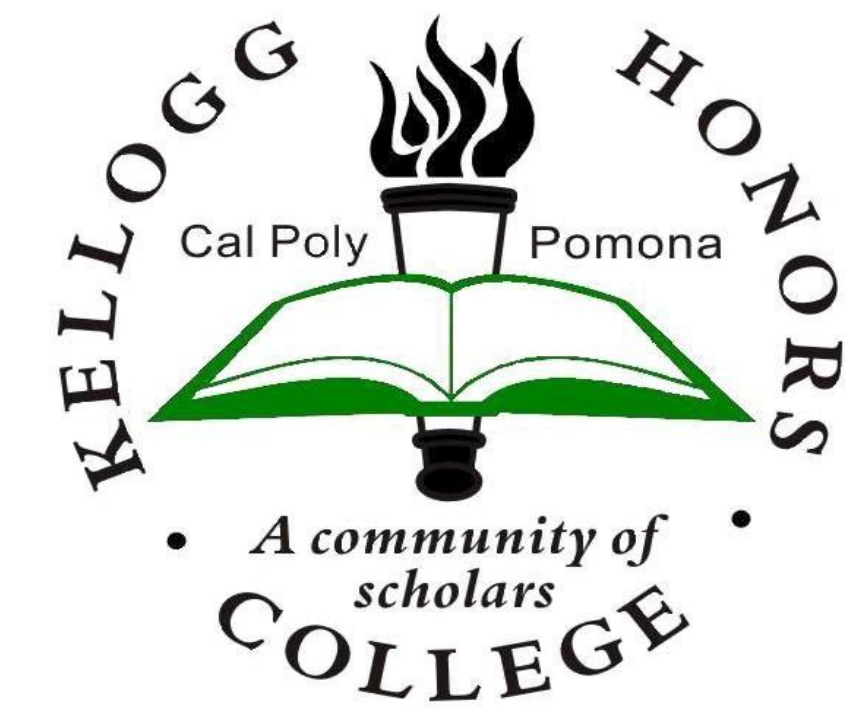


A CFD Investigation on a Generic Diverterless Supersonic Inlet of Ellipsoid Shape

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Introduction

The Diverterless Supersonic Inlet (DSI), or “bump” inlet, is a new and innovative design feature to aircraft that offers significant benefits in stealth while being lighter and simpler than inlets with traditional diverters. It is a state-of-the-art technology which is featured on the Lockheed Martin F-35 stealth fighter. Designing a DSI, however, is not a simple task and requires powerful design tools to develop a suitable geometry for an aircraft’s flight regime. Advances in Computational Fluid Dynamics (CFD) allows for an in-depth analysis of the complex 3D flow field a DSI generates, especially under supersonic and transonic flow. This CFD investigation objective is to provide insight to the performance behavior of a generic ellipsoid shaped DSI across different Mach numbers and with different geometry. The height, width, length, and distance of the 3D bump relative to the engine inlet are varied to provide an aerodynamic performance database and performance model of the DSI that could be used in designing aircraft.

