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Numerical Investigation of Effect of Throat Design on the Performance of a Rectangular Ramjet Intake

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Abstract : Integrated rocket ramjet engines are highly suitable for long range missile applications. Designing the fixed geometry intakes for such missiles that can operate efficiently over a range of operating conditions is a highly challenging task. Hence, the present study aims to evaluate the effect of throat design on the performance of a rectangular mixed compression intake for operation in the Mach number range of 1.8 – 2.5. The analysis has been carried out at four different Mach numbers of 1.8, 2, 2.2, 2.5 and two angle-of-attacks of +5 and +10 degrees. For the throat design, three different throat heights have been considered, one corresponding to a 3- external shock design and two heights corresponding to a 2-external shock design leading to different internal contraction ratios. The on-design Mach number for the study is M 2.2. To obtain the viscous flow field in the intake, the theoretical designs have been considered for computational fluid dynamic analysis. For which Favre averaged Navier- Stokes (FANS) equations with two equation SST k-w model have been solved. The analysis shows that for zero angle of attack at on-design and high off-design Mach number operations the three-ramp design leads to a higher total pressure recovery (TPR) compared to the two-ramp design at both contraction ratios maintaining same mass flow ratio (MFR). But at low off-design Mach numbers the total pressure shows an opposite trend that is maximum for the two-ramp low contraction ratio design due to lower shock loss across the external shocks similarly the MFR is higher for low contraction ratio design as the external ramp shocks move closer to the cowl. At both the angle of attack conditions and complete range of Mach numbers the total pressure recovery and mass flow ratios are highest for two ramp low contraction design due to lower stagnation pressure loss across the detached bow shock formed at the ramp and lower mass spillage. Hence, low contraction design is found to be suitable for higher off-design performance.

Keywords : internal contraction ratio, mass flow ratio, mixed compression intake, performance, supersonic flows
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