Simulation and Analysis of Flow through Sudden Expansion

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Abstract— This project is based on ticketing and identification of the passenger in the public transport. In the big city like Mumbai, Kolkata we have a severe malfunction of public transport and various security problems. Firstly, there is a lot of confusion between the passengers regarding fares which lead to corruption, Secondly due to mismanagement of public transport the passengers faces the problem of traffic, thirdly we have severe security problems in public transport due anti-social elements. This project suggest a user friendly automated ticketing system which will automatically deduct the passenger's fare according to the distance travelled as well as detect the passenger's identification. This could be only possible by use of NFC e-tickets. This project basically deals with the verification and ticketing of the passengers sitting in the bus.

Key words: NFC tags, Android based NFC Reader

I. INTRODUCTION

In the present study the computer simulations were conducted to control the base pressure with micro jets. In the present study the attention was focused on the static pressure at the base as well as suddenly expanded duct. The flow parameters considered in the present investigation are the inertia available at the exit of nozzle and the non-dimensional nozzle pressure ratio. The geometrical parameters considered are the area ratio between the enlarged duct cross-section and the exit area of the nozzle, which is kept 2.4, and the L/D ratio of suddenly expanded enlarged duct, which is varied from 1 to 10. All the simulations were conducted with as well as without microjets.

II. INTRODUCTION

The pressure at the blunt base is substantially low compared to the atmospheric pressure. The flow field at the base which is very complex is one of the significant and complex problems in fluid dynamics. The flow at the base will be wave dominated. When the flow at the nozzle exit is under influence of favourable pressure gradient, under these conditions when the jets are operated, wave will be positioned at exit of convergent flow accelerating device, where as in the case of correctly expanded case still waves are bound to be there at the nozzle exit, however, for correctly expanded case these waves are very weak. It is well known that at subsonic speed due to the sub-atmospheric pressure in the base the magnitude of the base drag will be 10% of the net drag, whereas the major contribution will be from the skin friction drag. However, at transonic speed the component of the base drag is significant and it may be 60 % of the net drag. Therefore, even a little enhancement in pressure at the blunt base could lead to substantial decrease in the drag and ultimately increase in the range of the projectiles and missiles.

The issues of suddenly expanded flow of high speed flow at the blunt base; like at base of unguided rockets, shell and their relation with pressure at the base which; is normally sub-atmospheric and hence; the drag, which is accounts for countable part of net drag is governed by the sub-atmospheric pressure at the base.

In view of above it has been the subject of intensive study for many years due to its academic interest and its real-world applications.

In order to reduce base drag and improve the base pressure several research and experimental has been done. For finding the base pressure there is an alternate option available, in contrast to the experimental method, which is computer based simulation and analysis.

There are two big advantages to performing a simulation rather than actually building the design and testing it. The biggest of these advantages is money. Designing, building, testing, redesigning, rebuilding, retesting,... for anything can be an expensive project. Simulations take the building/ rebuilding phase out of the loop by using the model already created in the design phase. Most of the time the simulation testing is cheaper and faster than performing the multiple tests of the design each time. Considering the typical budget cheaper is usually a very good thing. For example in the case of an electric thruster the test must be run inside of a vacuum tank. Vacuum tanks are very expensive to buy, run, and maintain. One of the main tests of an electric thruster is the lifetime test, which means that the thruster is running pretty much constantly inside of the vacuum tank for 10,000+ hours. This is pouring money down a drain compared to the price of the simulation.

The second biggest advantage of a simulation is the level of detail that you can get from a simulation. A simulation can give you results that are not experimentally measurable with our current level of technology. Results such as surface interactions on an atomic level, flow at the exit of a micro electric thruster, or molecular flow inside of a star are not measurable by any current devices. A simulation can give these results when problems such as it's too small to measure, the probe is too big and is skewing the results, and any instrument would turn to a gas at those temperatures come into the conversation. One can set the simulation to run for as many time steps he desire and at any level of detail desired the only restrictions are one's imagination, programming skills, and CPU capability.

The aim of this project work is to find base pressure ratio Pb/Patm using very popular analysis software ANSYS for both cases i.e. with and without control. At the same time how the wall pressure distribution is affected by microjets is also studied.

III. LITERATURE REVIEW

Kurzweg [1] conducted experiments in supersonic wind tunnels before 1951 for 3 years (N.A.C.A. and N.O.L.) showed that the pressure at the base of bodies is essentially a function of parameters that govern the boundary layer. Hence, the base pressure is closely connected to surface friction and heat-transfer phenomenon. Experimental results obtained by him in the N.O.L. supersonic tunnels in a Mach range 1.5-5.0 on cylindrical bodies with and without boat-tails with conical heads under various systematic mechanical and thermodynamic variations of the boundary layer are presented and compared with theoretical results.

Wick [2] studied experimentally for sonic flow. He conducted experiments for suddenly changing area. His main concern was to find the influence of boundary layer.

Korst [3] wrote comment on the boundary layer effects. He wrote Comments on suddenly changing area of sonic condition. He compared his theoretical results which utilize a two-dimensional flow model.

Wood [4] studied the effect of base bleed on a periodic wake. He concluded that Base bleed reduces the drag of an aerofoil, by delaying the onset of instability in the separated shear layers. The proportion of vorticity which actually enters the vortex sheet after being shed from the model falls from an initial value of about 0.5 as the shear layers increase in length. In his experiment, the optimum bleed was given by a bleed coefficient of 0.125. This gives a drag reduction equal to that produced by a long splitter plate and it was thought that little further improvement is possible by any method of wake interference. No attempt was made by Wood to explain either how base bleed stabilizes the shear layer or why very small bleed quantities appear to have the reverse effect. The method used by the Wood to determine the properties of the vortex street was an indirect one, based on the assumed validity of the VON KARMAN vortex street.

