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Computational Investigation of the Effects of Heat Source Position on the Performance of a Mixed Compression Supersonic Intake

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ABSTRACT: Investigation of the intake performance is one of the most important topics in the aerodynamic design of the aerial vehicles. In this study, the performance of a supersonic axisymmetric mixed compression intake, which was designed for the free stream Mach number of 2, has been investigated at zero degrees angle of attack. Then by applying a heat source and changing its position, the effects of this source on the intake performance have been studied. The flow has been simulated by a computational fluid dynamics code. The experimental results which were achieved in the wind tunnel at Imam Hossein University have been used to validate the numerical simulation. Results show that a heat source located at the proper location could have desirable effects on the total pressure recovery, mass flow ratio and drag coefficient of the intake. The critical back pressure ratio also increases, which widens the intake operating region. However, the flow distortion will increase a bit. At the design Mach number and critical condition, 9.68% increase in total pressure recovery, 26.6% decrease in drag coefficient, 16.16% increase in mass flow ratio, 8.7% increase in critical back pressure ratio and 17.13% increase in flow distortion have been observed.

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1- Introduction

The first part of an air-breathing engine is the air intake, which transfers the air from free stream to the next part of the engine with minimum total pressure loss.

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. Another method is applying a heat source to the intake [4]. A heat source is an area in front of the intake, which is heated in different ways, such as using laser energy, hot air jet, etc. In this paper, the method of applying the heat source is not discussed. The main purpose of this research is to investigate the location of a heat source to enhance the performance of a mixed compression supersonic air intake. Performance parameters considered in this paper are Total Pressure Recovery (TPR), Mass Flow Ratio (MFR), drag coefficient and flow distortion. Additionally, the critical Back Pressure Ratio (BPR) is further investigated.

Oswatitsch [5] studied adding energy to the flow upstream of an intake to reduce the drag for the first time. In 2003, Macheret et al. [6] presented a heat source called "virtual cowl", which guides the streamlines into the intake. After that, Kremeyer [4] researched adding energy to reduce the drag in supersonic and hypersonic flows. In 2011, Soltani et al. [7] investigated the effects of applying a heat source to a supersonic external compression intake and found that applying a heat source reduces the drag in all cases. In 2014, Li et al. [8] studied the effects of adding energy to the captured mass flow ratio in hypersonic intakes using laser energy. Their results showed that it could increase the mass flow ratio by about 7.64 %.

Many studies have been performed on adding energy to the upstream flow of the hypersonic and external compression supersonic intakes to improve different performance parameters, as mentioned. However, there is no research in this field on the mixed compression supersonic intakes. In this paper, the effects of applying a heat source to this kind of intake have been investigated. Also, a location at which performance parameters improve has been suggested.

2- Methodology

The intake used in this research is supersonic and mixed compression, which is designed for the free stream Mach number of 2. The flow is steady, viscose and compressible. A previously developed Computational Fluid Dynamic (CFD) code has been used to simulate the flow in which the RANS equations are solved. The turbulence model used in this code is SST k-ω.

The grid is structured and refined near the walls. The mesh independency studies showed that a grid with about 97000 cells would be suitable for this case.

Numerical results have been compared with the experimental data to ensure the accuracy of the numerical methods. Fig. 1 shows the static pressure on the spike for both experimental and numerical simulations. It is observed that the numerical results are in accordance with the experimental ones.

3- Results and Discussion

Before applying the heat source, the performance parameters should be obtained. Therefore, the back pressure

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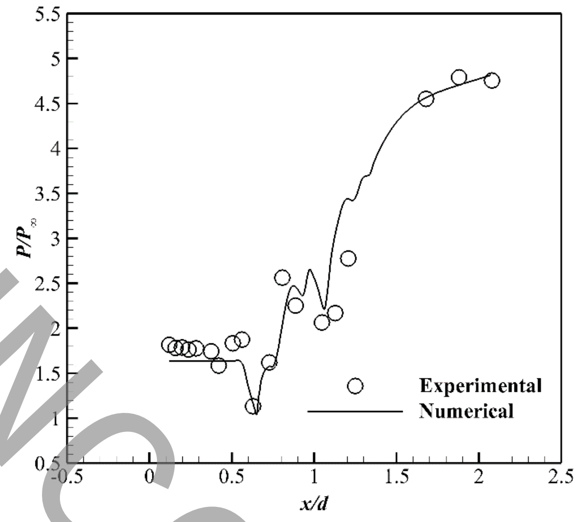

Fig. 1. Static pressure on the spike surface using experimental and numerical simulations

