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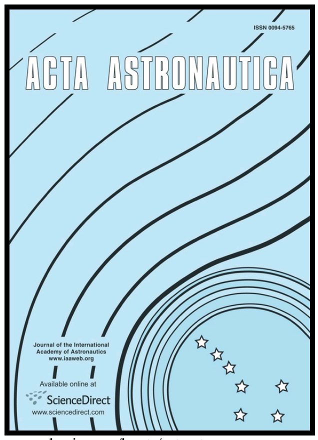

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Design and performance evaluation of a dual bell nozzle

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Abstract:

The main objective of a dual bell nozzle is the enhancement of performances based on the principle of auto-adaptation in accordance with the altitude. Indeed, this system has as advantage the auto-adaptation of the flow for two operating modes (at low and high altitude) without mechanical activation. The principle is theoretically simple but structural forces involved can be significant. In this study, a numerical method for the design of this type of nozzle is developed. On the one hand, it is based on a transonic flow approaches to define the starting line on which the supersonic calculations will be initiated. On the other hand, the method of characteristics is used to draw the base nozzle profile. Knowing that the latter is assimilated as a polynomial of the second degree, its constants are calculated from initial conditions. In order to minimize the weight of this nozzle, its truncation proves necessary; this is performed at a point where the best compromise (weight / performances) was respected. The profile of the second curve is calculated to give a constant wall pressure. This is achieved by using the direct method of characteristics applied for a centered expansion wave that the intensity is P_2/P_1 at the junction. Once the profile is generated, an analysis of the thermodynamic-parameters evolution (such as: pressure, Mach number) and aerodynamic performances is conducted. For more consistency, our results are compared with numerical databases of ONERA nozzle. Simulations of flow in the nozzle with Ansys 13.0 environment for different types of meshes are presented. Also, to offset the effects of the boundary layer, the simulations were performed by using the k-ω SST turbulence model. The obtained results by the method of characteristics and numerical simulation are compared to the computed results of the literature and it was found good agreement and similarity.

***Keywords**: dual bell nozzle; method of characteristics; supersonic flow; conception; Prandtl Mayer function; minimum length nozzle.*

Nomenclature

Coordinate system:

x: Axial Coordinate
y: Radial Coordinate

Latin letters:

A_w; B_w; C_w : Polynomial Coefficients Simulating the profile of the basic nozzle
C_d : Discharge Coefficient
C_f : Thrust Coefficient
F: Thrust
g: Gravity
I : Total Impulse
I_s : Specific Impulse
M: Mach number
M_d : Nozzle Mach design
$\dot{m}$: Mass flow
P: Static Pressure
P_t: Total Pressure
R_e: Exit section
r ' : Radius of the corrected profile;
r: Radius of the profile calculated by the method of the characteristics;
T_t : Total temperature
y_t : Throat radius

Indices:

a: Ambient
A: Attachment
J: Junction point
R_t : Nozzle throat radius
R_{tu} : Upstream throat curvature radius
R_{td} : Downstream throat curvature radius
1: Inflection point (base nozzle)
2: Inflection point (extension nozzle)

Greek letters:

δ^* : Thickness according to the longitudinal distance.
θ : Angle

Abbreviations:

NPR: Nozzle Pressure Ratio
MOC: Method of characteristics