Mathematical Simulation of Blow Through Supersonic Nozzles

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INTRODUCTION

- BOF Practice
  - Oxygen is blown into the hot metal;
  - Oxygen reacts with carbon of the hot metal;
  - Oxygen flow needs high speeds to penetrate into high density metallic bath;
  - The products are $CO_{(g)}$ and $CO_{2(g)}$;

- Computational Fluid Dynamics (CFD)
  - Velocities and pressure profiles within the domain;

OBJECTIVES

- ✦Use CFD to study the oxygen jet behavior in the nozzle and compare it with the analytic solution;

- ✦Use CFD to compare different geometries for the supersonic nozzles;

- ✦Analyze the effect of the turbulence on the flow inside the nozzle and on the interaction with atmosphere;

- ✦Propose new geometries for the nozzles;

LITERATURE REVIEW

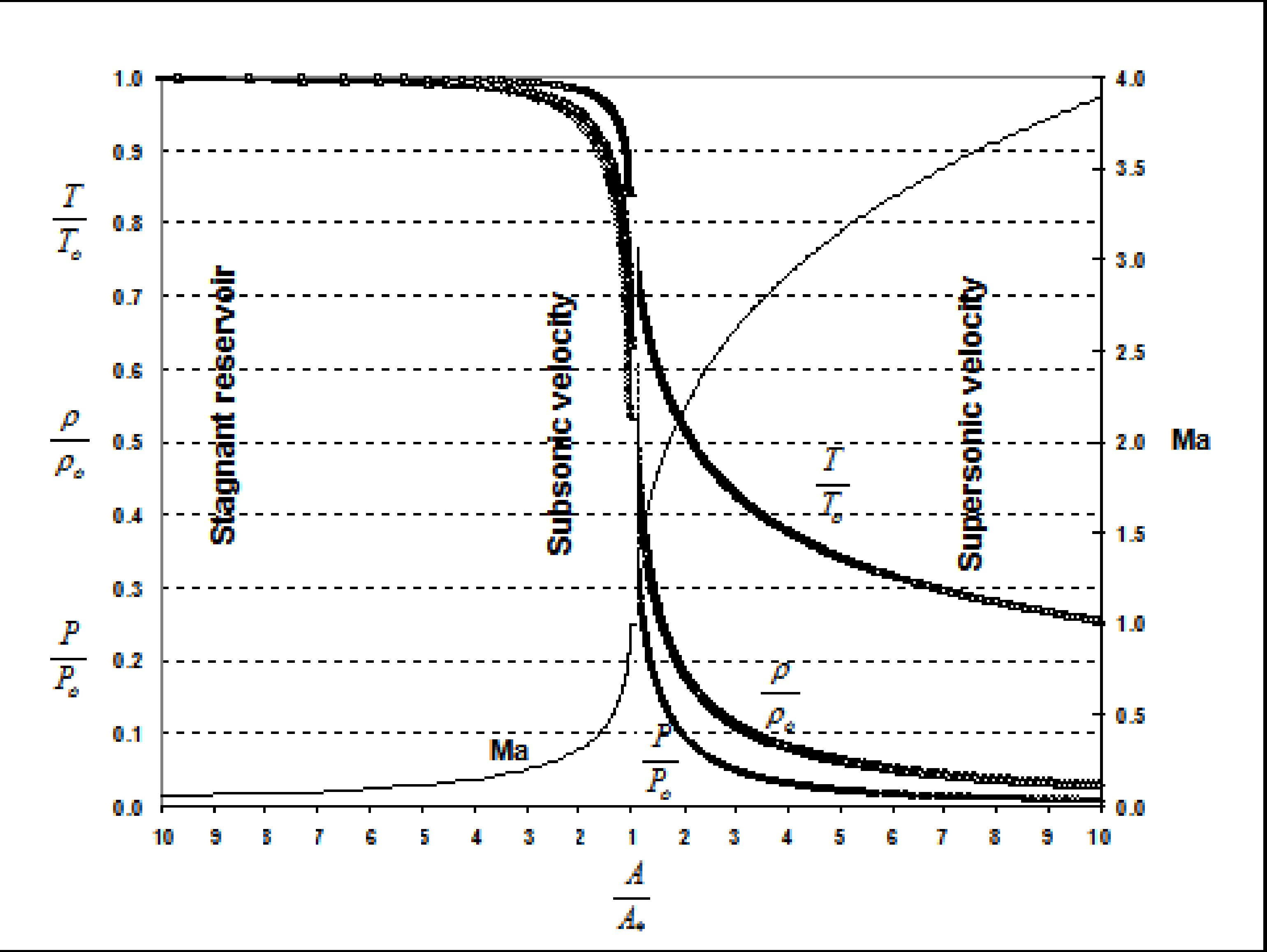
- Concepts involved in modeling supersonic jets:
  - Mass Conservation;
  - Energy Conservation;
  - State Equations;
  - Turbulent flow;
  - Ideal Gas and Compressible Flow;
  - One-dimensional flow.

