



Pre-injection of Cracked hydrocarbon fuel in hypersonic inlets

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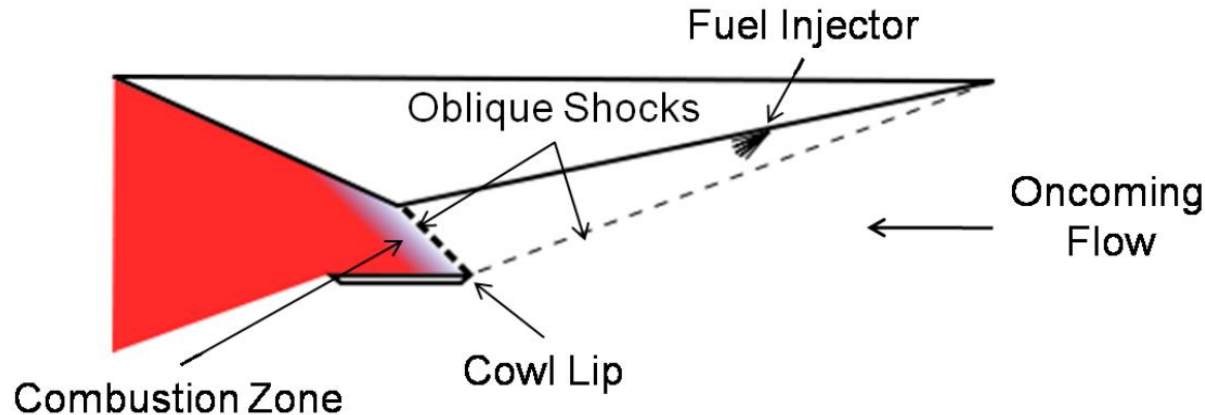
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Outline

- **Background**
- **Numerical setups**
- **Results and discussion**
- **Conclusion**

Background

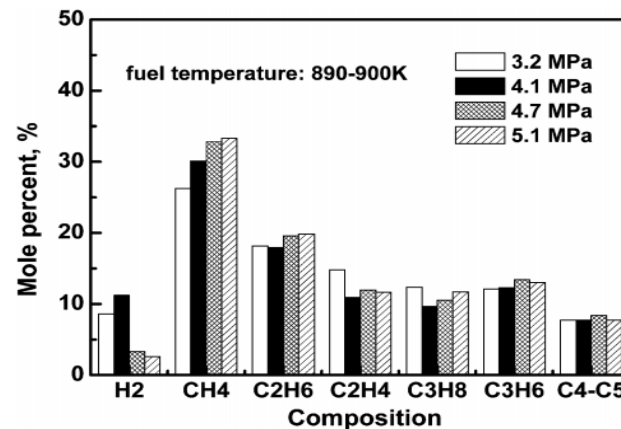
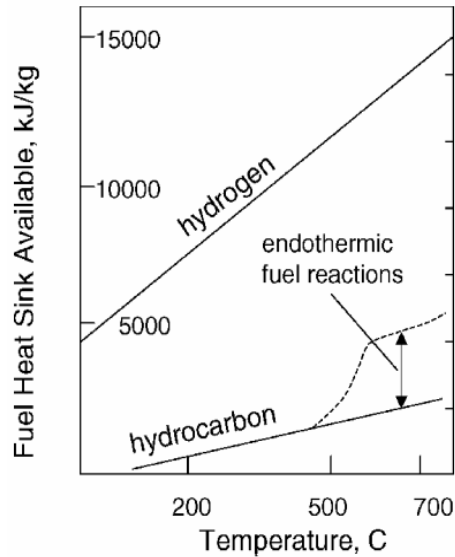


- Fuel mixing efficiency → propulsion of a hypersonic flight
- Hydrogen fuel does not have sufficient specific impulse ($4 < Ma < 8$)
- Liquid fuel is not suitable for pre-injection in hypersonic inlets