Heskestad [5] found that for one particular geometry, Reynolds number, and suction rate beyond critical value the initial border to the remaining pocket of separated flow behind the step appeared common to expansion ratios greater than a certain minimum. On the other hand, turbulence was found to propagate increasingly faster into the potential core of the flow as expansion ratio increased.

Roache [6] obtained a new method of implementing the re-compression condition which improves convergence properties for base bleed. A criterion for selection of the wake radius ratio was included in the flow model, thus eliminating all empirical parameters except the jet spread parameter (eddy viscosity). Calculations were made for base pressure, with and without base bleed, on cylinders, sharp cones, and on blunted cones.

IV. METHODOLOGY

A. *Conceptual Details:*

The magnitude of base pressure in such a flow field, i.e. suddenly expanded flow, depends on numbers of parameters such as inlet velocity, pressure, viscosity , level of turbulence (i.e. Reynolds no.) etc.

But in our project we will focus only on following three parameters for simulation.

Considering Area ratio of 2.4

Varying Length to diameter ratio

– Use of microjet

By varying above stated parameter results and simulation will be obtained and results will be tabulated and plotted on graph.

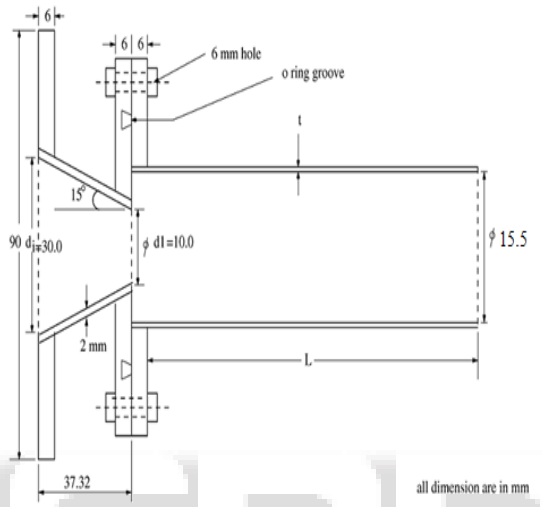
B. *Software and Analysis Detail:*

1) *Software to Be Used*

In the project Ansys will be used for analysis and simulation. Ansys is a very popular software used in both researches and industries. ANSYS offers a comprehensive software suite that spans the entire range of physics, providing access to virtually any field of engineering simulation that a design process requires. Organizations around the world trust ANSYS to deliver the best value for their engineering simulation software investment.

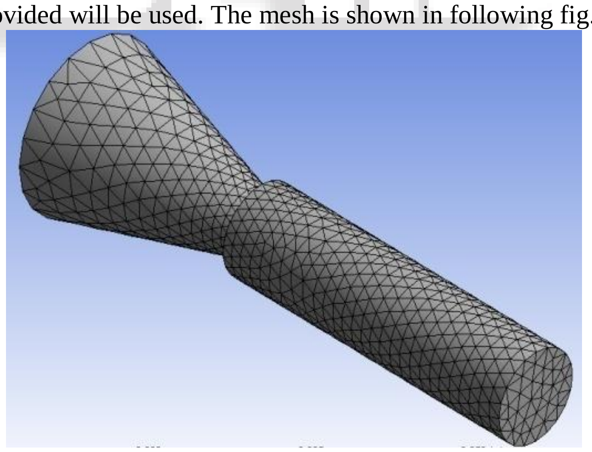
2) *Analysis Details:*

a) Geometry



b) Mesh:

Since geometry is not of very complex type, default mesh provided will be used. The mesh is shown in following fig.



c) Solver setting in fluent:

The solver type used is, "pressure based", which enables the pressure-based Navier-Stokes solution algorithm In time setting, flow is set to be steady.

1) Model details:

Effect of temperature, heat exchange and radiation etc is not considered. Flow is set to be turbulent and k-epsilon model was used.

2) Material:

Air as the fluid is used. Reason of choosing air is that, most of the experimental study of sudden expansion type of flow has been conducted using air. It helps us to compare our results with that of experimental one, in a better way.

The material of the pipe used is Aluminium.

3) Boundary condition:

As mentioned earlier following combination of NPR (Nozzle Pressure Ratio) and L/D is used along with area ratio 2.4.
L/D :- 1, 2, 5, 6, 8,.
NPR :- 1.5, 2, 2.5, 3.

All the above setting gave a convergent result within 200 iterations for all values of NPR and L/D. Convergence criteria, for every equation was set to 0.001 which is the default value.

V. RESULT

A. Introduction:

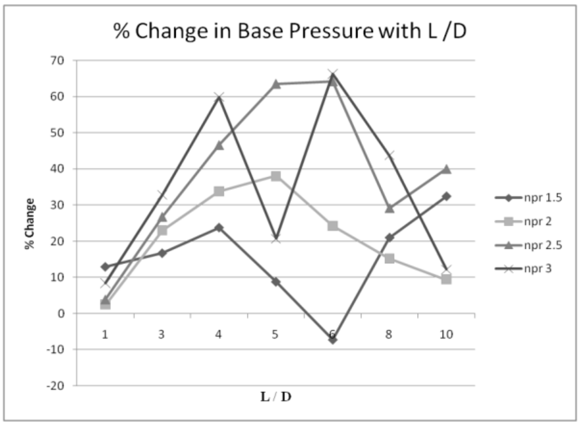
The present simulation study focuses on efficacy of the control in form of microjets as an active flow controller, located in theregion of base of suddenly enlarged tube having same axis as that of nozzle, to modify static pressure at base and also to study how it is going to manipulate the flow field. The parameters considered in the present experimental study are the area ratio (A2/A1) set to 2.4, (L/D) ratio, inertia of jet and Nozzle pressure ratio (NPR for level of expansion). All measured parameters like static pressure at base(Pb), static pressure at wall(Pw) converted into non-dimensional thru dividing them by ambient pressure (atmosphere) to which flow from suddenly expanded axi-symmetric duct was discharged.

