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Investigation Cold Flow of Can Combustor under Vibration Effect

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Abstract: This paper focus on studying the behavior of velocity profile under force vibration for a different frequency (34, 48, 65 and 80 Hz) for lower annulus of Can Combustor. An experimental rig was designed at Babylon University /Iraq by the author. The Can Combustor tested in this study is real part collected from Al-Khairat/Iraq gas turbine power station. The velocity profiles are examined at three positions in the annular for lower region. The velocity in X-direction calculating with a different frequency for lower annulus. The results were shown that the increase of frequency lead to increase the velocity profile and large recirculation zone will form in some points. Since the flow is turbulent, So the slope of the velocity profile at the wall is big but when forced vibration effect is applied it becomes much greater than without vibration effect about (25%).Reynolds number increasing with praise of velocity in X-direction. Also, the increase in vibration level produces non-uniform velocity profile which affects the spreading of cooling efficiency. Finally the shape of velocity profile change from flatter to non-uniform shape due to fluctuation vibration effect so, the cooling film air fails to protect the linear wall of Combustor from damage.
Keywords: Annulus Flow, Can Combustor, Pitot-Static Tube, Velocity Profile, Forced Vibration and Flow-Induced Vibration.

Nomenclature		Unit	Greek symbols		Unit
A	Area	m^2	μ	Dynamic viscosity	kg/m.sec
C_p	Specific heat	J/kg.ºC	$V^{\cdot}$	Volume flow rate	m^3/sec
D	Diameter	m	ρ	Density	kg/m^3
F	Friction factor	-	φ	Volume concentration	%
k	Thermal conductivity	W/m ºC	Subscripts		
L	Length of combustor	m			-
m	Mass	kg			-
Nu	Nusselt Number	-	in	Inlet velocity	-
f	frequency	Hz	out	Outlet velocity	-
P	pressure	N/m^2	Exp.	Experimental	-
r	Radius of combustor	m	w.o	Without vibration	-
Re	Remolds Number	-	w.v	With vibration	-
T	Temperature	ºC			
u	Velocity	m/sec			

I. INTRODUCTION

In this study, the researcher addresses to introduce the types of combustion chambers and the flow inside the chamber, the way of cooling and the vibration effect on it for type (can combustor) in gas turbine engine a real part from Al-khairat gas turbine engine. The idea came from having some serious problems faced by most mechanical equipment , these problems are the rise of vibration level on the bearings for a gas turbine, so the manufacturer of these turbines put a control screen called (HMI) the purpose is to protect the machine from high levels of vibration when this value reaches to 12 mm/sec give an alarm and 25 mm/sec give trip (the unit shutdown) and these value of vibration comes from compressor part or turbine part , so we study the effect of vibration level on flow inside combustor because the combustor lies around bearing especially bearing no.2 as shown in figure (1) GE et al (2017) below explain the HMI screen for vibration levels :

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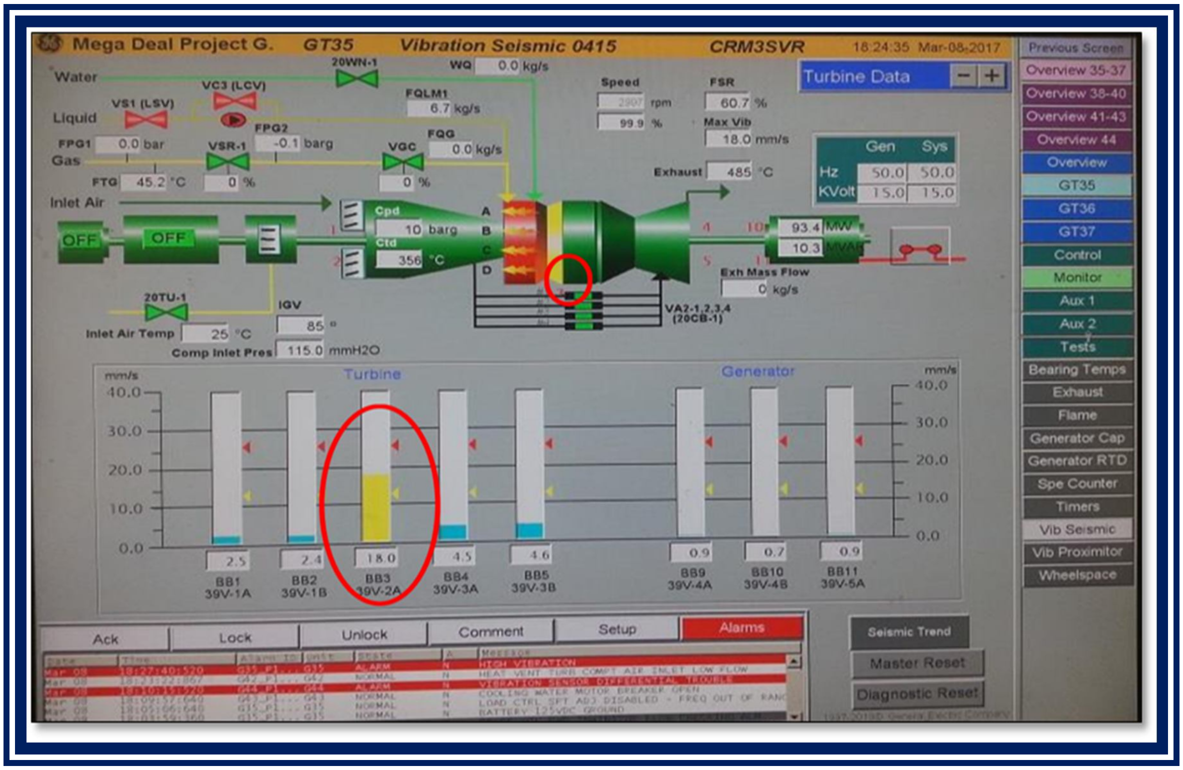

