Improved Operability of Hypersonic Inlets with Fluidic Injection

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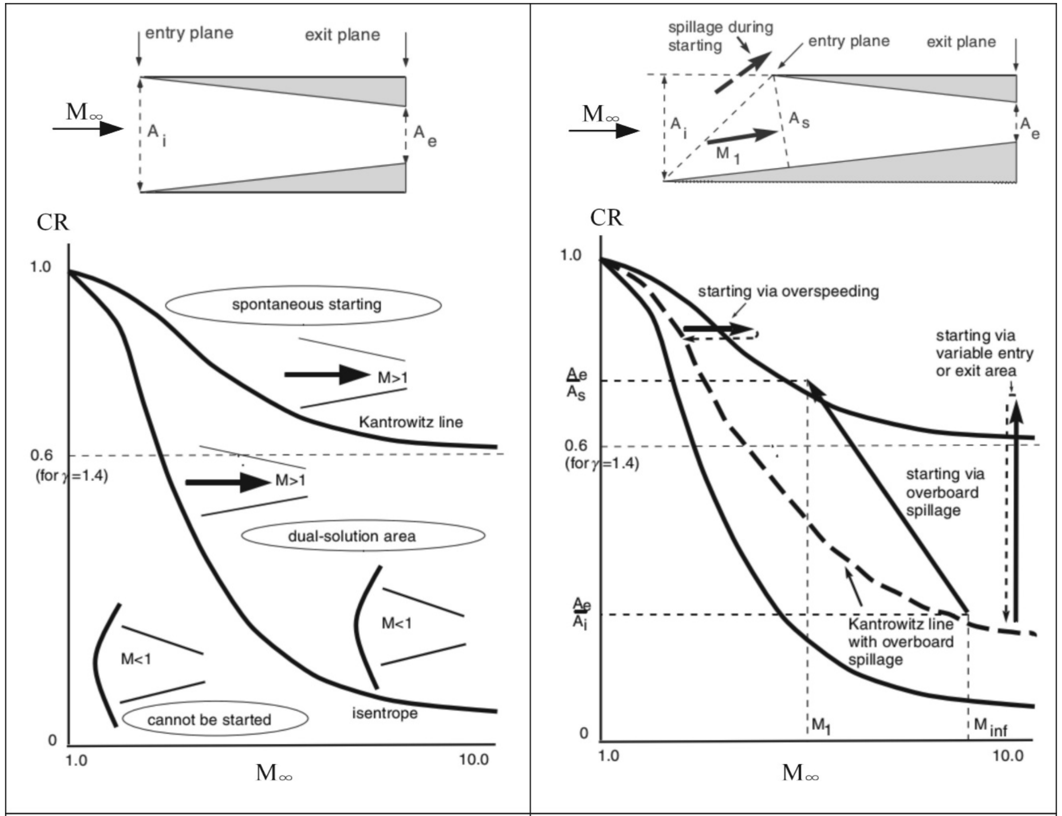
Background

- The original goal of this project was to develop an innovative flow management approach that utilizes the kantrowitz limit to expand the operating range of a hypersonic inlet
- The kantrowitz limit is a conservative estimate for measuring the startability of a hypersonic inlet



