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RESEARCH ARTICLE

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COMPUTATIONAL ANALYSIS OF FLOW IN AFTER BURNER DIFFUSER MIXER HAVING DIFFERENT SHAPES OF STRUTS

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ABSTRACT

In this paper, the subsonic flow analysis is carried out in diffuser mixer with struts and without struts. The total pressure loss, pressure gain, essential flow properties like Mach number, velocity, statics pressure, swirl are compared for both the cases. Analysis has been carried out using 45-degree sector model of the diffuser mixer without strut and with struts considering the periodicity of geometry. An unstructured grid has been generated and Simulation has been done using ANSYS FLUENT software, flow has been simulated by solving governing equation of mass, momentum, energy. Turbulence closure is achieved with k-epsilon turbulence model with standard wall functions. The analysis has been carried out with velocity components, total pressure and total temperature at inlet boundary conditions and a mass flow rate at the outlet. The present study shows that presence of combination of both aerofoil and cylindrical struts gives better increase in pressure in afterburner's combustion section and also helps in guiding the flow.

Key words – after burner , diffuser mixer , pressure loss , pressure gain , struts.

1. INTRODUCTION

When after burner concept came in to existence in the world, it is time to create enough pressure for afterburner to go under proper combustion as in combustion chamber where combustion chamber will get enough pressure for its combustion process with the help of compressors which will provide enough pressure to it.

*Berge Djebedjian, et al. [1].*says that increase of pressure in the flow with struts is beneficial as it leads to better mixing of air and fuel in the after burner unit.

Aerofoil and cylindrical struts also acts like guide vanes for the flow and also struts in diffuser helps in pressure recovery is given by *Stefano Ubertini. et al. [2].*

Presence of flame stabilizer/fuel ring assembly in the afterburner helps in holding the flame but in turn it leads to total pressure loss in diffuser mixer section is found from *Isaac, et al. [3]* paper. This problem of loss of pressure overcome from the method of inserting struts in the diffuser mixer as shown in this present study.

Because of presence of v gutters and struts total pressure loss will happen around 5 to 7%. To overcome from this pressure loss there need to be done some extra constructional work at turbine downstream like providing struts etc. and this concept is given by *Philip P. Wals, et al.[5].* By taking this as a reference constructing some struts in downstream of turbine we can get extra thrust using same amount of fuel.

Bheemaraddi.S.B, et al. [6] says that presence of struts in diffuser duct cause the pressure loss.

K. M. Pandey, et al.[7] says that hydrogen particles are injected on to the struts with mach 1 and it produces oblique shocks and these oblique shocks produced by the collision of the fluid particles to the strut and deflecting into itself. Across the shock wave, the Mach number decreases, and the static pressure, density, and static temperature increases.

The presence of Diffuser struts, Fuel injection rings, Flame holders inside the after burner makes the flow complex inside afterburner and makes variation in pressure, temperature and velocity of the flow and affect the performance as said by *Dr.N.Mohmed Sheriff, et al. [8]*

The combination of cylindrical and aerofoil struts gives enough pressure for proper combustion in afterburner section which is more compared to the pressure given by *Mattingly J.D, et al. [4].*

2. GEOMETRY

In present study a three dimensional model of a diffuser mixer has been modelled as per dimension using CATIA V5 R20 geometric modelling package. The after burner diffuser is incorporated with eight strut, owing to the rotational periodicity of the model, a 450 sector is considered for the analysis, which consists of one strut. CFD analysis is carried out for the after burner diffuser mixer with and without struts. The dimensions of diffuser mixer are taken from Mattingly J.D, et al. [4].The dimension of the diffuser mixer is given below table.

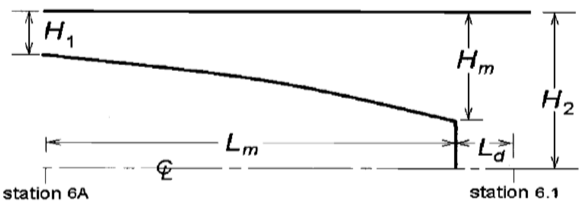

Figure 2.1 Geometry of the Diffuser mixer. *(Courtesy-Mattingly J.D.et al, [4]).*

Table 2.1 Dimensions of diffuser. *(Courtesy-Mattingly J.D.et al, [4]).*

SL NO	All are in mm	
1	H1	99.06
2	Hm	271.78
3	H2	398.7
4	Lm	894.08
5	Ld	127

3. RESULTS & DISCUSSIONS

3.1 Flow analysis for after burner diffuser mixer without struts.

In order to analyse the effects of struts on the aerodynamics inside the diffuser mixer, the flow has been simulated first without the struts.

