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Control-oriented low-speed dynamic modeling and trade-off analysis of air-breathing aerospace vehicles

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Key words: Control-oriented modeling; Horizontal take-off and landing; Stability and control analysis; Trade-off study

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Integrated Dynamic Modeling

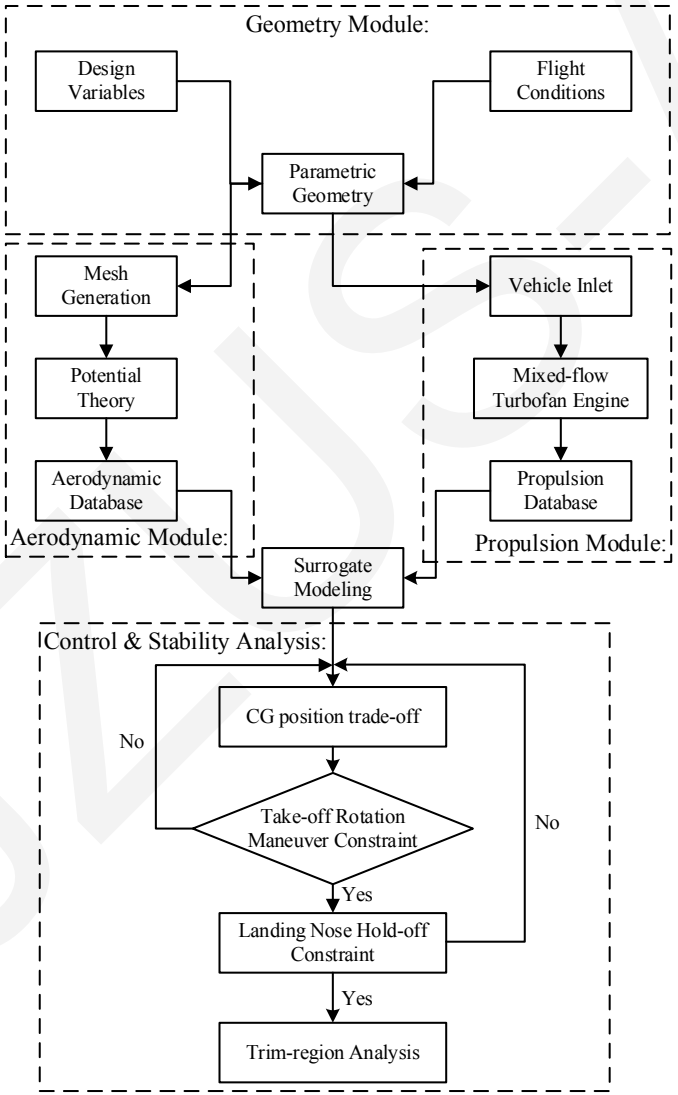
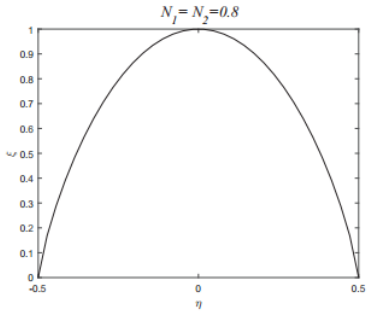


Fig.1 Control-oriented dynamic modeling and S&C analysis framework

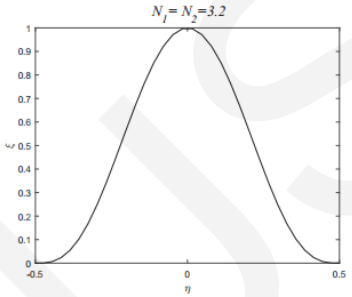
Integrated Dynamic Modeling

Geometry Module

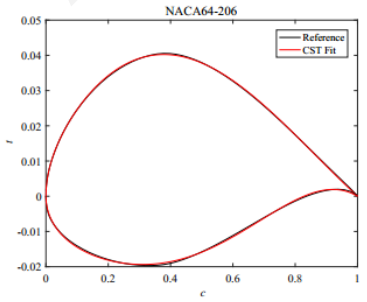
1. Cross-section definition (Class-shape transformation)