Cracked hydrocarbon fuel for pre-injection

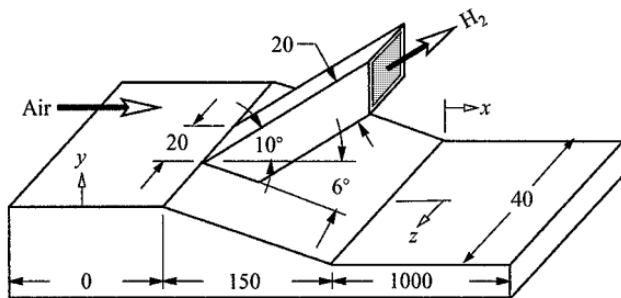
□ Cracked hydrocarbon fuel

- From 1970s
- With higher **heat sink** (over 50%)
- Larger combustion **efficiency** (10-15%)
- Complex composition

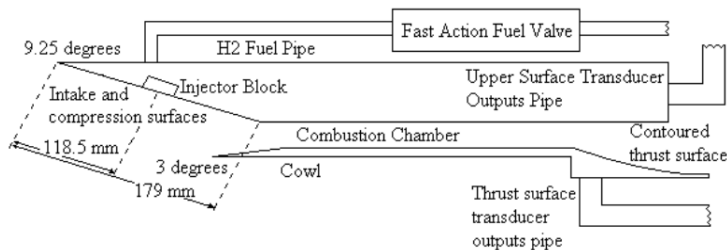


Background

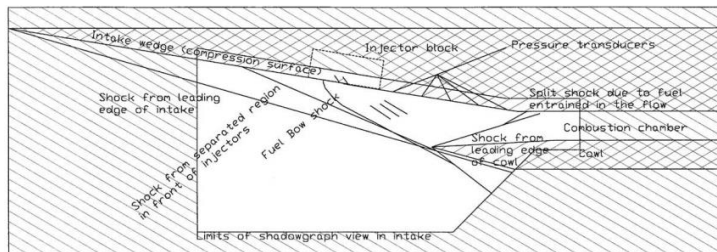
□ Fuel pre-injection



- Canada, Sislian, inlet fuel injector
- **Crossflow** affects mixing greatly



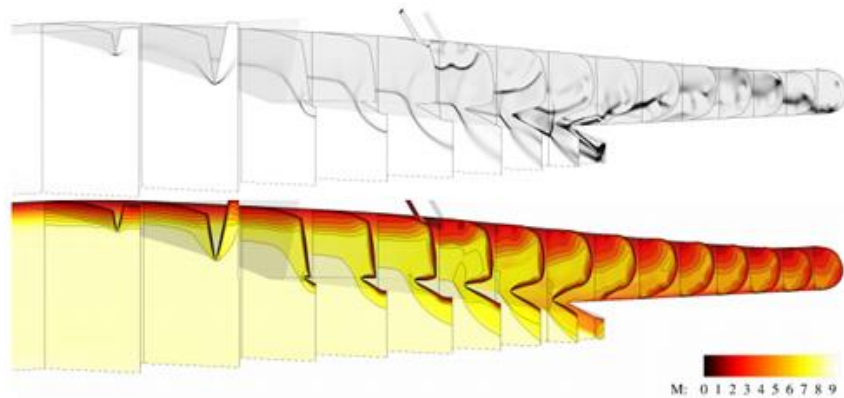
- Australia, Paull, wall injection
- Wind tunnel experiments



