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Design method for hypersonic bump inlet based on transverse pressure gradient

Shang-cheng XU, Yi WANG, Zhen-guo WANG, Xiao-qiang FAN, Bing XIONG

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Motivation

■ For hypersonic inlets, the low-energy boundary layer should be excluded as much as possible to improve the quality of the captured airflow. To divert the boundary layer, a type of bump inlet was proposed in the last century.

■ The integrated design of the bump/inlet is a potential way to improve the inlet performance under hypersonic condition and should be further investigated.

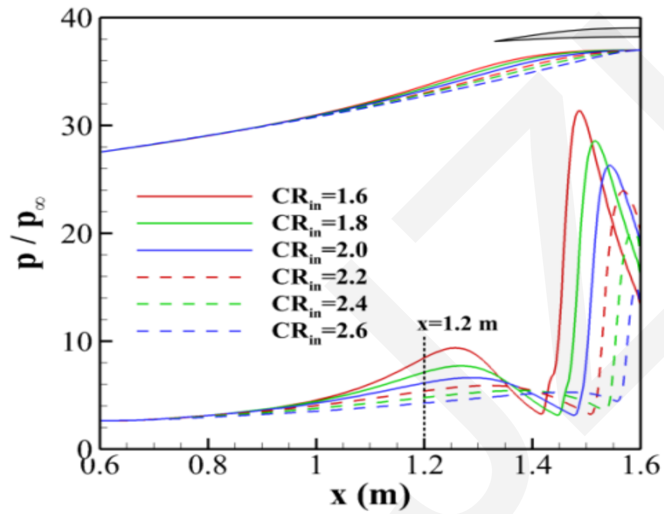
■ The key in the bump design was to properly arrange the transverse pressure gradient (TPG). However, there have been few studies on the bump design method based on the TPG.

This study focused on the design approach for a hypersonic bump inlet based on the TPG.

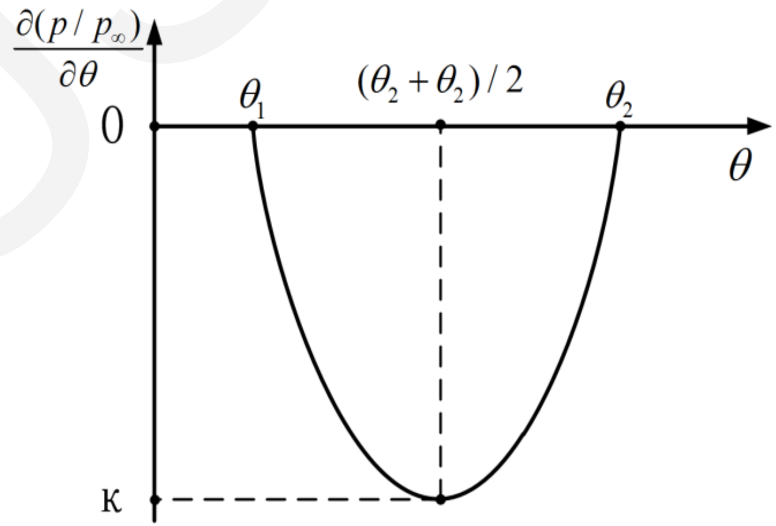
Design method

The proposed design method consists of two steps:

- First, various 2d inlets with different compression efficiencies are designed using a parametric optimization method;
- Second, the optimized 2D inlets are arranged in different osculating planes of the 3D inlet based on the prescribed TPG.



