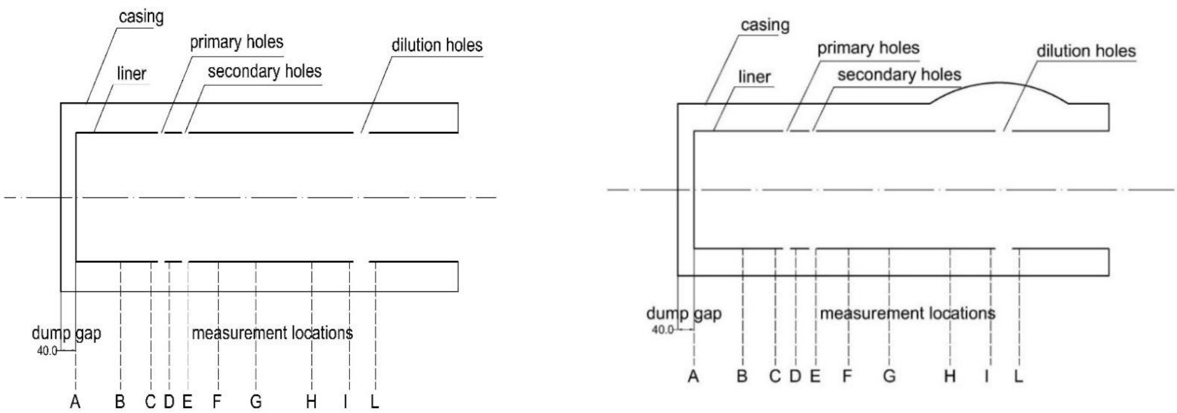


Figure 3 the deformation in air casing, from inside and outside

The geometrical details of can-annulus combustor consist of a cylindrical air casing of diameter 410mm and length 1060mm and internal liner with diameter 280mm and length 1020mm. This liner contain three types of holes Primary, Secondary and Dilution, distributed on the circumference of liner. The number of Primary holes are 8 with diameter 19.5mm. The Secondary holes also 8 with diameter 19.5mm. The Dilution holes 4 with diameter 40mm.

The Liner inserted co-axially with the casing that giving rise an annulus gap of 65mm between casing and liner and 40mm dump gap one. The deformation in the air casing has 340mm length and 50mm height and far 100mm from the end of casing. Figure (2) showing the deformation from inside and outside. Ten stations were chosen to study as it is explained in table 1 and figure (3).

Table 1 measurement location in the outer annular of can combustor

symbols	A	B	C	D	E	F	G	H	I	L
X/D	0	0.29	0.48	0.61	0.73	0.92	1.17	1.53	1.78	1.95

The air is derived from the wind tunnel at velocity 31m/s and inlet mass flow rate 4.5kg/sec, the air temperature is 314k and the pressure is 100kpa and the density 1.117 kg/m3. Used pitot static tube to measure the velocity which it insert inside the annular combustor from the opposite direction of air delivered, it is connected to the manometer to recode the value of velocity

3. PERFORMANCE FLOW PARAMETER

The parameters investigated in this paper are the most frequently used factors of the combustor flow performance and pre-diffuser combustor interaction flow .the two most influencing parameters, which affect the flow characteristics, are static pressure recovery coefficient CP, total pressure loss coefficient Cp_L. The static pressure recovery is defined as the ratio of static pressure rise through diffuser to the inlet dynamic pressure:

$$cp = \frac{Ps2 - ps1}{pt1 - ps1}$$

The stagnation pressure loss coefficient is defined as the ratio of loss in total pressure to the inlet dynamic pressure

$$Cp_L = \frac{pt1 - pt2}{pt1 - ps1}$$

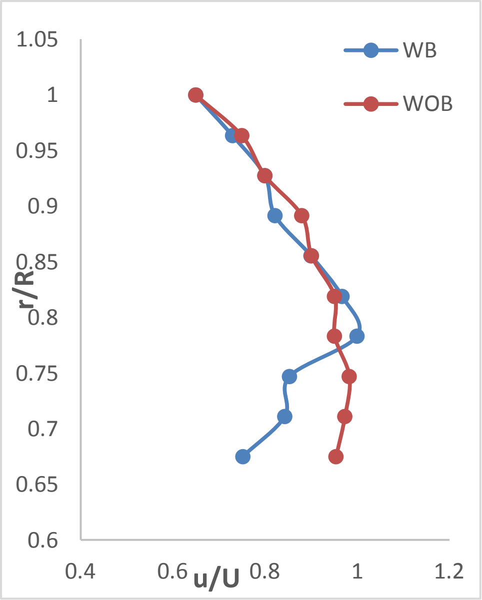
Where "1" and "2" denote upstream and downstream planes respectively.