B. Results:

From literature, it has been observed that not only relief ratio & NPR, inertia available at outside (i.e. exit) of the flow accelerating device has a very important role to play on the static pressure at the base. To specify the gain in static pressure at the base region likely to be obtained by causing micro jets, the plots of the static pressure at the base region are presented as % increase in static pressure at base area used for presenting the results.

1) % Change in Pb/Pa vs. L/D Ratio:

Fig. 4.2.1 shows percentage change in static pressure at base vs. L / D Ratio as function of (NPR). A maximum gain of around 66.3 per cent is achieved for NPR = 3. From the above results it is found that unlike passive controls the favourable pressure gradient does not ensure augmentation of the control effectiveness for active manipulator in the form of micro jets. To understand this phenomenon we need to look at the development of the flow at base and the interaction of the micro jets with the base vortex, the shear layer and shock waves present in the base region within the reattachment region (Fig. 1.1). Since the flow is being exited from a convergent nozzle to an enlarged duct, the NPR required for the flow to achieve the critical condition is 1.89. This means that the flow will be under expanded for NPRs up to 2 and above. Therefore, in case of micro jets as active manipulator, it is observed that favourable pressure gradient alone is not sufficient to ensure the effectiveness of the control which is true for passive control as discussed by Lovaraju et.al. [13].

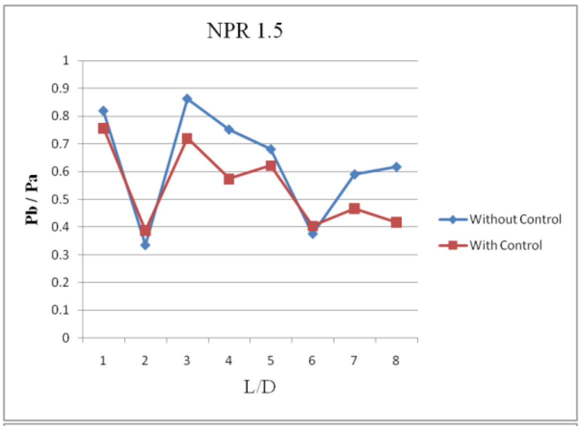


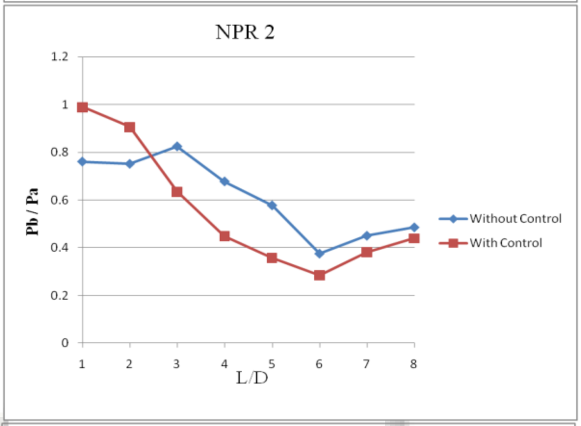
2) Pb/PaVariation vs. L/D Ratio:

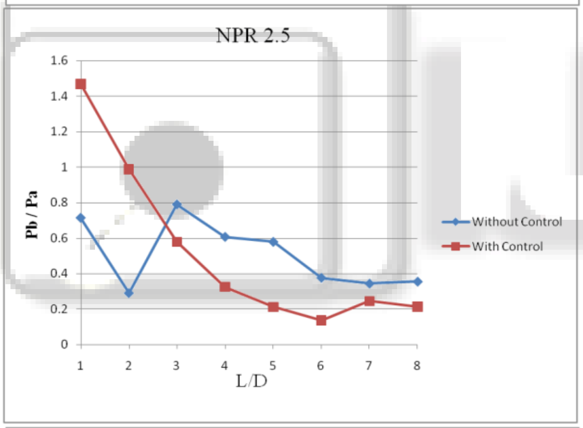
When the simulations were conducted to control the pressure at the base either to increase or decrease and to accomplish this goal the solver setting is kept such that flow exiting from the nozzle experiences becomes either correctly expanded or under expanded case. While scanning the literature it was concluded that weak waves will be located at the exit of the nozzle for underexpanded condition. To predict effect of expansion level on pressure at base in the presence of control and in the absence of control the static pressure at base was plotted with respect of L/D and NPR are presented. From the second order shock expansion theory it is concluded that, whenever an expansion fan is coming out from the exit of the nozzle the viscous shear layer emanating from the nozzle will get deflected towards the center line of the nozzle due the presence of the shock. Which is in turn likely to delay the reattachment of the flow with the enlarged duct wall and this will result in a larger length of the reattachment as compared to a case when the shock is not present. The reattachment length will strongly affect the strength of re circulation, increment or decrement of this span will change static pressure at base.

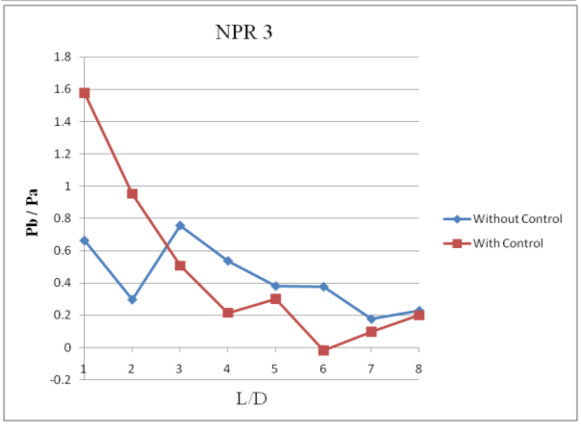
Non-dimensionalized static pressure at base vs.L/D ratio for NPR 1.5, 2, 2.5 & 3for present study of flow in presence as well as in the absence of the control mechanism are revealed in Figs.4.2.2 to 4.2.5. From the figure it is realized, the dependency of pressure at basewith NPR is unchanged by the control. Nevertheless, the control mechanism tends to modify static pressure in the base region. Further, it is also observed that the control mechanism and its effects in modifying static pressure at base gets substantially increased with the enhancement of the level of inertia.