Table 3.1 CFD analysis results for the afterburner diffuser mixer without struts.

Sl No	Description	Unit	Values at station 6.1		% Error
			Experimental	CFD	
1	Mass flow rate	Kg/sec	12.96	12.96	
2	Absolute Total pressure	Pascals	525249	529880	0.88
3	Absolute static pressure	Pascals	513921.	525068	
4	Total temperature	K	686.5	686.5	
5	Velocity	m/s	81.74	81.84	

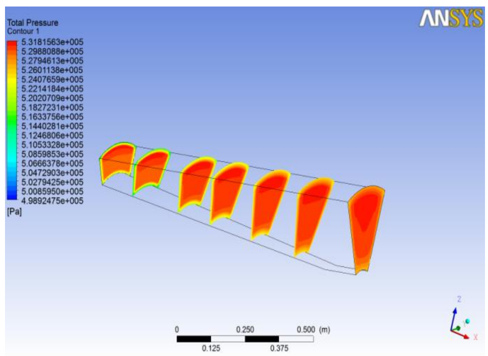

Figure 3.1 contours of total pressure (without strut).

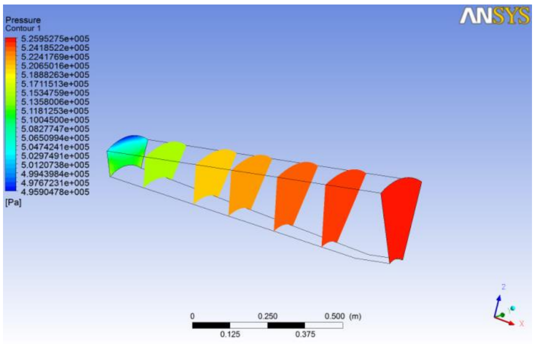

Figure 3.2 contour of static pressure (without strut).

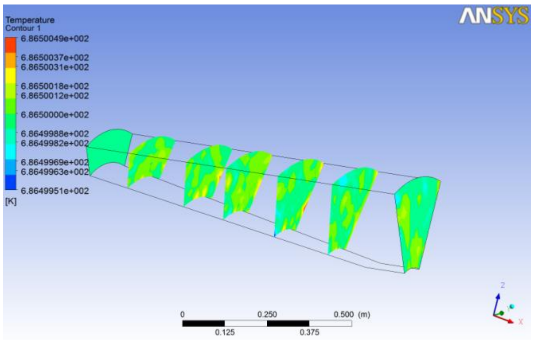

Figure 3.3 contours of total temperature (without strut).

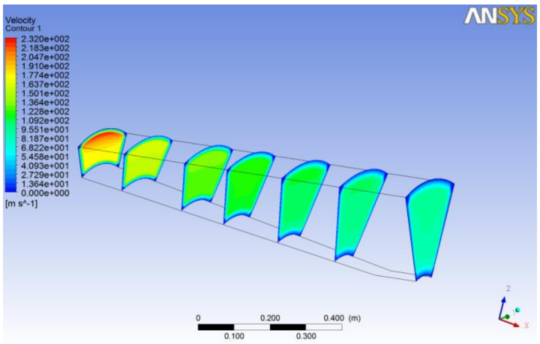

Figure 3.4 contour of velocity (without strut)

Table 3.1 shows CFD analysis results for after burner diffuser duct without struts. The analysis results are compared with the experimental data available in the literature *Mattingly J.D.et al. [4].*

Table 3.1 indicates that the experimentally measured total pressure loss between station 6A (Inlet) and Station 6.1(outlet) is 44 Pascal's, while that predicted by CFD analysis is Pascal's.

Figure 3.1 to 3.4 shows the plots of three important thermodynamic variables (viz: total pressure, static pressure, velocity) for the diffuser mixer from inlet to the exit. It can be seen that the total pressure decreases along the diffuser mixer without struts. This is due to the skin friction effect.

