STEALTH PERFORMANCE BY JET SIGNATURE REDUCTION

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Abstract: A numerical study was undertaken to study the effect of plates kept at X/D =1, 3 and 5 for the jet exit and the interaction between the flow and the plate and the flow has been studied at a free stream Mach number of 0.6 and 1.4. A baseline configuration along with three plate configurations was studied. A literature survey was conducted to understand the flow field and the need to reduce the jet temperature downstream of the jet. Based on the literature, an engine configuration was chosen as a baseline case. A validation study was undertaken and it was found that the temperature values predicted by software have error and similar studies are reported in the literature. The plates are seen to affect the distribution of pressure, velocity, Mach number and total temperature. The total temperature downstream of the plates are reduces which is effective in reducing the jet signature Plate at X/D=1 is suggested as optimum since the performance is better than other locations. The effect of plate is similar in both Mach numbers. The plate kept at X/D=5 is seen to offer adverse effect at free stream Mach number of 1.4 and it is suggested to avoid this case for Mach number 1.4.

Keywords: Jet Signature, Total Temperature, Mach number, Pressure and Velocity, Jet exit, Plume

I. INTRODUCTION

In wars, there is always a need to be at an advantage over enemy. In combat between combat aircrafts, the ability not to be detected by enemy radars plays a major role. Infrared is the major parameter used to track objects in the combat scenario. The difference between the IR emissions from the object from the low IR of background is used to distinguish object from the background.

This work mainly concentrates on the signature reduction from the plume. The temperature drops downs downstream of the jet exit in an uncontrolled case. We propose to reduce the distance the over which the temperature reduces by introducing a plate normal to the flow. Since this plate is a bluff body, it reduces the temperature distribution in the downstream direction by the separation of the flow over the plate.

Relation between IR signature levels (IRSL) depends on the IR emission from the body and the surroundings. The combat aircraft gets a lock on easily when viewed from the rear side due to the very high temperature range of 600 to 700^{o} C in the jet plume. Turbojets, turbofans and turboprops are the order of jet signature which varies from high to low.

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II. METHODOLOGY

- Initially a literature survey is carried out to study on IR signature and jet exit of a combat aircraft.
- A case study or validation study is done where in the boundary conditions are taken as a reference and CFD analysis is carried out and values are to be matched
- A baseline model design is taken from the research paper.
- A grid was generated for that particular model in the GAMBIT software.
- The equations are solved and the flow analysis is done in ANSYS FLUENT software.
- Now same steps have to be taken for jet exit flow by placing a bluff body for a subsonic and supersonic flow and results are taken and finally the results of baseline are compared with results of placing a bluff body i.e. a plate.

The test conditions are taken from research paper. Here we are considering an ideally expanded jet exit. The table 1 for test condition is shown below. For the bluff body that has to be placed after the jet exit, the bluff body is kept at different distances such as X/D= 1, 3 and 5 and results are compared for baseline and X/D= 1, 3, and 5. The domain created for the combat aircraft is shown in figure 2.1.

Table 1-Test Conditions

PARAMETERS	VALUES
Freestream Mach no.	0.6 and 1.4
Jet exit Mach no.	0.8
Jet exit temperature	800K
Jet Exit diameter	65mm
Freestream Total Temperature	288K
Plate jet diameters	0.33, 0.67 and 1 jet diameter
Plate location	1, 3 and 5 jet diameters downstream of jet exit

The domain created for the combat aircraft is shown in figure 2.1.

Figure 2.1- CFD domain

III. RESULTS AND DISCUSSION

Since this study is about reducing the temperature distribution downstream of the jet exit for a given condition, several simulations were undertaken to understand the effect of individual parameter such as plate size, location of plate and the free stream flow condition that is Mach number. The jet model that was modelled and for which grid was created earlier was used as a baseline case. The same domain size is used for all the simulation results that are carried out and discussed in the section.

3.1 Case 1- Baseline at Mach no. 0.6

The core of the jet is seen to reduce with the distance downstream. The jet temperature is seen to reduce in the downward direction. This could be due to the mixing between the hot jet and the cold freestream condition. Since ideally expanded conditions are given for the jet exit, the jet is seen to have a horizontal direction rather than under expanded or over expanded jet that will be caused due to the expansion fan or a shock wave at the jet exit.