Also, Rathakrishnan [8] presented that lowest length is three times dia. for sonic, subsonic & under expanded sonic jet with sudden expansion without control. In accordance with this here, it also realized that even length to dia. 1 and above experiences definite control of static pressure at basewith micro jets and the requirement of this lowest duct length happens to be L/D = 1. The above discussed trend may be due to the presence of i) expansion or ii) shock wave at exit of the nozzle lip, the relief available because of relief ratio will also affect pressure at base. Furthermore, it should be kept in mind that the control mechanism were kept at the base were located at the 1.3 times dia. (P.C.D.) in the base, however for 2.4 area ratio the microjets are very close to the exit of the nozzle and not at the middle of the base. This is because pitch circle diameter (P.C.D.) for micro jets were kept same for all area ratios.









3) Static Pressure at Wall:

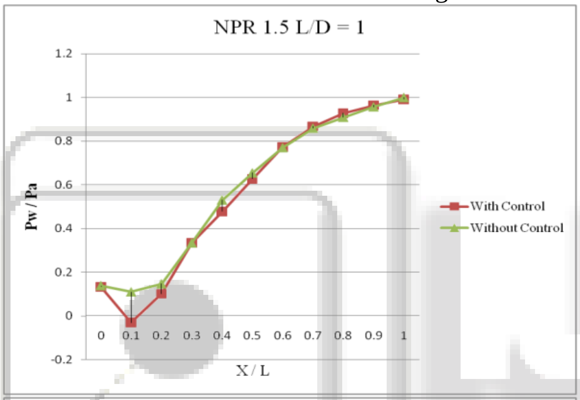
One of the common problems encountered whenever we study the sudden expansion flow field is that pressure field in the duct becomes oscillatory because of the "Ejector Pump" action (Wick [2]) at the base region i.e. the vortices are getting formed at the base because of expansion of the viscous shear layer from nozzle and getting ejected to main flow continuously. This action was referred to as the "Jet Pump action" by Wick [2]. This action renders the flow in the duct to become oscillatory. These oscillations are reflected as variation in the static pressure at wall of the duct. Therefore, it becomes mandatory on the part of a researcher working on sudden expansion problems to monitor static pressure at wall in the suddenly expanded duct. In other words when we employ a control to modify the base pressure level, there is a possibility that the control might augment the vibratory behaviour of the flow pattern in the suddenly expanded duct which is not desirable. To account for this undesirable phenomenon (aggravating the vibratory nature of the flow) spreading of pressure at wall for enlarged pipe was noted for all mixture of variables of existing simulation study.

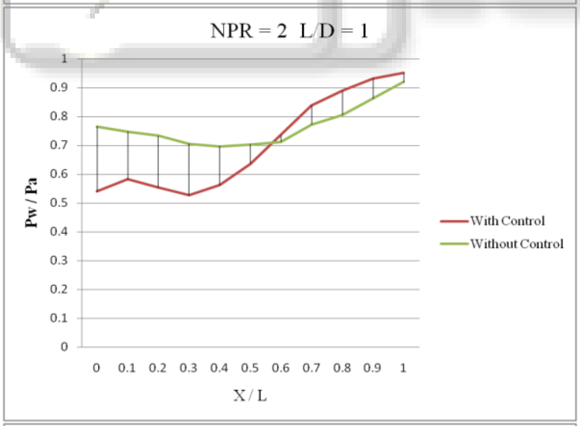
Pressure at wall for present 2.4 area ratio is presenting in Figs. 4.2.6 to 4.2.29. It is seen that when control is activated the quality of the flow in the enlarged duct is not disturbed as shown inFigs.4.2.6 upto 4.2.8 and also inFigs.4.2.10, 4.2.12, 4.2.14, 4.2.18 and 4.2.19. The pattern of wall pressure in the duct with and without control is same except for the higher NPRs namely 2.5 and 3.0 and also the wall pressure for few pressure taps is very low, the physical reason for this pattern may be due to the presence of base vortex, its interactions with the waves present at the nozzle lip, interaction with the shear layer, the dividing stream line and also the its proximity with the reattachment point.

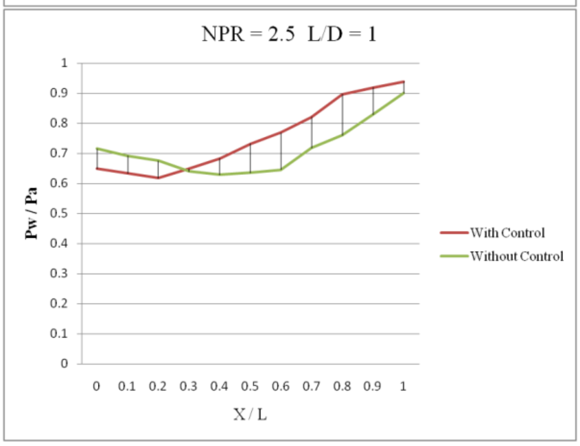
It is interesting to see from these results that even though most of the cases exhibit similar behaviour as those for the other L/D ratios, showing no negative influence of the control on wall pressure distribution, there are some combination of parameters influencing the wall pressure very strongly to assume much lower value compared to without control cases, as shown in figures 4.2.9, 4.2.10, 4.2.12, 4.2.14 and 4.2.17. All these cases, exhibited much reduced noise level compared to the without control case. A physical explanation for this interesting phenomena calls for a deeper investigation around these parameters. Fig. 4.2.9 indicates that the wall pressure in the duct was smooth and control renders the flow to become oscillatory. and at the time base pressure assumes low values and the jet noise is reduced significantly.