LITERATURE REVIEW

$$\frac{dA}{A} = -\frac{dv}{\bar{v}} \times \left(1 - Ma^2\right)$$

Flow Direction

LITERATURE REVIEW



Source: Glass e Smith, 1976

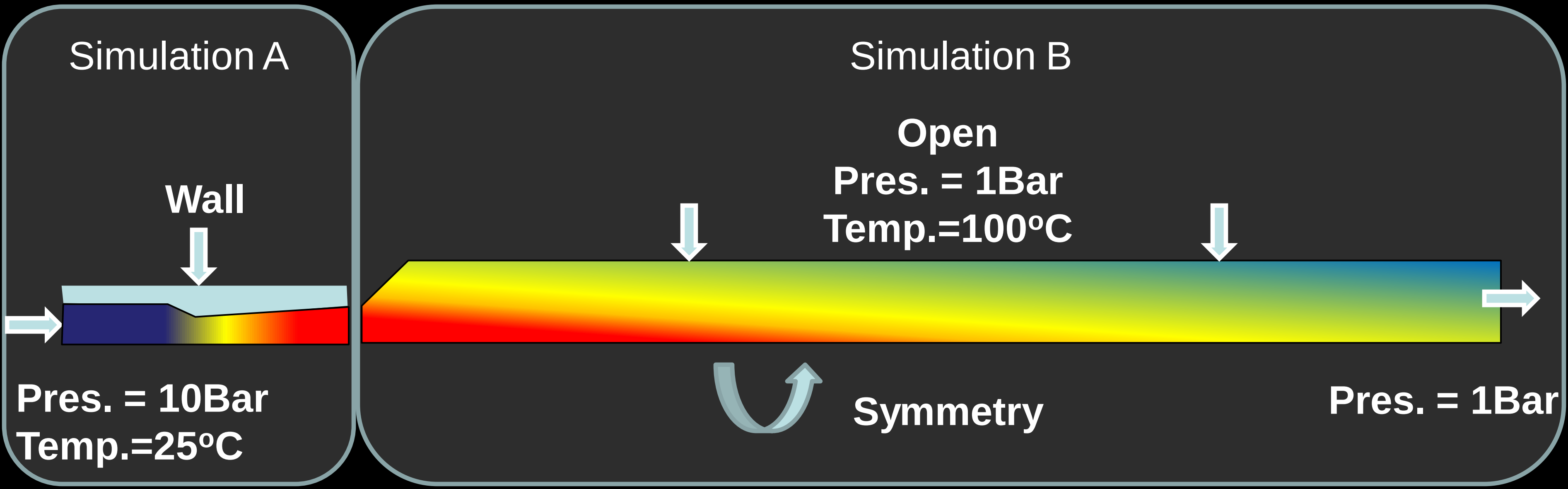
MATERIAL AND METHODS

DOMAIN

ANSYS CFX 12

Criteria of convergence - residual erro <10^{-6}

Resolution scheme = High Resolution



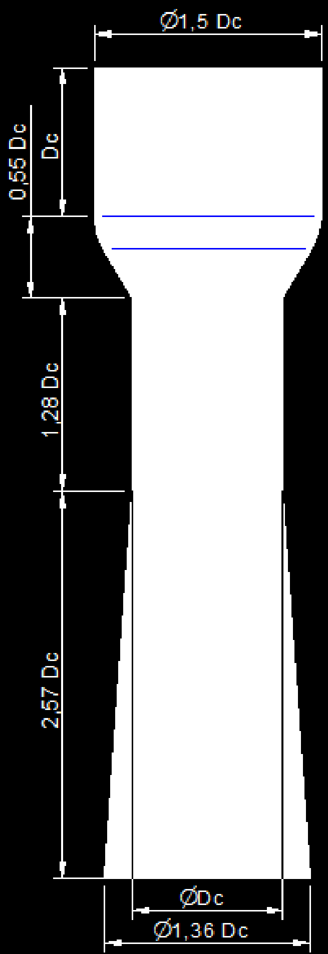
TURBULENCE MODELS

- Shear Stress Transport Model (SST)
- $\kappa-\omega$
- $\kappa-\varepsilon$

MATERIAL AND METHODS

COMPARISONS

Long Straight Section



Analytical Results

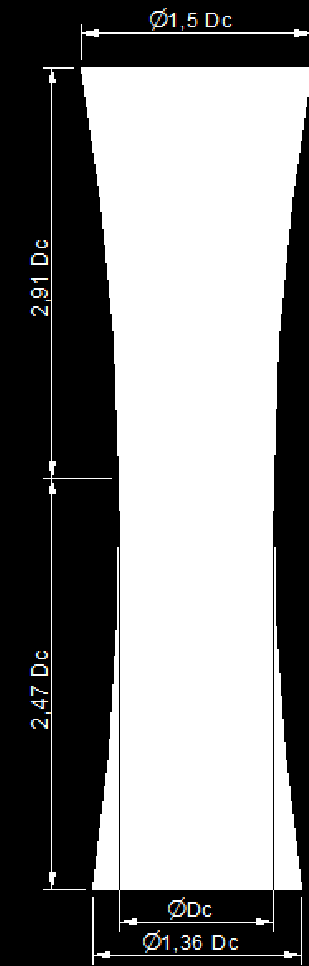
x

Numerical Simulation

PRESSURE (Bar)