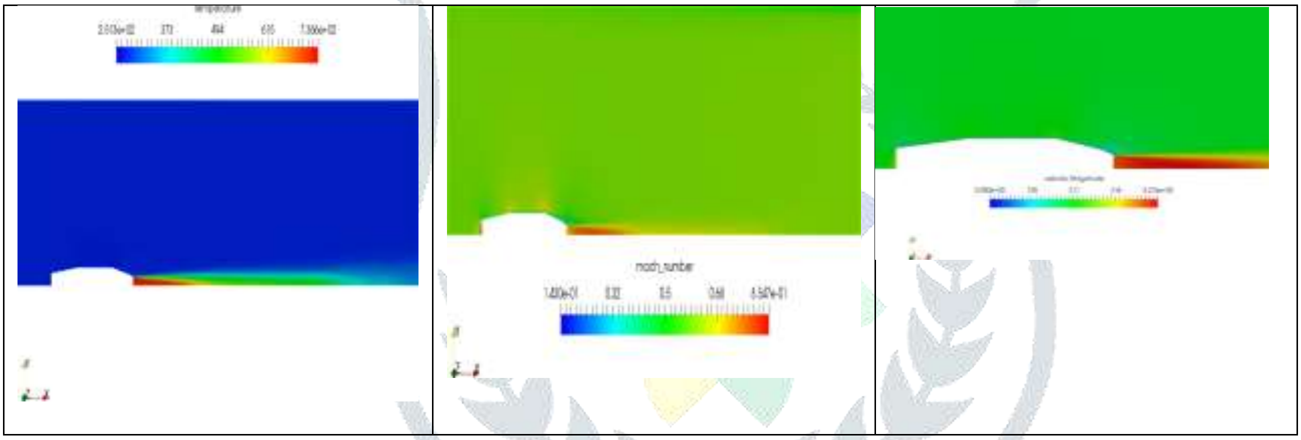

Fig 3.1- Distribution of Temperature, Mach no. and Velocity for baseline at Mach no. 0.6

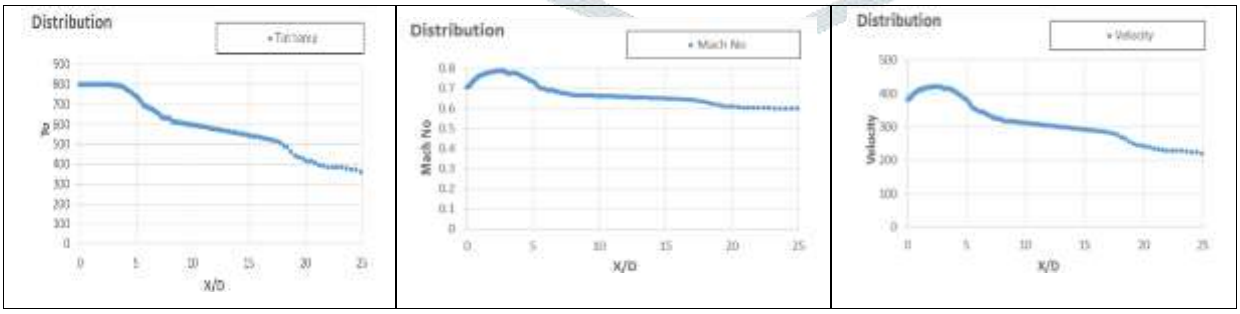

Fig 3.2- Distribution of Temperature, Mach no. and Velocity along the axis for baseline

3.2 Case 2 – Effect of Plate location at Mach number 0.6

To study the effect of plate location, different studies were under taken. Plates of 3 mm thickness were kept at three locations. The locations were chosen as 1D, 3D and 5D. These results will reveal the effect of the distance between the plate and jet exit.

