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Experimental Study of Effects of Bleed Geometric Parameters on the Performance of a Supersonic Axisymmetric Intake

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ABSTRACT: A supersonic axisymmetric mixed compression air intake has been experimentally studied in a wind tunnel at three free-stream Mach numbers of 1.8, 2.0 and 2.2 at zero degrees angle of attack. Shadowgraph flow visualization has been used as well as the pressure transducers. By applying a suction slot over the external compression surface upstream of the throat, the effects of changing the area of the bleed entrance and exit on the intake performance parameters such as mass flow ratio, total pressure recovery, flow distortion and bleed mass flow ratio have been investigated. The results showed that by increasing the area of the bleed entrance, total pressure recovery increases in critical and subcritical conditions and if simultaneously the area of the bleed exit increases, the pressure recovery will be further improved, especially in subcritical condition. The results also indicated that if the area of the bleed entrance becomes very large, it can have an adverse effect on the intake performance, especially in the critical condition even worse than the no bleed case. However, using a large bleed entrance can postpone the buzz onset at off-design conditions.

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1- INTRODUCTION

The air-breathing engines are used in all the airplanes and some missiles. In these engines, the required air for the combustion process and thrust production is supplied from the environment. Accordingly, an aerial engine should be equipped with an air intake. Efficient airflow compression through the intake is essential for the proper functioning of the air-breathing engines. As an example, for the combustion process of a ramjet engine, the Mach number at the inlet to the combustion chamber must be about 0.4, or in a turbojet engine, the Mach number at the compressor entrance must be below 0.4. Fig. 1 shows the supersonic intake in an air-breathing engine.

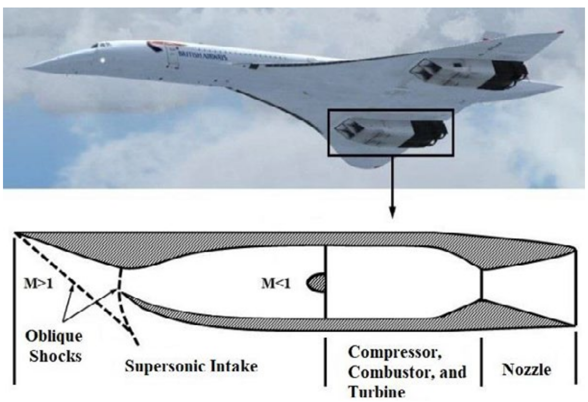

Fig. 1. The engine components in a supersonic airplane

Different methods have been introduced to improve the intake performance, such as bleeding and blowing of the boundary layer [1, 2], using vortex generators [3], etc. Among them, the boundary layer suction or bleed is seemed to be the better one because it can be simply applied and it is an efficient technique.

A series of the experimental study were performed by Soltani et al. [4, 5] to detect effects of the bleed on the performance of a mixed compression intake at free-stream Mach numbers of 1.8, 2.0 and 2.2. The bleed was a slot and was located over the spike tip. According to this research, when the bleed is applied downstream of the shock position, the intake performance is improved.

In this paper, effects of the width of the bleed slot (narrow bleed, mediocre bleed, and wide bleed) on the performance of a mixed compression intake have been studied experimentally. The intake was for a freestream Mach number of 2.0. However, tests were further performed for freestream Mach numbers of 1.8, 2.0 and 2.2 at zero degrees angle of attack. At every experiment, some back pressures were imposed at the intake exit using a conical plug. Performance parameters considered in this paper are Total Pressure Recovery (TPR), Mass Flow Ratio (MFR), Flow Distortion (FD), and Bleed Mass Flow Ratio (BMFR).

2- EXPERIMENTAL METHODOLOGY

All tests were performed in a wind tunnel with a rectangular test section of 60×60 cm^2. The turbulence intensity of the flow in this wind tunnel ranges from 0.4% to 1.4%, depending on

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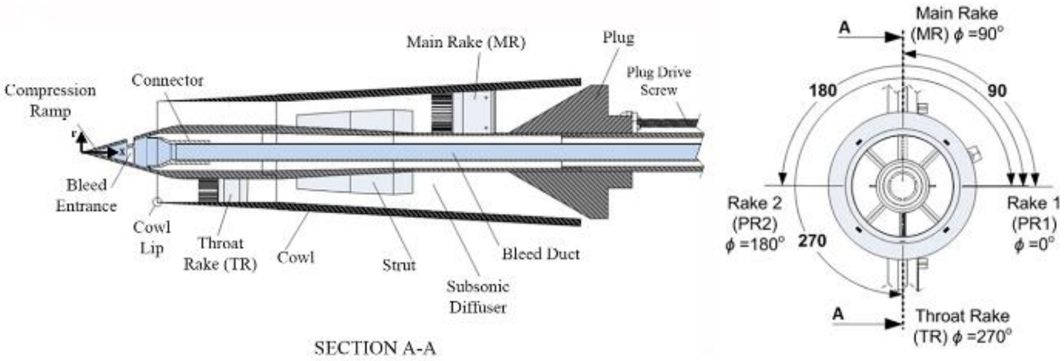