Figure (1) HMI Screen

The Can Combustion chamber has a difficult mission of burning large quantities of fuel, which supplied it by the fuel nozzles spray, with large volumes of air, it supplied by the compressor, while the gas turbine is running, filtered ambient air is drawn through the inlet plenum assembly, then axial flow compressor supply air into the annular space surrounding the combustion chamber, from which it flows into the spaces between the outer combustion casings and the combustion liners, and enters the combustion zone through metering holes in each of the combustion liners. Generally, the combustor has three main components: diffuser, casing, liner and annulus Wael et al (2014) This mission must be accomplished with the minimum loss in pressure and with the maximum heat release for the limited space available. The amount of fuel added to the air will depend upon the temperature rise required. Hsieh et al (2017) studied the flow characteristics around a circular cylinder undergoing vortex-induced vibration in the initial branch. Zhanget al (2015) studied the investigation on flow and mixing characteristics of supersonic mixing layer induced by forced vibration of the cantilever. Hadi et al (2015) Investigate enhancement of natural convection by vibration for the corrugated surface. Poursaeidi et al (2013) Investigation of choking and combustion products' swirling frequency effects on gas turbine compressor blade fractures. Huls et al (2007) It studied how to decrease NOx emissions from combustion systems, the higher sensitivity to combustion instabilities, leading to increased sound pressure levels in the combustor and resulting in an increased excitation of the surrounding structure the liner and this leads to fatigue, which reduces the life time of the combustor. Elbaloshi et al (2014) have made a comparison three k-ε family turbulence models and k-ω family models. Shih et al (2009)have studied combustion characteristics of a can combustor with a rotating casing for an innovative micro gas turbine.

II. EXPERIMENTAL WORK

The Can Combustor has been studied was a real part of Al-Khairat gas turbine power station - Iraq. This part was brought up to the mechanical fluid laboratory and connected it to the subsonic wind tunnel, which has a square section. The vibration shaker designed to give us the value of frequency such as Al-khairat power station. The forced vibration was applied by vibration shaker with different level of frequency (34, 48, 65 and 80 Hz) and amplitude value (0.0001 m). In this research is, the study of the practical side to calculate the pressures by using pitot-static tube and rack pressure then we obtain pressure difference to calculate velocity by using Bernoulli equation for three positions of can combustor it called upper and lower Can Combustor, the study of the experimental side was calculated the pressures by using pitot-static tube and rack pressure. The velocity was calculated at three positions in upper and lower annulus of can combustor where pressure difference was obtained at the select point and applied

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Bernoulli equation as shown in figure(1).The wind tunnel supplied the air to the Combustor at atmospheric pressure and the velocity 32 m/s and temperature 300 K. Figure (2) shows the experimental setup and figure (3) show the schematic diagram. The geometrical details of can-annulus combustor consist of a cylindrical air casing diffuser (42-52 cm) of as diameter and length 73 cm and internal liner with diameter 36 cm and length 100 cm.