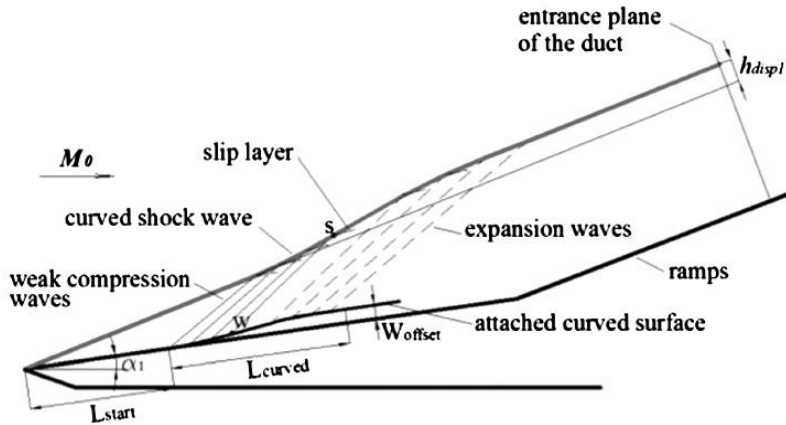
- Up to 800K wall, **no combustion**

Background

□ Fuel pre-injection



- Australia, Smart, inlet unstart
- Wind tunnel experiments
- Different **equivalence ratio** (ER)
- High ER leads to unstart



- China, Tan, inlet flow control
- Wind tunnel experiments
- Secondary **flow controls** shock shape

Outline

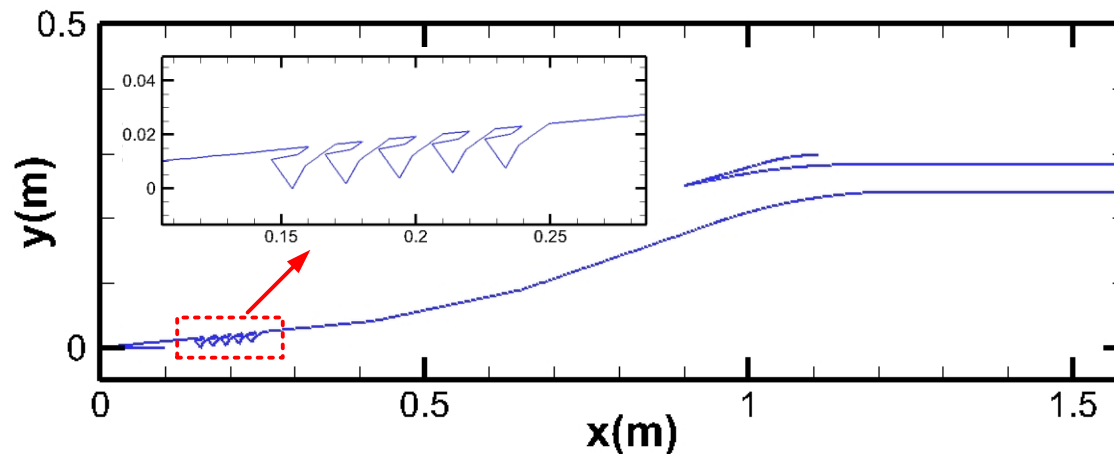
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□ Methods

- Ansys Fluent
- RANS: k- ω SST
- 1st order upwind → 2nd order upwind
- Injector width with 50 grids
- y^+ less than 10, CFL nearly 0.1

□ Model

- Design point: altitude: 26km, Ma: 5
- Inlet length 1.58m
- Five **pre-injectors** on the first wedge with angle 30 degree
- Variable fuel **pressure** to control the shock wave ($5 < \text{Ma} < 6$)