3.2 Flow analysis for afterburner diffuser mixer with aerofoil and cylindrical struts for 0^0 swirls.

Table 3.2 CFD analysis results for the afterburner diffuser mixer with aero foil and cylindrical struts for 0^0 swirls.

Sl No	Description	Unit	Values at station 6.1
			CFD
1	Mass flow rate	Kg/sec	12.96
2	Absolute Total pressure	Pascals	532466
3	Absolute static pressure	Pascals	525122
4	Total temperature	K	686.498
5	Velocity	m/sec	84

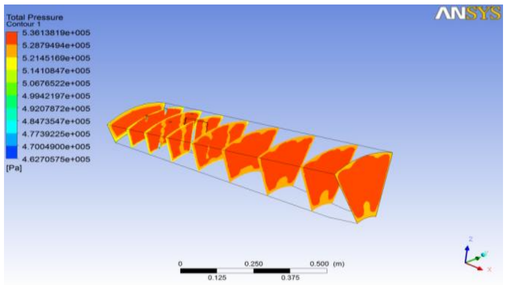

Figure 3.5 contours of total pressure

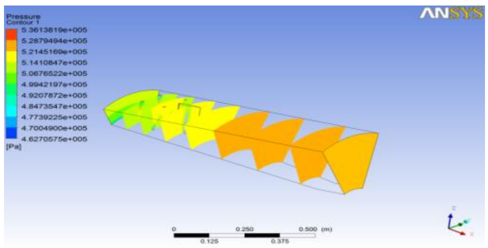

Figure 3.6 contours of static pressure

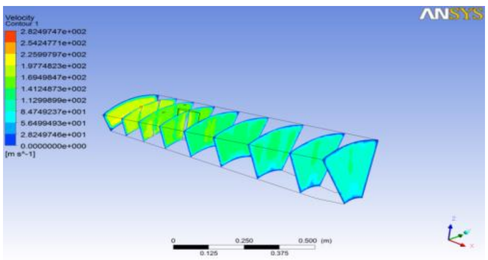

Figure 3.7 contours of velocity

Table 3.2 shows CFD analysis results for the afterburner diffuser mixer with aerofoil and cylindrical struts for 0^0 swirl.Figure 3.5 to 3.7 shows the plots of three important thermodynamic variables (viz: total pressure, static pressure, velocity, etc) for the diffuser mixer from inlet to the exit having aerofoil and cylindrical struts in it. It can be seen that the gain in total pressure of 2542 Pascal's and velocity of 84m/s. Where gained pressure and reduced velocity helps in proper mixing and combustion in afterburner which acts similar to combustion chamber condition. And presence of aerofoil and cylindrical struts in afterburner mixer increases the performance of after burner and helps in providing enough pressure for combustion.

3.3 Flow analysis for afterburner diffuser mixer with aerofoil and cylindrical struts for 0.25^0 of swirl.

Table 3.3 CFD analysis results for the afterburner diffuser mixer with aero foil and cylindrical struts for 0.25^0 swirls.

Sl No	Description	Unit	Values at station 6.1
			CFD
1	Mass flow rate	Kg/sec	12.96
2	Absolute Total pressure	Pascals	532665
3	Absolute static pressure	Pascals	525728
4	Total temperature	K	686.498
5	Velocity	m/sec	81.66

