Numerical and Experimental Investigations of Synthetic Jets: A Review

[1]Niravkumar L Mayatra, [2]Prof. Krishna Kumar

[1]M.E Thermal Engineering Student, [2]Assistant Professor,
Department of Thermal Engineering,
Shri S'ad Vidya Mandal Institute of Technology, Bharuch, India

***Abstract*—Synthetic jets are developed by the device called synthetic jets actuator, which contains the cavity, orifice and diaphragm. During suction, due to the excitation of diaphragm the jet injected to the orifice and during blowing it comes back to its normal position. During this phase synthetic jet is generated to the medium. Various literatures have been studied based on numerical and experimental. The purpose of the research is to find out the impact of parameters of synthetic jets. By analysis of this literature survey it has been found that synthetic jets are responsible for the delaying the flow separation. Important parameters are at low Reynolds number and low velocities ratios the hairpin vortices are formed and which is responsible for the separation of flow.**

***Keywords*—Synthetic Jet, Flow Separation, Diaphragm, Boundary Layer, Velocity Ratio, Reynolds Number.**

I. INTRODUCTION

Synthetic jets are also known as Zero net mass flux as they are mass less jets as they are formed from ambient fluids without net mass addition. A typical synthetic jet actuator consists of a cavity with rigid sidewalls, a rigid cap with a small orifice at one end and a vibrating diaphragm at the other as illustrated in Fig. 1. As the diaphragm vibrates the ambient fluid is drawn into and blown out of the orifice periodically, producing a jet made up of a train of vortical structures. These vortical structures, if released into a boundary layer through its no-slip boundary, are capable of entraining faster moving fluids to the near wall region hence delaying the flow separation.[1,2]

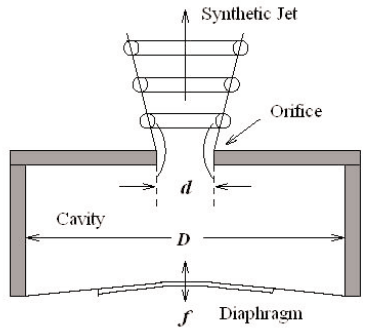

Figure 1. Schematic diagram of a synthetic jet produced with an oscillating diaphragm.

The orifice can be of rectangular or circular based on the application. Most preferable actuator are piezoelectric actuator. There is magnetic shaker which is also used instead of this actuators. The parameter like orifice diameter, orifice height cavity diameter has great impact on the vertical structures. The diaphragm movement is done with the frequency applied to it by the voltage. There are various instruments which is used for measuring the velocity of the synthetic jets are Particle Image Velocimetry, Laser Dopler Vebrometry. Numerical with commercial ansys fluent the simulation can be done for the analysis of the synthetic jets, where user define function is used to give the movement of the diaphragm.

II. LITERATURE SURVEY

***Crook Andrew, W.J Crowther and Norman J. Wood*[3]** has carried out parametric study to know the behavior of synthetic jet on cross flow. Experimental work has been carried out at Goldstein research laboratory at university of Manchester . Here closed return water tunnel is used which forms the cross flow. The jet which is injected is of food coloring dye .There are various result obtained by video camera and VCR. As by holding speed constant, the diaphragm displacements are varied two driving frequencies 5Hz and 10Hz. From results it is clear that at frequency of 5Hz the jet velocity is lower compared to 10Hz. Also lower jet velocity is favorably to roll up the ring to move regular fashion and it becomes the turbulent at 10Hz frequency. By these research it has been proved that synthetic jet have used to control the separation line of turbulent boundary layer.

***Travnıcek. Z, Z. Brouckova, J. Kordı´k,. Vı´t* [4]** here author has carried out experimental work of round synthetic jet in quiescent surroundings. Flow visualization of air as a medium is used to identify different flow regimes. Here hot wire

anemometer is used to find the parameters in terms of Reynolds number and stokes number. Also for verifying theoretical evaluation, additional experiments also has been performed using laser dopler vibrometry. By Reynolds (Re) and Stokes (S) numbers four regimes are developed. They are (a) creeping flow without SJ formation, (b) SJ formation and propagation without vortex rollup, (c) SJ with vortex rollup, and (d) vortex structure breakdown, instability and transition to turbulence. There are various geometry used for the synthetic jet actuator with different orifice diameter. The range of frequency is used is 12 hz -93hz and achieved different vertical structures in the medium. The last vertical structure found is at low Reynolds number.