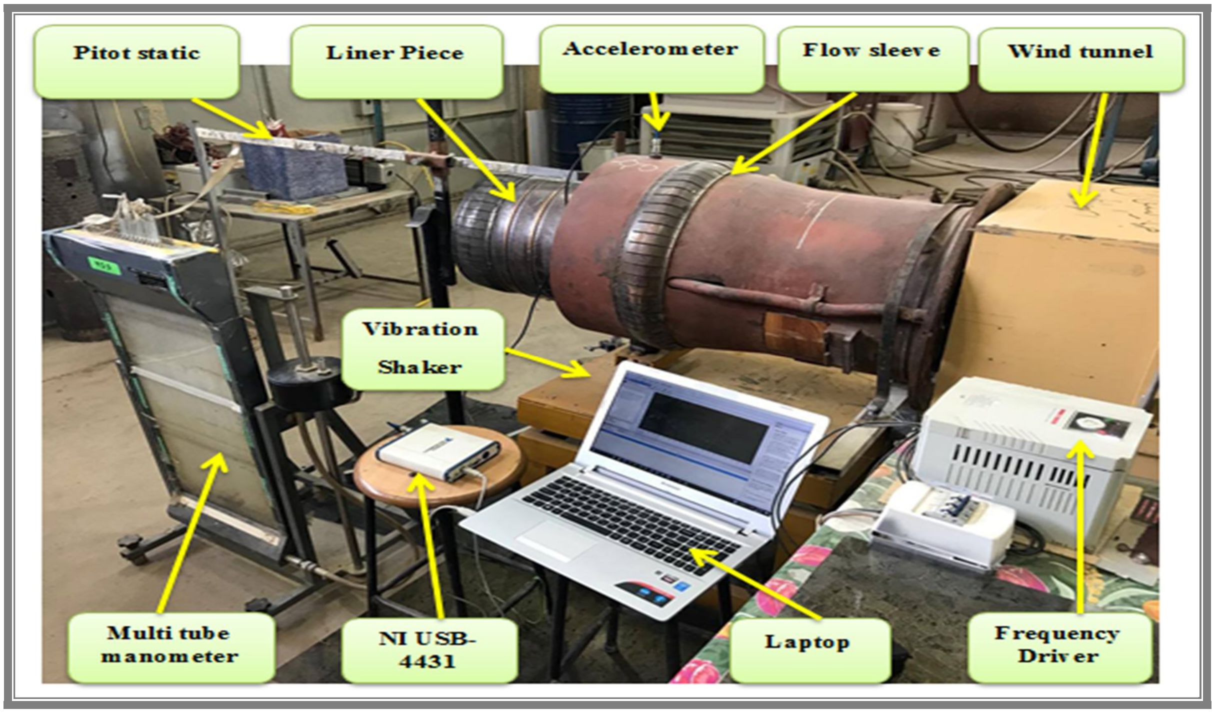

Figure (2) Experimental Setup

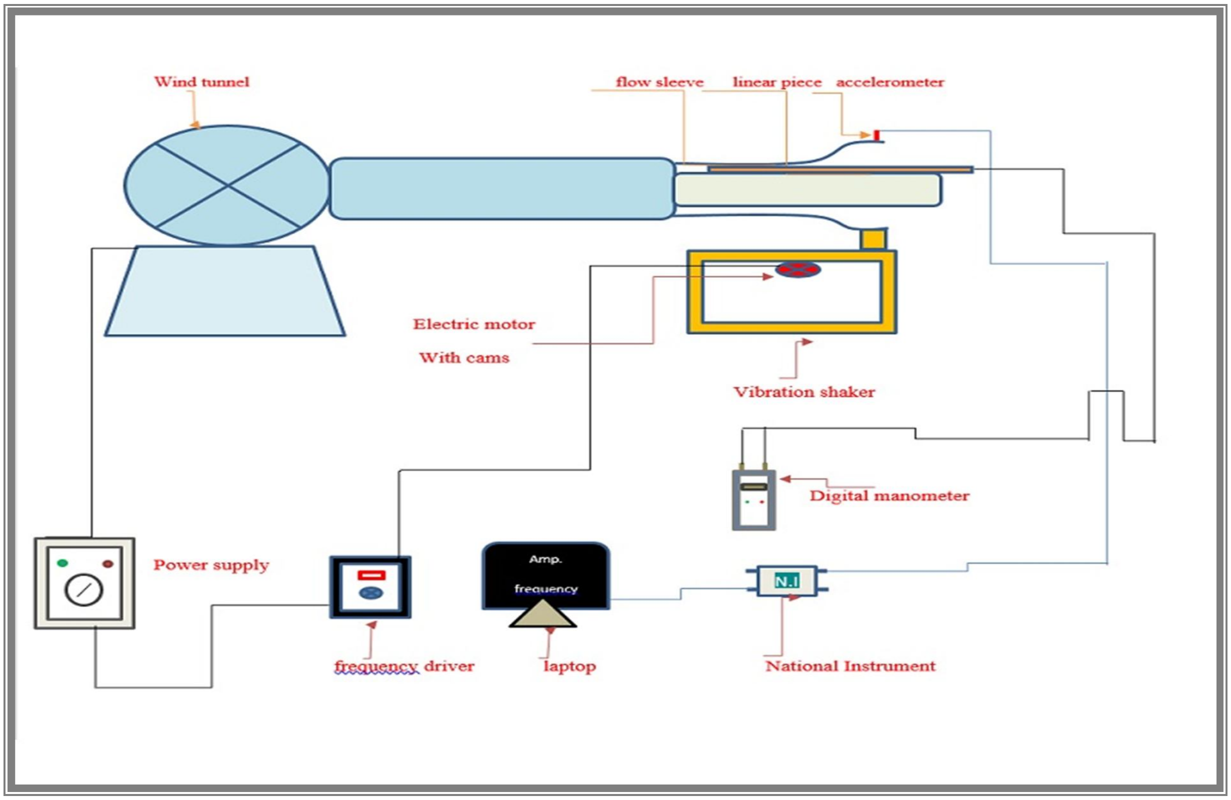

Figure (3) Schematic Diagram

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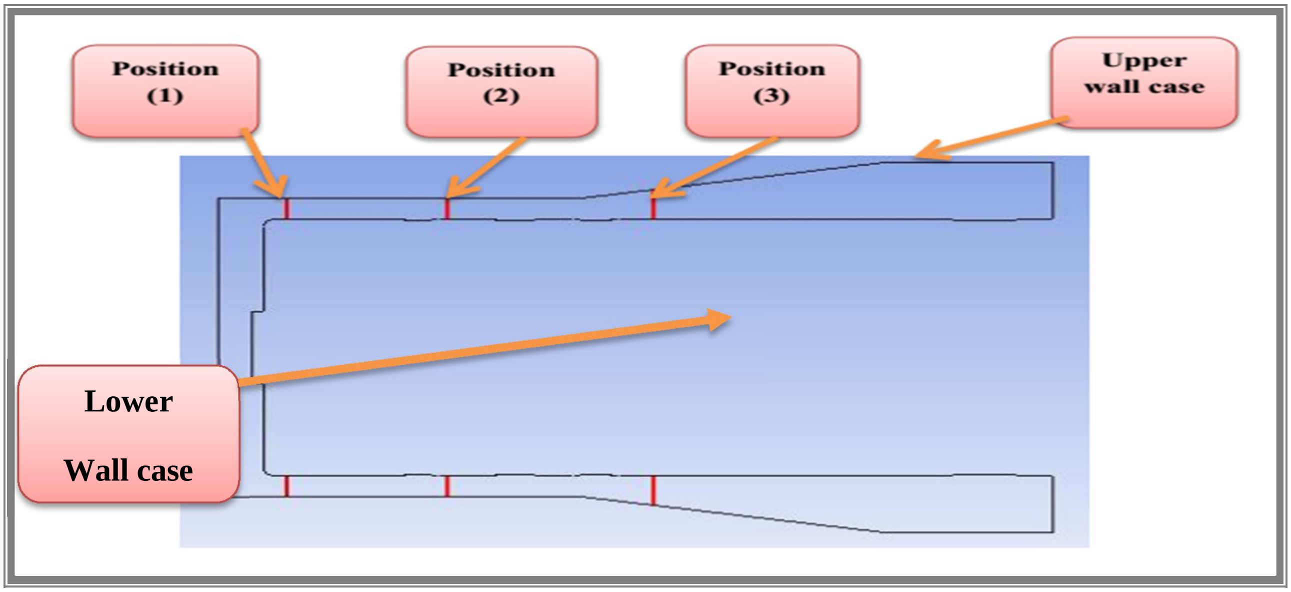

Figure (4) shows display the location of three positions for lower wall casing

III. VIBRATION RIG

The device(Vibration Shaker) is designed in an external workshop. The required vibration values were studied and determined to access the values in the Al-khairat power plant gas turbine engine , and these values are determined by using a vibration meter borrowed from the same power plant it called (Hofmann MI 2100). The device consists of an electric motor device consist of an electric motor with a capacity of 0.75 KW, speed is 2840 R.PM, it contains four cams, which in turn generate vibration. The table on which the electric motor was based then manufactured, to transmit vibration values of the desired part (Can Combustor). The vibration control method it was done by a control device called (Driver device), it increases and decreases engine speed, figure (5) explain the vibration shaker.