(a) $N_1 = N_2 = 0.8$

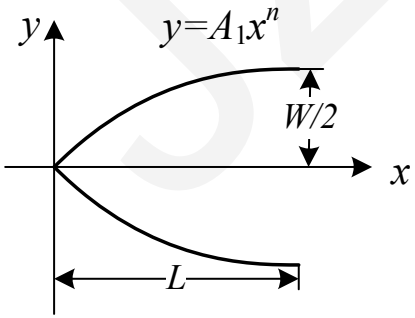


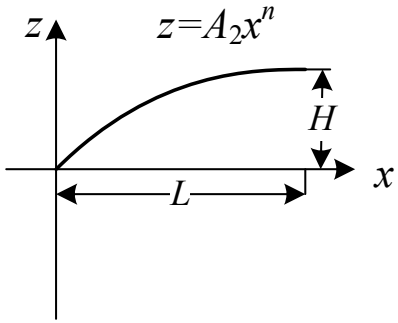
(b) $N_1 = N_2 = 3.2$



(c) NACA64-206

2. Outer-mold line (Power function)





Integrated Dynamic Modeling

Aerodynamic Module

1. Structured mesh generation

2. Potential theory

3. Parasite drag

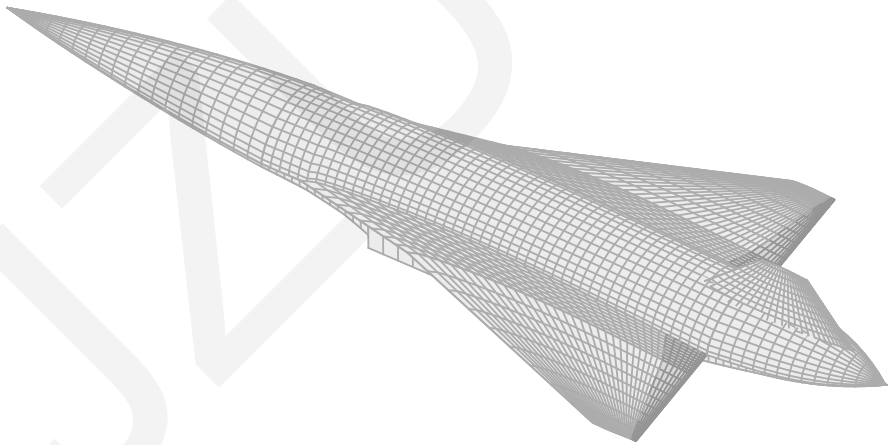


Fig.2 Aerospace vehicle concept

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Propulsion Module

1. On-design performance analysis

2. Off-design performance analysis

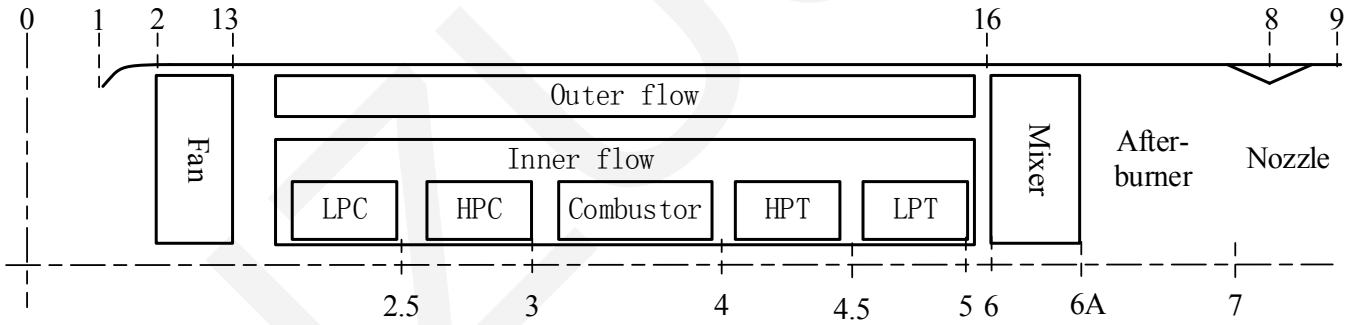
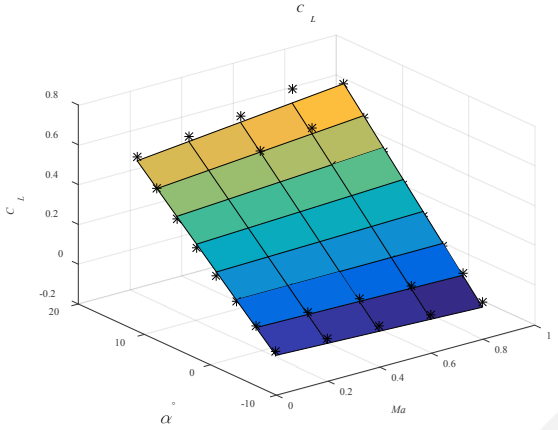