4. RESULTS AND DISCUSSION

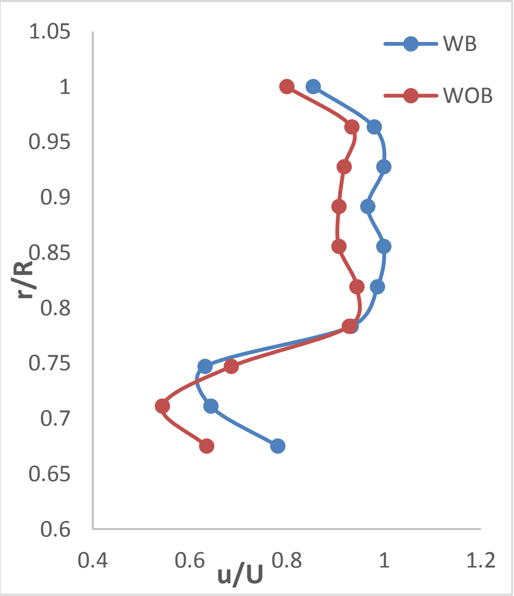
The fluid flow through the combustor is the air. The variation of axial velocity profile in the flow direction at ten locations X/D=0,0.29,0.48,0.61,0.73,0.92,1.17,1.53,1.78, and 1.95 are shown all this location at annulus region start from liner head at A and after small distance at B and near primary holes at C and between primary and secondary holes at D and E near the secondary holes. and F,G,H locating between primary and secondary holes and I,L on two sides of dilution holes .the variables presented have all been non dimensionalzed in the following manner. Axial velocity by the mass averaged axial velocity at inlet, static pressure by the inlet dynamic pressure. Also the flow performance parameters, CP, Cp_L along axial distance of each combustor models are presented in the subsequent subsections. The comparisons between two cases of can combustor casing, with deformation or bloating in casing (WB) shown in fig. (3b) and smooth casing (WOB) shown in fig. (3a).

Axial velocity distribution: Axial velocity distribution at ten selection stations A,B…..and L, for two cases of combustor casing shown in fig.4 (a),(b),(c),(d),(e),(f),(g),(h),(i), and (l) respectively. The profile of the axial velocity for two case at station A is shown in fig.4 (a). Shows the variation of axial velocity along the radial direction it was observed the velocity profiles are not uniform and it does not have the full shape of the known velocity profile this is due to the disturbance that happened to the flow at the beginning of its path. Which that in both cases of outer annuli. The sharp edge of the liner head (dome) it has negative effect on the flow uniformity which generate big recirculation region and revers flow near the liner wall. Variation of axial velocity along the radial direction is nearly similar for two cases, the velocity is high near liner wall and decrease gradually in radial direction towards the casing wall. In station B and C the velocity profile take another shape which happen reverse flow near liner wall and decrease the velocity due to recirculation region. Irregular because of the presence of swirls and reverse flow in the area entry. It was noted irregularity near the liner wall because the rough surfase of the wall. When got towards the end of combustor the velocity decrease gradualy due to pentration the air through cooling holes. at station D the velocity profile starting to take the common shape in the two models, also that`s obsorved in station E, and F, shown in fig.4(e),(f) which the velocity profile become more uniform. the effect of deformation apper at station G which the velocity profile are not uniform and it does not have the full shape of the known velocity profile this is due to the disturbance that happened to the flow at the beginning of deformed region.the last three station H, I, and L it was observed very low velocity near the liner wall and genaraet reciecolation region that`s happen due to the sudden expansion in the casing wall that's leads to incease in pressure loss and low the performance of cooling and decrease the pentration the air through the diluation holes.the stations G, H, I, and L shown in the fig.4(g),(h),(i), and (l).

