# Aerothermal Optimization of Hypersonic Vehicle Leading Edge Based on Genetic Algorithm

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**Abstract** This work is concerned with the design of a leading edge for hypersonic vehicles used to minimize the peak heat flux of the leading edge. The leading edge is parameterized by using B-spline curve method. The hypersonic flow field and the heat flux distribution around the leading edge is evaluated by computational fluid dynamics. Genetic Algorithm is used to obtain a novel leading edge shape that greatly reduces the peak heat flux of the leading edge. The aerothermal design of a 2D leading edge with the thickness of 5mm was carried out in the design condition Mach 6.5 and no flight attack angle. The peak heat flux reduced about 20% compared to the circular leading edge, and the optimization result is also effective with the attack angle less than 15° . Besides, the result is confirmed by different Mach number, wall temperature, altitude and thickness of the leading edge.
**Key words:** Hypersonic, Blunt leading edge, Aerothermodynamics, Optimization

## Numerical results

The design conditions are as follows: the Mach number is 6.5, angle of attack is 0 (degree), static pressure 1847.46 (pa), static temperature is 223.65 (K), wall temperature is 300(K). The K-Ɛ-Rt turbulence model is adopted.

An optimal 2D profile of leading edge is obtained in this work. Numerical results are shown in Figure 1,Figure 2,Table 1 and Table 2. It's flatter(a larger radius of curvature near the peak point) than the initial circular leading edge. As a result, the distance between the shock wave and leading edge increased obviously(Figure 2), and the distribution of heat flux around the leading edge is much flatter(Figure 1). The peak heat flux reduced about 20% compared to the initial circular leading edge, though the drag force increased about 12%(Table 1).

As shown in Table 2, it is effective to reduce the peak heat flux with the flight attack angle no higher than 15 degree. The optimized leading edge also applies equally to different flight Mach, flight altitude, wall temperature and thickness of leading edge. It is worthy pointing out that, the optimal 2D profile can simply scaled to the corresponding size predetermined by the thickness of leading edge. Therefore, the optimized 2D profile of leading edge is universal.

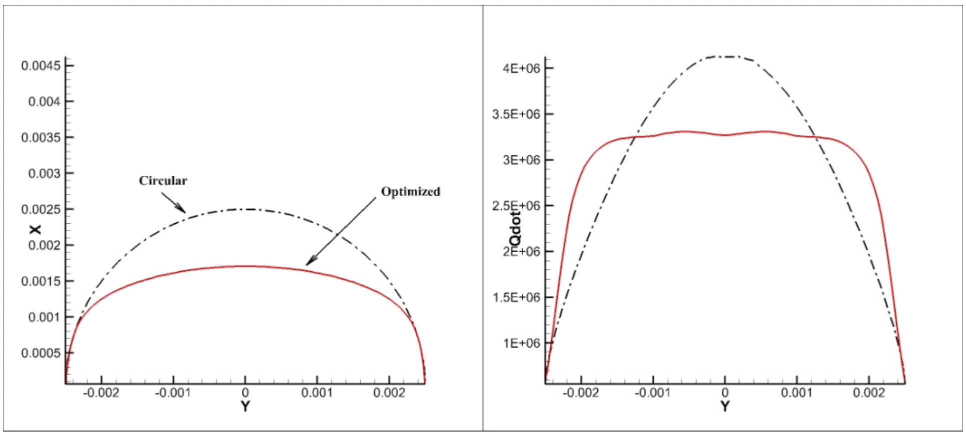


Figure 1 comparison between the circular and optimized shapes(left) and heating flux(right)

Table 1 comparison of the peak heat flux and drag force

| | Circular | Optimized | Reduced by |
|---|---|---|---|
| $Q_{max}$(W/m$^2$) | 4132495.5 | 3308691.5 | 19.93% |

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| | | | |
|---|---|---|---|
| $F_{drag}$(N) | 495 | 553 | -11.72 % |

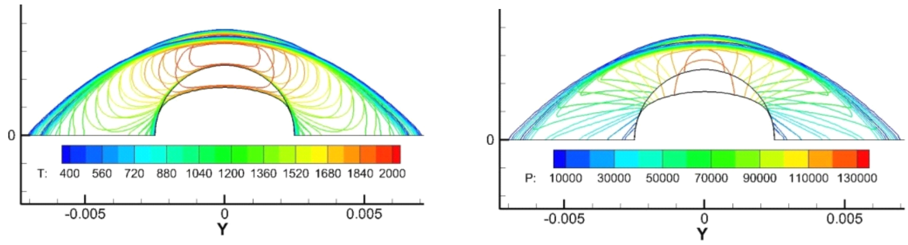


Figure 2 temperature(left) and pressure(right) contours comparison

Table 2 comparison of peak heat flux under different conditions

| | | Circular | Optimized | Reduced by |
|---|---|---|---|---|
| Attack angle | 0° | 4132495.5 | 3308691.5 | 19.93% |
| | 5° | ---- | 3472969.3 | 15.96% |
| | 10° | ---- | 3715737.3 | 10.08% |
| | 15° | ---- | 3965252.3 | 4.05% |
| | 20° | ---- | 4290240.0 | -3.82% |
| $Ma_\infty$ | 4 | 835783.6 | 677299.9 | 18.96 % |
| | 6.5 | 4132495.5 | 3308691.5 | 19.93% |
| | 8 | 8001004.5 | 6388588.5 | 20.15% |
| | 10 | 16108993.0 | 12837634.0 | 20.31% |
| | 12 | 28288982.0 | 22550940.0 | 20.28% |
| Altitude (Km) | 20 | 6111139.0 | 4905992.0 | 19.72% |
| | 23 | 4824684.5 | 3880997.8 | 19.56% |
| | 25 | 4132495.5 | 3308691.5 | 19.93% |
| | 30 | 2838345.3 | 2255883.8 | 20.52% |
| | 35 | 2062320.6 | 1608656.8 | 22.00% |
| | 40 | 1596527.8 | 1222057.8 | 23.46% |
| Wall Temperature (K) | 300 | 4132495.5 | 3308691.5 | 19.93% |
| | 600 | 3473824.5 | 2785081.3 | 19.83% |
| | 900 | 2796267.0 | 2229367.8 | 20.28% |
| | 1200 | 2113293.0 | 1692545.9 | 19.91% |
| | 1500 | 1425652.4 | 1139362.5 | 20.08% |
| | 1800 | 736821.2 | 584651.4 | 20.65% |
| Thickness (mm) | 5 | 4132495.5 | 3308691.5 | 19.93% |
| | 10 | 3005784.5 | 2413445.5 | 19.71% |
| | 20 | 2186993.5 | 1757907.8 | 19.62% |
| | 40 | 1591611.4 | 1276121.9 | 19.82% |

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