Optimization of Aspect Ratio for Cooling Channels in Rocket Engines

A Parametric Study on the RL10 Engine

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Introduction

- **Objective**: Find the optimal mass flow rate and aspect ratio (AR) for the cooling channels at the throat section of the RL10 engine.
- **Context**: Importance of aspect ratio in enhancing cooling performance and minimizing power loss.

Methodology

- **Parametric Study**: Conducted to determine the optimal AR by varying mass flow rate and observing the resulting pressure drop and power loss.
- **Design**: Channel height constant, width is twice the rib thickness.

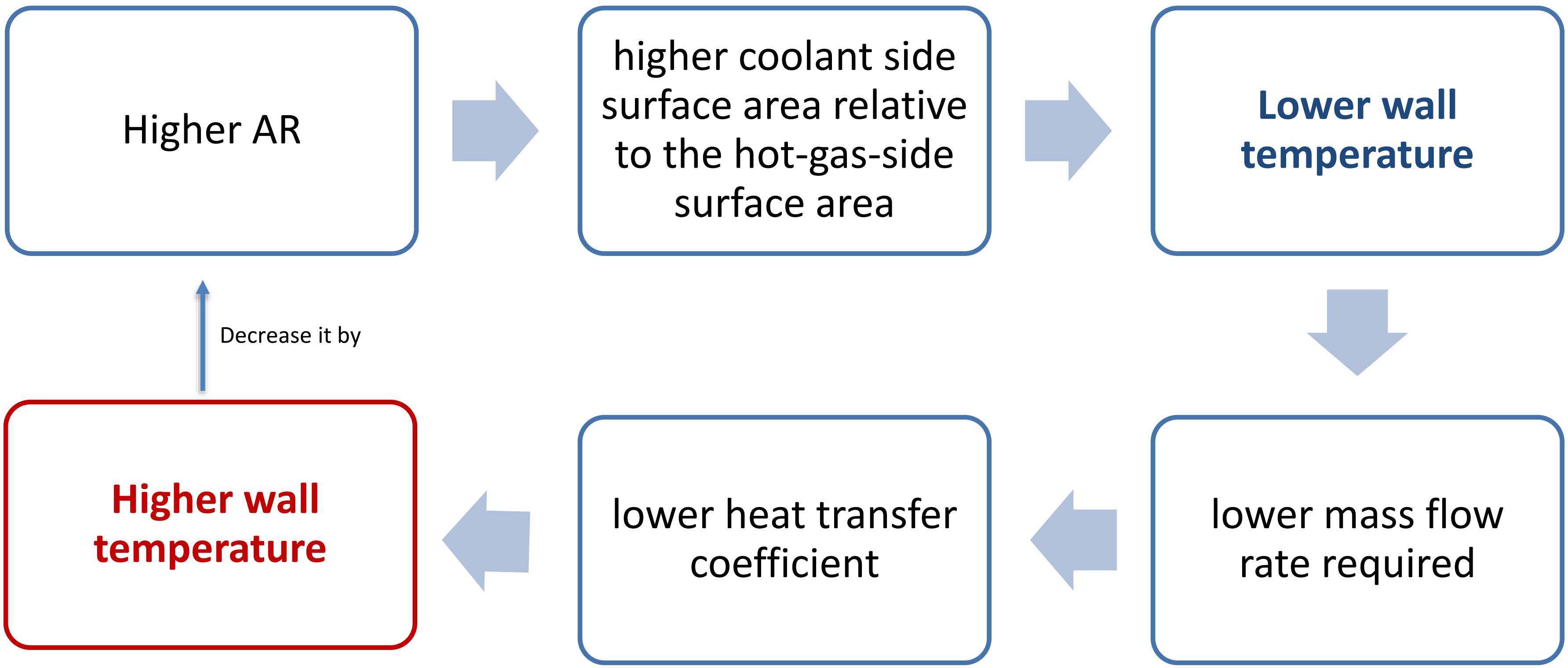
Key Equations and Concepts

- **Aspect Ratio (AR):** Ratio of channel height to width.
- **Heat Transfer Coefficient**:
  - Coolant: Explained through the Dittus-Boelter correlation for the Nusselt number
  - Hot gas: Bartz correlation
- **Wetted Perimeter and Hydraulic Diameter**: Their role in pressure drop and heat transfer.