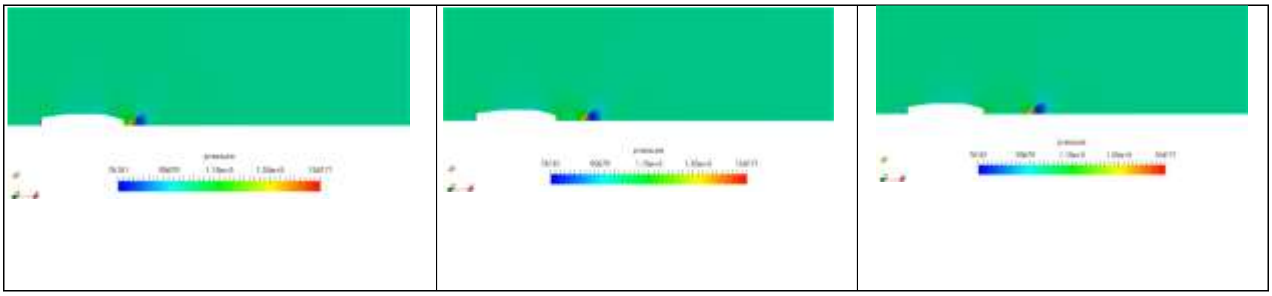

Fig 3.3- Pressure distribution with plate at X/D=1, 3 and 5

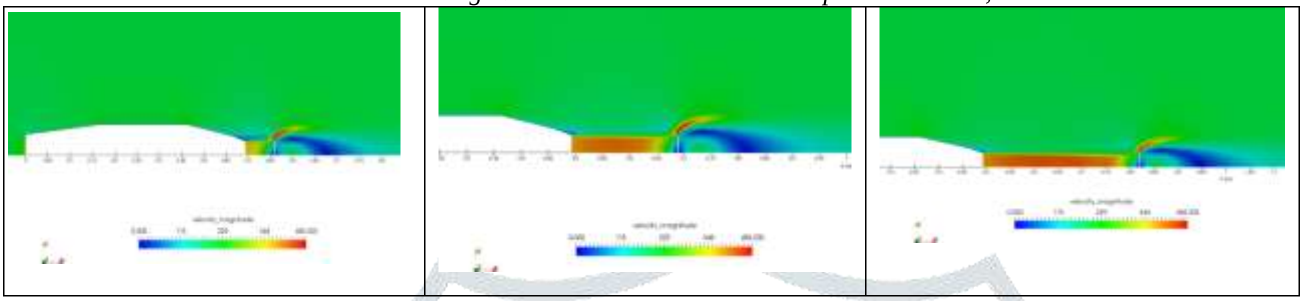

Fig 3.4- Velocity distribution with plate at X/D=1, 3 and 5

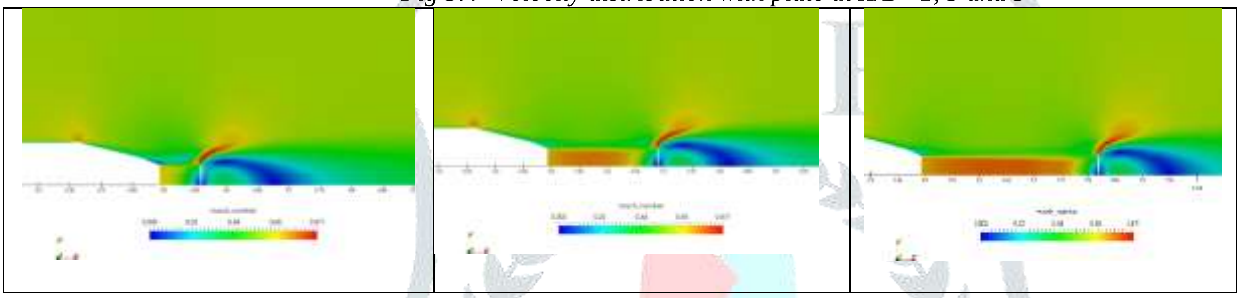

Fig 3.5- Mach number distribution with plate at X/D=1, 3and 5

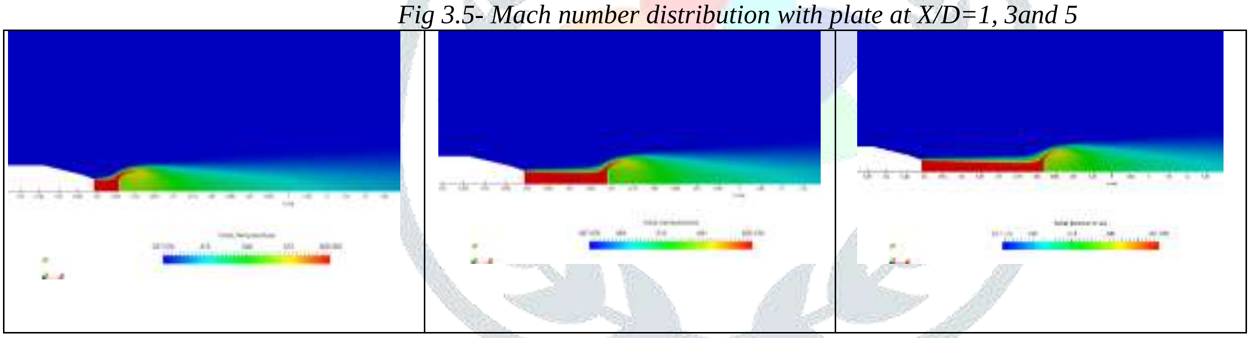

Fig 3.6- Total Temperature distribution with plate at X/D=1, 3, and 5

3.3 Case-3: Comparison between baseline and plate at different locations at Mach number 0.6

The distribution of Pressure, Velocity, Mach no. and Total Temperature were known and it was seen that the total temperature is dropping enormously downstream of the plate. The maximum total temperature is limited to the region upstream of the plate. The divergence of the flow around the corner of the plate seems to be independent of the plate location. From these figures, it seems that the plate kept at X/D=1 seems