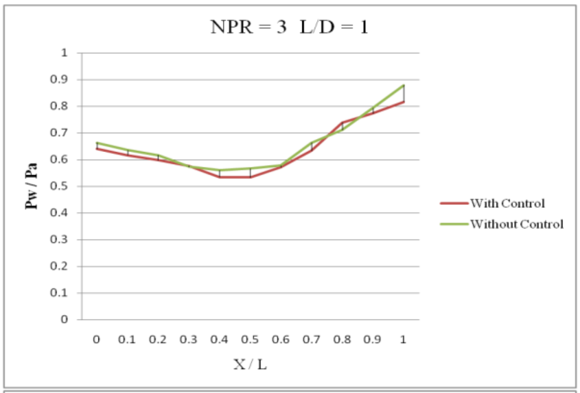
Pressure at wallfor L/D = 6 and NPR = 2 are illustrated in Fig. 4.2.23. It is seen from figure that static pressure at wall is oscillatory in nature for without control case and when the micro jets are activated the control outcomes in the reduction of pressure at wall & reduction in the noise level of the jet. Further, it is seen that when micro jets are activated the vibratory trend of the flow in the duct is being suppressed and the wall pressure is progressively increasing which indicates that shock wave which was present in the absence of micro jet is no more present. Whenever the wall pressure has increased due to the control this has resulted in increase of the noise.

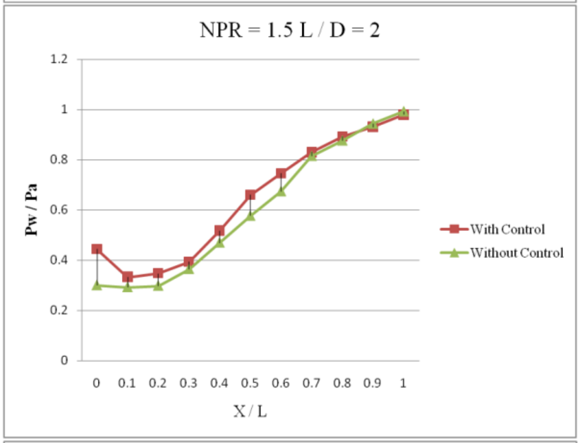
Static pressure at wall results for L/D = 6 and NPR = 2.5 is described in Fig. 4.2.24. It is seen that initially static pressure at wall assumes low values then increase progressively then there is a decrease and then continuously it increases. This dip may be due to the presence of the shock waves as well as due to the mixing of the flow. Fig. 4.2.25 presents the static pressure at wall results for L/D = 6 and NPR = 3, here the trend is on the similar lines discussed, however, in this case flow field remains oscillatory for with and without control case except near the reattachment point and control outcomes in rise of static pressure at wall, further, in downstream of the flow static pressure at wall recovery takes place. This oscillatory nature of the flow field may be because of the vortex at base, viscous-inviscid interaction, interaction with the viscous shear layer as well as the interaction with the shock wave. Static pressure at wallfor L/D = 5 and NPR = 3 is shown Fig. 4.2.21, they show the similar trends as discussed for Fig. 4.2.24. Static pressure at wall results for L/D = 3 and NPR = 3 is shown in Fig. 4.2.17. Here, again control outcomes rise of pressure at wall & small fluctuations are due to the presence of waves, also may be due to lower L/D which may be just suffice the lowest value for flow to be with duct wall and the wavy nature is due the presence of waves well as due to the influence of back pressure. Fig. 4.2.12 presents the results for L/D = 2 and NPR = 2.5, from the beginning the static pressure at wall assumes high values this may be due to the combined effect atmospheric pressure, shear layer, the vortex in the base region, & dividing stream line. Similar results as discussed above are revealed in Fig. 4.2.11.