- **10**
- **12**
- **14**
- **16**

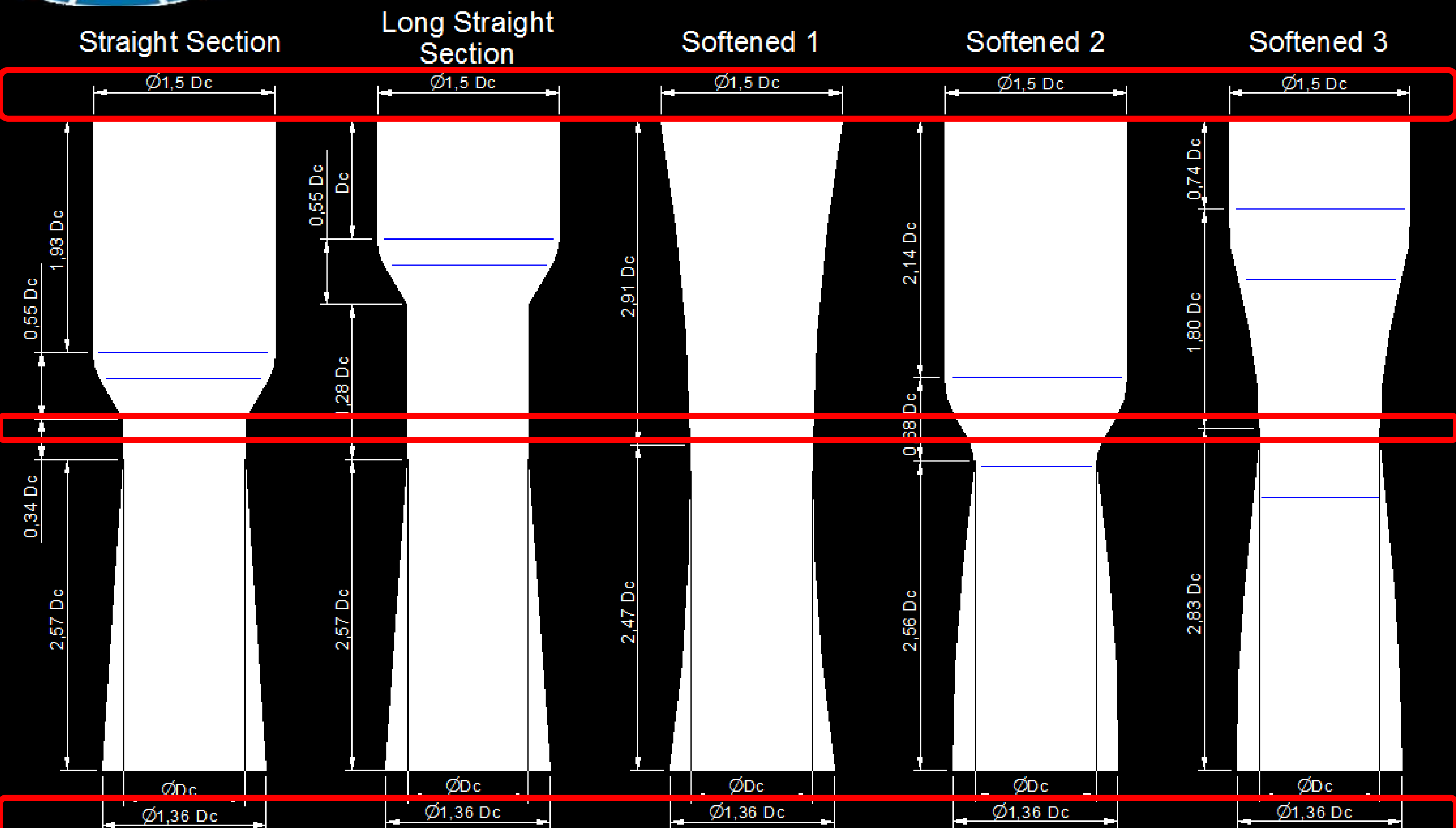
Softened 1



MATERIAL AND METHODS

Simulation A

GEOMETRIES & VELOCITIES

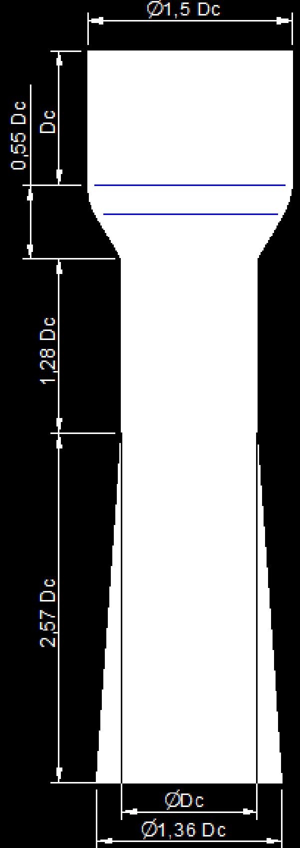


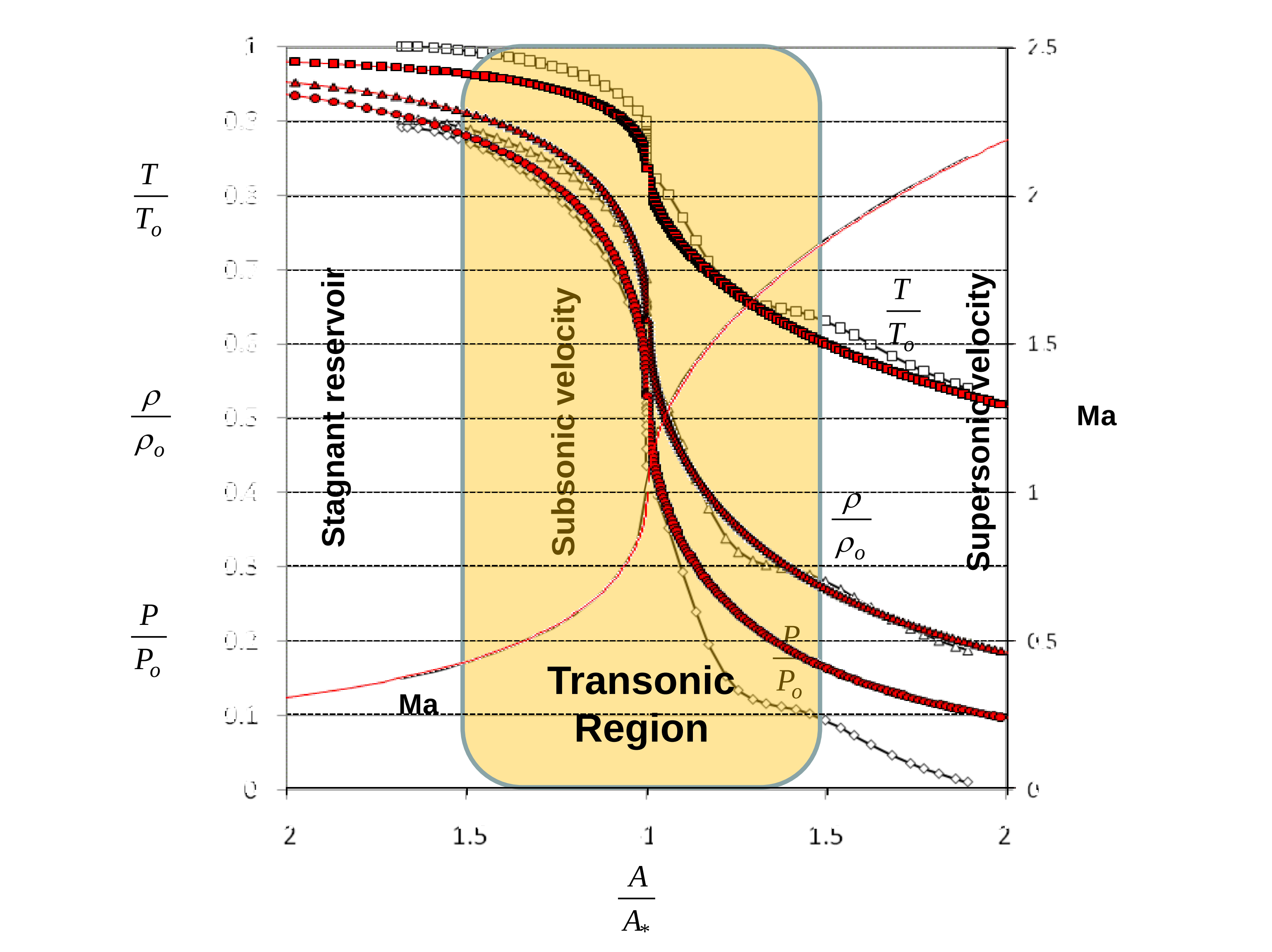
RESULTS AND DISCUSSION

Simulation A