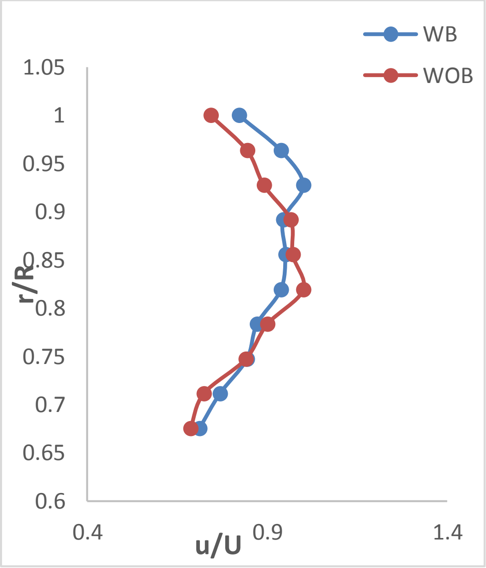
Performance flow comparison: the dynamic parameters of the flow are important aspect of flow performance in the diffusion region of combustor, where the air flow take away from combustor inlet, and dump cavity to the primary, secondry and dilution ports, that means the flow characteristics in annuli is one of flow performance comparison factor in combstor systems. To evaluate the flow performance along combustor models, there are two important factors namely static pressure recovery coefficient, and stagination pressure loss coefficient, chosen for the flow performance comparison between the two different models. Measured values at the ten stations are ploted aginest nondiemensional axial distance (X/D_c) along the combustor model. Fig.5 shows the varition of static pressure recpvery coefficient of all invstigated models. the two models, smooth casing and deformation casing, at the inlet of combustor are same start from



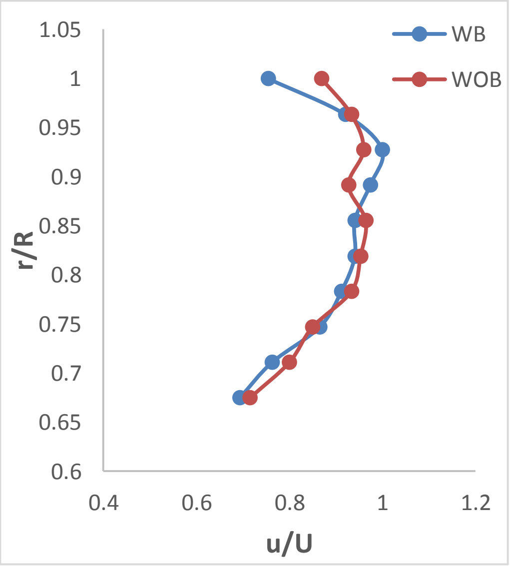
Axial velocity profile at (A) (a)



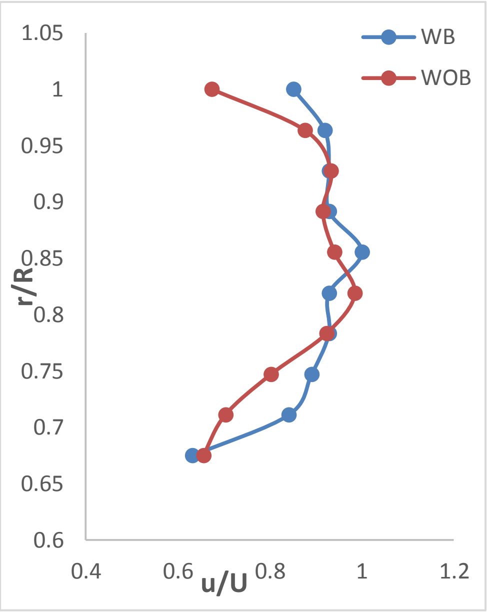
Axial velocity profile at (B) (b)