a) start boundary of fully enclosed internal contraction inlet

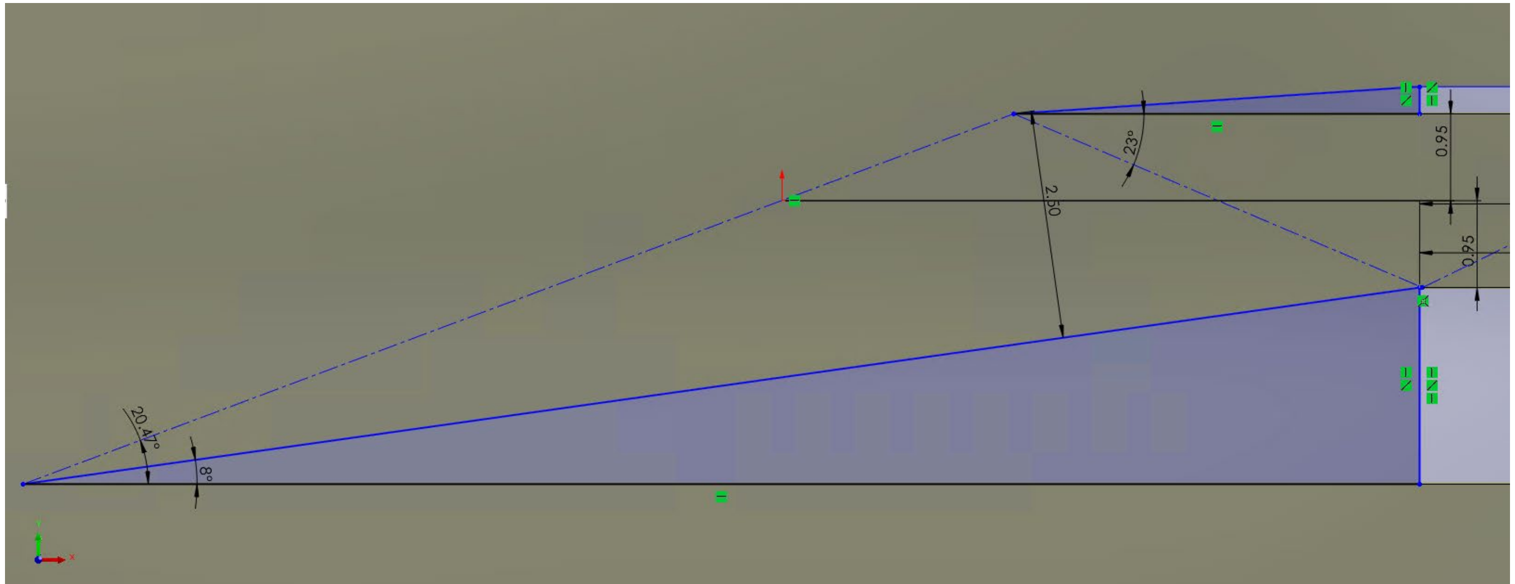
b) starting via overspeeding, overboard spillage, and variable geometry

Background

- The goal of our approach is to use the fluidic injection of air to expand the lower limit of the inlet
- Our original design was based on what could be physically tested at UC, therefore we went with a square Mach 4 inlet that begins to unstart at Mach 2
- Then fluidic injection would be added to the inlet to restart the inlet at Mach 2

Inlet Design

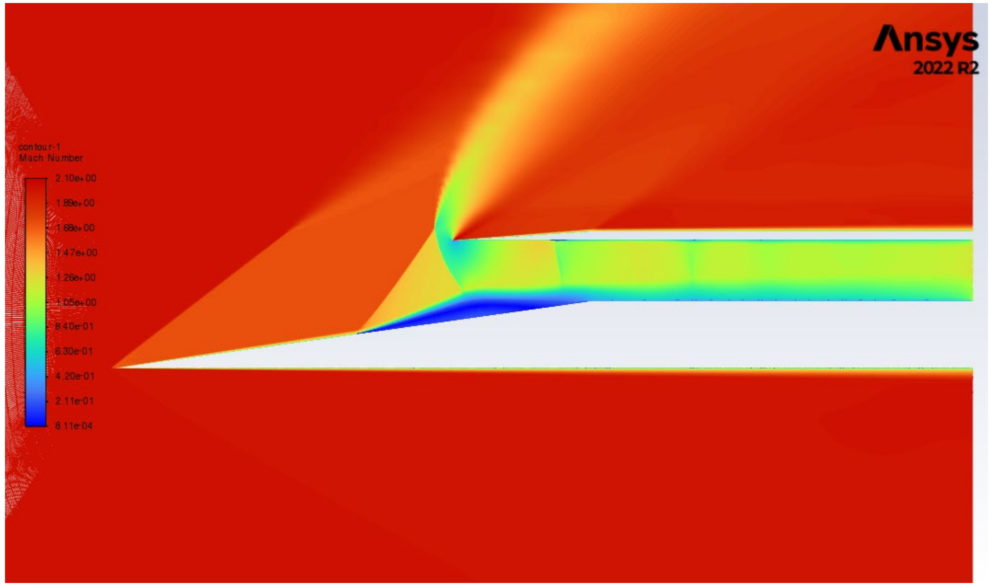
- The desired contraction ratio for a guaranteed started Mach 4 inlet is about 1.5 and the current design is 1.316
- The angle of the compression ramp is 8° and the design goal was to have the shock from the cowl hit the throat to allow for a less complex flow within the isolator