Fig. 2. Schematic view of the intake model and its instrument [1]

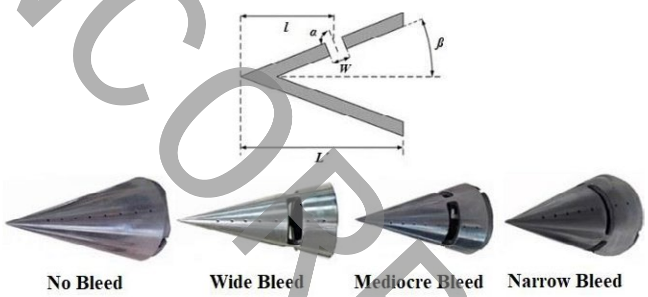


Fig. 3. Spike tip cones used in this study

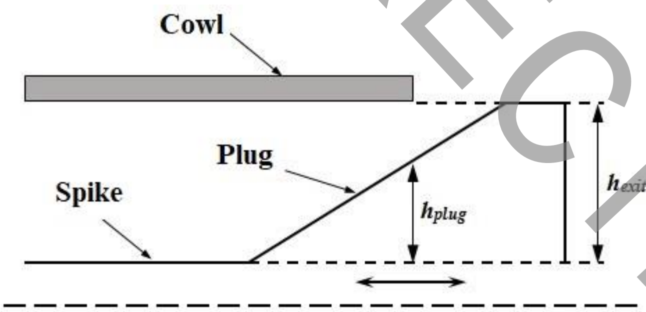
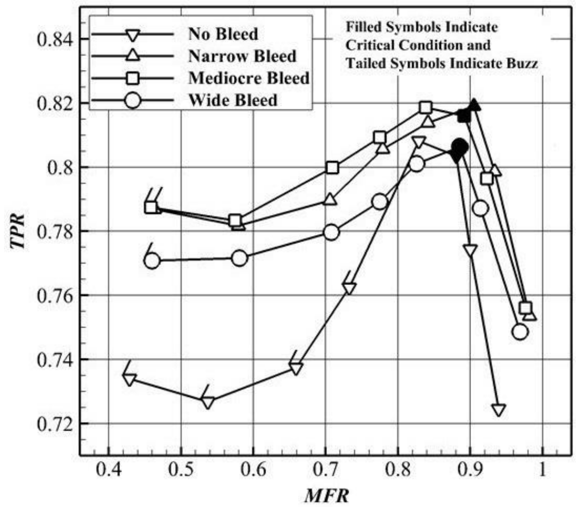
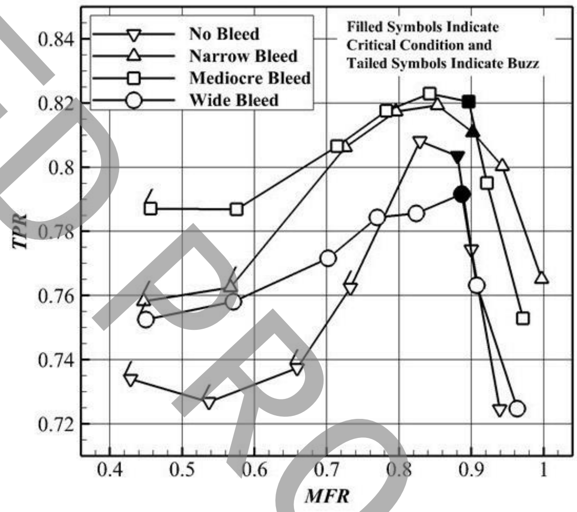


Fig. 4. Parameters used in the definition of EBR



(a) $A_{be}=2A_{bd}$



(b) $A_{be}=4A_{bd}$

Fig. 5. Performance curves of the intake for every tip cone at M_∞=2.0

the freestream Mach number. The Reynolds number in the test section was varied from 6.37×10^6 to 7×10^7 per meter. The wind tunnel is trisonic; $0.4 \leq M_\infty \leq 3.0$; and freestream Mach number is controlled using a variable nozzle and by setting the engines. The flow angle in the test section for a Mach number of 2.0 is about 0.5°. A pitot tube is used to measure the freestream Mach number with a maximum error of 0.8% [1].

Fig. 2 shows the intake model used in the experiments. It is an axisymmetric intake with the design Mach number of 2.0 and has an *L/d* of 3.4. The intake has a semi-cone angle of 16°. The tip cone of the spike can be replaced to investigate the effects of the bleed entrance area. Four tip cones are used in this study that have been depicted in Fig. 3 [1].