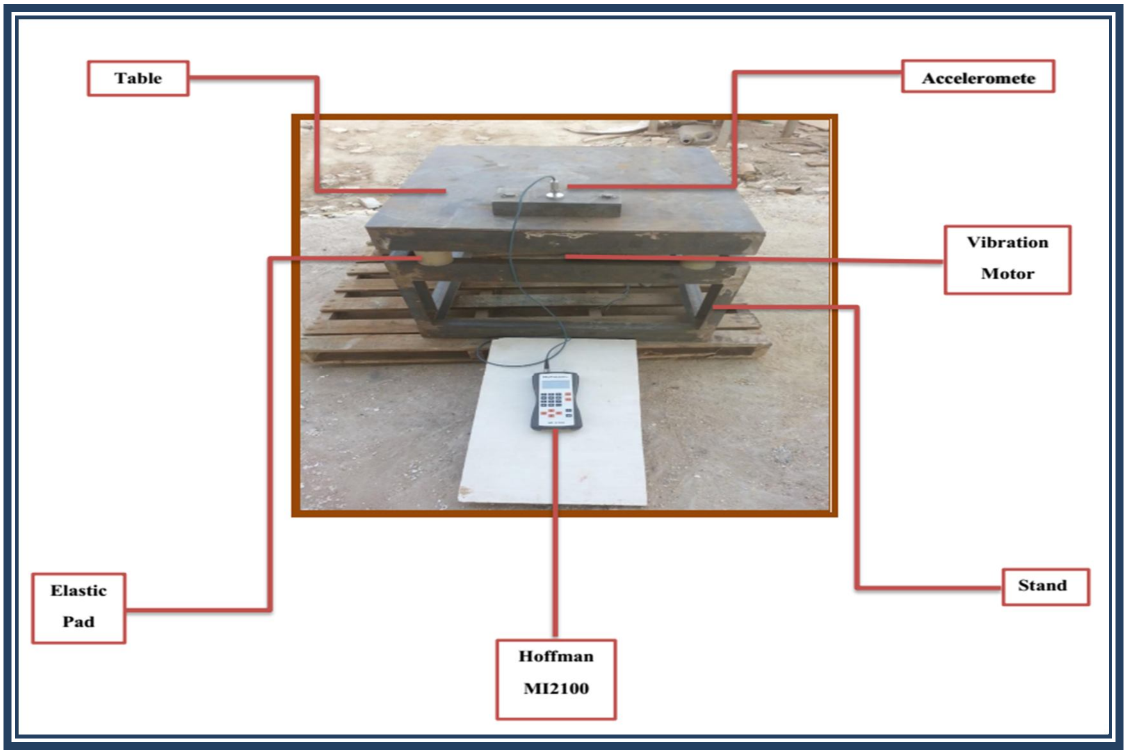

Figure (5) The Vibration Shaker

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IV. EXPERIMENTAL PROCEDURE

A. This experiment is accomplished according to the following procedure

1) Install all the devices and equipment of the experiment in the appropriate place with the accordance of operating conditions to ensure a perfect and a safe operation. Setup the pressure rack in lower casing of the can combustor.
2) Run Wind Tunnel from the main source power.
3) Take measure for lower casing (position (1),X=4 cm) and measure the pressures after five minutes to reach a steady state without vibration and from this, we can calculate the velocities, and the same procedure for the position (2)and (3) (X=20 cm and X=34 cm).
4) Stop wind tunnel from main source power.
5) Move the rack pressure from position (1) to position (2) then run the wind tunnel again to measure the pressure after five minutes to reach steady state then record the measuring data.
6) Stop wind tunnel.
7) By repeating step (6) but for another position (3).
8) Same procedure above but with vibration effect.

B. Flow velocity calculation

To measure the velocity of incompressible fluid it used the Bernoulli's equation Yunus A.Cengel:

$$V = \sqrt{\frac{2(p_{total} - p_{static})}{\rho}} \qquad \textbf{(1)}$$

C. Air Properties and boundary condition conditions

The air is the working fluid which used in this project, so the properties of air are taken at atmospheric pressure and Temperature 300 K, as shown in the table (1):

Table (1): Air Properties

Parameters	Units	Values
Density (ρ)	kg/m^3	1.225
Specific Heat (C_p)	J/(kg .K)	1005
Thermal Conductivity (k)	W/(m. K)	0.0258
viscosity (μ)	Kg/m s	1.789 x 10−5

Table (2): Boundary condition

Boundary condition	Value	
Velocity inlet	32m/s	
Outlet	Flow outlet	
Temperature inlet	300 k	
Moving Wall	Case One	34 Hz
	Case Two	48 Hz
	Case Three	65 Hz
	Case Four	80 Hz

V. RESULTS AND DISCUSSION

A. Vibration Effect on lower Casing

The figures from (1) to (3) represent the velocity profile in three positions at upper case annuli, which compare the flow at upper annuli with and without vibration. Air is the fluid that flows through the combustor. All presented variables have been non-

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dimensional zed parameters. Figure (1) represents the position (1) at X= 4 cm, which shows the variation of axial velocity along the radial direction. The range of force vibration is (10-25 mm/sec). It was observed that the velocity profiles are not uniform and it does not have the full shape of the velocity profile due to the disturbance that happened as a result of the flow at the beginning of its path in both cases of the outer annuli. The sharp edge of the liner head (dome) has a negative effect on the flow uniformity, which generates big recirculation region.