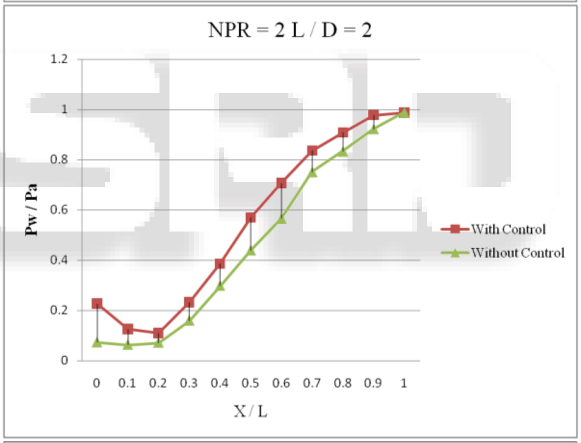


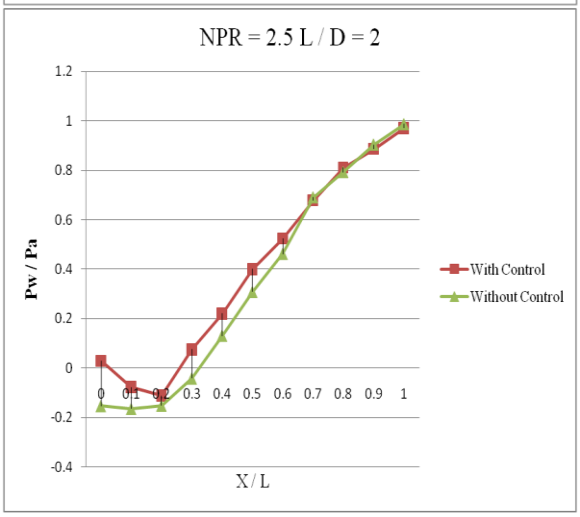


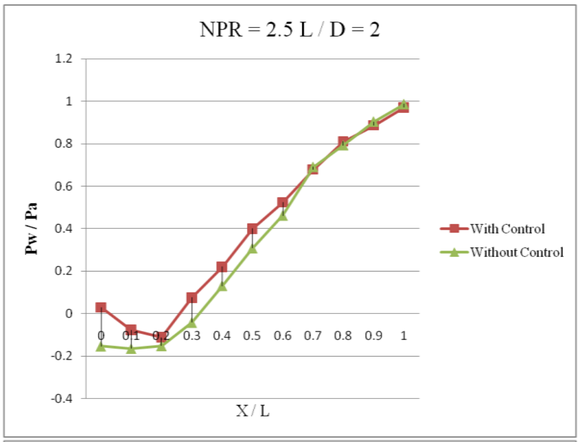


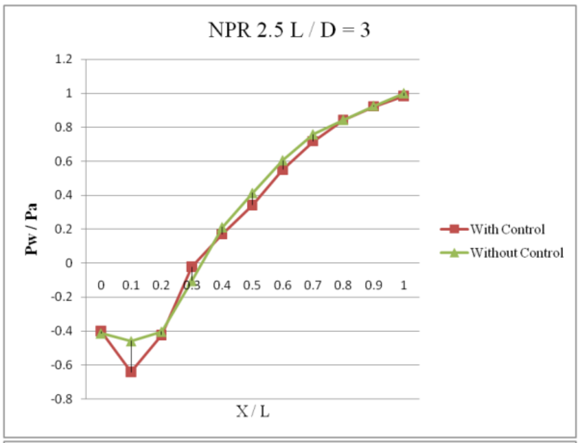









NPR = 2.5 L / D = 2
Pw / Pa
X / L
With Control
Without Control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Pw / Pa
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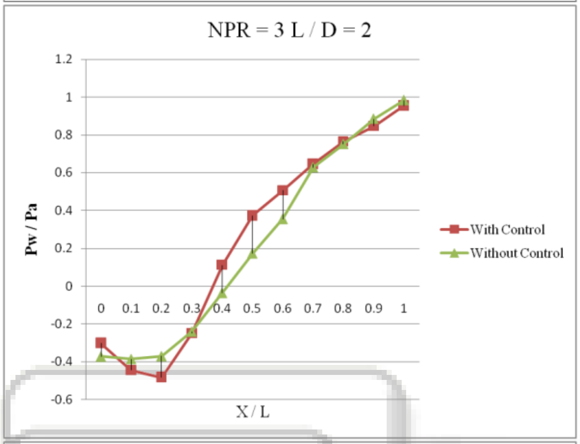
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Pw / Pa
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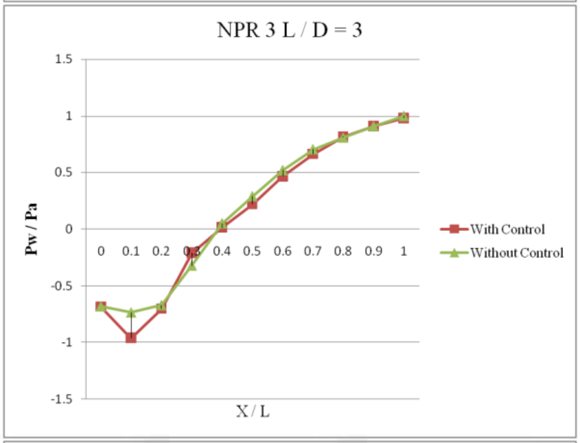
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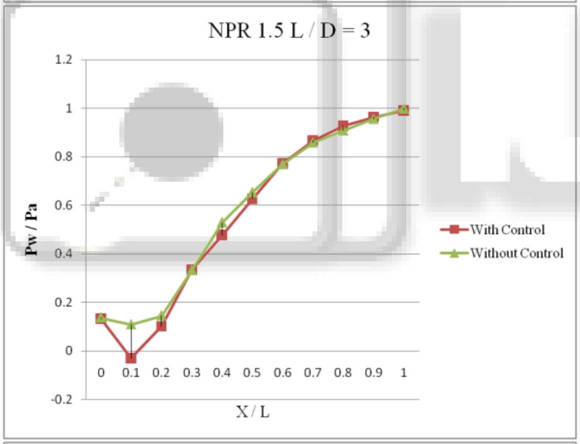
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Pw / Pa
X / L
With Control
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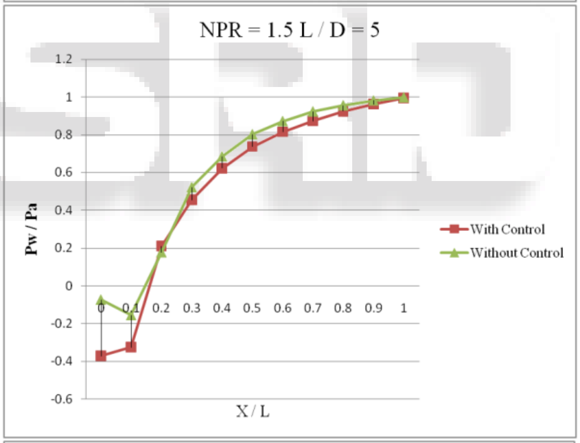
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Pw / Pa
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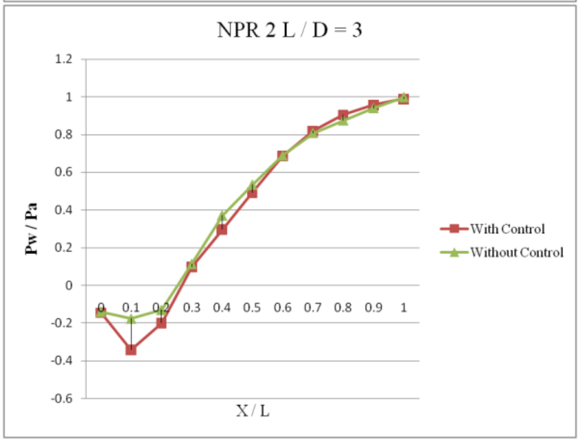
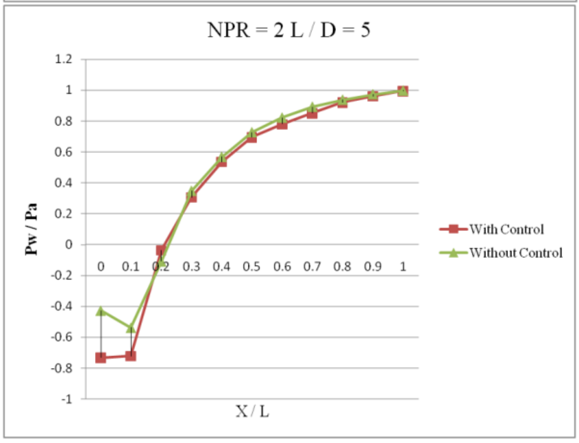