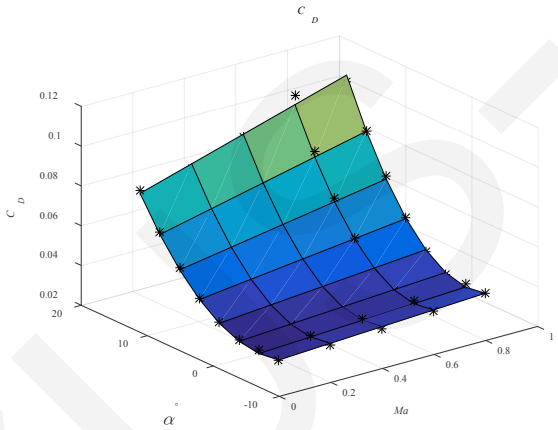
Fig.3 Reference stations of mixed-flow turbofan engine

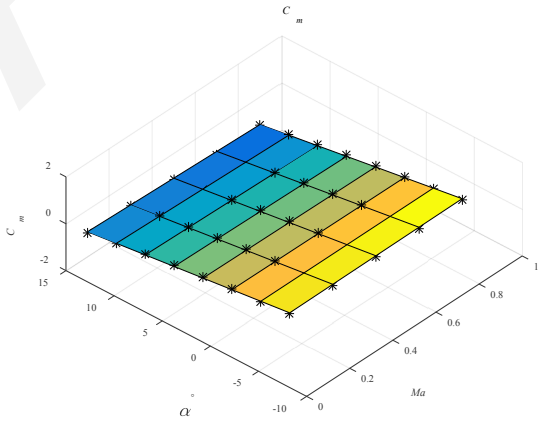
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Surrogate Modeling