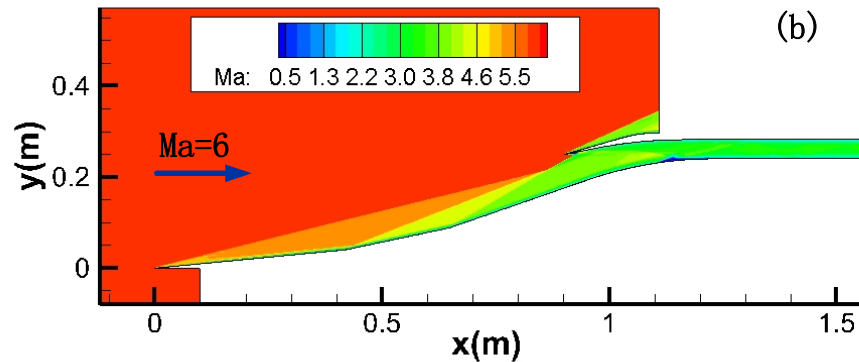
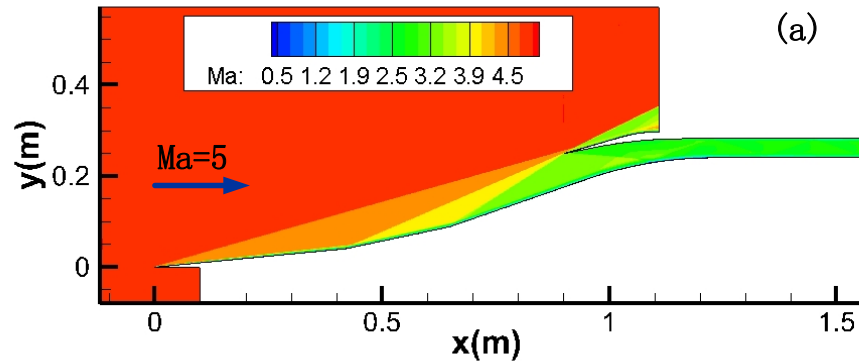