to be optimum in reducing the total temperature downstream of the jet exit. As seen in the figures, the flow experiences a change due to the addition of the plate. The plate makes the flow to negotiate around that plate and this may be the reason behind the reduction in temperature downstream of the plate.

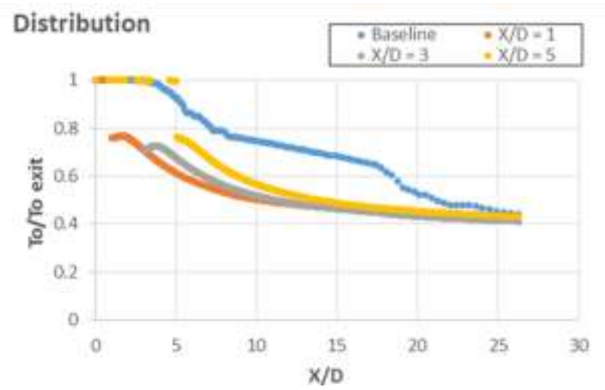

Fig 3.7-Comparison of Total Temperature along axis for different plate locations

3.4 Case-4: Baseline at Mach number 1.4

The distribution of temperature for a freestream Mach number of 1.4 is shown in figure below. The distribution is almost similar to the one for the freestream Mach number of 0.6. However, weaker waves can also be observed in the contour. These are the waves created in the supersonic flow such as shock waves and expansion fan.

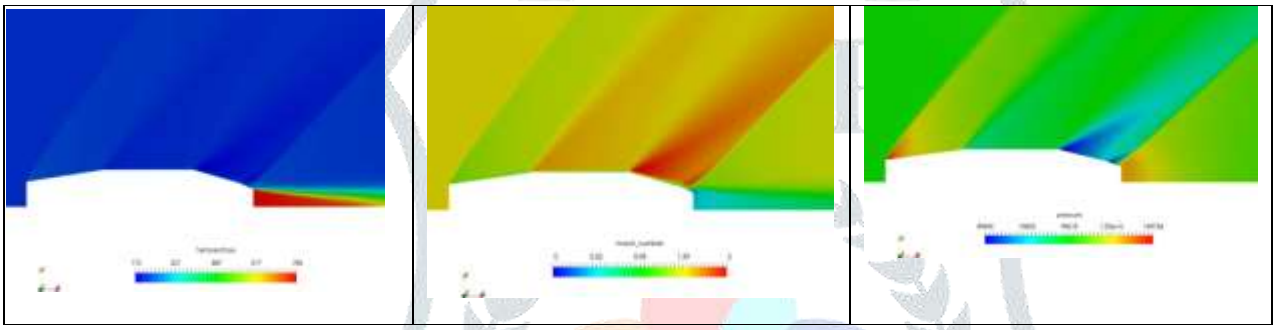

Fig 3.8-Distribution of temperature, Mach no. and Pressure for baseline at Mach no. 1.4