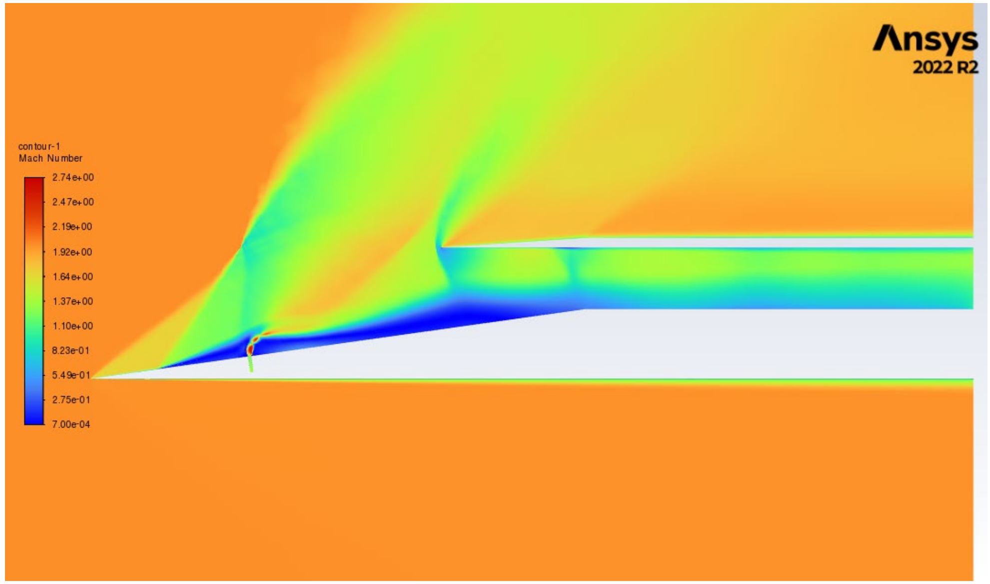
Results: Contours

- The turbulent contours that are discussed are in the following order for all results: Baseline, 0.1in injector at 5in, 0.02in injector at 13in, 0.1in injector at 11in, variable geometry cowl moved back toward the throat, variable geometry cowl moved down toward the compression ramp.
- These were investigated to determine the effects of perpendicular injection at different locations with different sized injectors and variable pressures.
- The inviscid contours are all the baseline inlet at Mach 2-5 to determine if the separation bubble that forms at Mach 2 was causing the unstart or if it was the geometry as a whole causing the unstart.

