POLITECNICO
MILANO 1863

Modeling of a blow-down propulsion system

Course of Space Propulsion
Academic Year 2023-2024

Lockheed Martini Group

Alessandro Pallotta	alessandro1.pallotta@mail.polimi.it	10712370
Alex Cristian Turcu	alexcristian.turcu@mail.polimi.it	10711624
Chiara Poli	chiara3.poli@mail.polimi.it	10731504
Daniele Paternoster	daniele.paternoster@mail.polimi.it	10836125
Marcello Pareschi	marcello.pareschi@mail.polimi.it	10723712
Paolo Vanelli	paolo.vanelli@mail.polimi.it	10730510
Riccardo Vidari	riccardo.vidari@mail.polimi.it	10711828

Contents

Notation

SYM	Description of symbol	**SYM**	Description of symbol
SYM	Description of symbol	**SYM**	Description of symbol[1]

1 Introduction and literature overview

1.1 Blow-down heritage

1.2 Additive manufacturing state of art

1.3 Analysis of losses

Real life is far away from an ideal world, this is also true for propulsion systems, especially around the nozzle. The considered modelling is based on some ideal assumption of the propulsion process, but in the nozzle some irreversibility and losses were analyzed and compared with the ideal case. The losses considered are specifically the ones caused by throat erosion and displacement thickness. The throat erosion of a nozzle, is mostly caused by the propellant passing through the throat with a high velocity and with high temperature and thus causing the nozzle's material around the throat to erode and fail more easily. This effect causes an unwanted increases of the nozzle's throat area during the propulsion and thus increase the rate at which the combustion chamber pressure decreases. Therefore, the propulsion system loses in its performance. The second analyzed irreversibility is the one caused by the viscosity between the propellant's flow and the nozzle's surface. Due to the fact that the nozzle is stationary and the flow is moving a boudery layer is created causing a slitely decrease in the total

2 Modeling of propulsion system

Initial considerations (req + hyp / assumptions + constraints + criteria)
Flowchart

2.1 Tanks sizing

2.2 System dynamics

3 Results analysis

4 Nozzle losses

In order to calculate and evaluate the nozzle losses, modifications and further calculations were made to the model presented earlier. In particular, the boundary layer required further calculation. First of all, the CEAM program was used to find some initial parameters of the propellant flow, such as the density, the dynamic viscosity, the temperature and the adiabatic dilatation coefficient, all taken at the nozzle throat. After this step, the calculation can begin, starting from the calculation of the velocity of the propellant flow (the velocity can be found by using the speed of sound) and the Reynolds number in the throat.
[aggiungere equazione della volocita del suono e reynold].
Finally, the modified Reynolds number can be calculated using the throat radius and curvature. The datas were taken from the nozzle modeling part.
[aggiungere formula raynold modificato].
With all these data it is possible to calculate the discharge coefficient [qui si può aggiungere reference alle slide di maggi], so that the real mass flow at the throat can be calculated, also taking into account the ideal mass flow found in the previous section of the report.
[aggiungere formula Cd e mre].
This procedure is also repeated in the various iterations of the modelling code. Furthermore, from the first iteration of the code, an erosion rate will be considered to evaluate the losses caused by the nozzle erosion. An analysis of the literature has been done to find a suitable erosion rate. Due to the small dimension of the propulsion system and the lack of experiments in this field carried out on similar engines have led to these rates being considered unacceptable. Therefore, an approximation was made that allowed to have an approximately increase of 2% of the initial throat radius in our computation time. It is important to note that this is a very large approximation because no consideration about the propellant properties and throat material were made [qua si può aggiungere la citazione alle slide the maggi]. Normally the erosion rate is calculated by performing experimental measurements of the propulsion system and so every possible factor can be considered.

5 Additive manufacturing influences

6 Cooling analysis

Bibliography

[1] Richard Grammier. *Overview of the Juno Mission to Jupiter*. Site: https://www.jpl.nasa.gov/missions/juno. 2006.