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Performance Enhancement of Single Expansion Ramp Nozzle in Scramjets

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Abstract: Single expansion ramp nozzle is a type of nozzle which is mostly used for higher thrust in scramjet engines. This study is a numerical analysis on the production of thrust with the help of a simple expanded ramp nozzle. In this analysis, thrust at different lengths and angles of cowl and ramp were compared to bring the optimized configuration of the nozzle. CFD simulation has been used for the analysis. RNG K-Ɛ model was used to solve the solve the Navier- Stokes equation. The length of the inner nozzle, the external ramp and the internal cowl length are the main parameters in the performance of the thrust and the lift.

Keywords: SERN, supersonic, scramjet, CFD

I. INTRODUCTION

Scramjet engines are the emerging air breathing propulsive systems with various advantages. They do not have any rotating parts and the required oxygen need not be carried, which makes it simpler in construction [1,2]. Their major applications are found in the defense-missile operations, high speed aviation and hence researchers across the world are actively working on the design of scramjet engines. One of the major problems of scramjet engines is to increase the thrust of the vehicle considering all the parameters. Researchers have been testing different nozzle systems in scramjet engines in order to increase the thrust of the vehicle[3,4].

Single expansion ramp nozzle is a very essential component in scramjet vehicles to produce most of the thrust[5]. Hirschen et al. [6] have investigated the performance of the single expansion ramp nozzle at different flight altitudes and run conditions by varying the Reynolds number, nozzle pressure ratio and the heat capacity ratio, and pressure measurements and Schlieren photographs were employed to study the effect of the capacity ratio on the interactions between the external and the nozzle flows.

Thiagarajan et al. [7] have investigated the effects of interactions between the engine exhaust and hypersonic external flow numerically, and the effects of ramp angles, cowl lengths and side fences on the nozzle performance have been performed. Gruhn et al. [8] have examined the influence of the flow at the flap on the nozzle efficiency, and an improved aerodynamic flap has been employed in the nozzle configuration to improve the performance of the single expansion ramp nozzle.

In this paper In this paper, the 2-D coupled implicit Reynolds Averaged Navier–Stokes (RANS) equations and the two-equation RNG k–e turbulent model have been introduced to numerically simulate the flowfield in the single expansion ramp nozzle, and the interactions between the design variables.

II. PHYSICAL MODEL AND THE NUMERICAL METHOD:

The basic model with inlet 'h' mm, h=15.24mm, ramp angle 18deg, inner cowl length 1.7h, cowl angle as 12deg and the horizontal length of the whole nozzle as 20h is considered as the physical model of the scramjet nozzle.

With the help of Ansys Fluent 18, the results were obtained and analysed. The RNG K-epsilon model was used to solve the Navier-Stokes equations with standard wall functions. The courant number was kept at 0.5 and with proper under relaxation factors to ensure stability.

The air is considered as ideal gas. No slip boundary conditions are used for the walls.

The inlet air flows from the right and moves towards left with supersonic veloicty at mach number 1.78 at 1.72bar and 475k. This is the basic geometry and the values of the problem. Different mach numbers at inlet are chosen to compare their results such as the thrust and the lift. different geometric parameters are also used to improve the performace of the nozzle.

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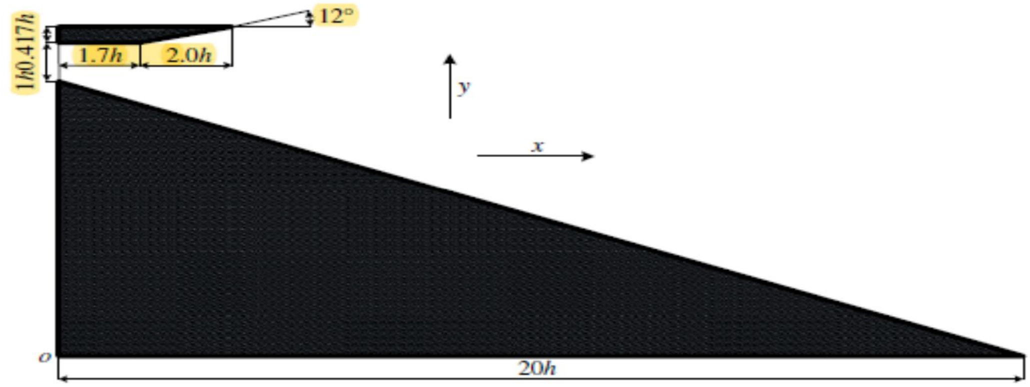


Fig.1: Schematic diagram of a single expansion ramp nozzle.

III. MESHING

Meshing is done with the help of Ansys mesh. Maximum face size is set to 1.2mm for finer mesh. The walls of the nozzle are densely clustered. Grid independence tests were performed with three different grids of 70900, 212000 and 176000 elements.

