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Effects of bump parameters on hypersonic inlet starting performance

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Motivation

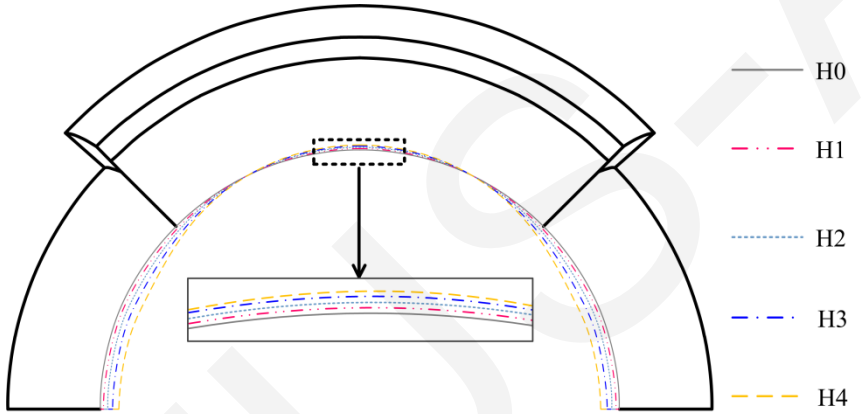
- Starting performance is one of the most important parameters for determining the operating range of a hypersonic aircraft powered by a scramjet.

- The bump inlet was proposed by the Lockheed Martin Corp to divert the boundary layer (BL) flow. Because it has recently been shown that a bump can improve the inlet starting ability, a study of the effect laws of bump parameters on the inlet starting performance is important to provide guidance for bump design. In addition, the underlying flow mechanism while using bumps should be further evaluated.

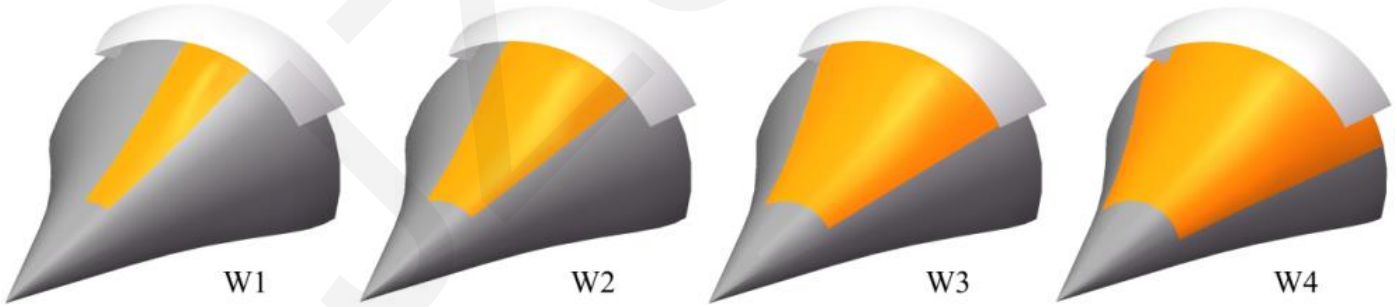
This study focused on the effect laws of bump parameters on the starting performance of a hypersonic inlet.

Bump inlet design

Various bump configurations with different heights and widths were designed and integrated with a hypersonic inlet.



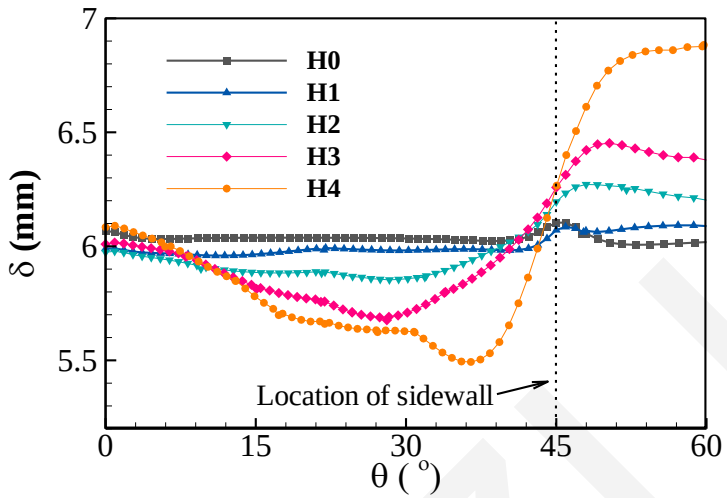
Five hypersonic inlets with different bump heights