The air flow at the center of the annulus (r/R =0.5-0.6) is faster than the air flow which near linear piece and case of the combustor due to the roughness of these surfaces for positions one and three, but in the position 2 the maximum velocity at (r/R=.118-0.236) due to the flow in this region is not uniform.If we compare between the velocity profile in case non-vibration effect and with vibration effect at x= 4 cm we see the velocity profile becomes more than at middle at (r/R=0.5-0.6) about (26)%, but in case the value of vibration is maximum the velocity profile at (r/R=0.5-0.6) is about (28%).By comparison between the position (1) x= 4 cm at the first value of forced vibration and the position (3),X=34 cm when the forced vibration is maximum we see the velocity profile is increased significantly especially in the middle, due to effect of on dynamic response of the combustor on flow velocity subjected to single-phase flow excitation. The bigger the structural vibration leads to a higher in the flow velocity. AS velocity is increased, velocity fluctuations increase due to turbulence. Then pressure fluctuations are also more intense and consequently the structural vibration. Moreover, the rate of increase of the structural response is more significant at higher velocities. From figures (1)to (3) shows the velocity profiles for all positions a reverse flow is noticed near the linear piece of can combustor compare with wall of combustor due to the dilution holes of linear piece, therefore, the velocity at this region decrease, so when the frequency increased gradually the velocity is increased, and velocity fluctuations increase due to turbulence.

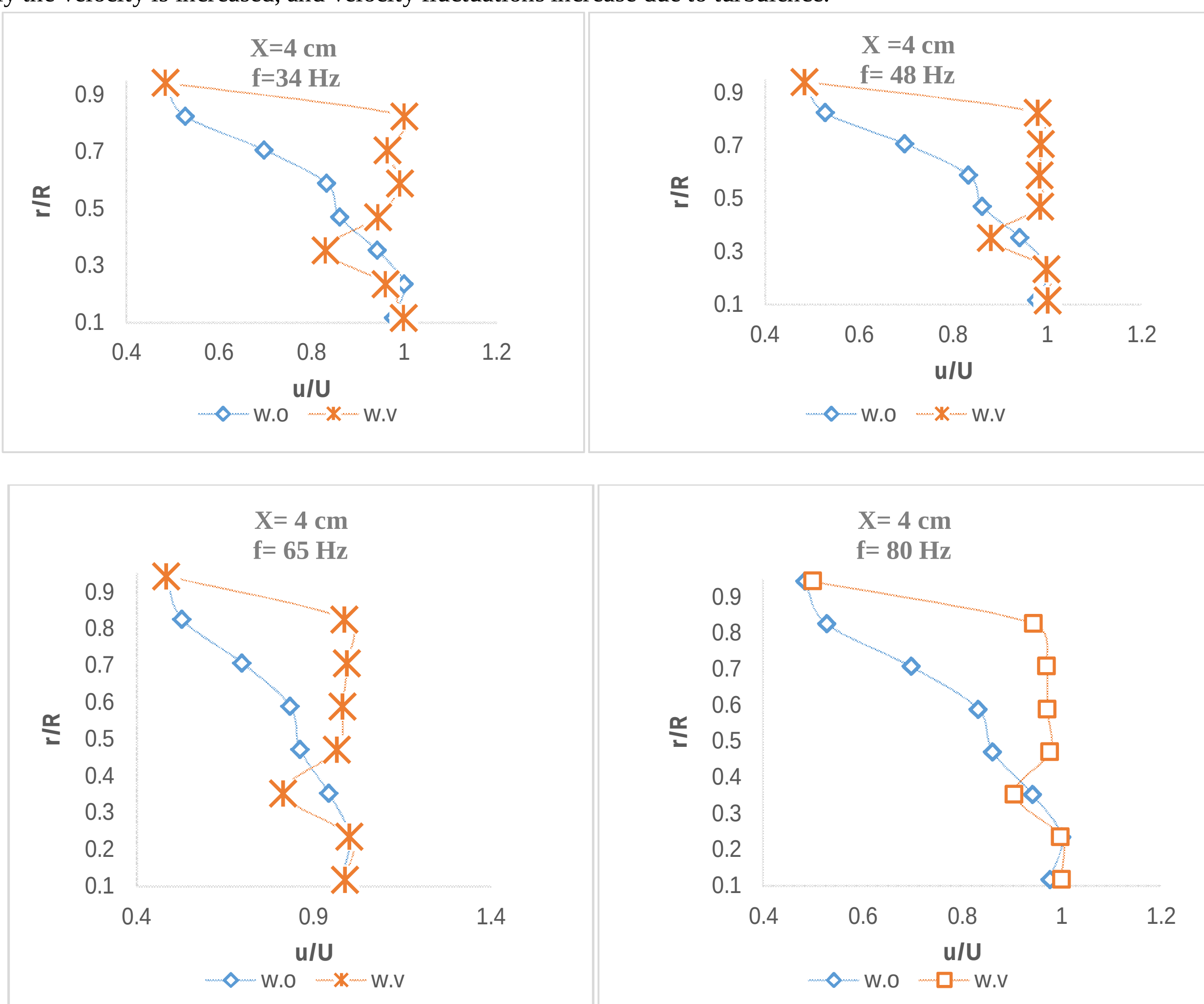


Fig.(1): The velocity profile with different frequency at first position (X= 4 cm) for lower