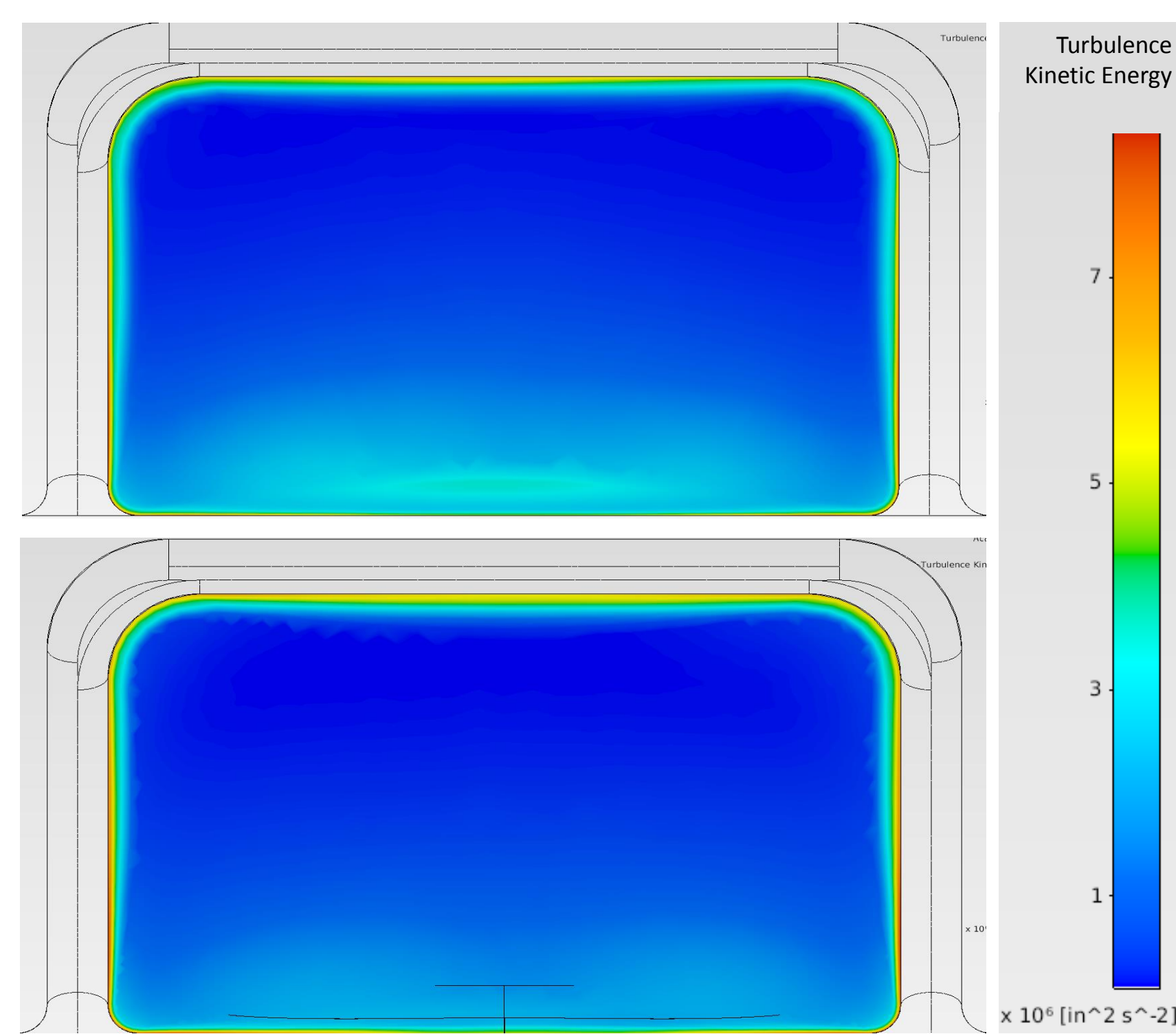


Diverterless Supersonic Inlets as Seen on the Lockheed Martin F-35 Multi-Role Stealth Fighter

CAD Model Generation

Each tested geometry was modeled in SolidWorks and featured a change in bump geometry. The bump varied by height, width, and length in nondimensional units. Each bump will be compared to a baseline geometry which features no bump. Below summarizes the geometry matrix that was analyzed with CFD:

Height (h/h_{inlet})	Width (w/w_{inlet})	Length (l/w_{inlet})
0% (Baseline)	0% (Baseline)	0% (Baseline)
5%	50%	50%
10%	75%	100%
20%	100%	200%
30%	125%	300%



