
Oral presentation | Reduced order models

Reduced order models-I

Mon. Jul 15, 2024 10:45 AM - 12:45 PM Room C

[1-C-04] Analysis of Supersonic Retropropulsion Flow using Modal Decomposition

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Keywords: Supersonic Retropropulsion , Proper Orthogonal Decomposition, Spectral Proper Orthogonal Decomposition, Dynamic Mode Decomposition

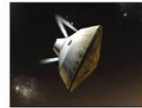
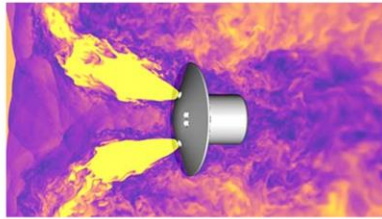
Analysis of Supersonic Retropropulsion Flow using Modal Decomposition

Jiaye Qiao
Supervised by Salvador Navarro-Martinez
02/07/2024

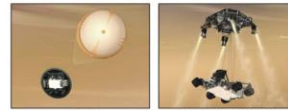
Introduction

Background

- Propulsive deceleration initiated at supersonic Mach numbers
- Improve payload mass
- Improve landing precision



Aeroball

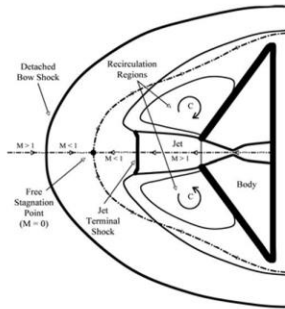


Parachute

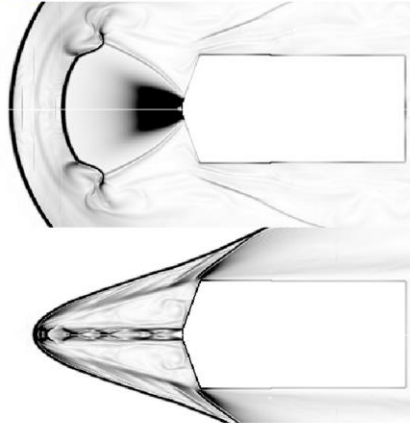
Powered Descent Vehicle

Introduction

Supersonic retro-propulsion(SRP) flowfield



Blunt Penetration mode(Up)
Long Penetration mode(Down)



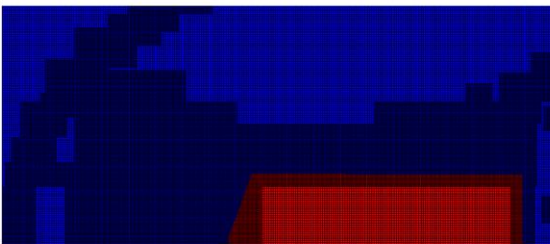
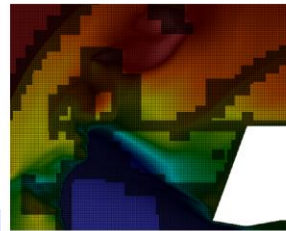
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Numerical Approach

- In-house solver **CompReal**
- Immersed Boundary Method
- Adaptive Mesh Refinement
- 2D axisymmetric coordinate used



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Wind Tunnel Test Summary

Ma_{∞}	P_{∞}	T_{∞}	D_{ref}
4.6	574.56Pa	65K	0.127m

C_{thrust}	P_{total}	T_{total}	D_{nozzle}
2	$7724 \cdot P_{\infty}$	$5.34 \cdot T_{\infty}$	$0.1 \cdot D_{ref}$