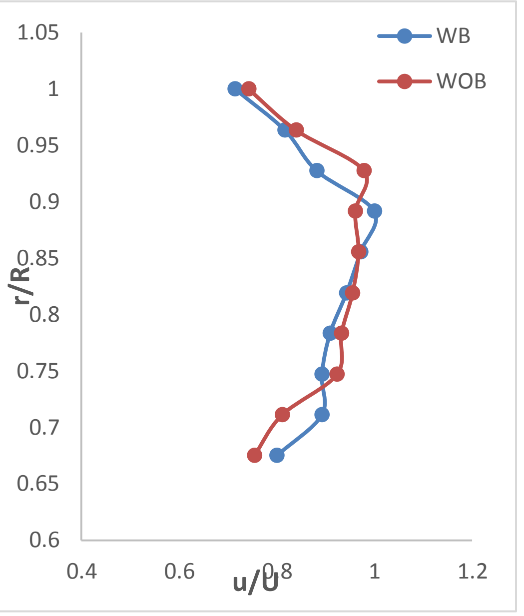
Axial velocity profile at (C) (c)



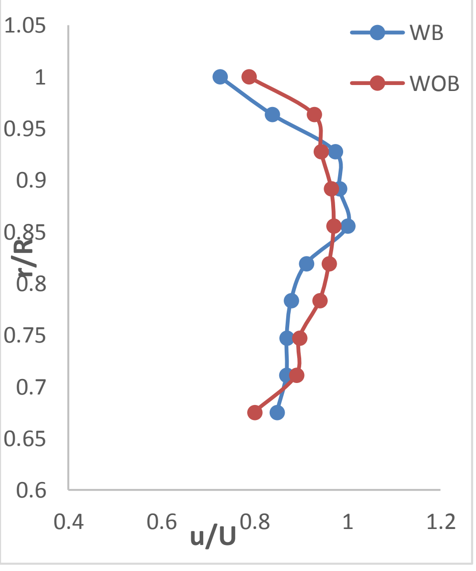
Axial velocity profile at (D) (d)



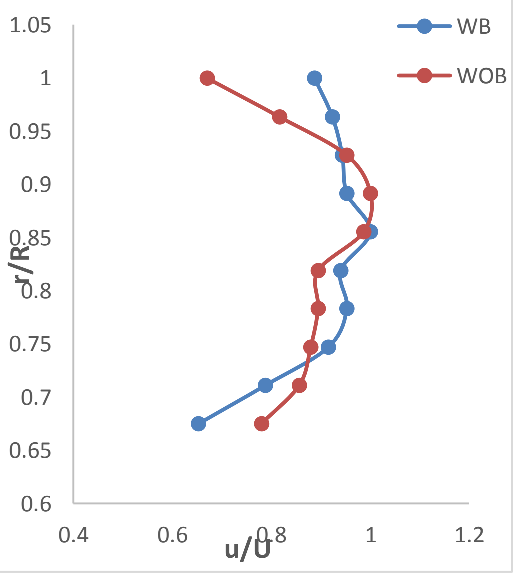
Axial velocity profile at (E) (e)



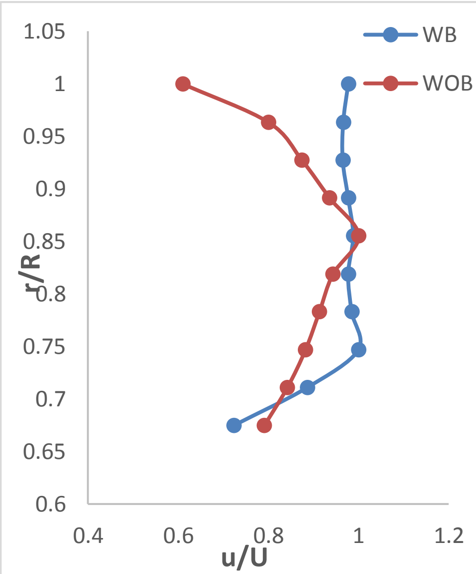
Axial velocity profile at (F) (f)



