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MACH ANALYSIS ON IMPINGING JETS

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ABSTRACT

Impinging jet finds applications in wide variety of engineering problems. In the vertical takeoff and landing of V/STOL, rockets, and missile firing applications, the jet impingement plays vital role in the field of aerospace engineering. As the jet impinges vertically on the launching ground, jet flow might influence the rear part of vehicle and body balance. This may act adversely on the vehicle systems, so there is a necessity to study the jet impinging characteristics for designing proper launching stations to divert the jet flow away from the vehicle vicinity in order to understand the impingement jet characteristics a thorough study investigation on the behavior of its characteristics is very much necessary the present problem dealing with a subsonic and sonic jet impingement on normal planes for Mach number 0.4, 0.8 . At an axial distances X/D 1, 5, 10, 15.

KEYWORDS: Impinging Jet, Characteristics, Subsonic, Mach number, rockets.

INTRODUCTION

The jet may be defined as a continuous fluid flow issuing from an orifice in to a medium of lower speed fluid, by possessing the characteristics of that "the ratio of width to axial distance is a constant" with respective to the distance from the orifice. Impinging jets have wide applications in aerospace engineering, like in V/STOL, rockets, missile firing and turbines. As the jet impinges vertically on the plane (boundary), jet flow will influence the rear part of the vehicle, balance of the vehicle and the boundary also. This may act adversely to the vehicle systems. So there is a need to study the jet impingement characteristics for designing proper launching stations and to design the structures of the ships (for analyzing of

balance of vehicle). At same time there will be a need to divert the flue gasses from the vehicle vicinity. There will be requirement to study the far-field losses also to analyze the vehicle performance. Generally the impinging flow produces the fountain flow characteristics. Fountain flow or the reverse flow resulting from the collision of the radial wall jet that develops after impingements

EXPERIMENTAL SETUP AND PROCEDURE.

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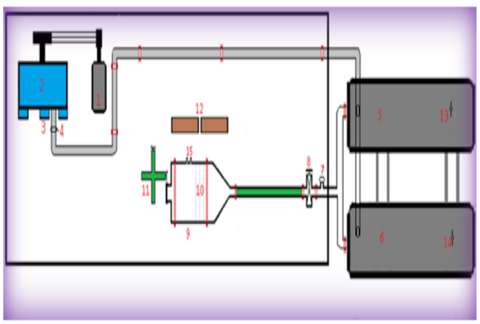
The experiments were conducted in the open jet facility at the Aerodynamics laboratory, Lakireddy Bali Reddy College of Engineering, Mylavaram, India. The test facility consists of compressed air supply system and open jet test facility. The layout of the experimental jet facility laboratory is as shown in Figure.



1. 20 hp induction motor
2. Reciprocating compressor
3. Activated charcoal filters
4. Non-return valve
5. Storage tank 1
6. Storage tank 2
7. Pressure gauge
8. Pressure regulating valve
9. Stagnation chamber
10. Screens
11. Traversing system
12. U-tube manomètres
13. safety valve 1
14. Safety valve 2
15. Two pressure ports

Lay-out of the open jet facility laboratory

Calculations:

The head difference in U-Tube manometer for corresponding inlet Mach number can be calculated by using the following steps.

Calculation of head Mach number:

From the gas tables for M = 0.1,

From the isentropic relation:

Corresponding Pressure ratio is, (P_{atm}/ P_{stag}) = 0.9930

We know that, $P_{gauge} = P_{absolute} – P_{atmospheric}$

P_{gauge} = 709.27 N/m^2 [P_{atm} = 101325 N/m^2]

We know that, $P_{gauge} = \rho gh$

For Water: h = 7.23 cm and For Mercury h = 0.5 cm

RESULTS AND DISCUSSIONS :

1. **Centerline Mach-number decay**:

Measured pitot pressure along the jet centerline, with the assumption that static pressure in the jet field is the atmospheric pressure, were converted to Mach numbers 'M' using the isentropic relation. This assumption on the static pressure is valid for all subsonic Mach numbers since they are always correctly expanded. The calculated Mach numbers were normalized by the corresponding nozzle exit Mach numbers (M_e). The Mach number (M/M_e) variation along the axial distance (X/D) for Mach 0.4 and 0.8, jets with various wall distances are shown in bellow. Centerline Mach number decay is the basic measurement in the jet flows study. This measurement captures various zones of jet, such as potential core zone, characteristic decay zone, fully developed zone.In present study the centerline decay with respect to different wall distance is studied.