Analytical x Numerical

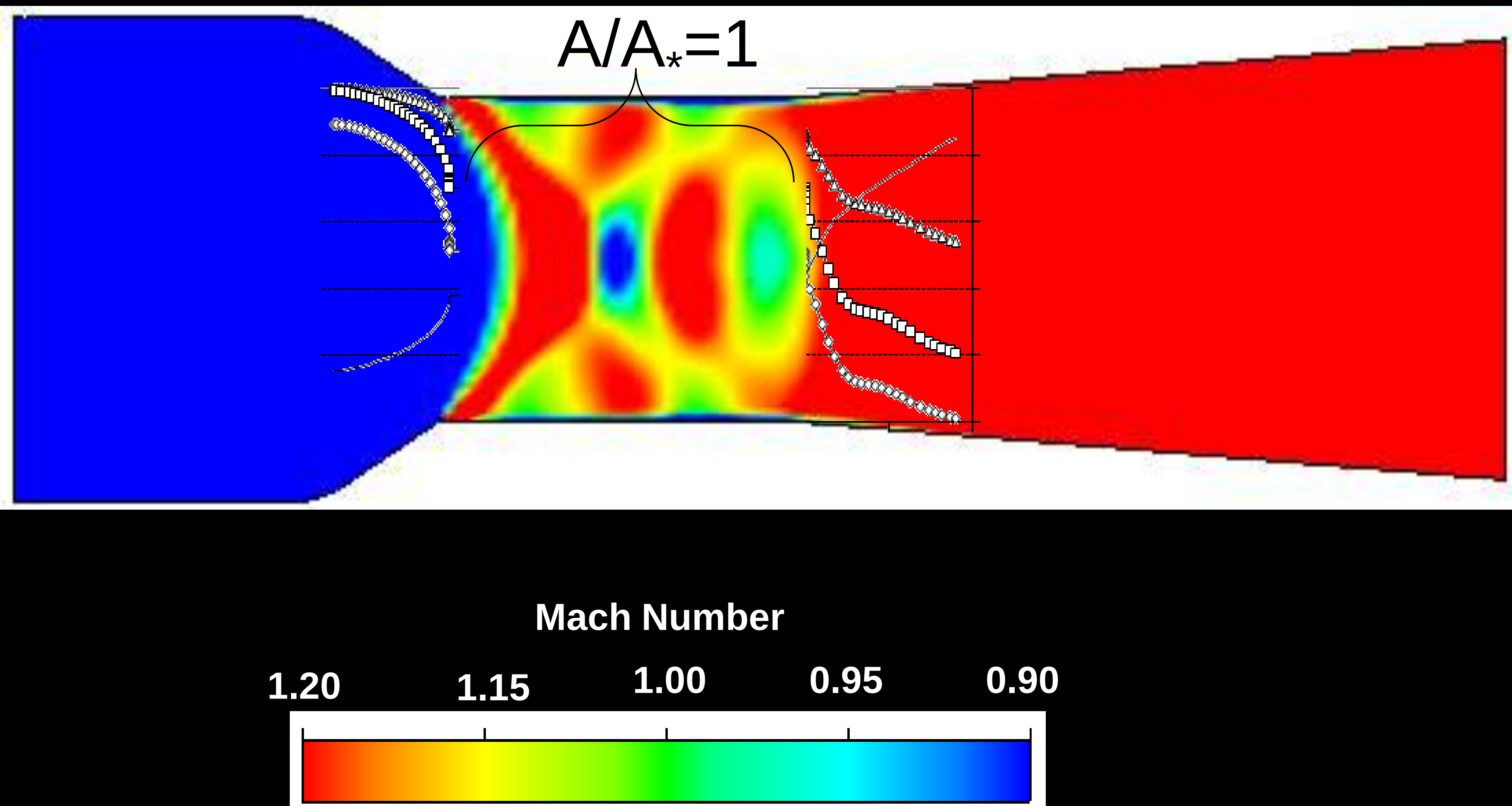
Long Straight Section





RESULTS AND DISCUSSION

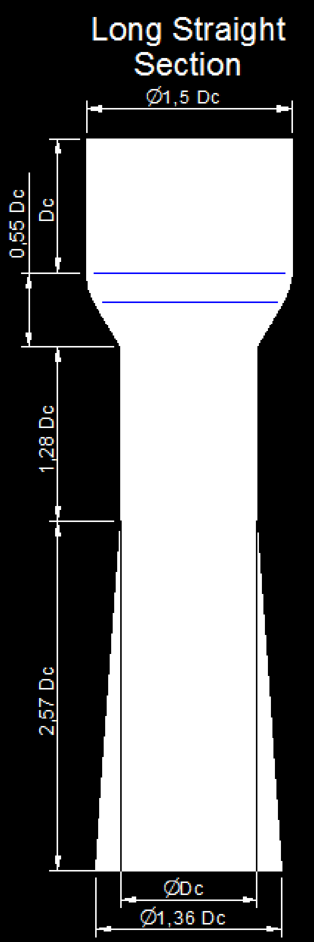
Simulation A

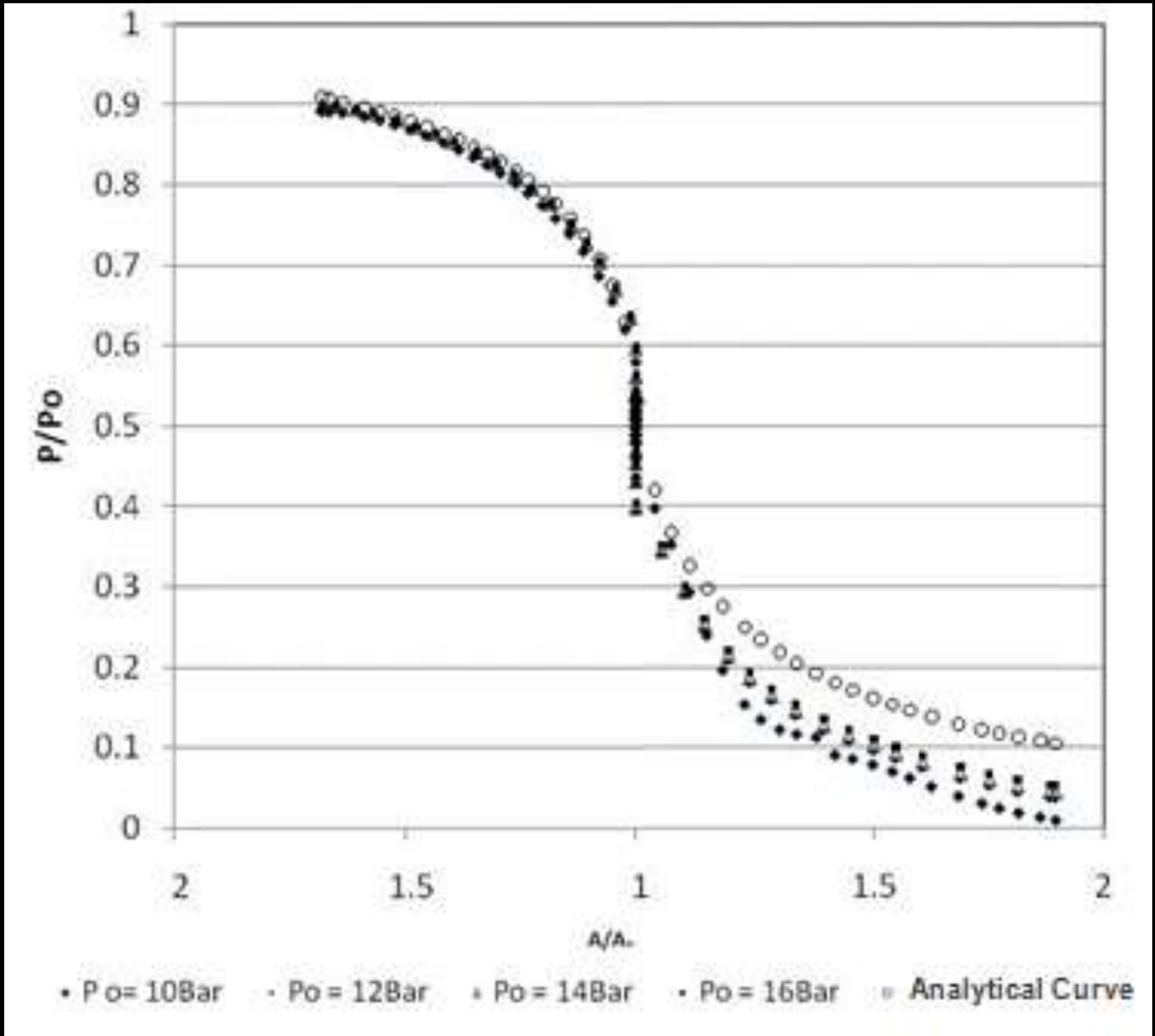


RESULTS AND DISCUSSION

Simulation A

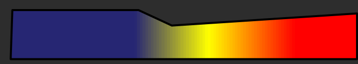