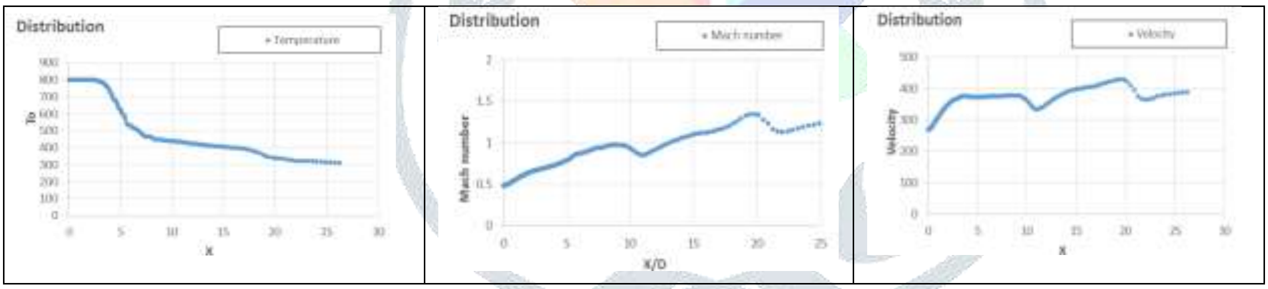

Fig 3.9- Distribution of Temperature, Mach no. and Velocity along the axis for baseline

3.5 Case-5: Effect of Plate location at Mach no. 1.4

The pressure distribution at Mach 1.4 for different plate locations is shown in figures below. As seen in the figs, the flow is dominated by the shock waves and expansion fan. These are unavoidable in supersonic flows. Similar to the flow at Mach 0.6, there is a difference in pressure upstream and downstream of the plates. However, the pressure distribution between the nozzle exit and the plate seen affected by the plate location. The presence of the plate also creates a shock wave and an expansion fan at the corner of it.