Exit Blockage Ratio (EBR), is defined to incorporate effects of the plug position. It is defined as the ratio of the exit duct height blocked by the plug to the total height of the exit duct. As a result, when EBR is 100%, the exit area is fully closed and when it is 0% it is fully open. Eight values for EBR; 55.0%, 60.0%, 62.5%, 65.0%, 67.5%, 70.0%, 75.0%, and 80.0% have been examined at every Mach number and tip cone [1].

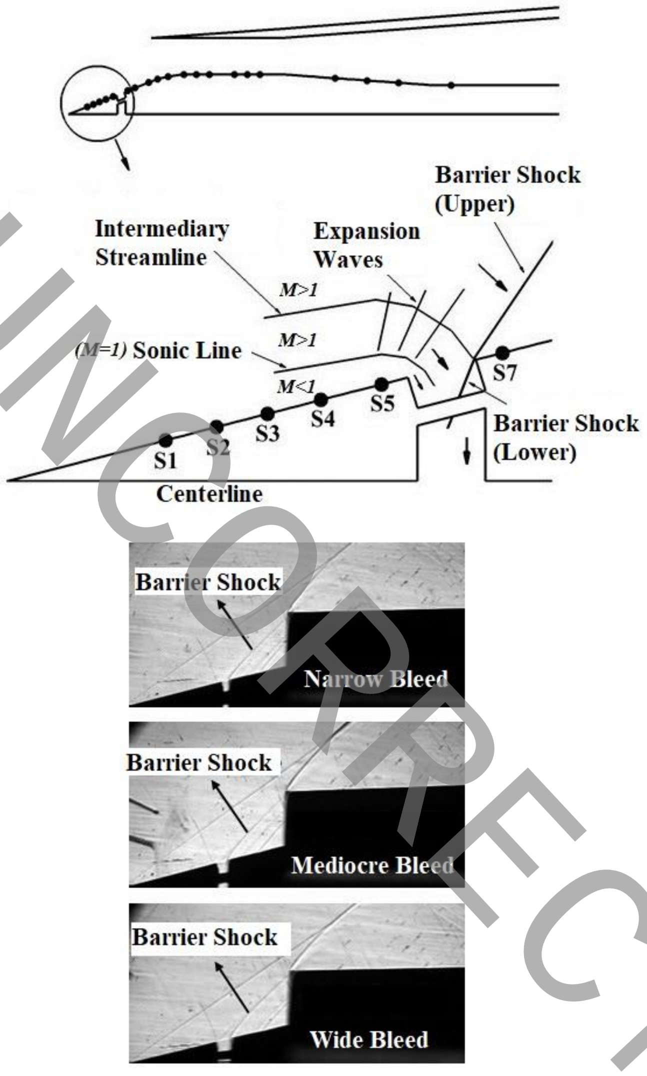


Fig. 6. Flow characteristics around the bleed slot along with the shadowgraph pictures

3- RESULTS AND DISCUSSION

As seen from Fig. 5, applying the bleed has been improved the intake performance and postponed the buzz onset significantly. As seen the mediocre bleed has a better performance as compared with the others. As seen in Fig. 6, a barrier shock is formed around the bleed entrance that its strength and orientation have considerable effects on the intake performance and stability.

4- CONCLUSIONS

In this study, the effects of changing the area of the bleed entrance and outlet on the performance of an axisymmetric mixed compression air intake at three freestream Mach numbers of 1.8, 2.0, and 2.2 have been experimentally investigated. Results showed that narrow bleed decreases the bleed mass flow rate, however, the intake is less stable when it is equipped with this cone. The mediocre bleed showed a better performance as compared with the narrow and wide bleed cones. The exit area of the bleed duct had considerable effects on the bleed mass flow rate.

REFERENCES

[1] M.R. Soltani, J. Sepahi Younsi, M. Farahani, Effects of Boundary-Layer Bleed Parameters on Supersonic Intake Performance, Journal of Propulsion and Power, 31(3) (2015) 826-836.

[2] R.H. Tindell, Blown boundary layer control system for a jet aircraft, United States, Grumman Aerospace Corporation, (1995) 5447283.

[3] B.A. Reichert, B.J. Wendt, Improving Curved Subsonic Diffuser Performance with Vortex Generator, AIAA Journal, 34(1) (1996) 65-72.

[4] M.R. Soltani, J. Sepahi Younsi, A. Daliri, Performance Investigation of a Supersonic Air Intake in the Presence of the Boundary-Layer Suction, Journal of Aerospace Engineering, 229(8) (2015) 1495-1509.

[5] M.R. Soltani, A. Daliri, J. Sepahi Younsi, M. Farahani, Effects of Bleed Position on Stability of a Supersonic Inlet, Journal of Propulsion and Power, 32(5) (2016) 1153-1166.