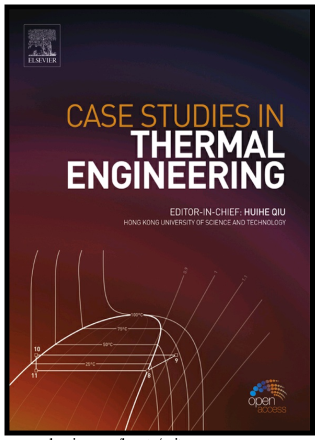
Author's Accepted Manuscript



www.elsevier.com/locate/csite

Optimization of Area Ratio and Thrust in Suddenly Expanded Flow at Supersonic Mach Numbers

Khizar Ahmed Pathan, P.S. Dabeer, Sher Afghan Khan

PII: S2214-157X(18)30210-7
DOI: https://doi.org/10.1016/j.csite.2018.09.006
Reference: CSITE335

To appear in: *Case Studies in Thermal Engineering*

Received date: 14 July 2018
Revised date: 4 September 2018
Accepted date: 22 September 2018

Cite this article as: Khizar Ahmed Pathan, P.S. Dabeer and Sher Afghan Khan, Optimization of Area Ratio and Thrust in Suddenly Expanded Flow at Supersonic Mach Numbers, *Case Studies in Thermal Engineering,* https://doi.org/10.1016/j.csite.2018.09.006

Optimization of Area Ratio and Thrust in Suddenly Expanded Flow at Supersonic Mach Numbers

Khizar Ahmed Pathan[a], P. S. Dabeer[a], Sher Afghan Khan[b]

[a]Trinity College of Engineering and Research, Pune, India.
[b] Mechanical Engineering Dept., Faculty of Engineering, International Islamic University Malaysia, Kuala Lumpur, Malaysia.
kn.pathan@gmail.com

Abstract –*In this investigation the flow field has been computed by the numerical approach using Computational Fluid Dynamics (CFD) Analysis to investigate the efficacy of the supersonic Mach numbers due to the flow from supersonic nozzle exhausted in a larger circular duct and the corresponding thrust force created due assess the flow development in the circular pipe, its measurement and the magnitude. For this study the nozzles were modeled using academic licensed ANSYS Workbench software. The nozzles were modeled for the Mach numbers 1.5, 2.0 and 2.5. The flow from the nozzles was numerically simulated for nozzle pressure ratios (NPRs) in the range from 2 to 8, and the area ratios of the study were 2, 4, 6, 8 and 10. The simulation results were compared for geometrical and the kinematical parameters. The results indicate that the pressure in the base corner of enlarged duct is influenced by the level of expansion (i.e. Nozzle pressure ratio), inertia level (i.e. Mach number) at the nozzle exit and the relief available (i.e. area ratio) to the shear layer. If the maximum thrust is the aim then the optimum area ratios should be considered. Lower area ratio is not suitable for higher NPR and higher area ratio is not suitable for lower NPR. The higher area ratio provides more space to expand compressed air. Also, the lower area ratio will offer minimum base drag. The base drag is strongly influenced by the area ratio up to certain limit. If the area ratio is again increases then there is no effect of increase in the area ratio on the base drag and Thrust. As the Mach number increases for the same Nozzle pressure ratio and the area ratio, the net thrust force also increases. From the obtained results the optimum area ratio can be selected to maximize thrust for a given Nozzle pressure ratio and Mach number.*

Keywords*: Area ratio, Base drag, Mach number, Nozzle pressure ratio, Thrust.*

Nomenclature

AR/A	Area ratio
C-D	Converging Diverging
CFD	Computational Fluid Dynamics
M	Mach number
NPR/N	Nozzle pressure ratio

1. Introduction

Suddenly expanded flows have applications in many areas like nozzle of the rockets/ missiles or the aircraft. As the flow from nozzle is suddenly expanded in the axi symmetric duct of circular cross-section of larger area, the pressure in the re-circulation zone of the duct attains very low values [2-7, 10-15]. Under these circumstances the base pressure in most of the cases is less than the atmospheric ambient pressure due to which the base drag is very high. The shear layer coming out of the nozzle gets reattached with the circular duct and that point is called the reattachment point [8, 9, 19-21]. The distance from the nozzle exit to the point at which the flow hits the wall of enlarged duct is called reattachment length [2-21]. The reattachment point depends on the expansion area available to the shear layer, the length to diameter ratio of enlarged duct, the level of expansion i.e. Nozzle pressure ratio (NPR) and the inertia level i.e. Mach number (M). The flow recirculation occurs because of suction created in the base corner due to the presence of a powerful vortex in the base region of the circular duct [24-27].

Since the main objective of the nozzle is to accelerate the flow and generate the maximum thrust. The thrust from the nozzle is the most important parameter to be considered while designing a rocket/missiles or design of an aircraft. Due to the flow from the nozzle the thrust will depend upon the mass flow rate from the nozzle, the pressure at the exit of the nozzle, the cross-sectional area of the nozzle at throat and the level of expansion.

In view of the above problems encounter in the nozzle flow it is very important to study the effect of Mach number, the expansion area and the NPR on net thrust force [21-23]. Here it is important to note that in case of C-D nozzles which are generating the supersonic stream are not ideally expanded as in the case of converging nozzles. The flow