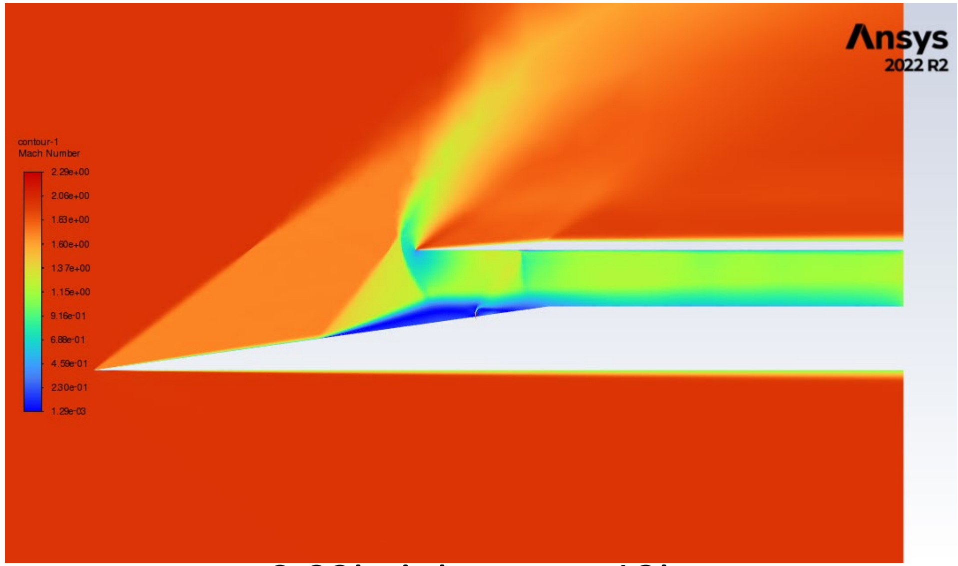
Results: Contours



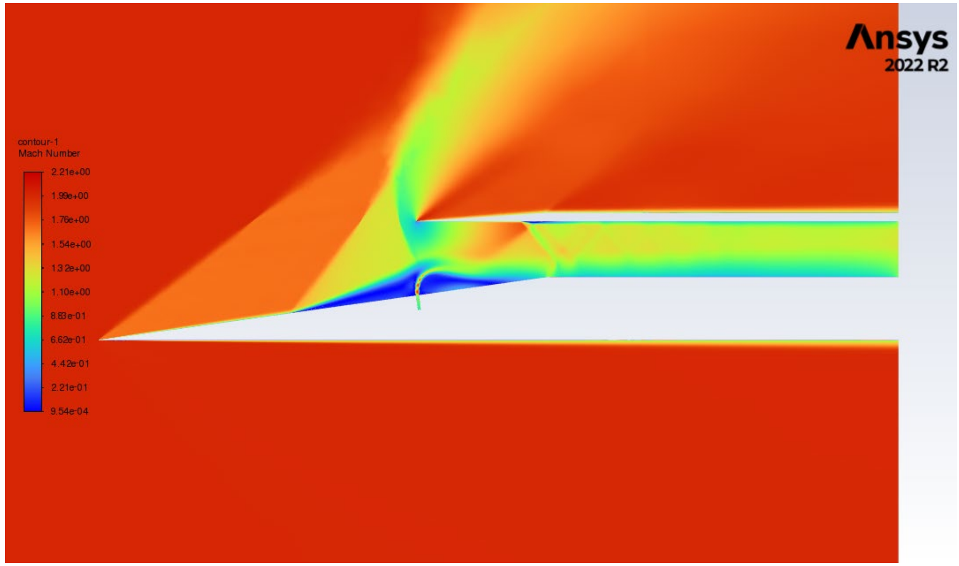
Baseline



0.1in injector at 5in

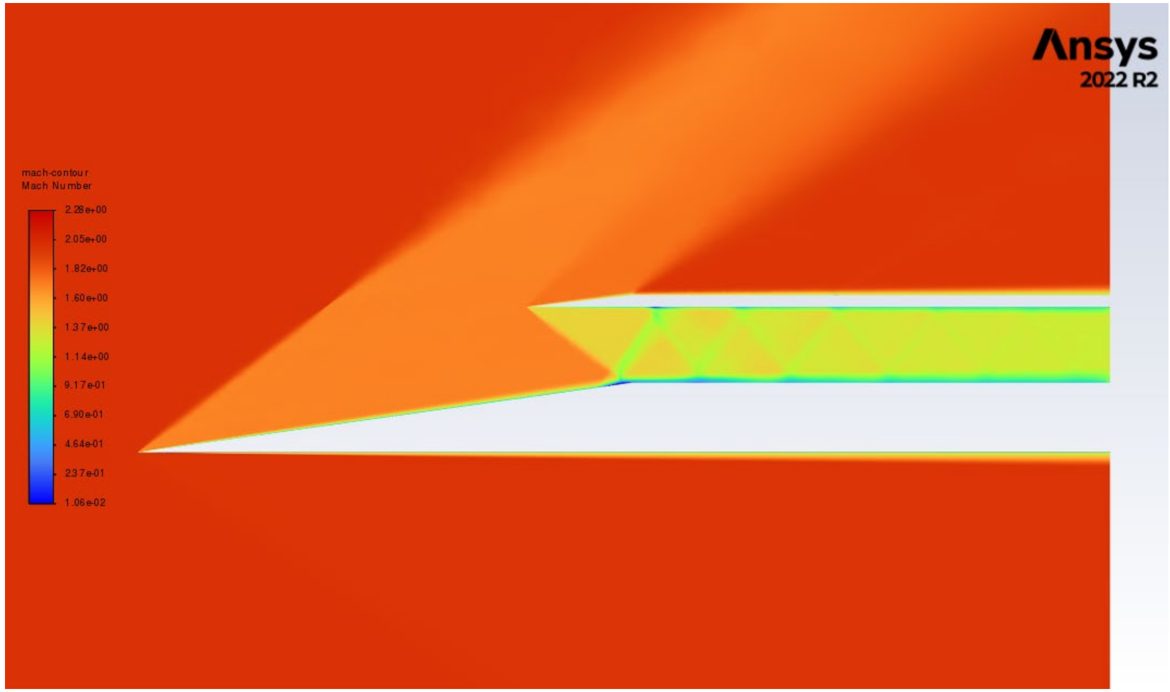


0.02in injector at 13in

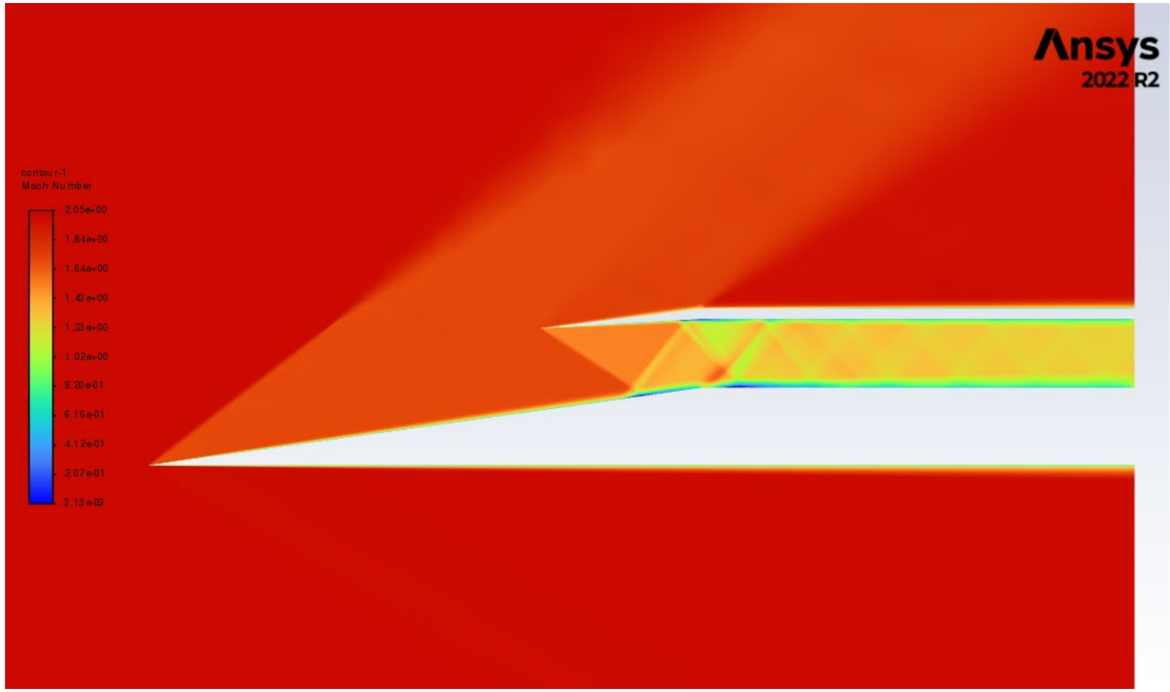


0.1in injector at 11in

Results: Contour



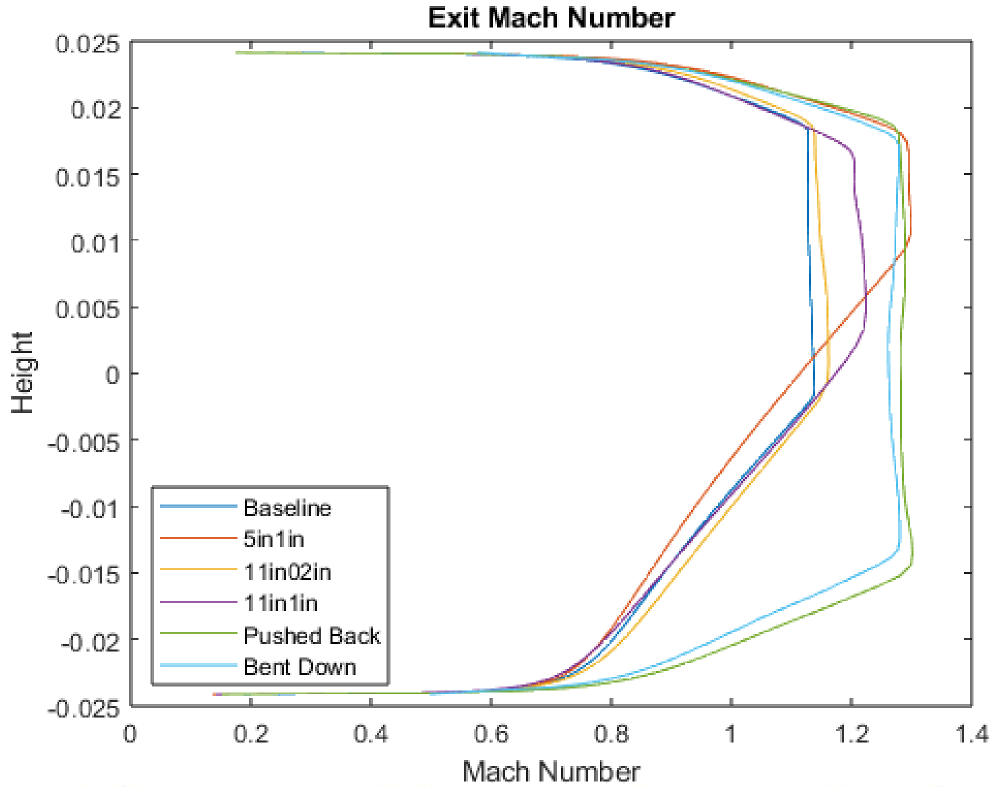