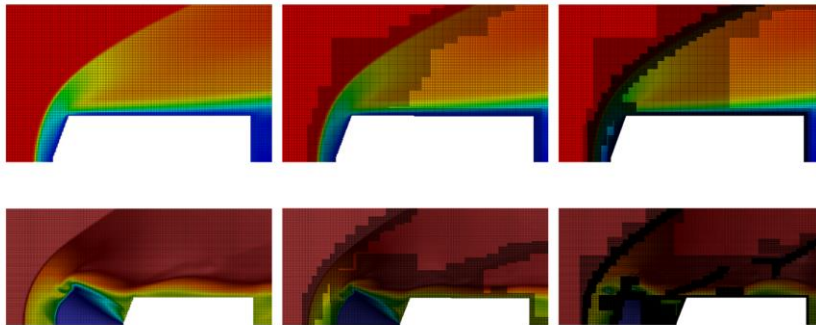
a) Single image from video b) Average intensity of all frames c) Standard deviation of all frames

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Numerical Approach



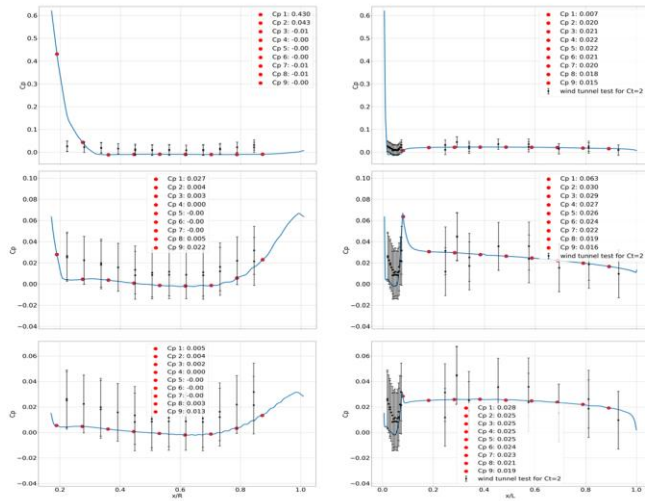
Refinement with 0, 1 and 2 level

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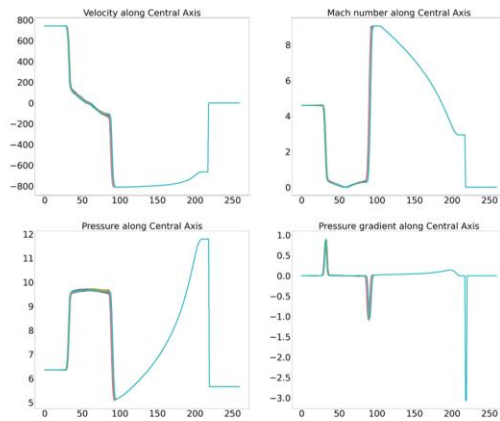
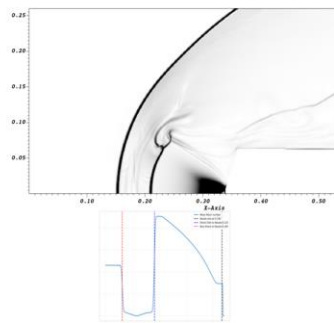
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Pressure coefficient along surface under different refinement level