NPR 2 L / D = 3
Pw / Pa
X / L
With Control
Without Control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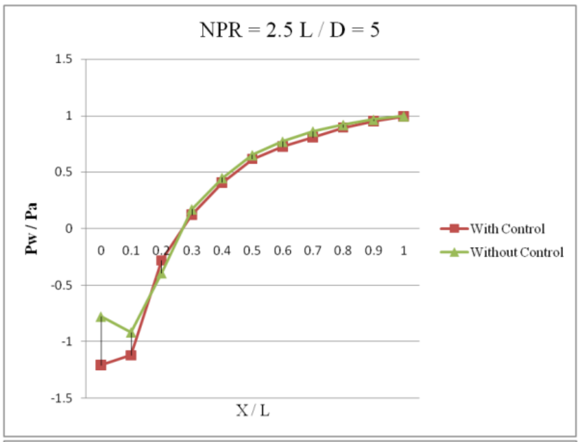
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Pw / Pa
X / L
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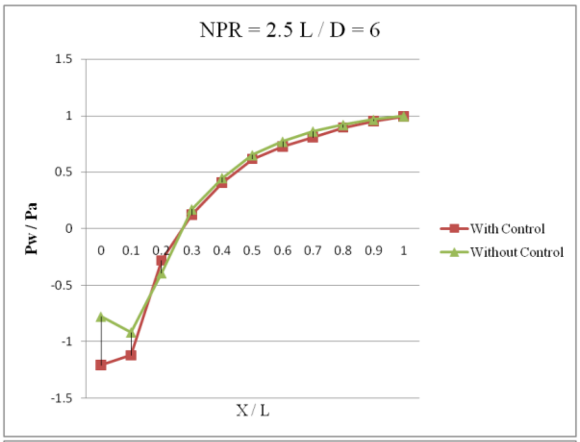
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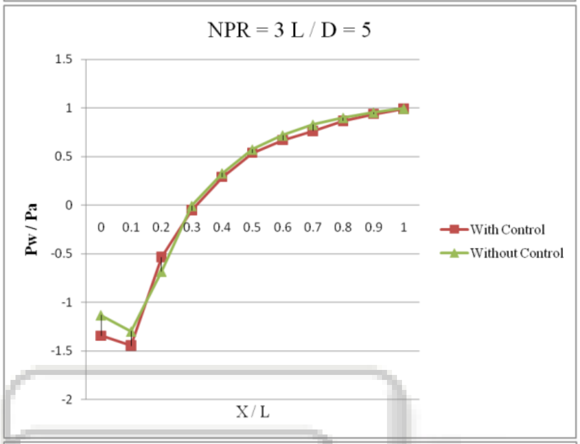
Pw / Pa
X / L
With Control
Without Control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Pw / Pa
X / L
With Control
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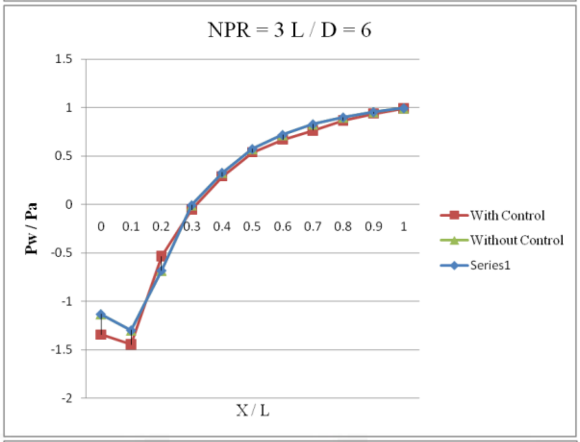
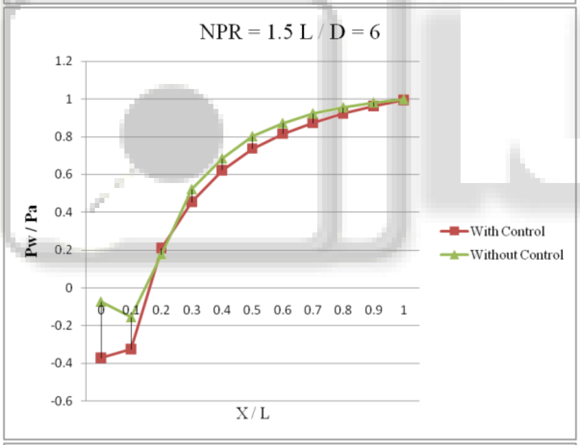