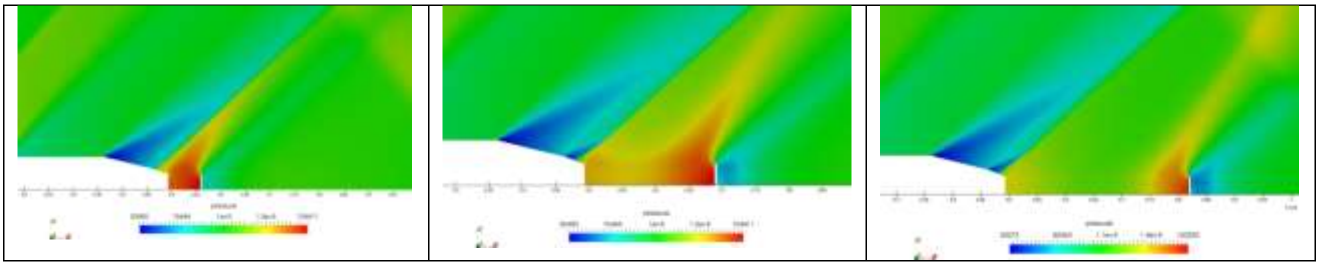

Figure 3.10- Pressure distribution with Plate at X/D=1, 3 and 5

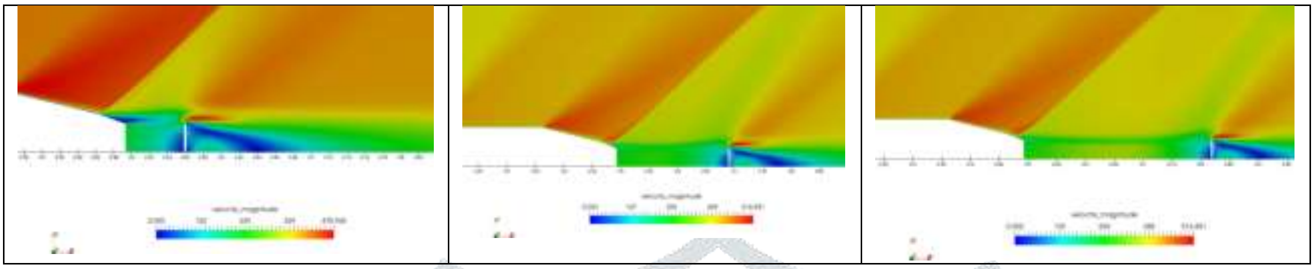

Figure 3.11-Velocity distribution with Plate X/D=1, 3 and 5

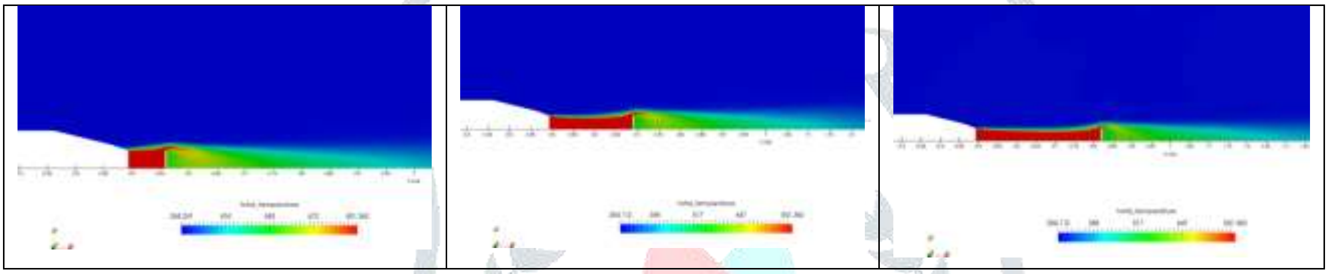

Figure 3.12- Total Temperature distribution with Plate X/D=1, 3 and 5

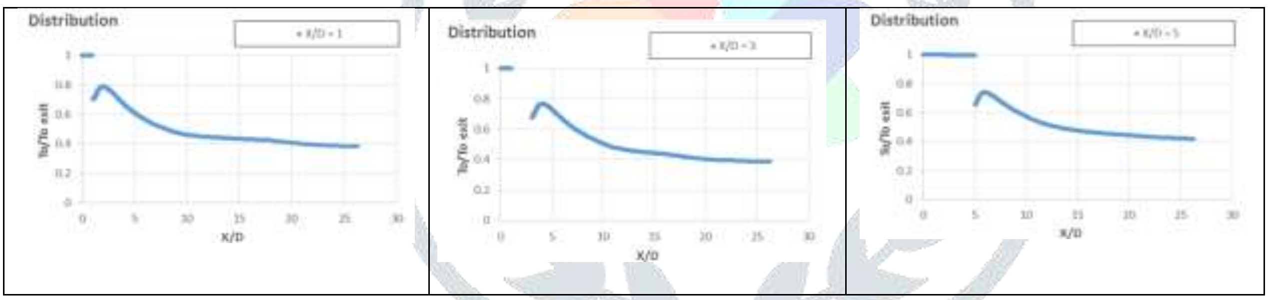

Figure 3.13- Total temperature distribution along the axis at Mach no. 1.4

3.6 Case-6: Comparison between baseline and plate at different locations at Mach no. 1.4

The comparison of the temperature distribution against the baseline case is shown in figure below. As shown in the fig, the effect is almost like the one at Mach 0.6. However, the plate at X/D=5 is seen to have mild adverse effect as the temperature distribution with plate at X/D = 5 is greater than the baseline case. Since the plate results in an increased temperature, this may be avoided.

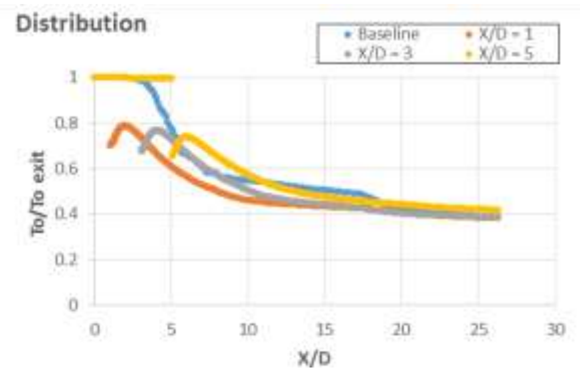

Figure 3.14- Comparison of total temperature at Mach 1.4along axis for different plate locations

IV. CONCLUSION

A numerical study was under taken to study the effect of plates kept at X/D =1, 3 and 5 for the jet exit and the interaction between the flow and the plate and the flow has been studied at a freestream Mach number of 0.6 and 1.4. Baseline configurations along with three plate configurations were studied. The plates are seen to affect the distribution of pressure, velocity, Mach number and total temperature. The Total Temperature downstream of the plates are reduced which is effective in reducing the Jet Signature. Plate at X/D=1 is suggested since the performance is better than other locations. The effect of plate is same for both Mach Numbers. The plate kept at X/D=5 is seen to offer adverse effect at freestream Mach number 1.4 and is suggested to avoid this case.

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