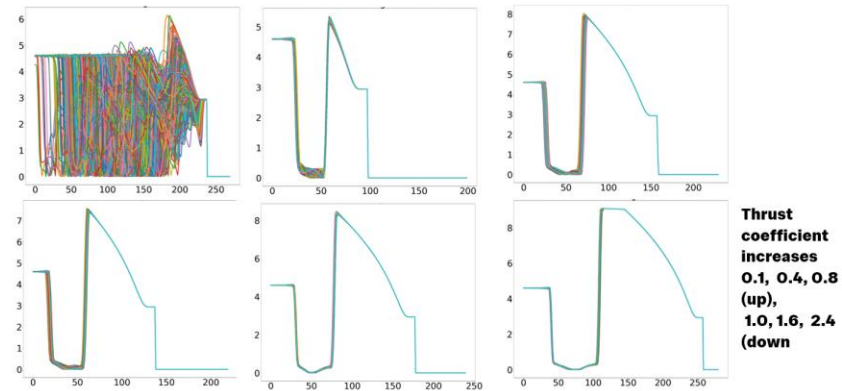


Results and Discussion

Shock Position for C_{thrust} equal 2.0



Results and Discussion



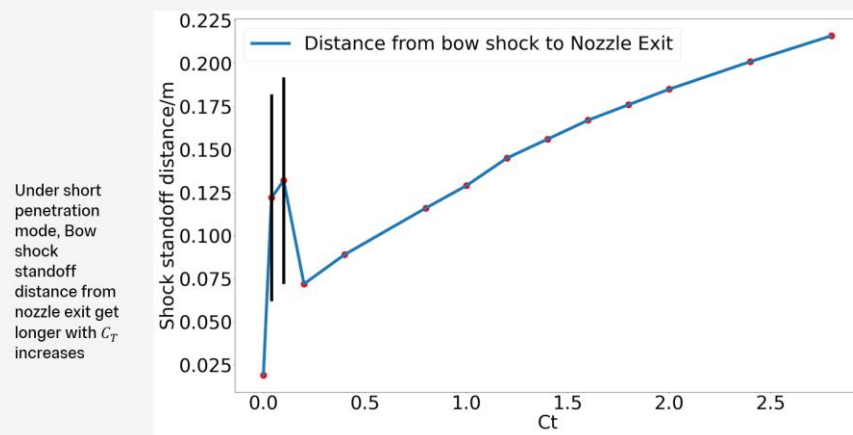
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Results and Discussion



Under short penetration mode, Bow shock standoff distance from nozzle exit get longer with C_T increases

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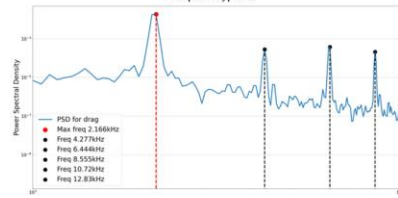
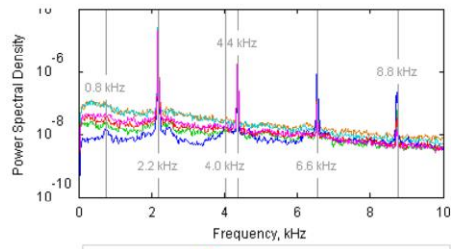
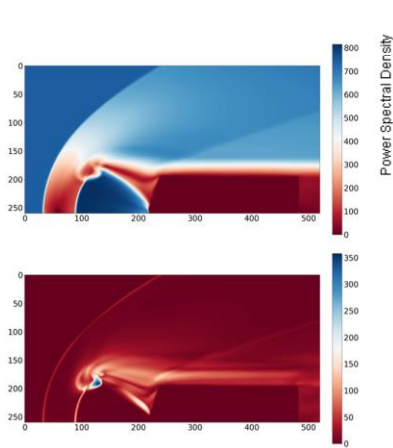
10

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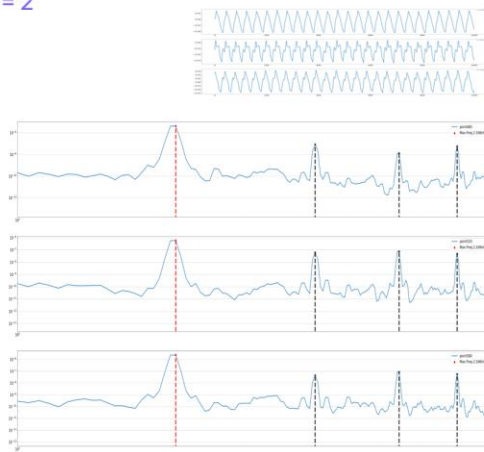
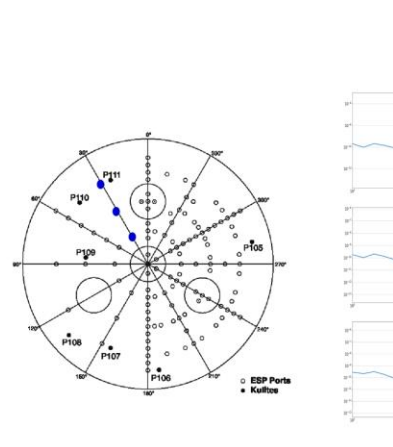
Results and Discussion