Variable geometry moved back



Variable geometry bent downward

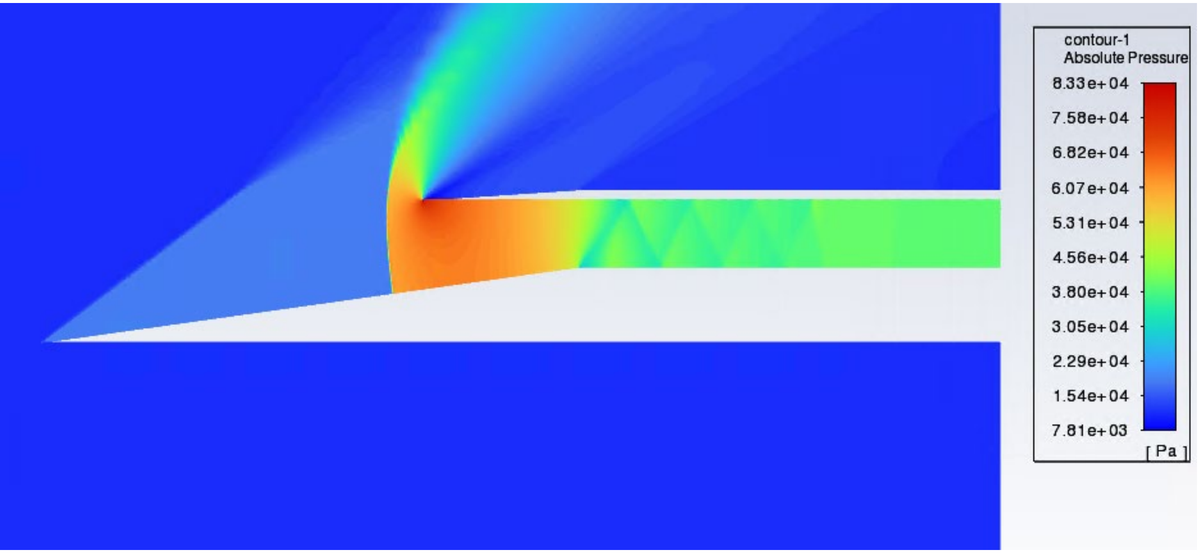
Results

- The results shown are for the turbulence cases that were run either with or without the injector on as well as the variable geometry solutions that we are trying to replicate with injection.
- The results show that the 0.1in injector 5in from the compression ramp tip resulted in the highest peak Mach number although the resulting mass capture and total pressure recovery aren't favorable for any of the injection cases resulting in a lose of performance with every case and was worst for the 5in case.