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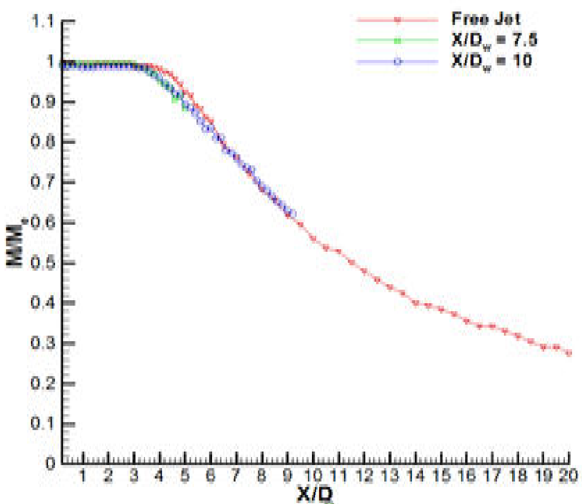
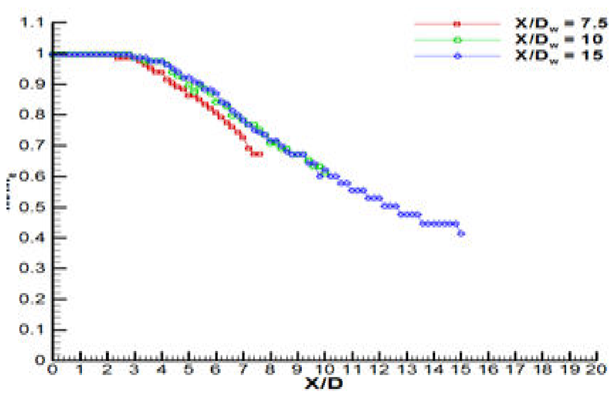


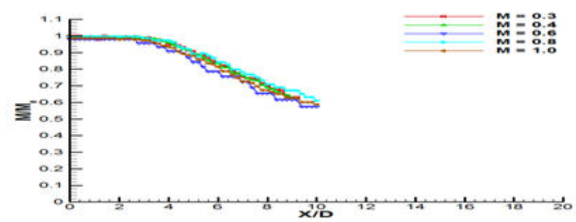
Centerline Mach number decay for Mach 0.4 at various impingiment l

Centerline Mach number decay for Mach number 0.8, at various impingement locations

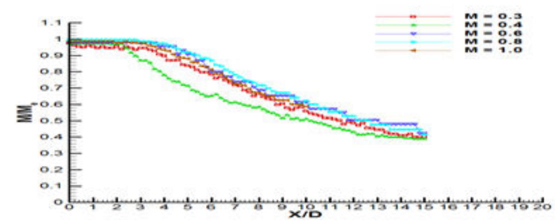


it is seen that the Mach number 0.4 free jet core length is little longer than other impinging jets. Here impinging jets X/D_w = 7.5, 10 are propagating almost similar in the decay at X/D = 3 onwards. Free jet and impingement jets behave in the similar fashion in the far field.

For Mach number 0.8 The impingement jet at X/D_w = 7.5, shows the shorter core length compared to the two other impinging jets. The impinging jets at X/D_w = 10 and 15 behave in the same manner. The decay for impingement jet X/D_w = 7.5 is faster compared to the other impinging jets in this study.



Centerline Mach number decay at impingement location for wall jet 10

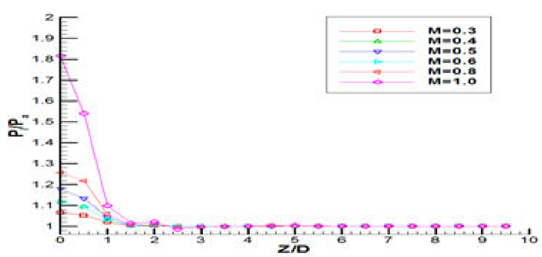


Centerline Mach number decay at impingement location For wall jet 15

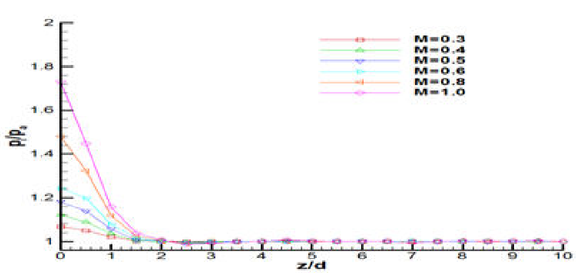
From the above studies it is clear that the effect of Mach number is very much less on the field distribution. It influences only the field strength point of view only. But their behavior is same for all the Mach number.