NPR = 3 L / D = 6
Pw / Pa
X / L
With Control
Without Control
Series1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X / L
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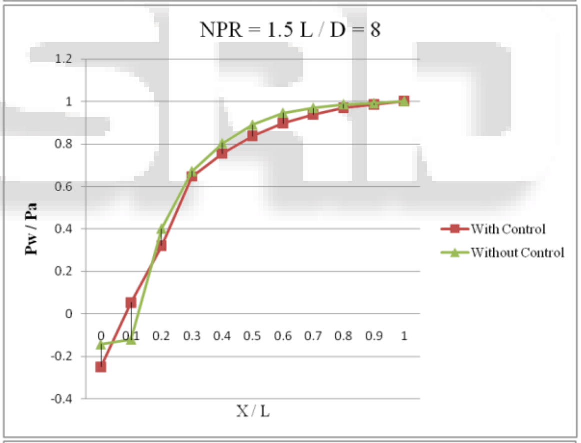
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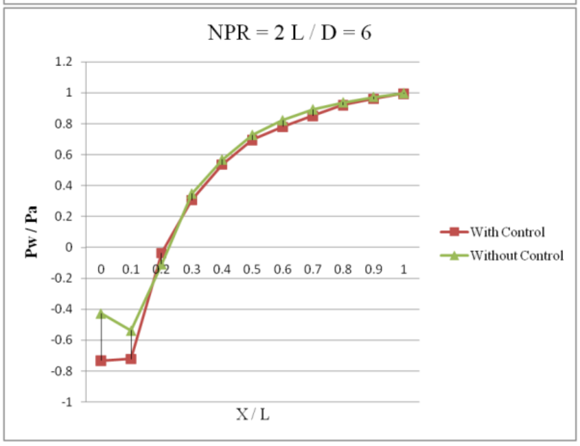
Pw / Pa
X / L
With Control
Without Control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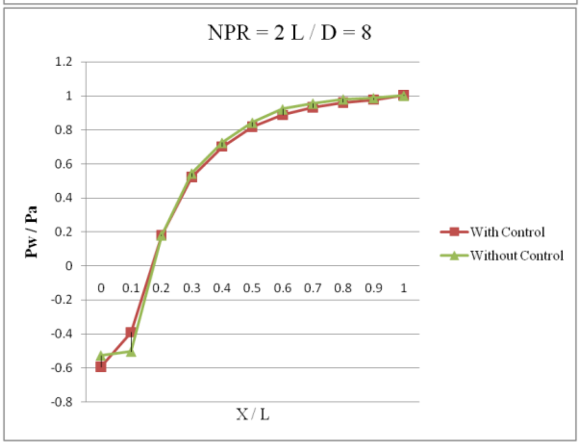
Pw / Pa
X / L
With Control
Without Control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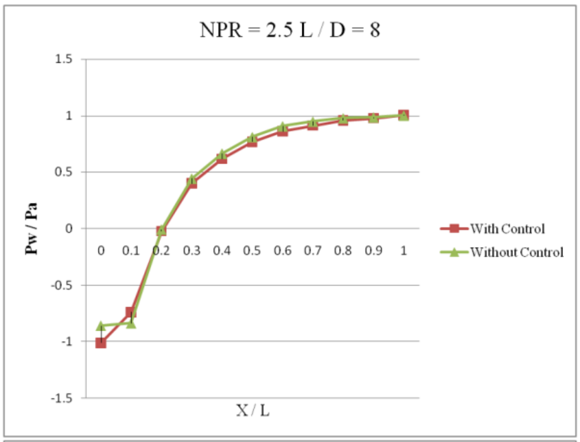
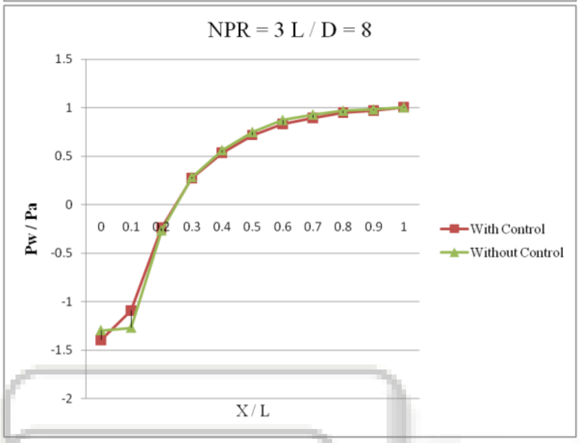
X / L
With Control
Without Control





Outcomes for pressure at duct wall for the lowest 2.4 area ratio are exposed in Figs. 4.2.6 to 4.2.29. It is realized that when control is activated the quality of the flow in the enlarged duct is not disturbed. The pattern of static pressure at wall in the duct with and without control is same except for the higher NPRs namely 2.5 and 3.0 and also the static pressure at wall for few pressure taps is very low, the physical reason for this pattern may be due to the presence of base vortex and also this area lies within the reattachment length.

As per previous discussion, it is realized that control has got no adverse effect for the flow in the suddenly expanded duct static pressure at wall. With this it can be taken that the present control mechanism can serve as static pressure at base controller without imposing any adverse effect in the pressure field in the enlarged duct.

VI. Application

A sudden expansion of flow both in subsonic and supersonic regimes of flow is an important problem with a wide range of applications. The use of a jet and a shroud configuration in the form of a supersonic parallel diffuser is an excellent application of sudden expansion problems. Another interesting application is found in the system used to simulate high altitude conditions in the jet engine and rocket engine test cells; a jet discharging into a shroud and thus producing an effective discharge pressure, which is sub atmospheric. A similar flow condition exists in the exhaust port of an internal combustion engine, the jet consisting of hot exhaust gases passes through the exhaust valve. Another relevant example is to be found in the flow around the base of a blunt edged projectile or missile in the flight where the expansion of the flow is inward rather the outward as in the previous example.

VII. Future Scope

Since in the project only three parameters are mainly considered which are area ratio, length to diameter ratio and use of micro jet and the combination of these but there are various other parameters which one must have to consider such as nozzle pressure ratio, inlet velocity, Reynolds number and viscosity of different fluids. In future further study can be conducted using these parameters or combination of these parameters. Further, since in project only subsonic and sonic velocities are considered, one can also take into account supersonic velocities as well.

VIII. Conclusion

Conclusion from this project it is evident that all these parameter that is length to diameter ratio, area ratio and use of microjet are very effective in controlling the base pressure of suddenly expanded flow field. Base pressure is mainly dependent upon these parameters. Though there are other significant parameter but those are not much significant like these things. Since till now all the researchers have studied controlling base pressure using passive control our project focuses on active control and from project it is evident that the result generated from experiments, active control is a very great way of controlling base pressure and also it does not affect the pressure field of wall also results can be obtained through computer based analysis for various pcd and orifice hole diameter and we have a number of result for different combination.

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