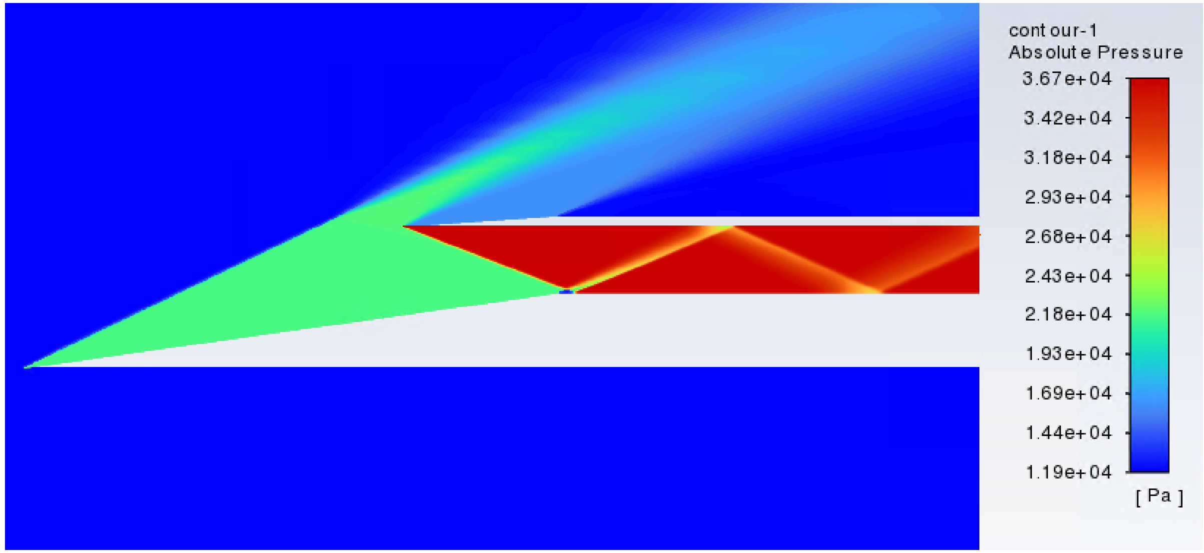


Case	Pt_Inlet	Pt_throat	Pt_exit	outlet mdot	injector mdot	Capture area (m)	Capture area (in)	Geometric Contraction Ratio
Mach 2	90.66	88.34	85.11	7.84983	0	0.078287647	3.082184676	1.622202461
M2L5I1	79.63	76.21	70.27	6.5368745	0.90163637	0.065193326	2.566661241	1.350874338
M2L13I02	90.41	88.02	84.86	7.79361	0.11325466	0.077726956	3.060110259	1.610584347
M2L11I1	88.15	83.43	79.24	7.29649	0.63964947	0.072769096	2.864919325	1.507852276
M2 back	96.7	94.55	90.85	8.007	0	0.07985513	3.143896454	1.654682344
M2 bent	96.67	94.24	90.3	7.9996	0	0.079781328	3.140990892	1.653153101