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Results and discussion

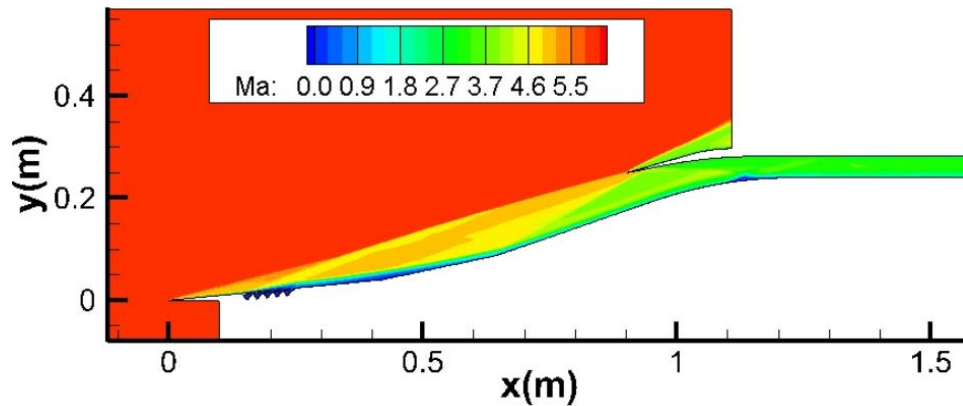
□ Initial inlet without injectors



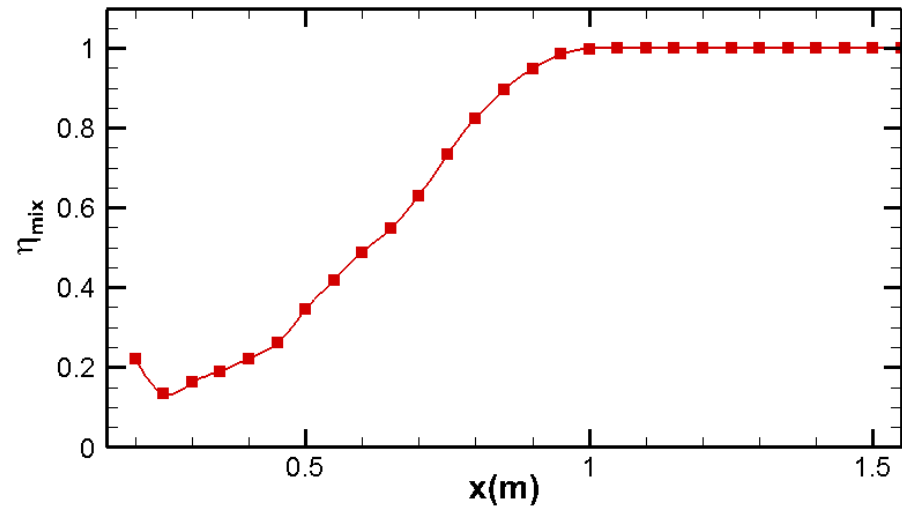
➤ Mach number contour at Mach 5 and 6

Results and discussion

Five parallel injectors