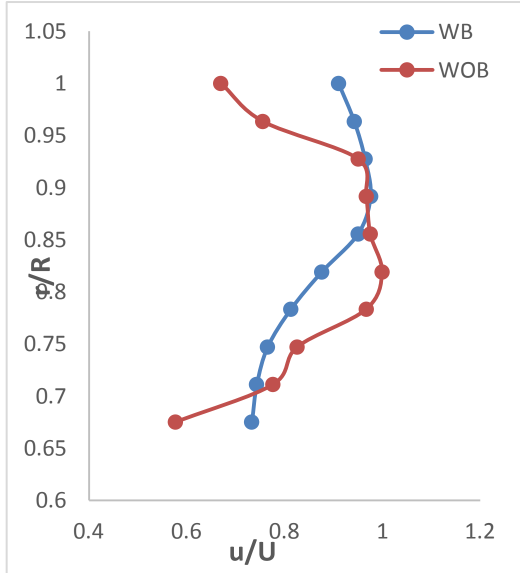
Axial velocity profile at (G) (g)



Axial velocity profile at (H) (h)



Axial velocity profile at (I) (i)



Axial velocity profile at (L) (l)

Figure 1Axial velocity profiles at different stations for smooth and deformation casing

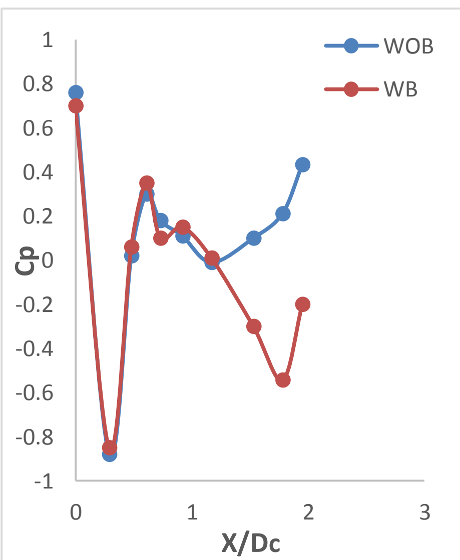


Figure 5 pressure recovery comparison

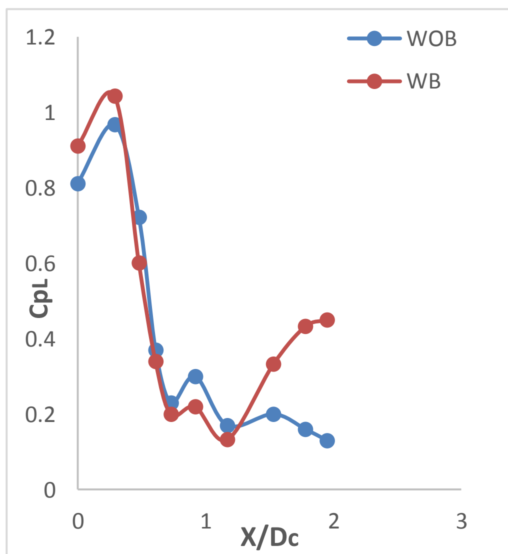


Figure 6 pressure loss comparison

positive value and decrease ripadly to the negative value this happen in the dump gap and the entrance of annuli. Dumping losses can also be affected by the physical spacing between the inlet plane, and cowling leading eadges. If this spacing is too small, the flow into the dump region will be accelerated around the cowling leading edges and the pressure losses will be higher and static pressure will be drop in the entrance of annuli, then the static pressre recovery start to increase gradualy in two models until arive to deformation region which the deformation affected on the performance which happen decrease in static pressure coefficient and increase in pressure losses espatioly in last three station which the deformation genarate reciecolation region and the velocity decrease. Fig.6 shows the varition of pressure loss for the models, it was been observed high pressure loss in the dump gap for two models and it will be deacrease when the flow enter the annuli, in the deformation model increase in pressure loss in last three station espationaly, but continue in deacrease in smooth casing model.

1. CONCLUSION

The flow structure in the annular chamber section of the inlet system combustor was investigated experimentally. The velocity profile is measured using the pitot static tube and then computing static pressure coefficient and total pressure loss coefficient. The following conclusion can be drawn:

1. The velocity profile at the entrance region is irregular in both cases begin in regularity as we get into the combustor.

2. upon arrival to the area of deformation note decrease in the rate of speed and thus lead to a decrease in the amount of air inside dilution holes.

3. A decrease in the amount of static pressure coefficient and an increase in the pressure loss coefficient in the deformation region

4. The deformation effected on the cooling performance due to the flow velocity in this region become very slow near the liner wall. As well as the total power from the Babylon power station will be decrease so this combustor should be maintenance or replaced.

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