Pressure





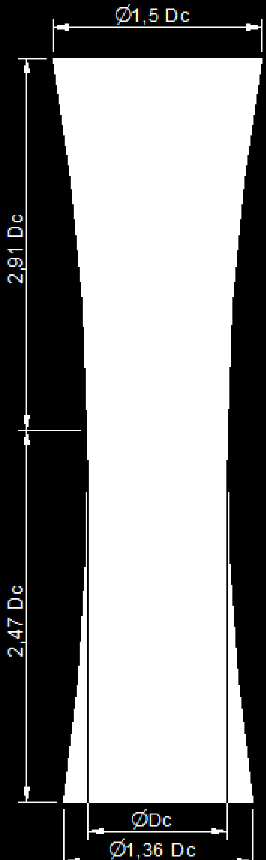
RESULTS AND DISCUSSION

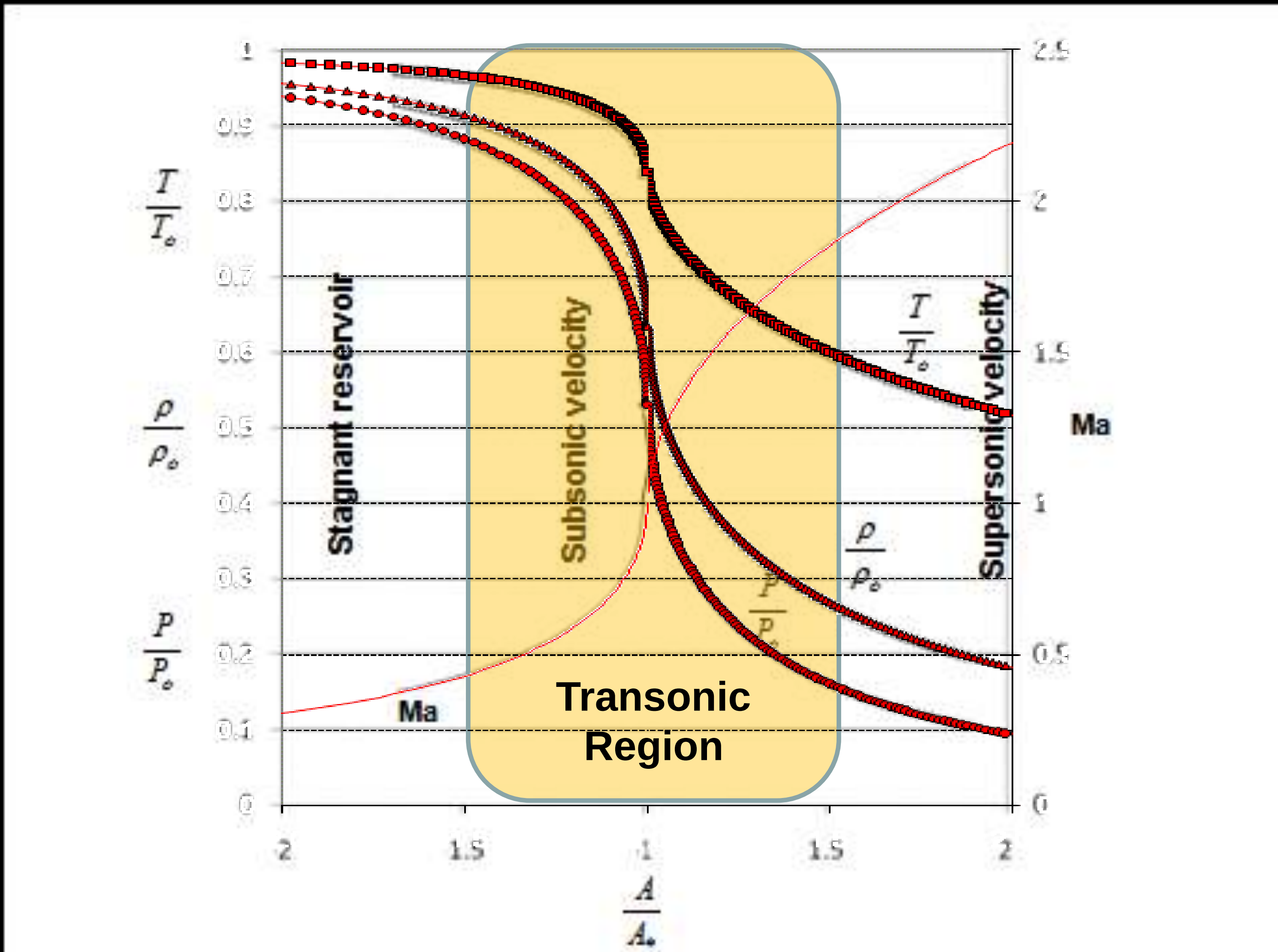
Simulation A



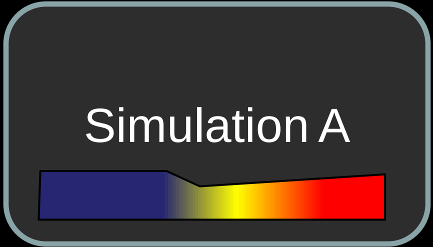
Analytical
x
Numerical

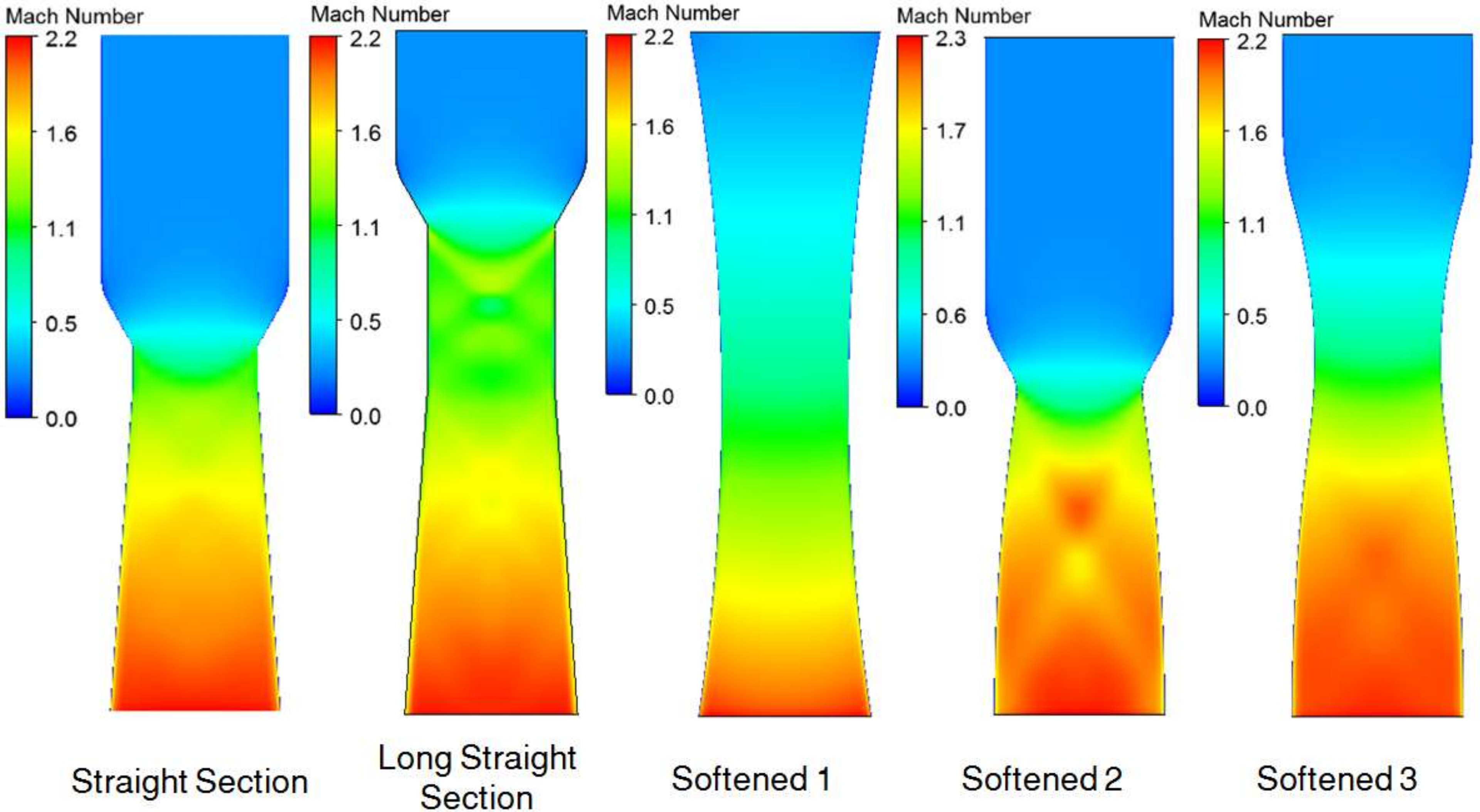
Softened 1