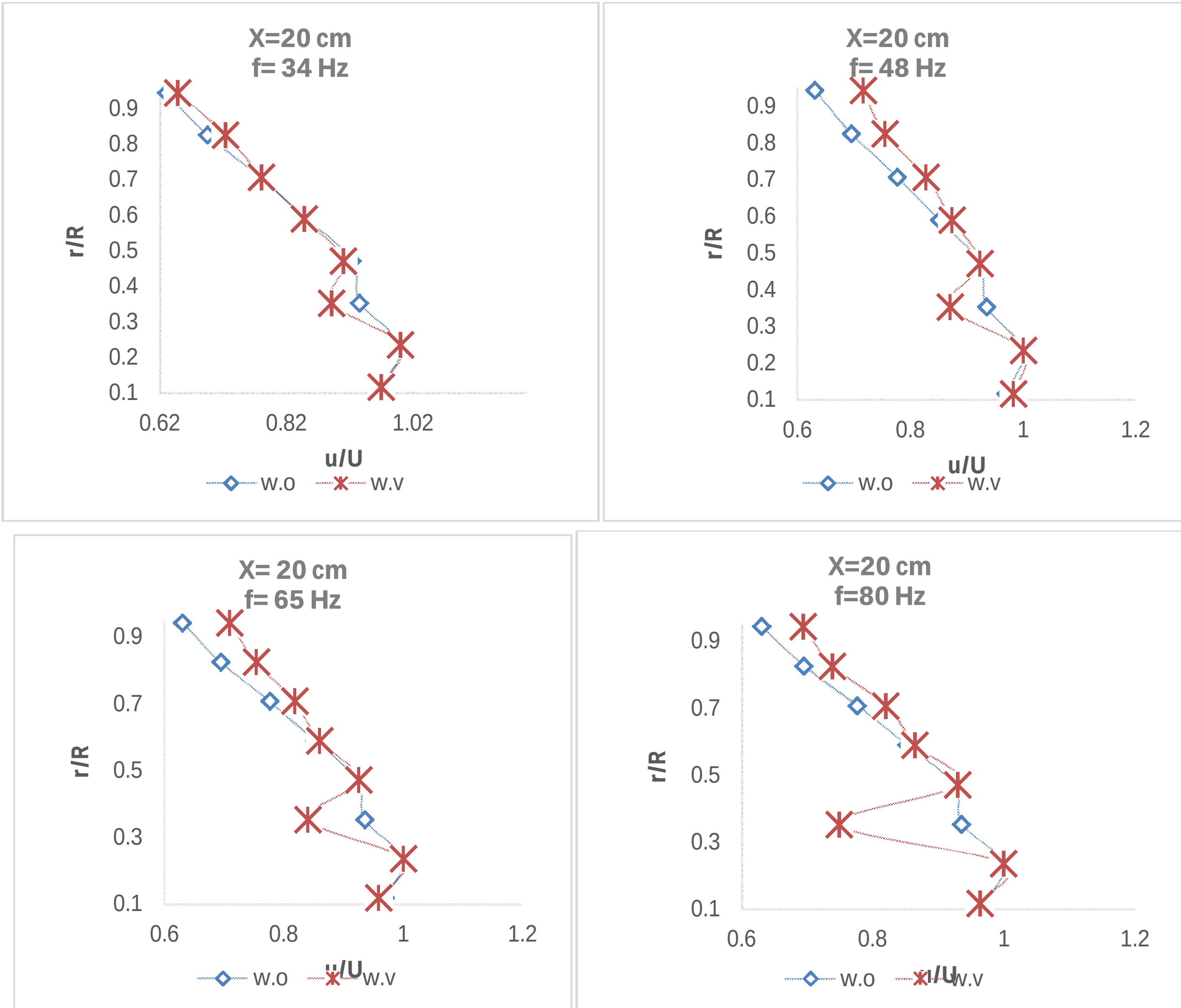
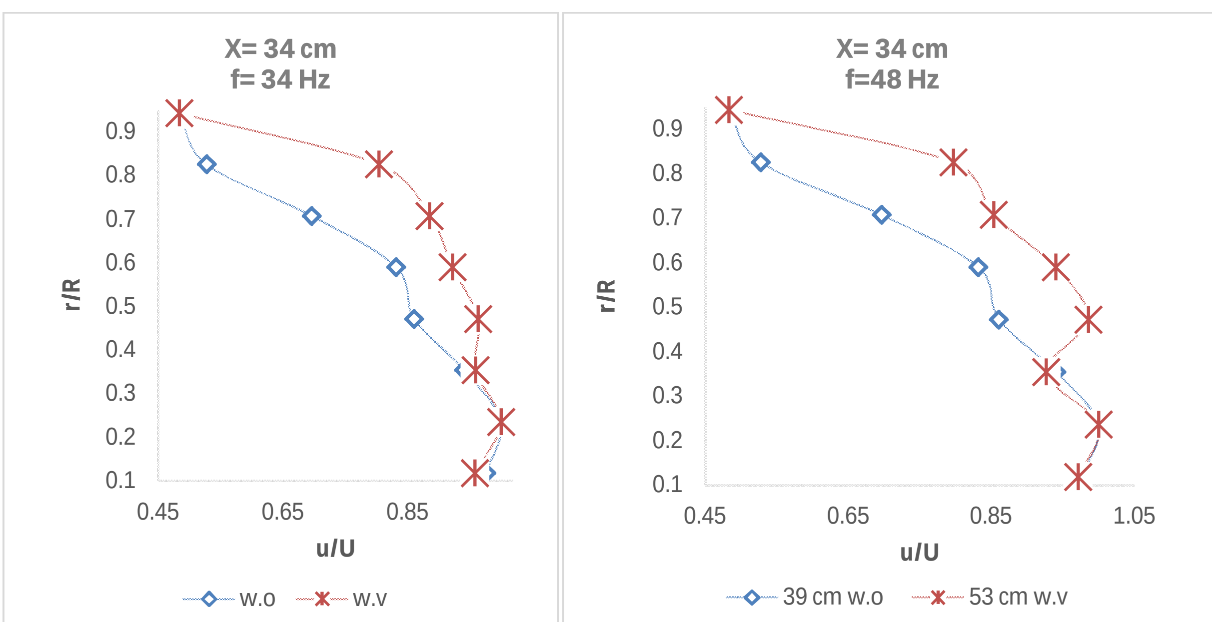
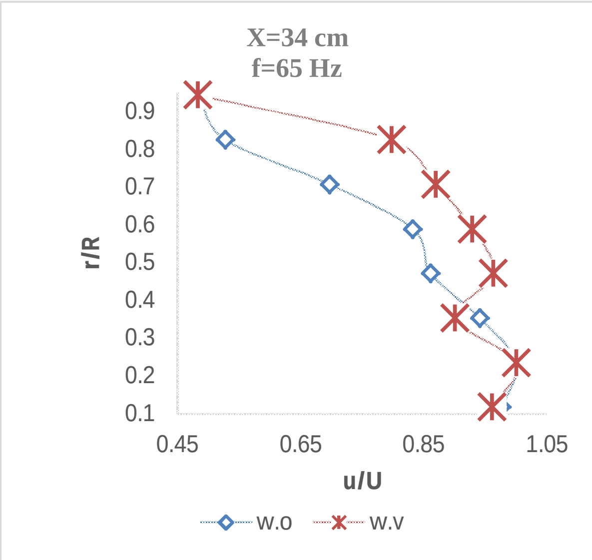