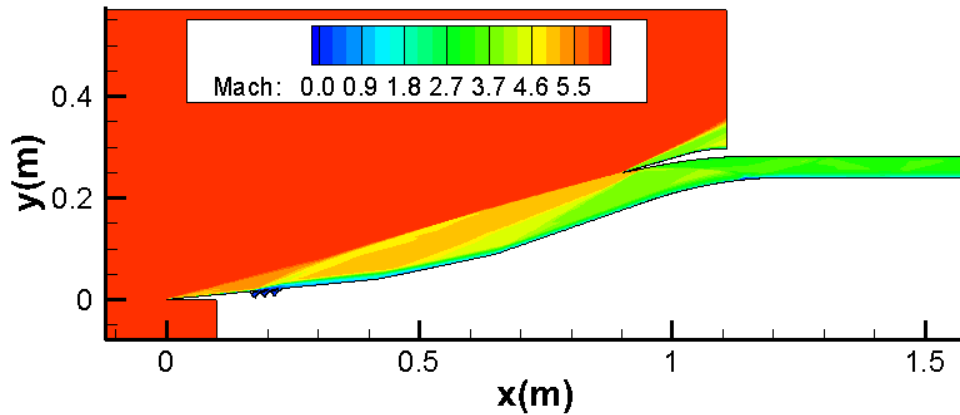
➤ Five injectors, Mach 6, $4 \cdot p_0$



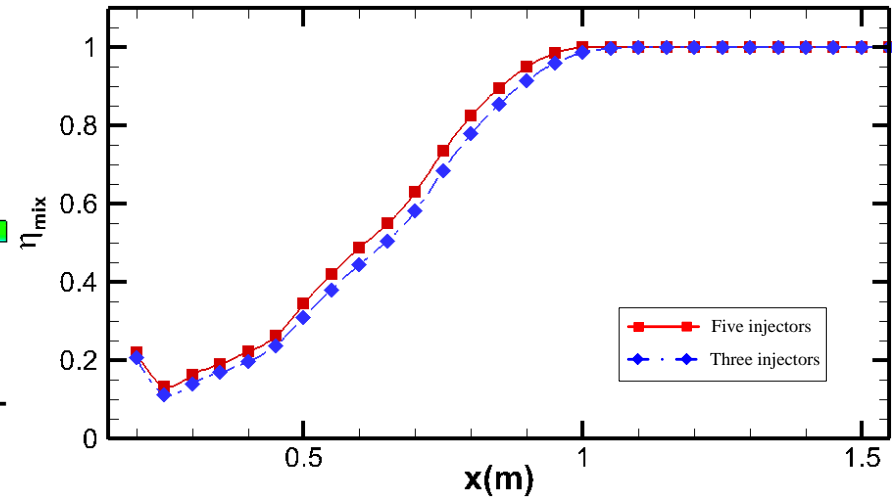
➤ Mixing efficiency

Results and discussion

Three parallel injectors



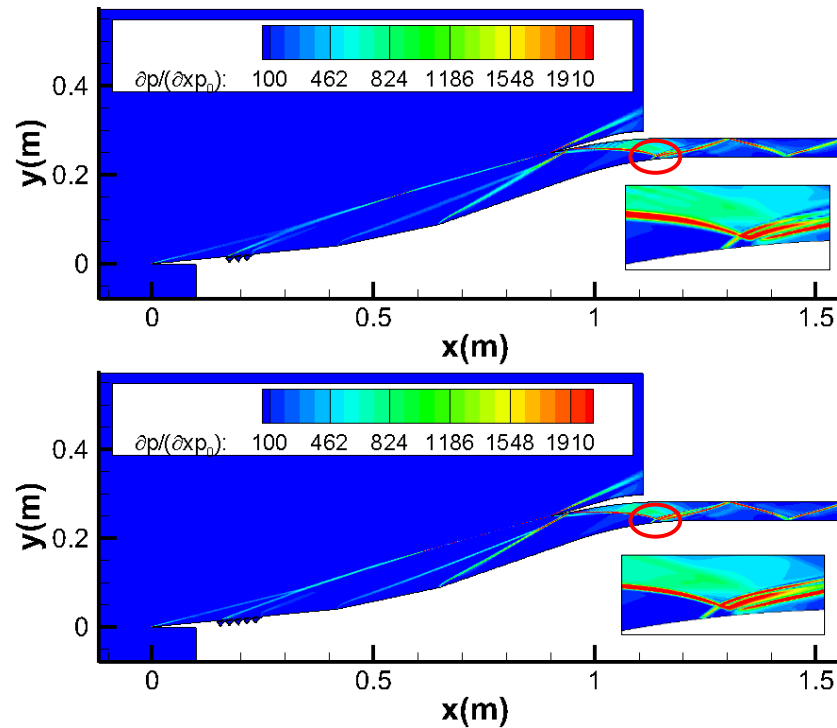
➤ Three injectors, Mach 6, $5 \cdot p_0$