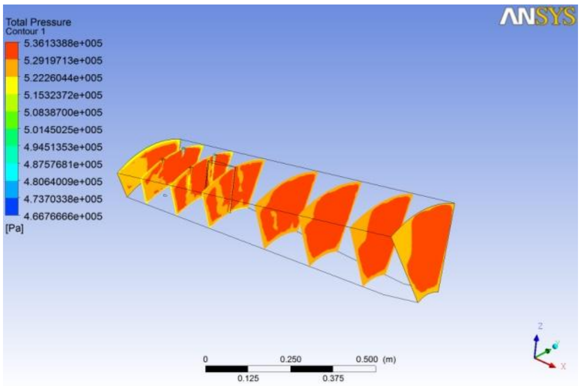

Figure 3.8 contours of total pressure

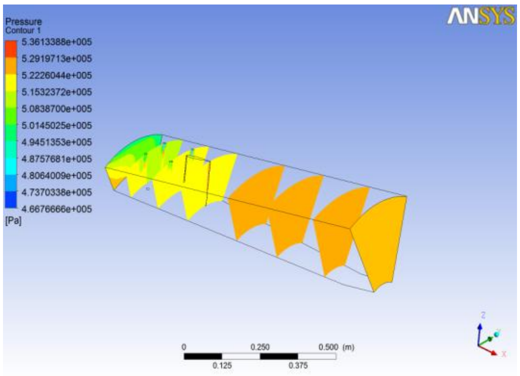

Figure 3.9 contours of static pressure

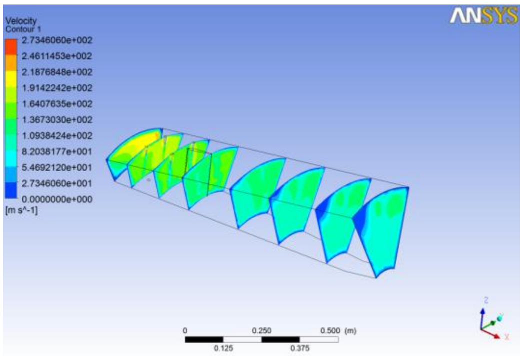

Figure 3.10 contours of velocity

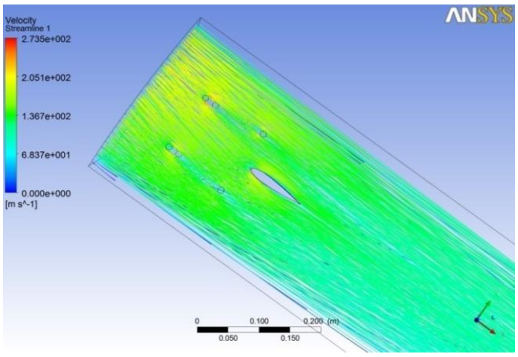

Figure 3.11 contours of stream line

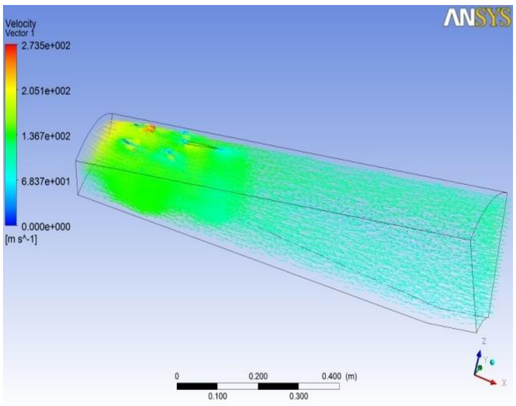

Figure 3.12 vectors around the Airfoil and cylindrical struts

Table 3.3 shows CFD analysis results for the afterburner diffuser mixer with aerofoil and cylindrical struts for 0.25^0 swirls.

Figure 3.8 to 3.12 shows the plots of three important thermodynamic variables (viz: total pressure, static pressure, velocity, etc) for the diffuser mixer from inlet to the exit having aerofoil and cylindrical struts in it. It seen that the gain in total pressure of 2741 Pascal's and velocity of 81.66m/s. Where gained pressure and reduced velocity helps in proper mixing and combustion in afterburner which acts similar to combustion chamber condition. And presence of aerofoil and cylindrical struts in afterburner mixer increases the performance of after burner and helps in providing enough pressure for combustion. And also these struts are converting turbulent flow of gas into stream lines which helps in creating less vortexes and ejecting out easily.

This presence of aerofoil and cylindrical struts in diffuser mixer from inlet to the exit is the one of the best method to obtain good performance from afterburner and it will reduce the possibility of amount of unburnt fuel in afterburner section since it reduces the flow velocity and increase the total pressure.

4. CONCLUSIONS

CFD analysis results for the after burner diffuser mixer without struts is compared with the experimental data given by *Mattingly J.D.et al. [4]*.

The use of combination of aerofoil (NACA 0015) and cylindrical struts are the better for application in gas turbine engines which are equipped with afterburner.

Increase of pressure in the flow with struts is beneficial as it leads to better mixing of air and fuel in the after burner unit and this gives efficient pressure gain for proper combustion.

Aerofoil and cylindrical struts also acts like guide vanes for the flow and also converts swirl flow into stream line as shown in Figure 3.11.

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