2. **Wall pressure distribution pattern::**

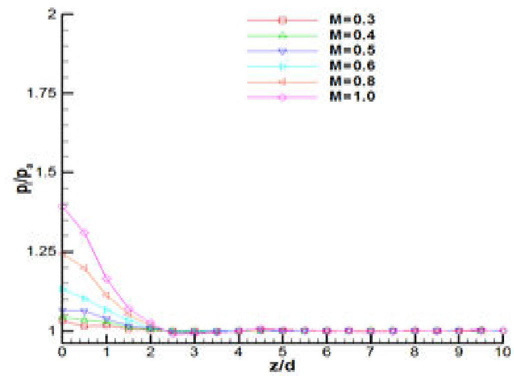
   To probe into the physical reasoning's of effect of wall influence, it is very much essential to make measurements in the complete impingement plane. Keeping this point in the mind apart from centreline measurements, the pressure measurements in the transverse direction at wall is carried out. In present study the profiles of Mach numbers 0.4, and 0.8 are studied for X/D = 1 to15, in steps of 5. The pressure distribution is limited for smaller circular area with higher intensity. It represents the diameter of positive pressure zone(it is in potential core region). It is evident that field will maintain fluctuations in periodic motion especially for Mach number 1.0, 0.8. It is the turbulence representing in the flow separation from wall. With respect to wall distance pressure intensity is falling down after the potential core region. They are showing increment in pressure distribution up to fully developed region. After that there will be no effect of wall on the jet.



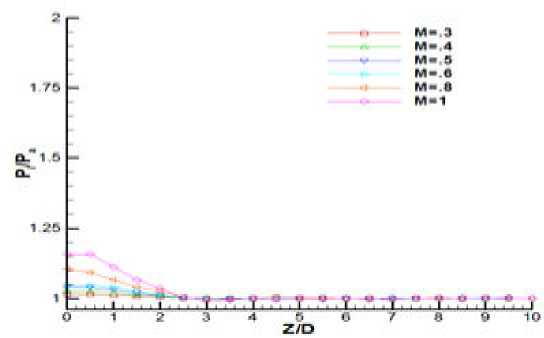
Wall pressure distribution at impingement location X/D = 1 for various jet Mach numbers



Wall pressure distribution at impingement location X/D = 5 for various jet Mach numbers.



Wall pressure distribution at impingement location X/D = 10 for various jet Mach numbers.

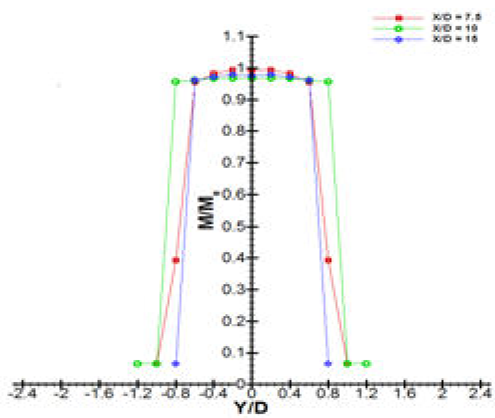


Wall pressure distribution at impingement location X/D = 15 for various jet Mach numbers.

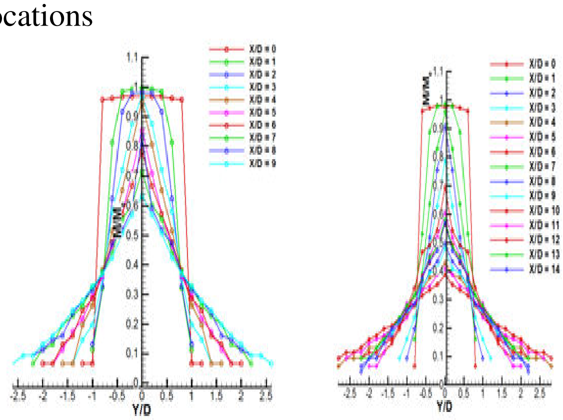
3. Mach Number Profiles:

to probe into the physical reasoning's of effect of wall influence, it is very much essential to make measurements in the complete jet field. apart from centreline measurements, the pressure measurements in the transverse direction is carried out. The pressure distribution in the field is symmetric about their axes by the result of the flow visualization technique in impinging jets . For this study pressure measurements in the radial direction of various axial locations are considered. The axial locations chosen are X/D = 1 to 15 insteps of 5. This measurement gives an idea on how the impinging jets are behaving in radial directions. In present study the profiles of Mach numbers 0.4, and 0.8 are studied for X/D = 1 to15, in steps of 5.