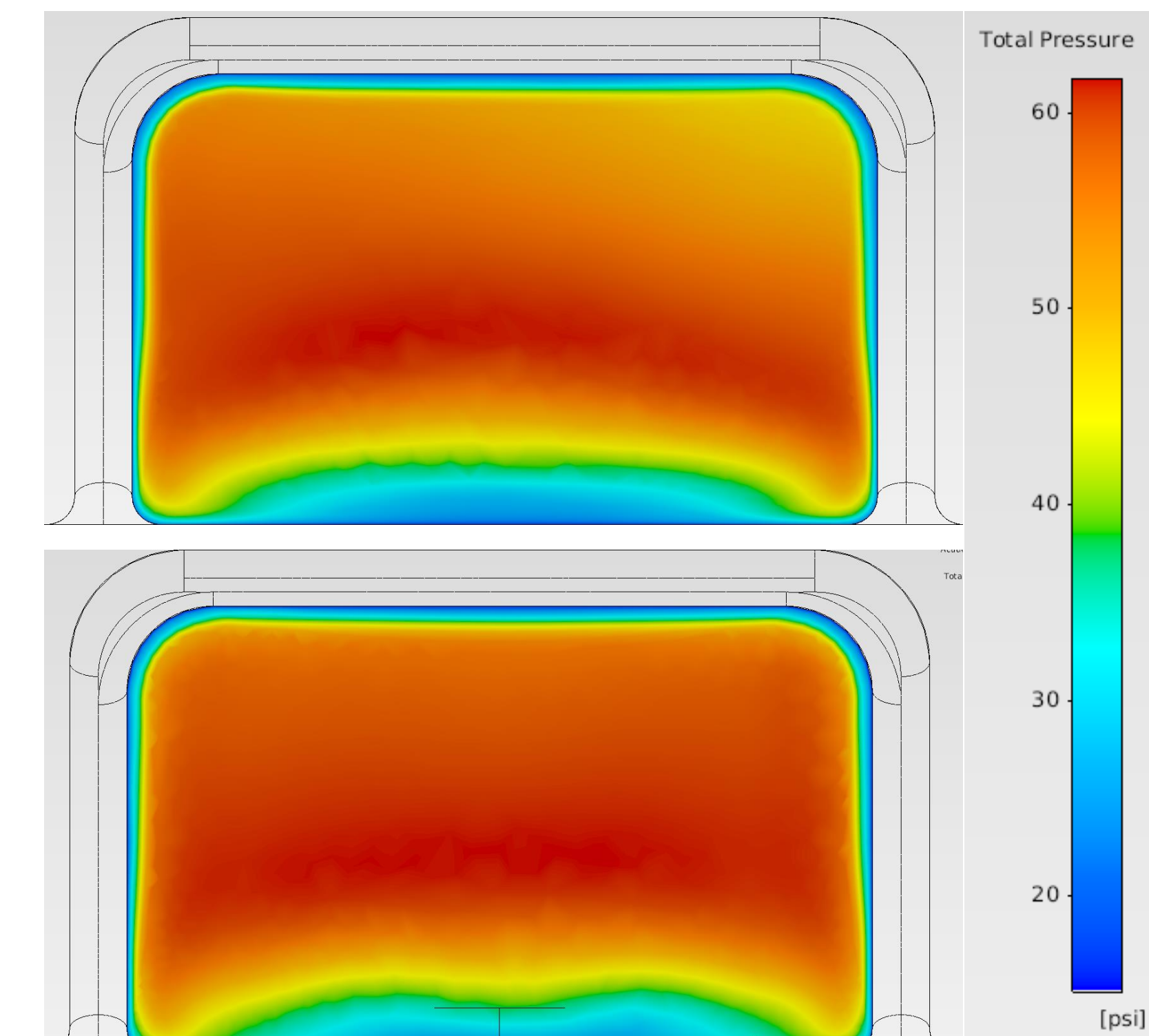
Turbulence Contours of Baseline (top) and Optimal (bottom) Designs

CFD Analysis

ANSYS AIM 17.2 was used to conduct the CFD analysis and performance evaluation. Each geometry was placed under Standard Sea Level conditions from Mach 0.8 to Mach 1.6 with no incidence. An ideal gas is assumed, and the energy equation with thermal heating effects is enabled to ensure accurate simulation. The turbulence model used was a full Navier-Stokes k-omega SST model, which is very effective for modeling compressible flows and critical for predicting flow separation.

The performance criteria used to distinguish the different geometries is typical of the aerospace industry standard. The performance criteria are defined as:

- Pressure Recovery: A ratio of the total pressure at the inlet interface (P_{t1}) over the total pressure of the free stream (P_{t0}). Values vary between 0 and 1, where 1 indicates no loss of energy. Higher pressure recoveries are better, and this parameter significantly affects engine thrust
- Turbulence Kinetic Energy (in^2/s^2): Describes the kinetic energy or motion of the airflow that is perpendicular to the main flow. Lower energy turbulence is better, and this parameter affects the stability of the engine. Too high of a turbulence leads to shortened engine lifespan or engine stall.