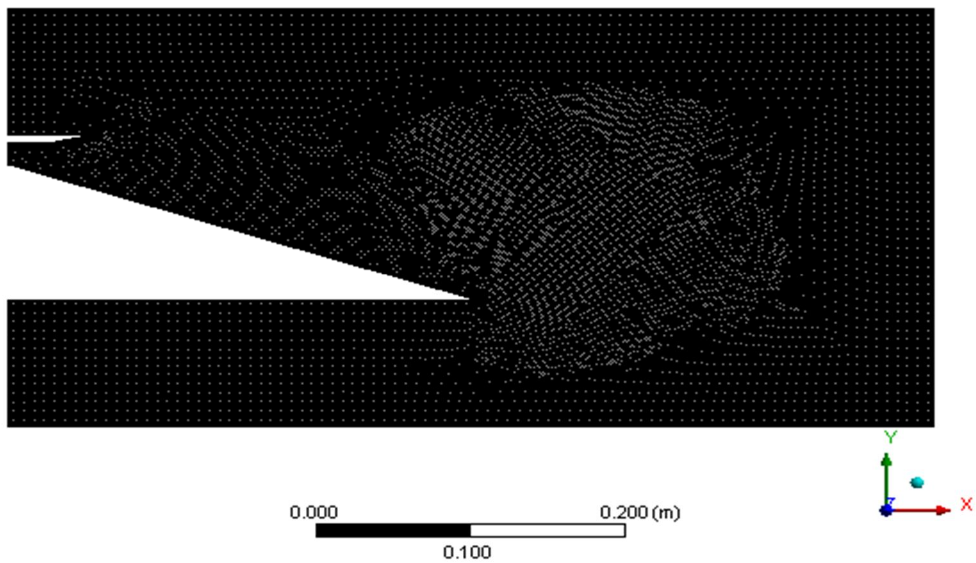


Fig.2. Mesh of the total geometric model

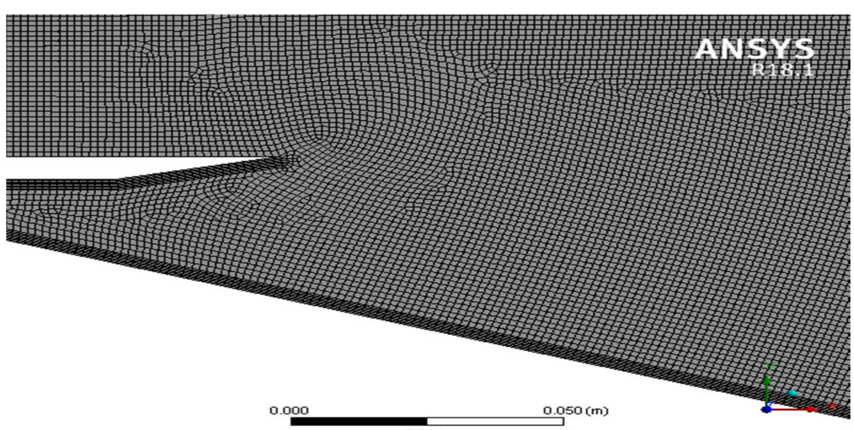
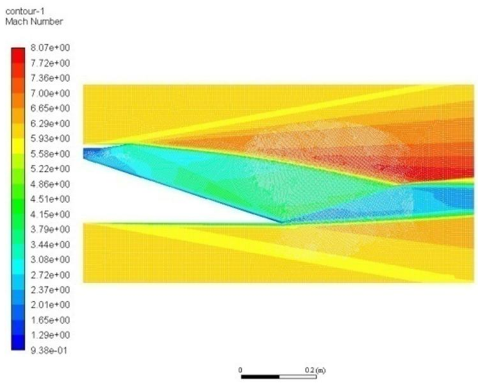


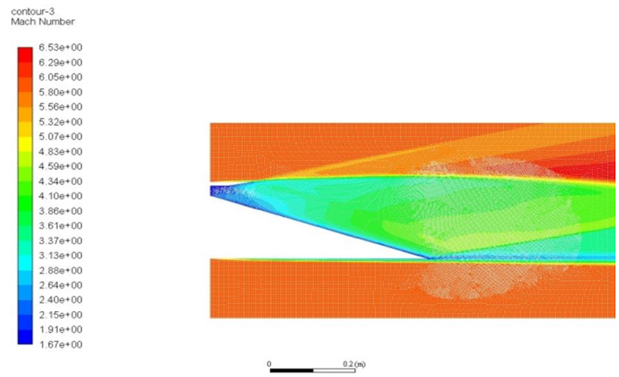
Fig.3. Closer view at the inlet boundaries of the nozzle

IV. RESULTS

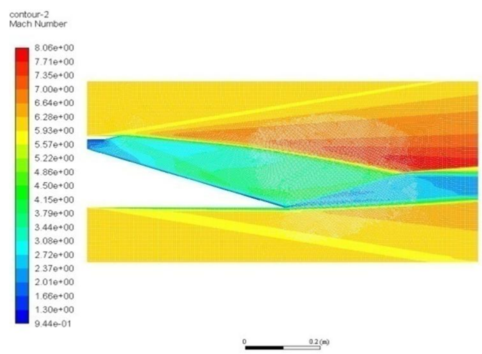
Different inner nozzle lengths are used to compare the thrust force. Lengths of 1.3h, 1.7h, 1.5h and 1.9h were considered. Similarly cowl angles of 8, 10 and 14 degrees were compared at the same inlet mach number of 1.78.