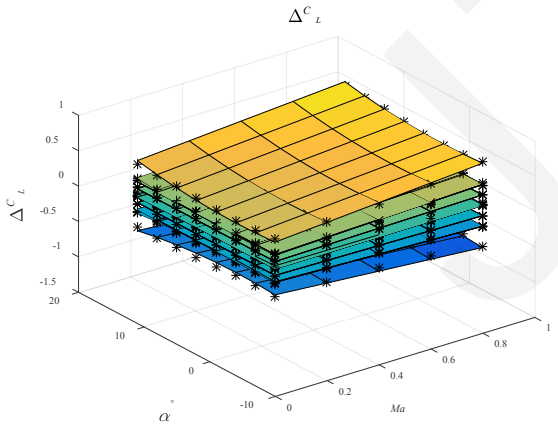
Clean configuration

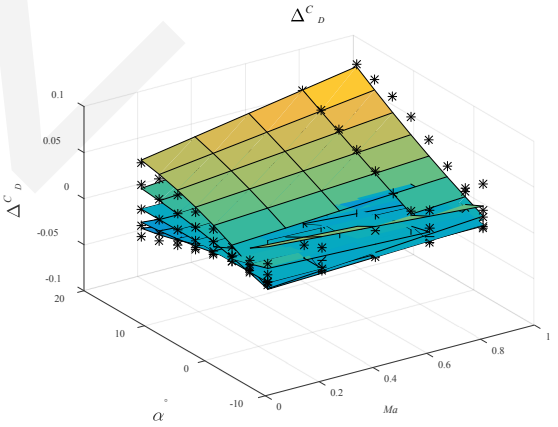


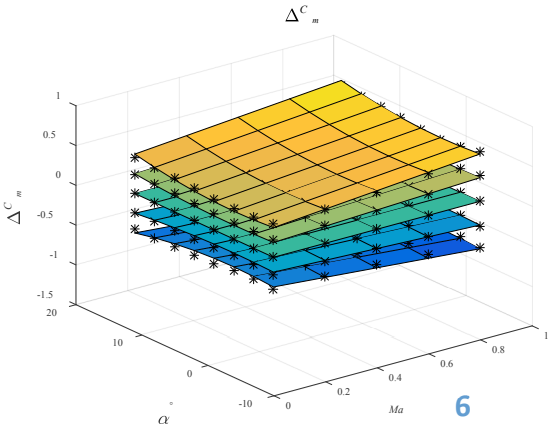




Incremental coefficients







Trade-off Trade-off Analysis

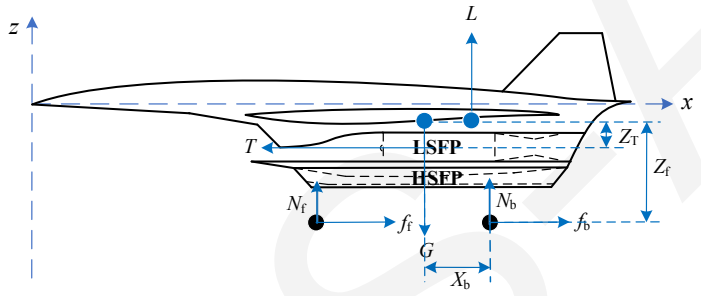


Fig.4 Major forces and moment arm definitions during rotation

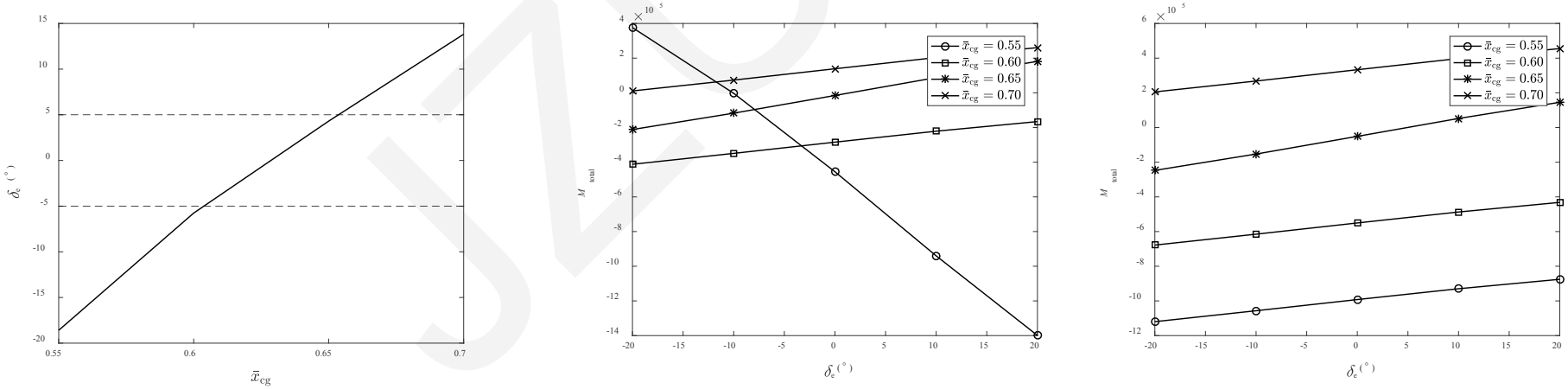


Fig.5 Take-off rotation and approaching performance with different CG positions

Trim Analysis

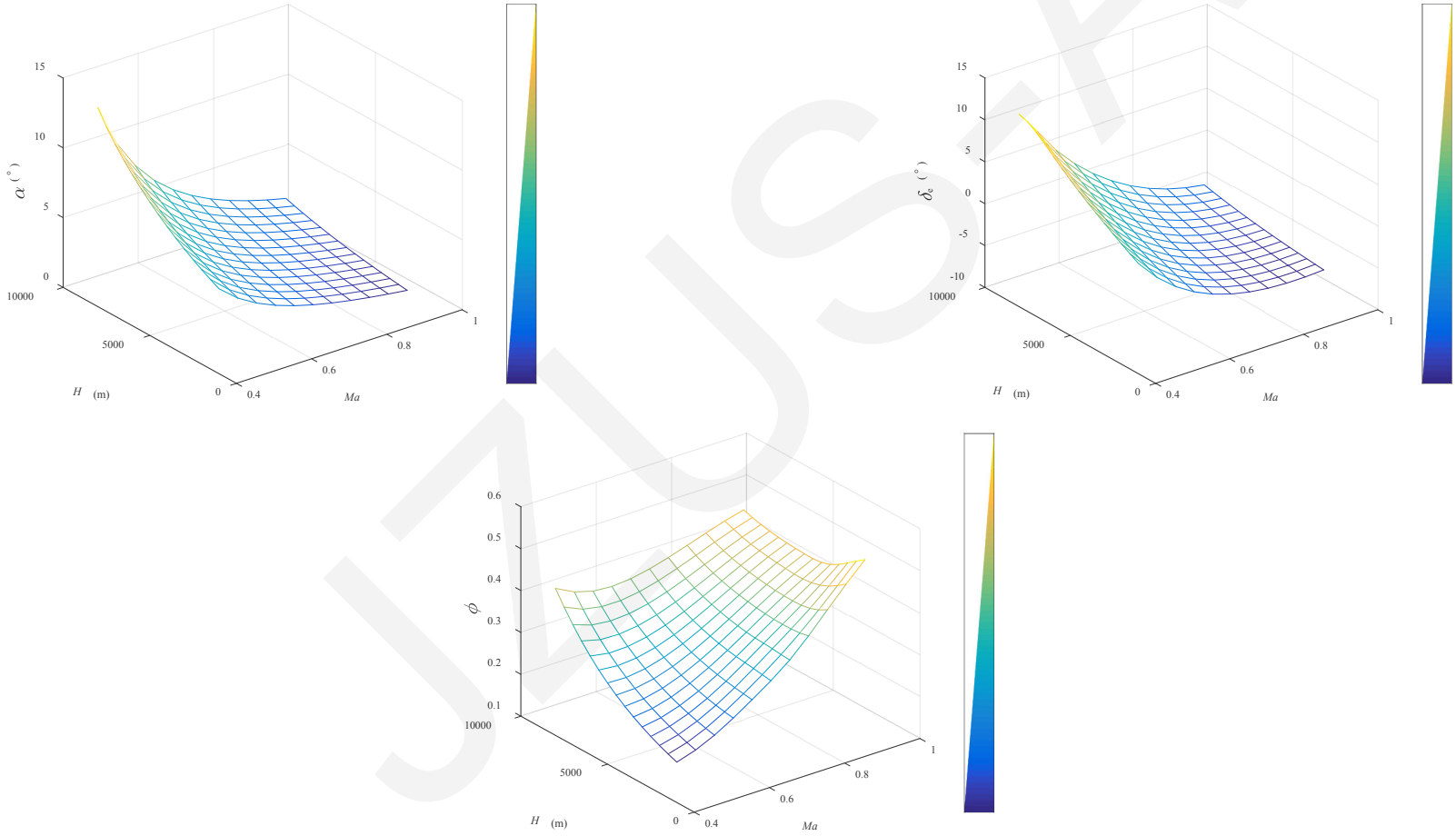


Fig.6 Trim states as functions of altitude and Mach number

Conclusions

In this paper, a control-oriented low speed dynamic modeling and trade-off analysis framework is proposed, which consists of the following five main parts:

- Parametric geometry modeling;
- Potential theory based panel method;
- Quasi-one dimensional mixed-flow turbofan engine model;
- Surrogate modeling;
- Stability and control trade-off analysis.

The effectiveness of the proposed framework is verified through a HTHL aerospace vehicle concept, with the emphasis on center-of-gravity trade-off analysis, guaranteeing the take-off rotation and approaching performance.

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