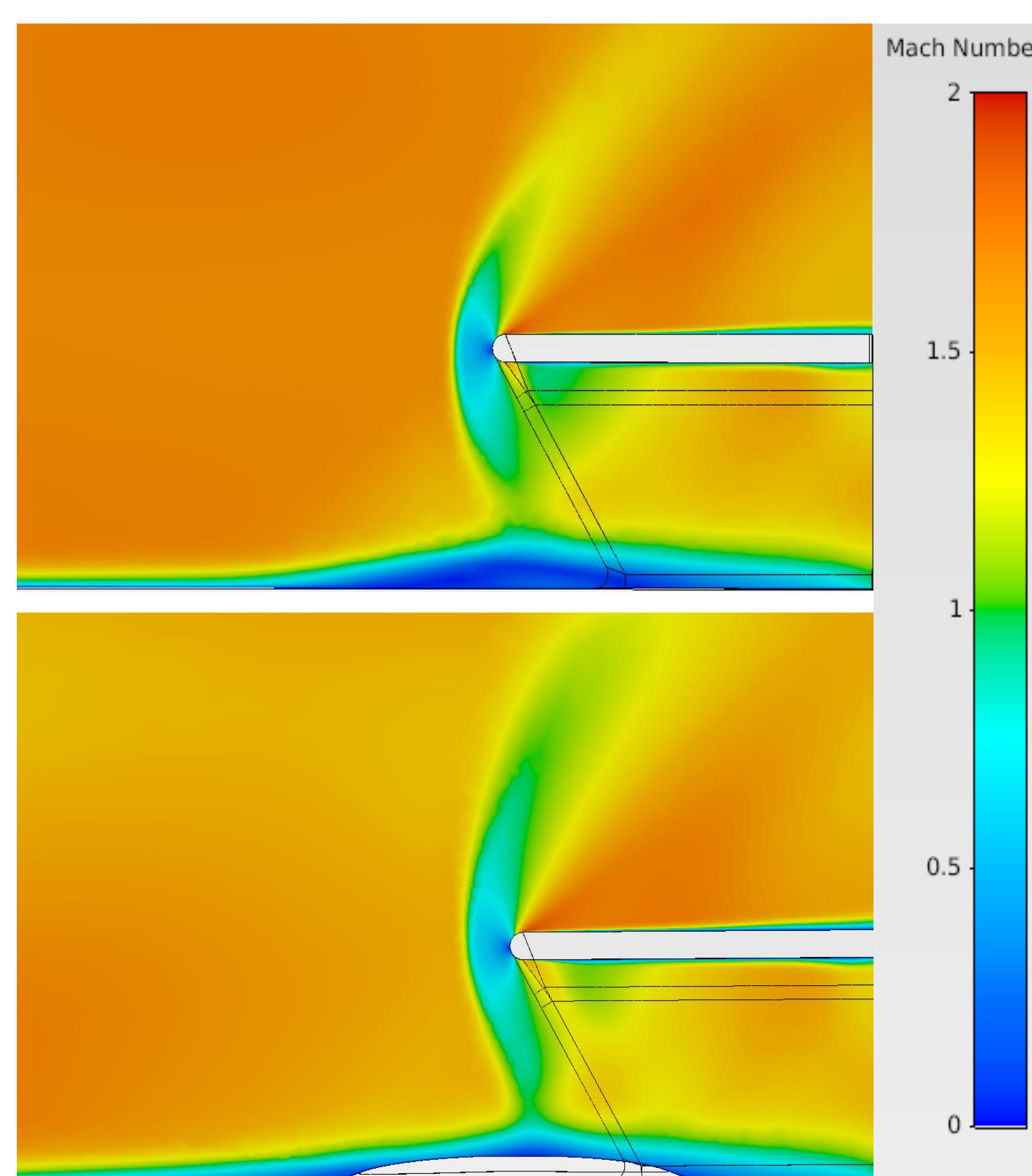


Pressure Contours of Baseline (top) and Optimal (bottom) Designs