Fig.(2): The velocity profile with different frequency at second position (X=20 cm) for lower





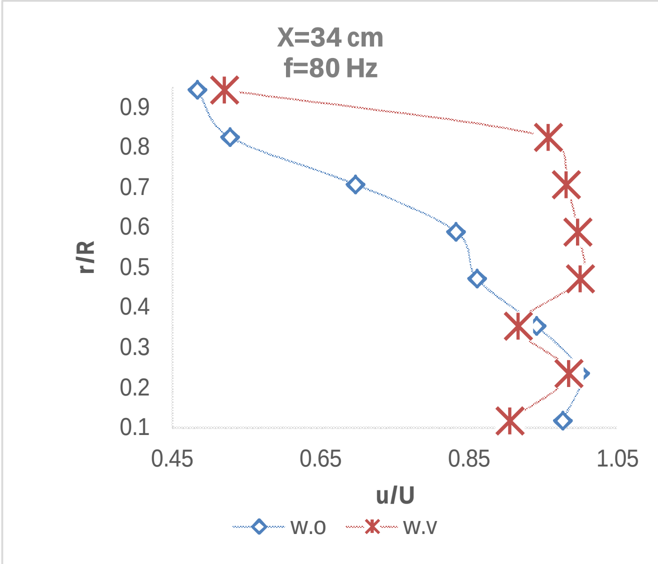


Figure (3): The velocity profile with different frequency at third position (X=34 cm) for lower

VI. CONCLUSION

A. The analyses of annulus flow of axial velocity show an increase in frequency levels cause an increase in the velocity profile in annulus region which undesirable effects will occur such as reversible flow and large recirculation zone in some points. The increase in velocity profile at middle points after comparison without and with vibration effect was 25 %.

B. The velocity of air at the linear piece is more than the velocity at the case of combustor about (15 %) since the effect of vibration on fluid.

C. the velocity profile is increased significantly especially in the middle about (35 %), due to the effect of on dynamic response of the combustor on flow velocity subjected to single-phase flow excitation.

D. At last of the combustor, it can be seen the reverse velocity becomes large due to the vibration shaker is connected directly at this position.

VII. ACKNOWLEDGEMENTS

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