Jabbal .M , S. Zhong **[5]** have carried out this works to understand and analyze the near wall effect on laminar boundary by synthetic jets. The purpose for these research is to identify the different vertical structure which is responsible for delaying the separation on 2D circular cycle. Here dye visualization technique is used by stereoscopic imaging system which provides quasis three dimensional vertical structure. Also the effect on wall is also been identify by thermochromic liquid crystal bas convective heat transfer sensing system in which liquid crystal change the color when thermal foot prints of passing flow structure. By varying actuator parameter hair pin and stretched vortex rings are the vortical that are interacting with the separation line and hence shows that either of these structure are responsible for delaying the separation.

Chaudhry. Ishtiaq A and S. Zhong **[6]** have carried out experimental investigation to study the behaviour of single circular synthetic jet which is issued into turbulent boundary layer produce on flat plate in cross flow. Initially free stream conditions jet is issued to laminar boundary layer to achieved effective evaluation by interaction of vortices by changing boundary layer could be made . Initially, the laminar boundary layer is produce over flat plate with zero pressure gradient then later with trigger device turbulence id triggered on same boundary layer. Here velocities profiles are drawn for laminar as well as turbulent boundary layers with the help of free stream conditions which are justified by PIV measurements. Parameter space is obtain in graphical presentation for various structure and formation of vertical structure like no jet formation, hair pin vortices stretched and tiled or distorted formation of vortices. The result shows that for maximum flow control in boundary layer is done by hairpin which is form at operating condition at VR between 0.4-0.5. Also hair pin is produced at lowest possible velocity ratio and stoke length and it consumes less input energy.

Xia Qingfeng, ShenghuiLei, Jieyan Ma, Shan Zhong **[7]** have carried out numerical work which is compared with experimental work. Here numerical analysis is done for knowing the behaviour of a circular synthetic jets at low Reynolds number. The quiescent condition is used which is responsible for different flow regimes like no jet formation, jet flow with roll up and jet flow without roll up. These regimes are which is produce in near field of jet orifice during various actuation cylces obtained by tracking the structure. Here velocity profiles are also obtained at central axis. Good correlation is obtain between flow patterns and the jet Reynolds number. These study is useful in designing the more effective synthetic jet actuators which gives momentum transfer at low Reynolds number.

Kral Linda. D, John F. Donovan, Alan B. Cain, and Andrew W. Cary **[8]** have carried out Numerical Simulation of Synthetic jet Actuators. A promising design of fluid actuators for flow control is investigated. Two-dimensional, incompressible simulations of synthetic jet actuators are performed. A modelled boundary condition is developed for the actuator. Three different velocity distributions were examined along the orifice and all three distributions give qualitatively similar flow features. Both laminar and turbulent jets were investigated. Results show good agreement with experimental measurements. A jet flow develops, even though no net mass flow is transfered. Pairs of counter rotating vortices are observed near the jet exit as are observed in the experiments. computational work of synthetic are made to compare with both pulsed jets and steady jets. Little difference is seen in the turbulent flow regime, but the laminar flow shows markedly different results between a steady jet and a synthetic jet. It has been revealed that the modelled boundary condition captures the essential features of the jet without modelling the details of the cavity flow or the detailed breakdown of the vortices.

Chaudhry .Ishtiaq A and S. Zhong**[9]** have carried out this work in flay boundary layer. Here with respect to streamwise, vortical structures with near wall has been investigated. Parameteric analysis have been carried out. Those who are near the wall that is responsible for the delaying the separation of flow. They have shown the graphical represent of blausis profile with respect to the streamwise locations. For the visualization they have used the stereoscopic image system for the visualization of dye. With respect to the parameters various vortical structure have been developed. Like at different stroke length , velocity and Reynolds number . At different operation conditions the stretched vortex rings, hair pin structure rings and tiled structures are developed. Due to the impact of the jet on fluid these vortical structure have been developed.