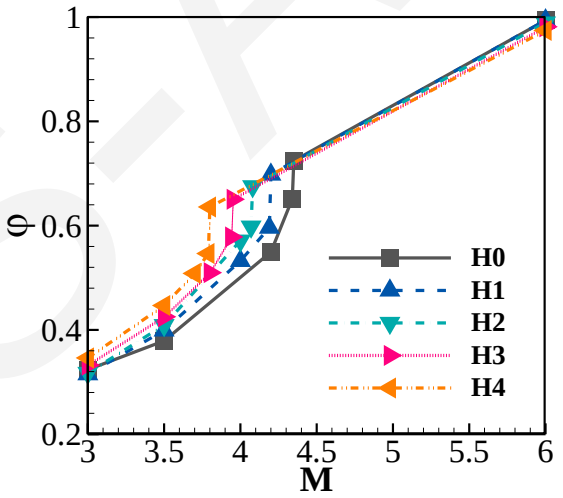
Four hypersonic inlets with different bump widths

Results and discussion

Inlet performance with different bump heights



Boundary-layer thickness distributions (in the plane x = 1400 mm)

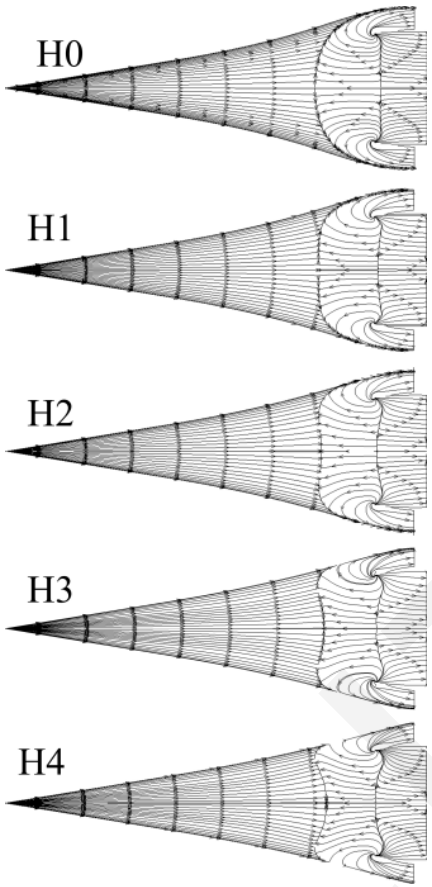


Mass flow rate distributions during the starting process

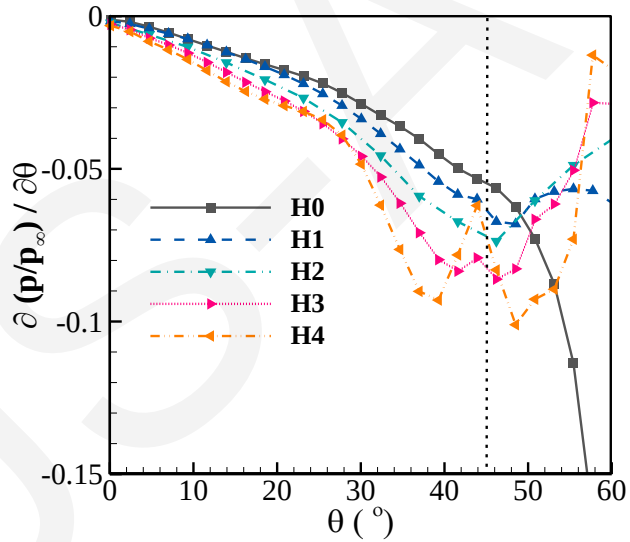
The BL diversion effect and starting performance could be significantly improved by increasing bump height