Pressures of various 2d inlets with different compression efficiencies

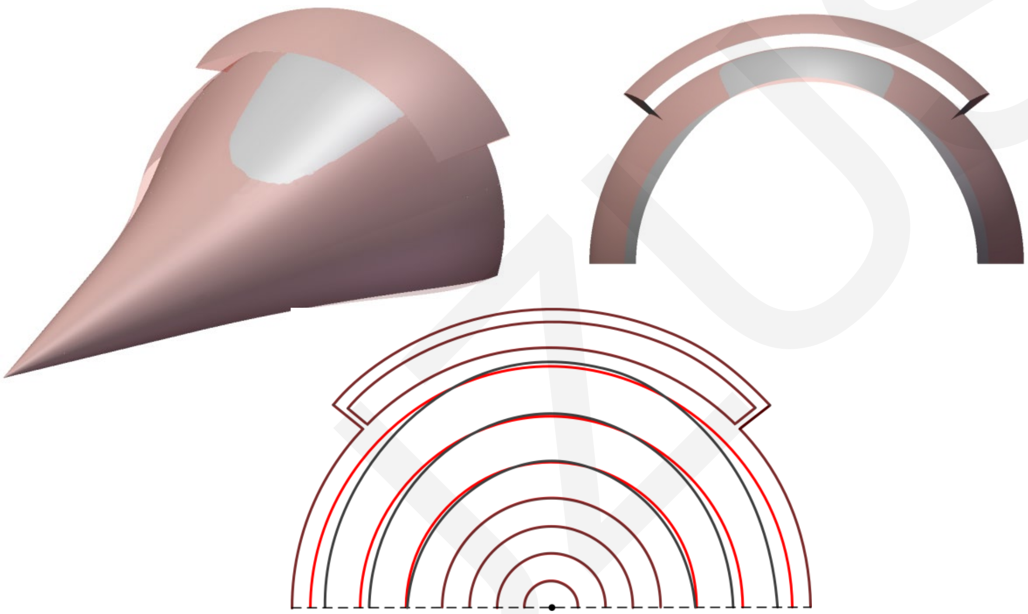


Prescribed TPG

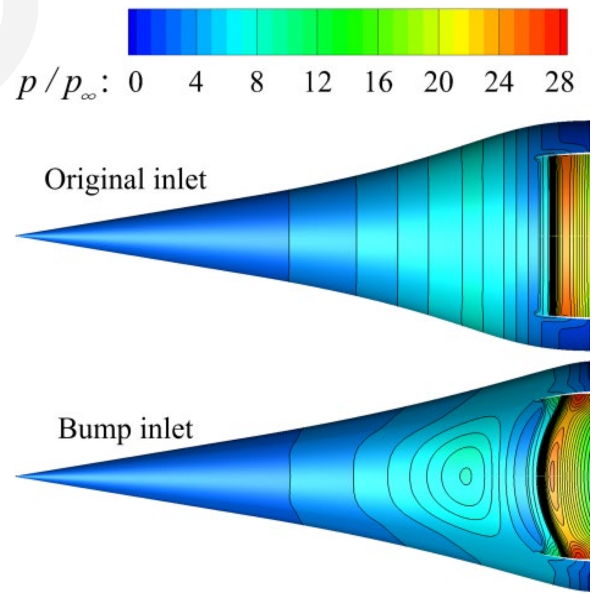
Design method

■ Obtained bump inlet

The compression wall of the bump inlet is high in the central region but low at both sides. Correspondingly, a transverse pressure gradient is formed on the bump surface



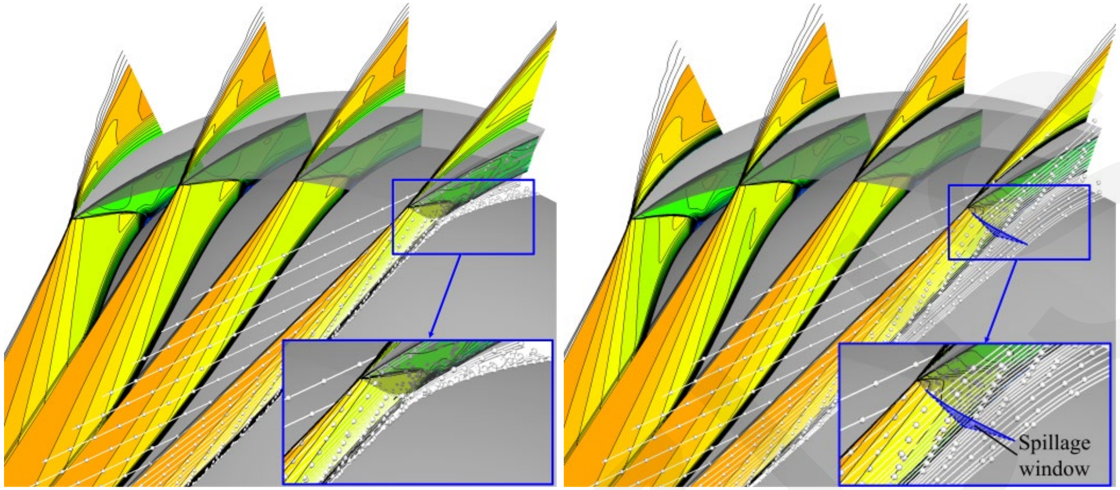
Comparison of original inlet (red) and bump inlet (grey)