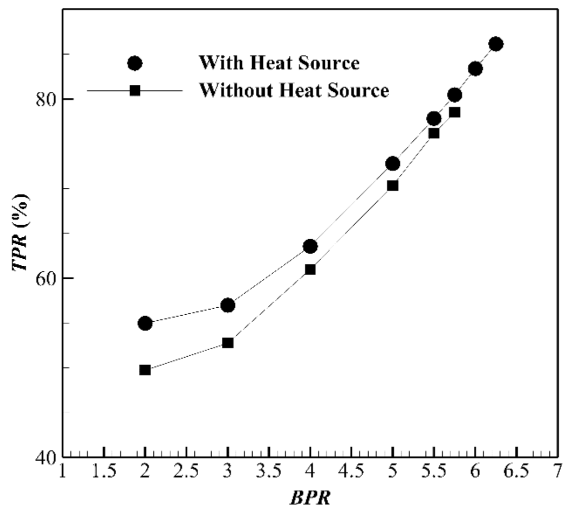

Fig. 2. Variations of the total pressure recovery in the presence and absence of the heat source

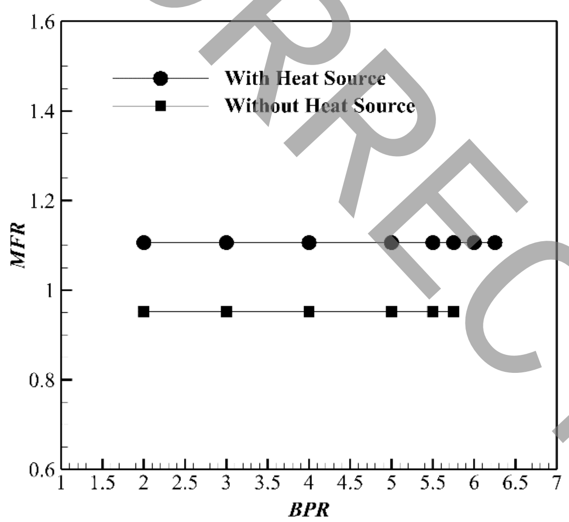

Fig. 3. Variations of the mass flow ratio in the presence and absence of the heat source

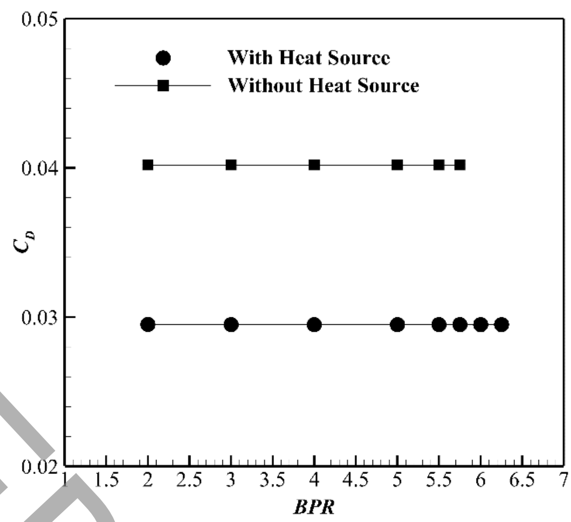

Fig. 4. Variations of the drag coefficient in the presence and absence of the heat source

is increased step by step and the performance parameters are assessed for each back pressure.

The annular heat source has a circular cross-section with a non-dimensional radius of r/D=0.047 which is dimensionless with the maximum diameter of the intake. The heat flux value is selected to be 2×1010 W/m3. Studies on the location of the heat source showed that at x/d=-0.2 and y/d=0.8 the total pressure recovery, mass flow ratio, drag coefficient, and critical back pressure ratio are improved considerably. However, the flow distortion worsens a bit. Fig. 2 and Fig. 3 show TPR and MFR for different back pressures in the presence and absence of the heat source.

It can be observed that the total pressure recovery and mass flow ratio increase by about 9.68% and 16.16% respectively at critical condition. On the other hand, the drag coefficient decreases by 26.6%, which is shown in Fig. 4. Furthermore, the critical back pressure ratio increases by 8.7% and the flow distortion increases by about 17.13%. However, if the intake is used in a ramjet engine, the increase in the flow distortion would not have destructive effects on the engine.

4- Conclusions

In this research, a previously developed CFD code was used to simulate the flow field in a mixed compression supersonic air intake. Then, by applying a heat source and investigating the performance parameters, a location was suggested at which most of the performance parameters improve. If the main goal of applying the heat source is to improve a specific parameter, the location should be selected in such a way that the heat source affects that special parameter directly. It is worth mentioning that this research is done to investigate the effect of the heat source on all of the parameters. Therefore, the suggested location is not the optimum location of the heat source.

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