Mach profiles for Mach 0.4



at X/D =0 and 5 for various impingement locations

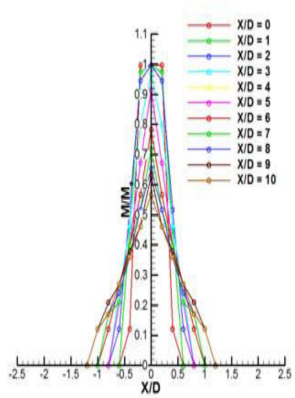


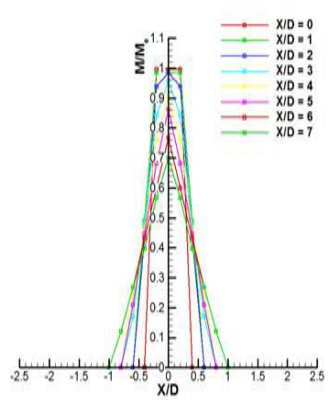
at X/D =10 and 15 for various impingement locations

above figures shows the mach profile for Mach 0.4 at X/D = 0, 5, 10 & 15. At X/D=0 In the potential core region, the pressure distribution is almost same. It possesses top hat profile, which represents the uniform pressure distribution. It is the positive pressure zone, which dominates overall impinging region. For X/D = 5 they are following same trend. Here also impinging jet 15 has weak field than the impinging jet 10. In impinging jets field strength and distribution are increasing by the effect of wall. But intensity of the field is decreasing with respect to the distribution area increment in increasing wall distance. From upstream of the jet the shear layer separation is representing in this profile data. Shear layer is dominating in transition region. All remaining profiles follow decay in same trend. In far field pressure distribution area has slight variations and the edges of the profiles are merging.

At X/D = 10 and 15 profiles follow decay in same trend. In far field pressure distribution area has larger area with mild variation.

Mach profiles for Mach 0.8





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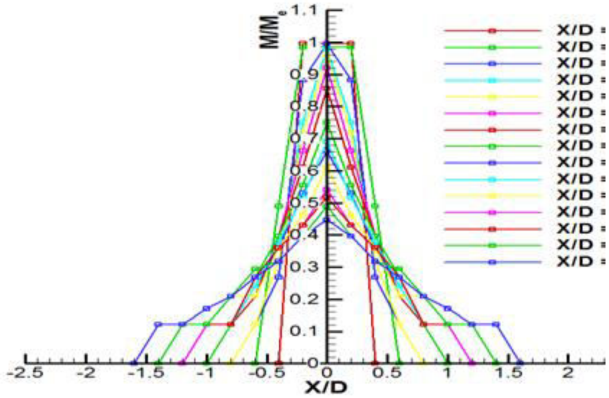
at various axial locations, at impingement location $X/D_w = 7.5$ and 10



at various axial locations, at impingement location $X/D_w = 15$.

Above Figures show the Mach number profiles of Mach number 0.8 jet fields. The wall jets have the potential core lengths up to X/D = 2.8 to 3.0 followed by gradual pressure variations, with steep decay. Wall jet 15 is having larger distribution area. Here the wall jet 10 is behaves like wall jet 7.5. Here the distribution width is also same for the X/D = 9 for wall jets 10, 15. It is seen that from the Mach profile, here also the profile of impinging jet 15 has become fully developed flow before impingement. The jet field becomes stronger in positive pressure zones only. It is clear that the field strength is high for close wall distances . It is shown that the pressure concentration area is reducing, but the distribution area is increasing.

CONCLUSIONS

From the above studies it is clear that the wall jet is influencing the flow field. In subsonic flows the potential core length is decreasing because of the wall. But in far field all jets will merging and behaving in same manner. Wall pressure distribution is increasing with respective distance but the intensity is decreasing. In the above studies there will be less influence of vertex formation. We have only positive pressure zone and zone of dominance of shear layers. Finally analyzed the impinging jet field and there influence on the ground in the sense of intensity under isentropic relations. It may help full to design proper launching stations and balancing the vehicles which are working under the principle of jet propulsion.

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