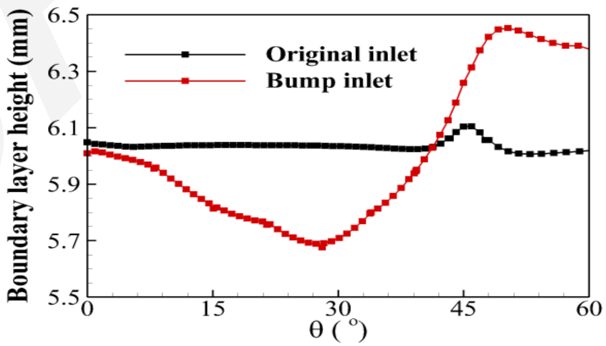
Pressure contours of original and bump inlets

Results and discussion

■ Boundary layer diversion



Original inlet   Bump inlet

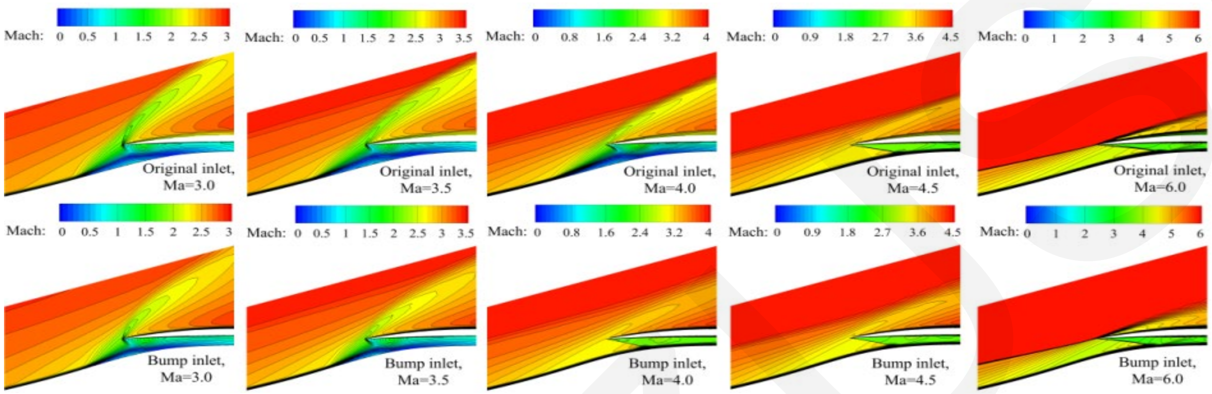


Comparison of boundary layer thicknesses

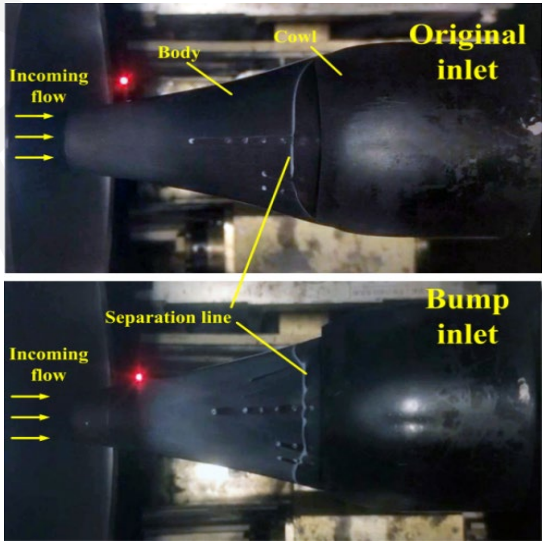
The boundary layer flow is excluded by the bump and forms a triangle-shaped spillage window. As a result, the boundary layer thickness in the capture range of bump inlet is lower than that of the original inlet.

Results and discussion

Starting performance



Mach number contours during the starting processes



Oil flow distributions of unstarted inlets

The bump has a three-dimensional rebuilding effect on the large-scale separation bubble of the unstarted inlet, thereby improving inlet starting performance.

Conclusions

- The designed bump was highly integrated with the inlet compression wall without additional flow loss under hypersonic condition;
- The boundary layer flow was excluded from the inlet capture range owing to the TPG on the bump surface;
- The bump had a 3D rebuilding effect on the large-scale separation bubble of the unstarted inlet, thereby improving the inlet starting ability;
- Full flow capture was successfully achieved in the bump inlet by performing the proposed mass flow correction.