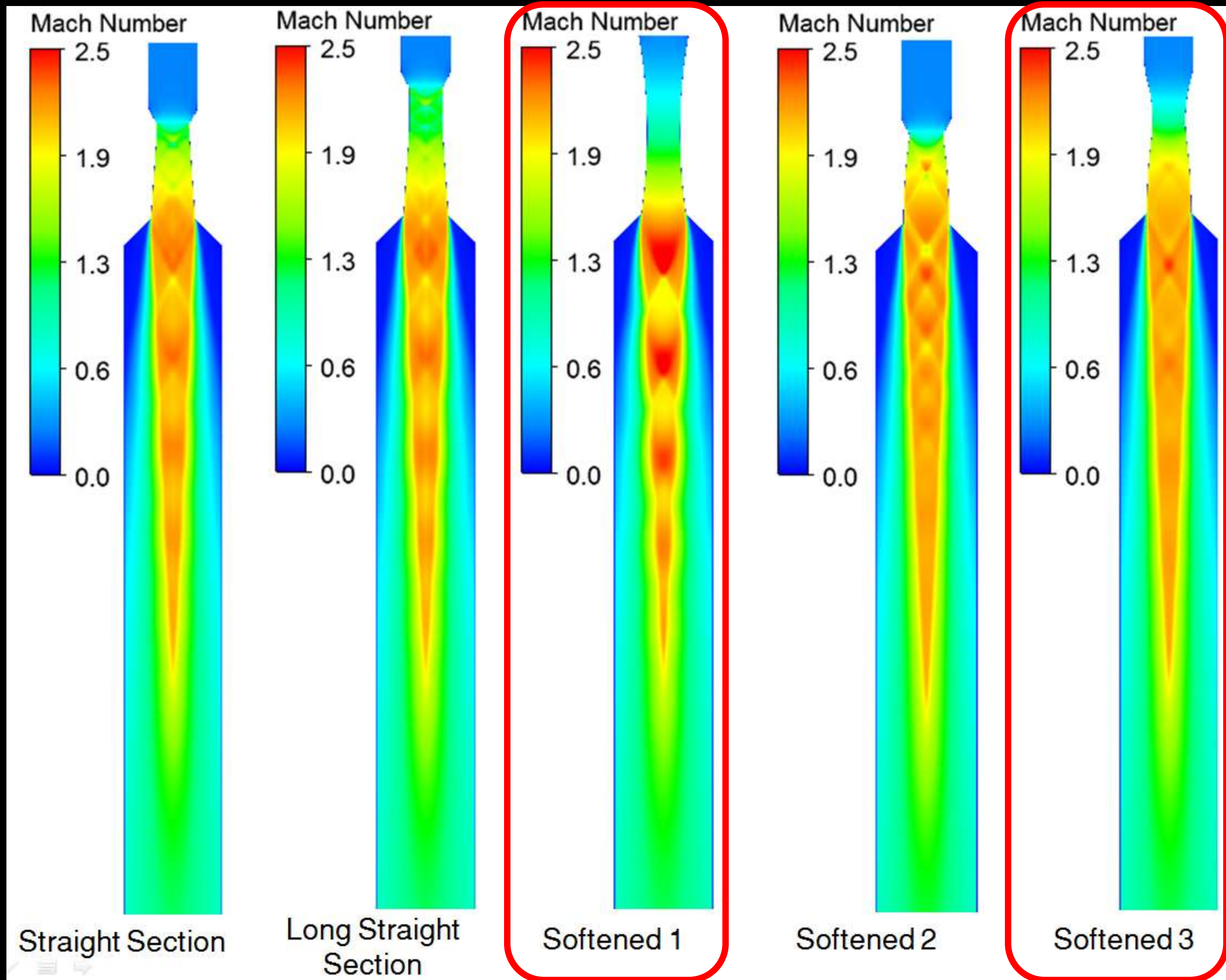
RESULTS AND DISCUSSION



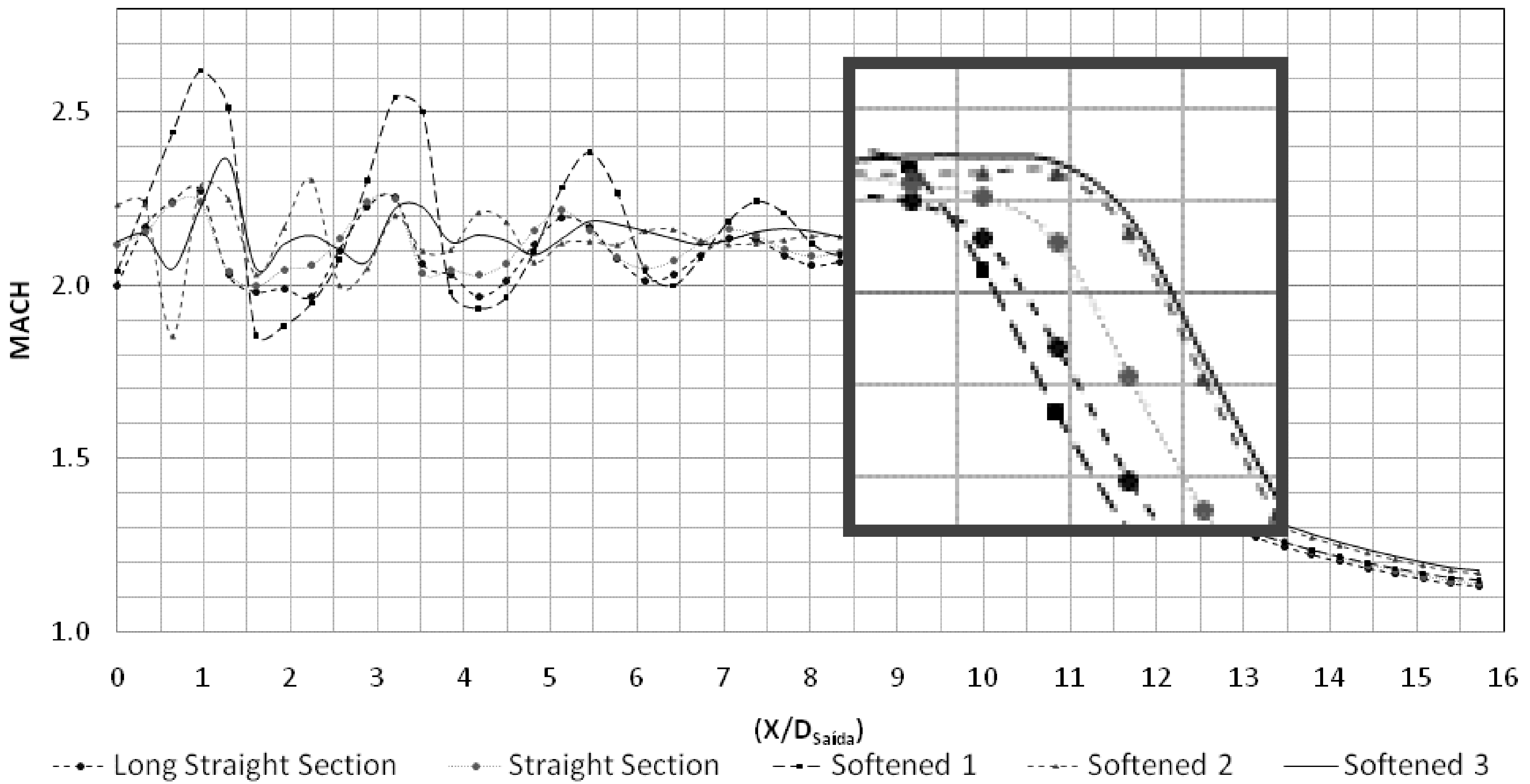


RESULTS AND DISCUSSION

Simulation B



RESULTS AND DISCUSSION



CONCLUSION

1. The straight section at the throat causes a reduction in efficiency in the transition of the properties of the gas;
2. divergent section has influence in the shape and distances reached with high velocities;
3. The drop in efficiency causes premature loss of jet velocity and consequent loss of penetration in the bath;

CONCLUSION

4. Penetration loss implies loss of efficiency of oxygen in the bath decarburization;
5. The steel industries already have at their disposal the ability to obtain geometries of nozzles more efficient in their operations by reducing the blow time.

Thank You

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