Zhong S, F. Millet and Wood **[10]**have carried out experimental work to know the behaviour of synthetic jets. Synthetic jets are proceed in laminar boundary layer. Dye flow visualization has been used with the range of actuator operating conditions and free stream velocities of 0.05 ms^{-1} to 0.1 ms^{-1}. The range of frequency used is 2hz to 5hz Here the purpose is to know the interaction effect on vortical structure on flat boundary layer. They studied effect of operating parameters like strouhal number, Reynolds number and velocity ratios. Velocity ratio shows the strength of the jet against the free stream velocity. Based on stroke length, Reynolds number has adequate in quantifying the vortices strength of the vortical structures.

Zhong S, L. Garcillan and N. J Wood**[11]** have carried out this research work for skew and inclined synthetic jets. Here also dye visualization technique has been used. The results are compared with normal synthetic jets. The jets are issued in cross flow. The

Process of vortex roll-up near the orifice exit and how the structure develops and interacts with the cross-flow as it propagates downstream was investigated so as to obtain an understanding of the effect of orifice orientation on the behaviour of synthetic jets. Effects of parameters like Reynolds number, velocity ration and strouhal number has been examined. As the orifice is skew and inclined , the vortices are developed at the orifice exit and that is the region where flow separation is occur. So at that area flow can be delayed with skew and inclined synthetic jets.

III. CONCLUSION

Synthetic jets actuators are used to developed synthetic jets. These synthetic jets have great benefits against the normal continuous jets. Here detail literature survey has been carried out to know the behavior of the synthetic jets in quiescent and cross flow. The are various parameters like stroke length, Reynolds number, strouhal number and velocity ratio has an impact on synthetic jets . the survey shows us that there are three types of vertical structure is seen in the medium. Like stretched, titled and hairpin like structures. Stretched are developed at the high at low velocity ratio and at high Reynolds number. While at low Reynolds number and high velocities ratio, hairpin structure has been developed which is responsible for the delaying the separation of flow and this actuator for flow separation applications.

REFERENCES

[1] JAMES, R.D., JACOBS, J.W. and GLEZER, A. A round turbulent jet produced by an oscillating diaphragm, Phys of Fluids, 1996, 8, (9), pp 2481-2495.

[2] SMITH, B.L. and GLEZER, A. The formation and evolution of synthetic jets, Phys of Fluids, 1998, 10, pp 2281-2297.

[3] Crook, A., W. J. Crowther, and N. J. Wood. "A parametric study of a synthetic jet in a cross flow." In Proceedings of the 22nd International Congress of Aeronautical Sciences. 2000.

[4] Travncek,Z , Z. Brouckova, J Kordik and T. Vit.(2013) “Visualization of synthetic formation in air. Journal of Visualization 1-15

[5] Jabbal, M., and S. Zhong. "The near wall effect of synthetic jets in a boundary layer." International Journal of Heat and Fluid Flow 29, no. 1 (2008): 119-130.

[6] Chaudhry, Ishtiaq A., and S. Zhong. "A single circular synthetic jet issued into turbulent boundary layer." Journal of Visualization 17, no. 2 (2014): 101-111.

[7] Xia, Qingfeng, Shenghui Lei, Jieyan Ma, and Shan Zhong. "Numerical study of circular synthetic jets at low Reynolds numbers." International Journal of Heat and Fluid Flow 50 (2014): 456-466.

[8] Kral, Linda D., John F. Donovan, Alan B. Cain, and Andrew W. Cary. "Numerical simulation of synthetic jet actuators" AIAA paper 1824 (1997): 1997

[9] Chaudhry, Ishtiaq A., and Shan Zhong. "Understanding the interaction of synthetic jet with the flat plate boundary layer." ICARME, Trivandrum, India(2012).

[10] Zhong S., F. Millet, and N. J. Wood. "The behaviour of circular synthetic jets in a laminar boundary layer." Aeronautical Journal 109, no. 1100 (2005): 461-470.

[11] Zhong, S., L. Garcillan, and N. J. Wood. "Dye visualisation of inclined and skewed synthetic jets in a cross flow." Aeronautical Journal 109, no. 1093 (2005): 147-155.