➤ Mixing efficiency

Results and discussion

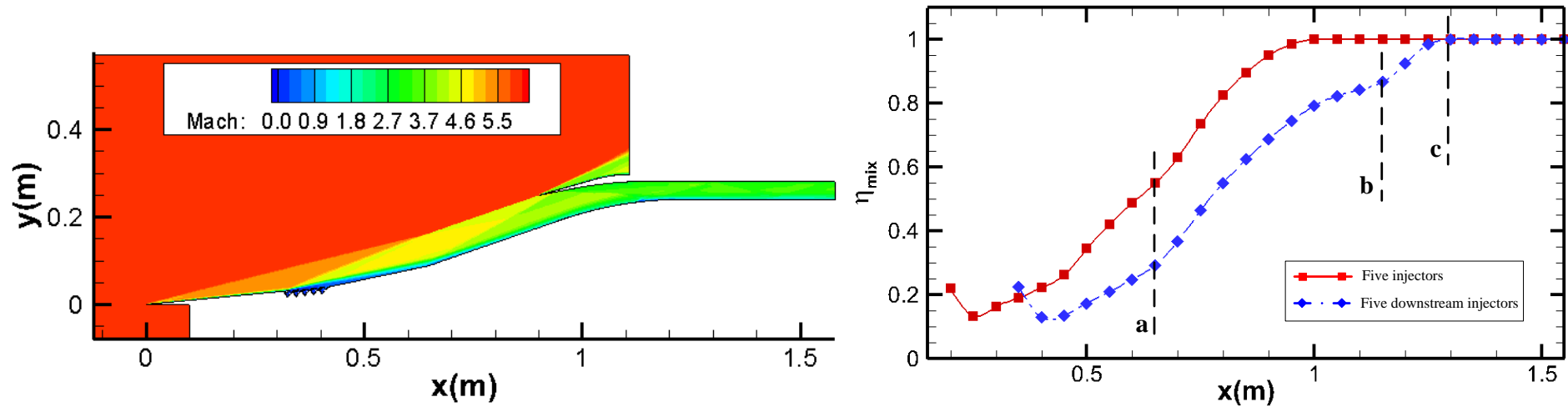
□ Three parallel injectors



➤ Comparison with five injectors

Results and discussion

Five downstream injectors

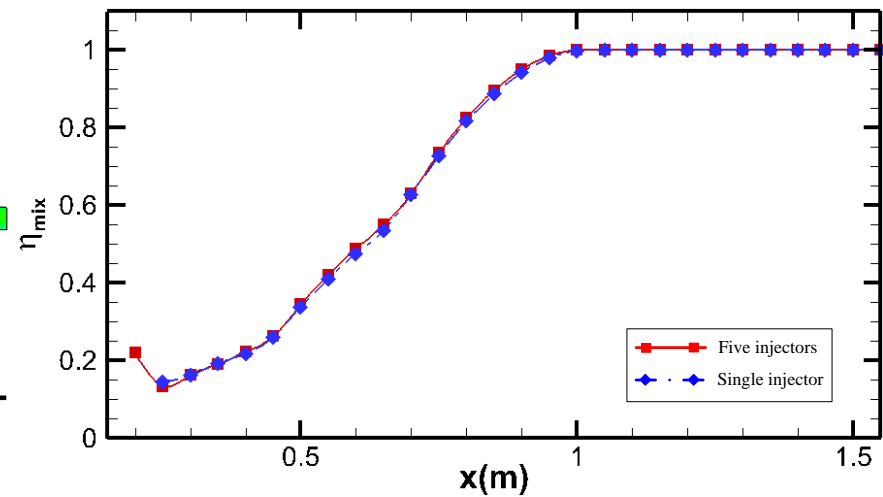
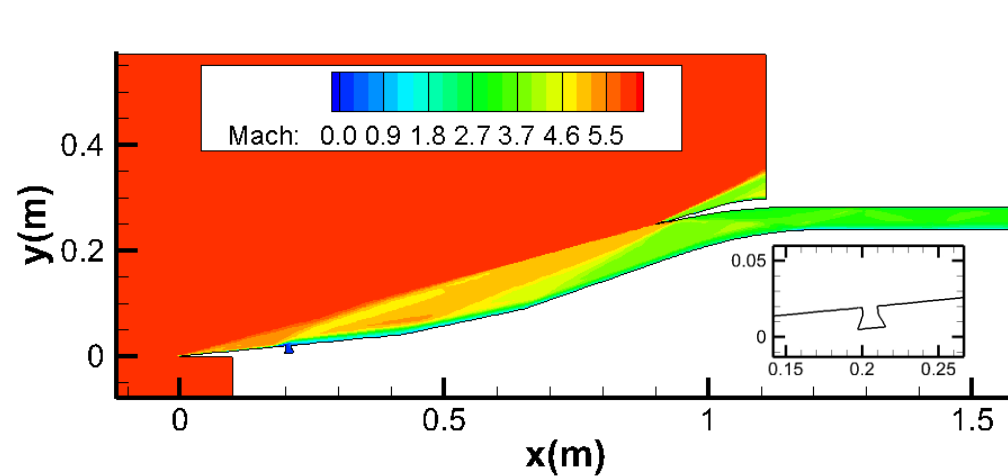


➤ Five downstream injectors, Mach 6, $5 \cdot p_0$

➤ Mixing efficiency

Results and discussion

□ Single 90 degree injector



➤ Single 90 degree injector, Mach 6, $6.6 \cdot p_0$

➤ Mixing efficiency

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Conclusion

- **Shock on lip** at Ma 6 for all the configurations, but with different **pressures**
- **Five** injectors with **4 times** the incoming pressure, **three** injectors and **five downstream** injectors with **5 times**, **single** 90 degree injector with **6.6 times**
- Fully-mixing is achieved inside the inlet for all the configurations
- The mixing efficiency for **five** injectors and **single** 90 degree injector is on the same level, **three** injectors is **5% lower**, while **five downstream** injectors has the **longest mixing length**
- Three or five injectors can **be adjusted by closing part of the injectors** according to the distribution of pre-injection. Further insight into this concept will be focused on the **pre-combustion**.

Thank you for your attention!