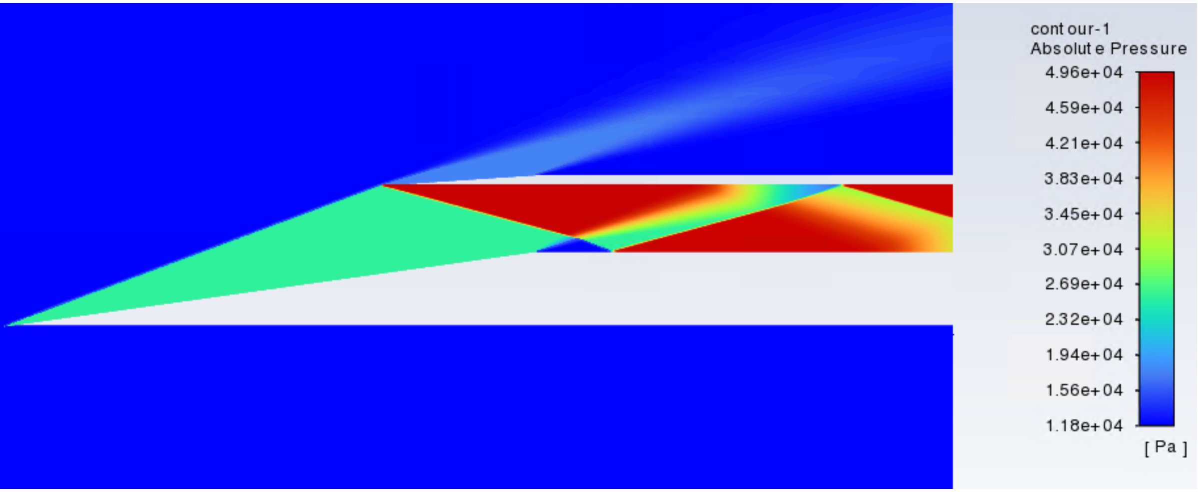
Inviscid Simulations



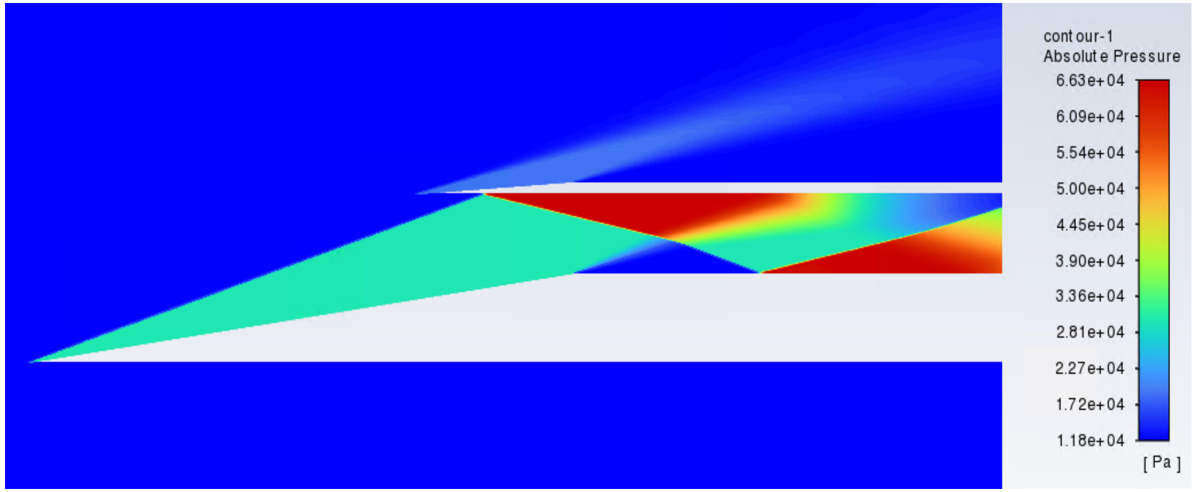
Mach 2



Mach 3

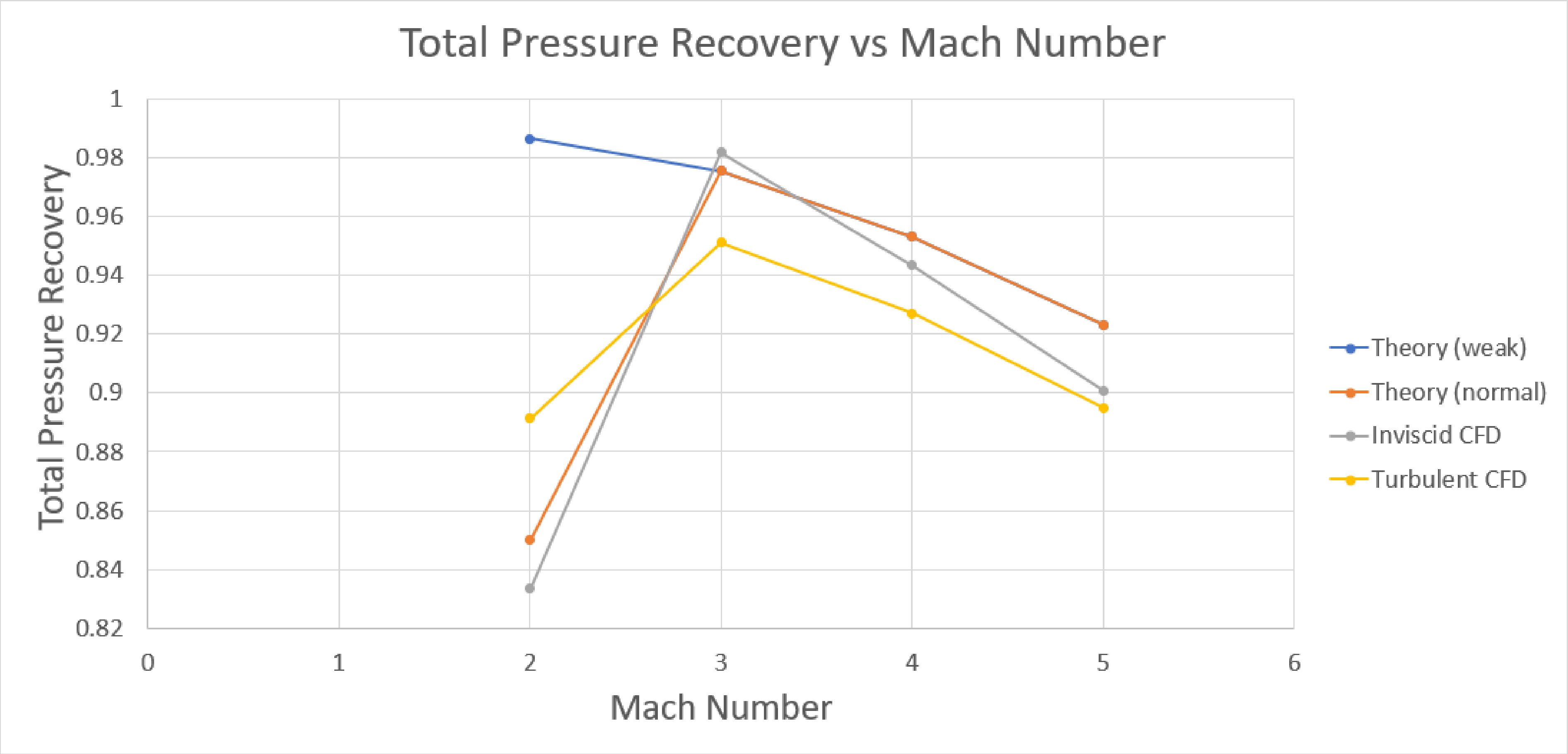


Mach 4



Mach 5

Total Pressure Recovery



- The inviscid and turbulent results align with normal shock/strong shock theory at Mach 2, although the turbulent results might be measured in a slightly different location than the inviscid results which could account for the lower losses between Mach 2 and 3