Requirements

- Cooling jackets outlet pressure: 5.6 Mpa
- Wall temperature < 1200K (Copper-Nickel Alloy)
- Coolant is subsonic in the cooling channels

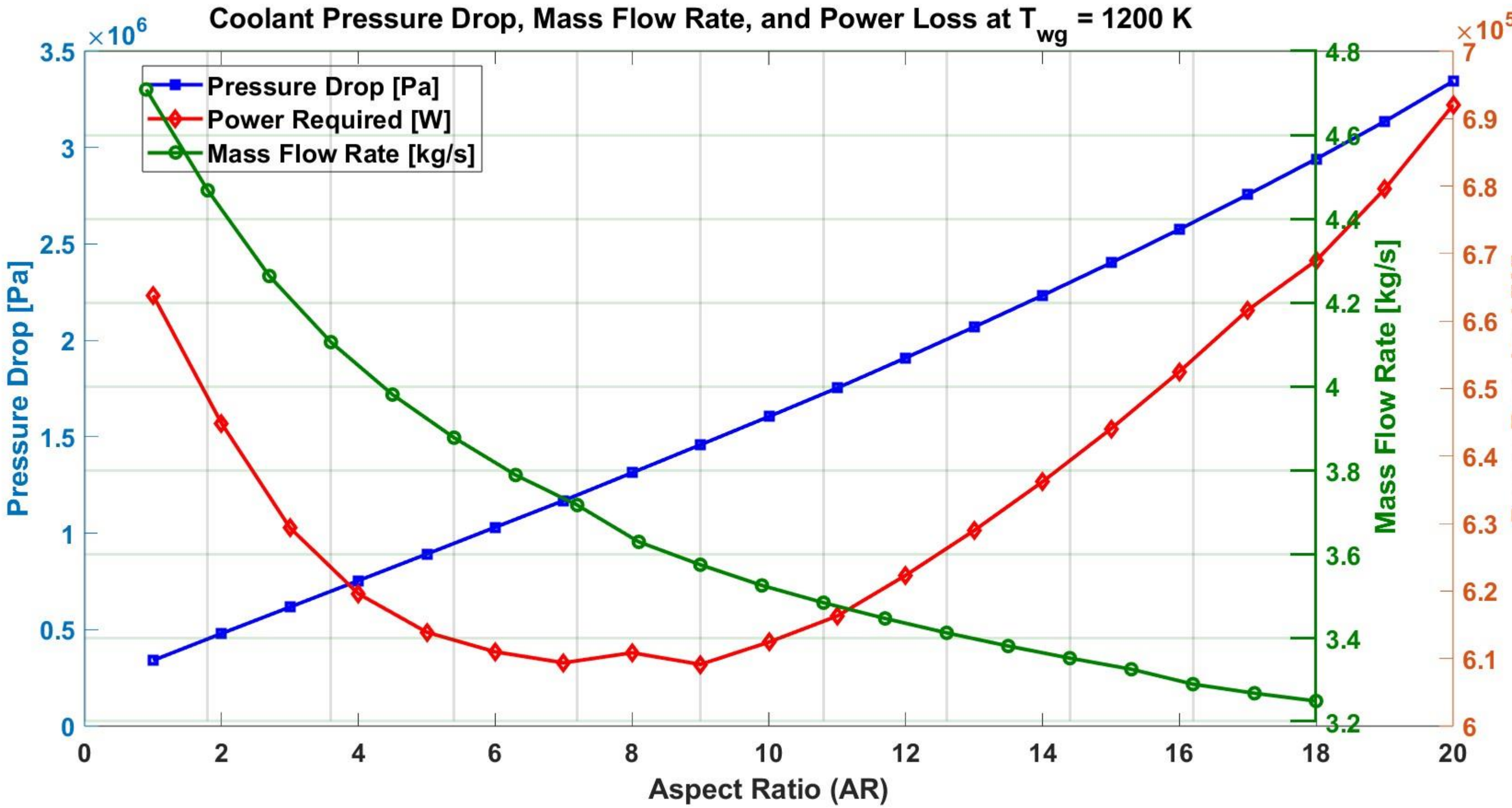
Need for a parametric study



Results Overview

- Minimum pressure drop at AR=8, minimum power loss at AR=10.
- Current RL-10
    - mass flow rate = 4 lbm/s
    - Power consumption: 0.65 MW
- Optimized RL10
    - Hydrogen mass flow rate = 3.7 kg/s
    - Power consumption = 0.61 MW
- Power saving with optimized AR: 6%

Graphical Results



Coolant pressure drop, mass flow rate, and power required as a function of AR.

Discussion

- **Trade-offs**: Higher AR improves cooling but increases pressure losses.
- **Manufacturing Considerations**: Challenges in achieving high AR with conventional machining.

Conclusion

- **Optimal AR**: Identified as AR=7 for minimizing power loss while maintaining acceptable cooling.
- **Future Work**: Suggestions for further parametric studies with more variables.

References

- Pizzarelli, Trade-off analysis of high-aspect-ratio-cooling-channels for rocket engines.
- Haberbusch, Modeling the RL IO with Densified Liquid Hydrogen and Oxygen Propellants.
- NASA Sp8107, Turbopump systems for liquid rocket engines.
- Bartz, Technical notes.

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