(a) cowl angle=8deg



(b) cowl angle=10deg



(c) cowl angle = 14deg

From all the results we observe that all the variables are depended on each other for optimum solution except for the inner nozzle length. The optimum design variables are those which give higher thrust and also the values of lift should be satisfied. Hence from all the results the optimized design parameters are; inner nozzle length 1.9h, cowl angle 14deg, ramp angle 16deg.

V. CONCLUSIONS

In this paper 2-D RANS equations and RNG K-e model were employed to analyse the flow field of a single expansion ramp nozzle. The thrust and the lift both are considered as the main parameters for the single expansion ramp nozzle with supersonic inlet velocities. In some cases the lift was negative and we cannot consider such cases. Hence the optimum solution must be selected for the performance enhancement.

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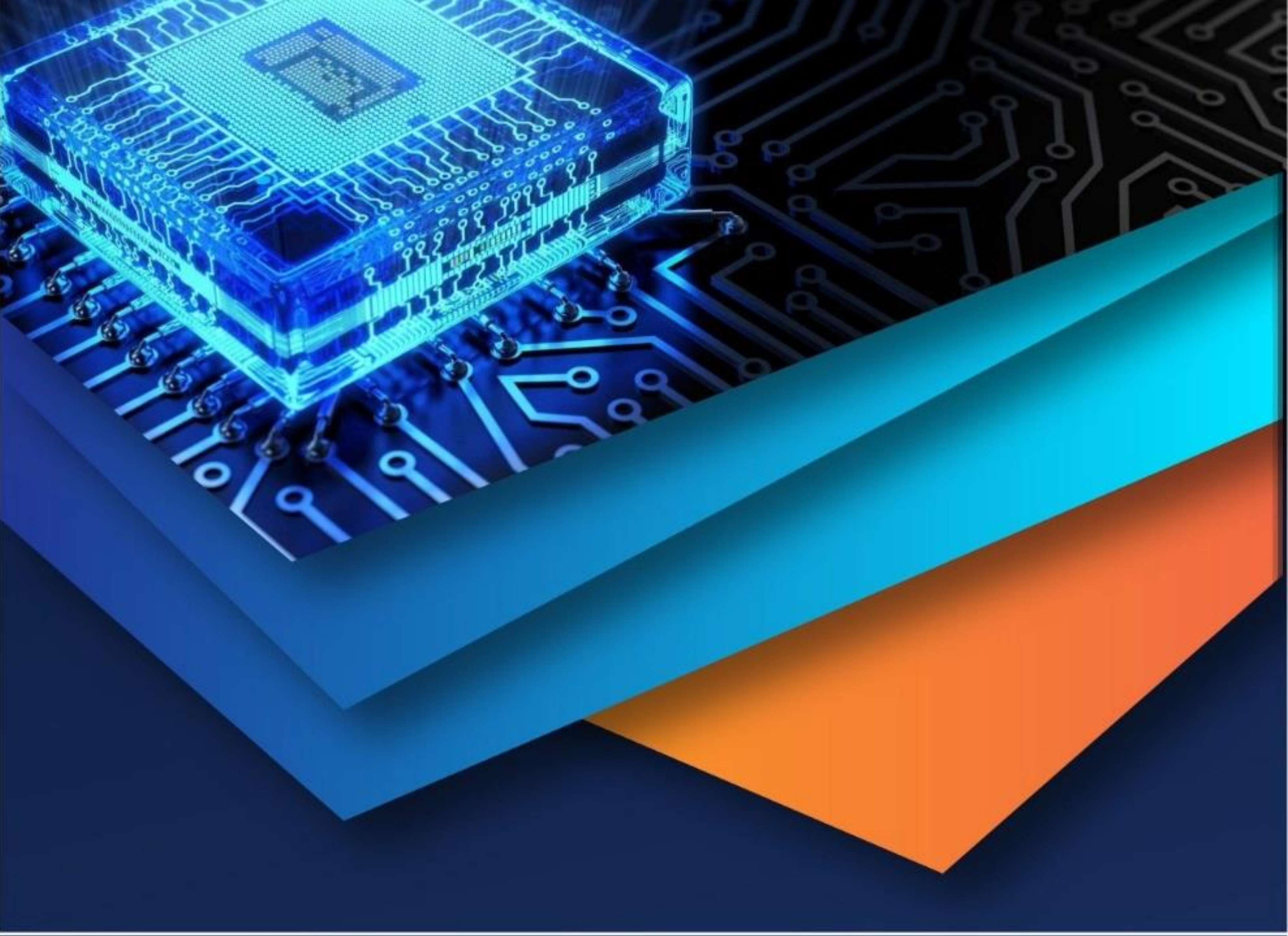

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