Results and discussion

Effect of bump height on separation bubble



Near-wall streamline distribution of the unstarted inlets

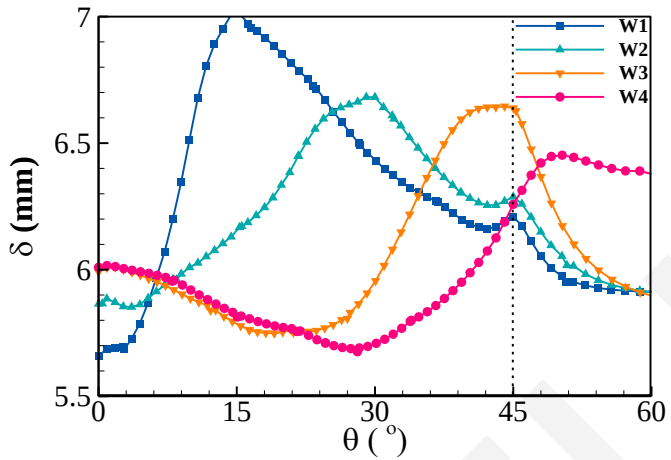


Transverse pressure gradient (TPG) distributions of the unstarted inlets

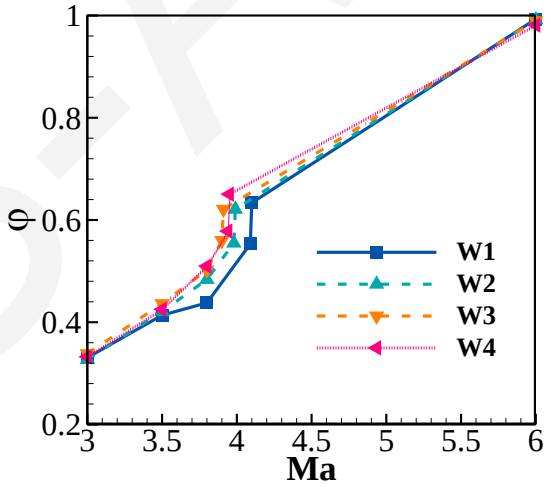
Large-scale separation bubble was restructured by a bump. A higher bump facilitated the side movement of the flow in the separation zone by a large TPG, thereby accelerating the starting process.

Results and discussion

Inlet performance with different bump widths



Boundary-layer thickness distributions (in the plane x = 1400 mm)

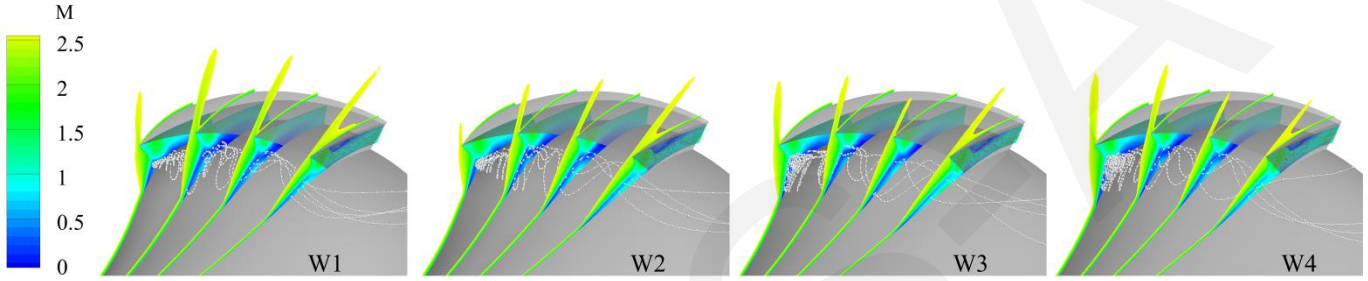


Mass flow rate distributions during the starting process

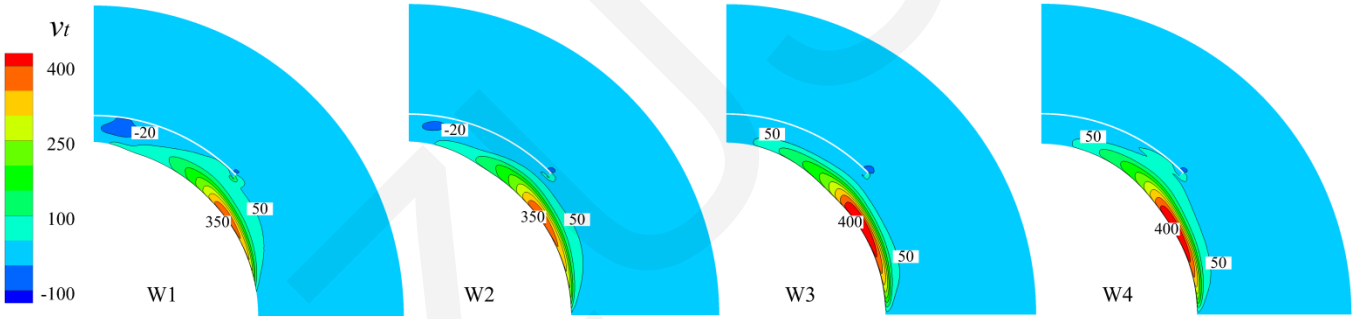
A good displacement effect could be achieved when the bump surface was designed to be wider than the capture range. Moreover, the starting ability could be improved by designing a relatively wide bump.

Results and discussion

Effect of bump width on separation bubble



Mach number contours and streamlines of the unstarted inlets



Transverse velocity contours of the unstarted inlets

When bump was designed to be the same width or wider than the capture range, a growing transverse spillage along the transverse direction could be formed such that the subsonic airflow in the separation bubble could be easily excluded.

Conclusions

- The performance of the boundary-layer diversion could be improved by increasing the bump height. Moreover, when the bump surface was designed to be wider than the inlet capture range, a good diversion effect could be achieved.
- The starting performance could be improved by increasing the bump height, the starting Mach number decreased by 0.55 for the inlet with the highest bump;
- The starting performance could be improved by designing a relatively wide-bump configuration, which resulted in a decline in the starting Mach number of 0.44;
- Analysis revealed that the high and wide bump surface had significant 3D-rebuilding effect on large-scale separation bubble, thereby improving starting ability.