Frequency analysis for $C_{thrust} = 2$

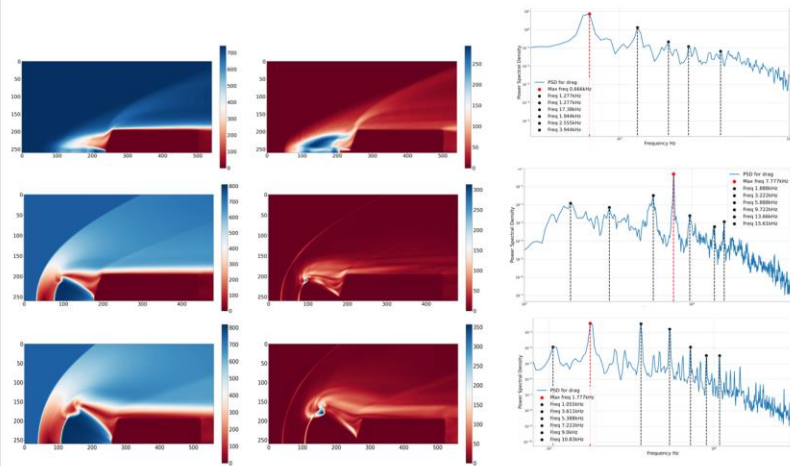


Results and Discussion

Frequency analysis for $C_{thrust} = 2$

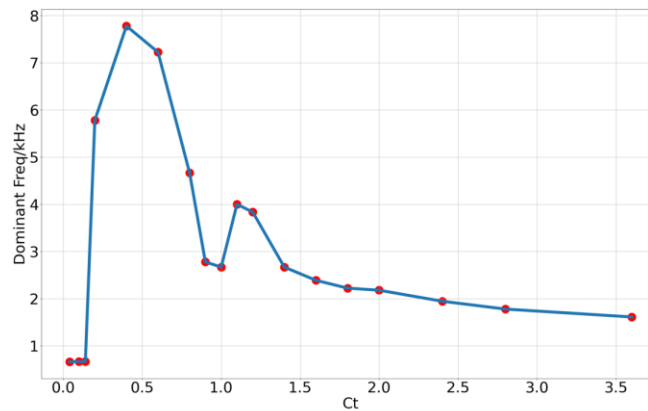


Results and Discussion



C_{thrust}
equal to
0.1, 1.2
and 2.4

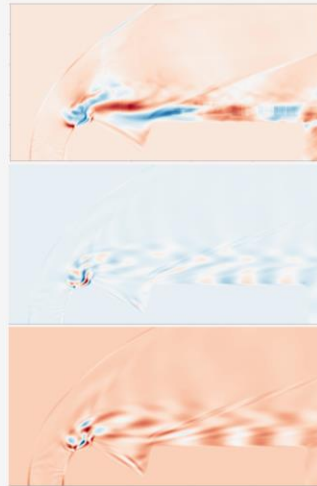
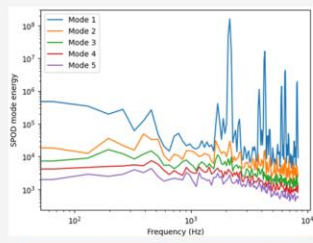
Results and Discussion



Dominant frequency goes
down as the thrust
coefficient increase,
except at C_{thrust} around 1

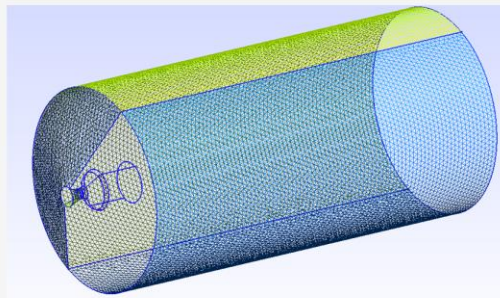
Modal decomposition

Spectral Proper Orthogonal Decomposition of $C_t = 2$ SRP flow field, and four most energetic mode plot right.



Future Work

- Full 3D case will be tested under different AOA
- Flow field reconstruction with SPOD mode



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Thank you!