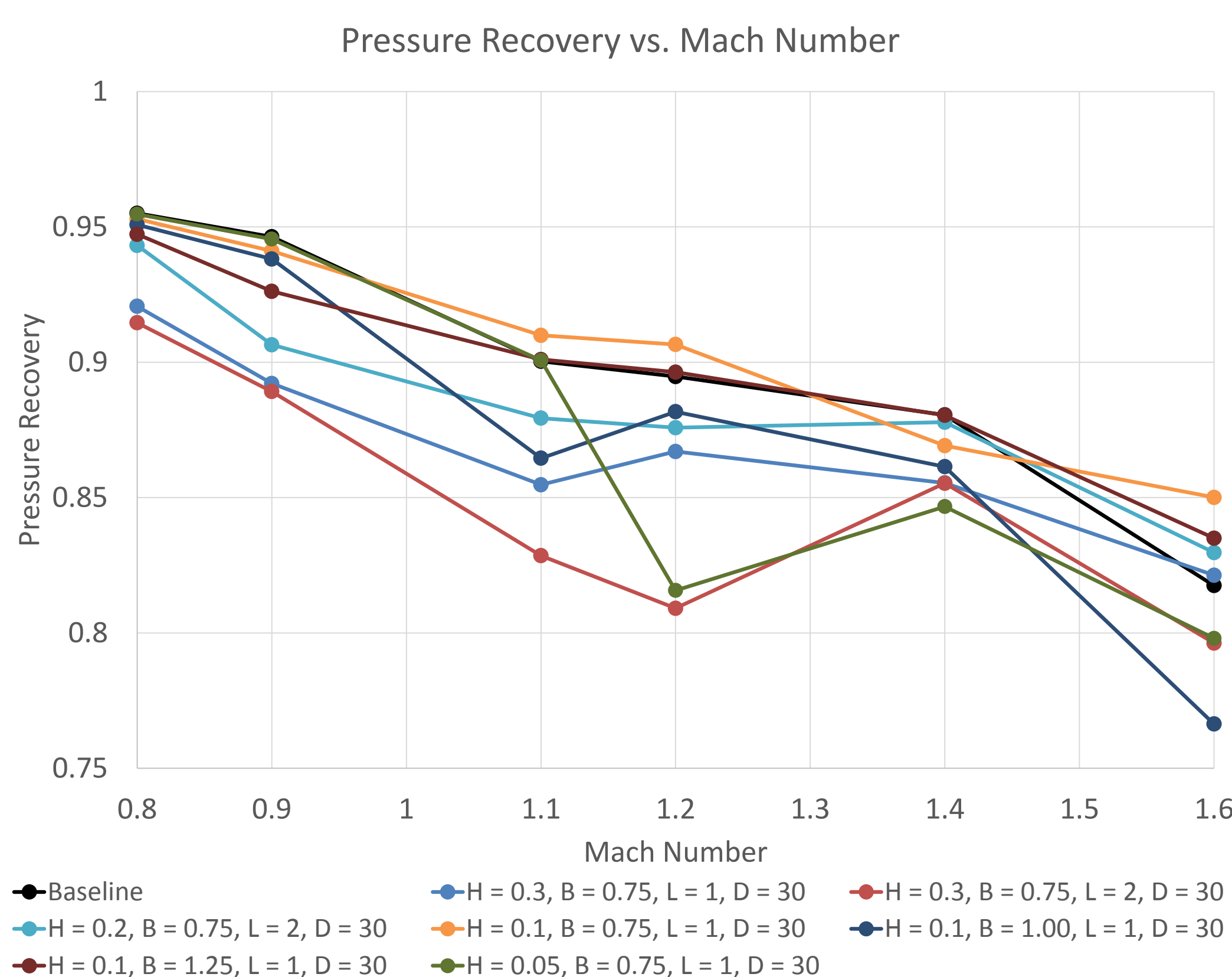
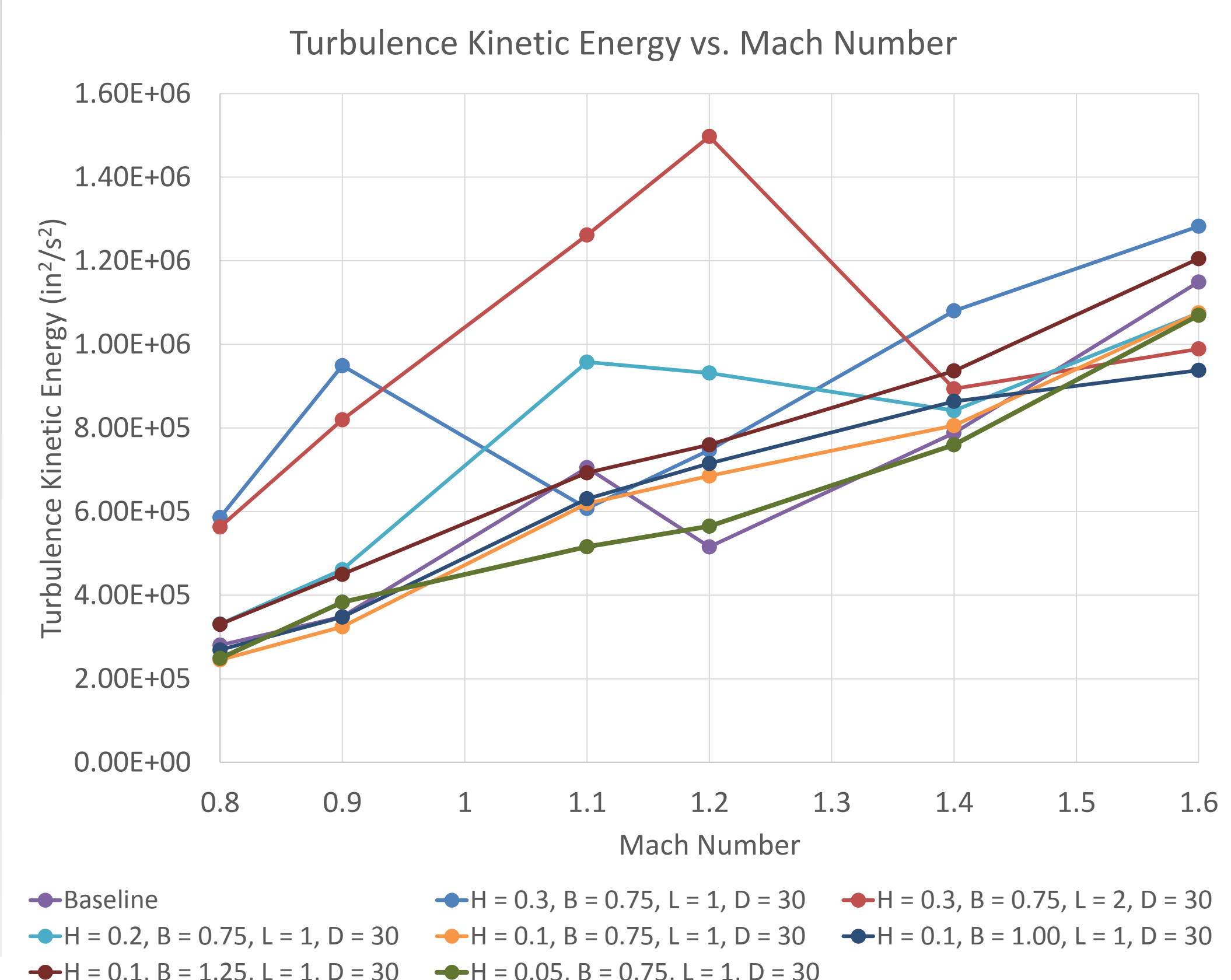
Results

The pressure recovery and turbulence kinetic energy were recorded for each geometry and their performance is summarized as a function of Mach number. Trends show that changing the height of the bump has the greatest effect on performance in both pressure recovery and turbulence. The geometry change with the least significant effect was a change in the bump width. The length of the bump has some effect on performance, but should be kept to a minimum such that flow doesn’t separate aft of the bump.

The best performing geometry tested was with a bump height of 10% (roughly the height of the developed boundary layer), a bump width of 75%, and bump length of 100% (which roughly conforms to the shock-affected boundary layer). Pressure, turbulence, and Mach contours of the optimal geometry versus the baseline geometry visualize the effects of the bump. Overall, the optimal geometry has no performance change in the subsonic regime, a 1% increase in the transonic regime, and a 3% increase in the supersonic regime.



Mach Contours of the Baseline (top) and Optimal (bottom) Designs



Conclusion

The diverterless supersonic inlet is a viable design feature on stealth aircraft where traditional diverters are not an option. Advances in computational fluid dynamics allows for an in-depth analysis of the complex 3D flow field. In terms of using an ellipsoid bump for the 3D compression surface, performance improvements can be made over a baseline configuration. However, the ellipsoid shape is limited, as steep aft sections can cause flow separation. This separation caused detrimental loss in performance and thus, a different bump shape should be considered. A tear-drop shaped bump, for example, can alleviate separation and may obtain better aerodynamic performance than an ellipsoid bump. The study of diverterless supersonic inlets is still relatively new to both industry and educational researchers, further study should be encouraged to better understand its unique performance benefits to stealth aircraft.

Acknowledgements

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