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.

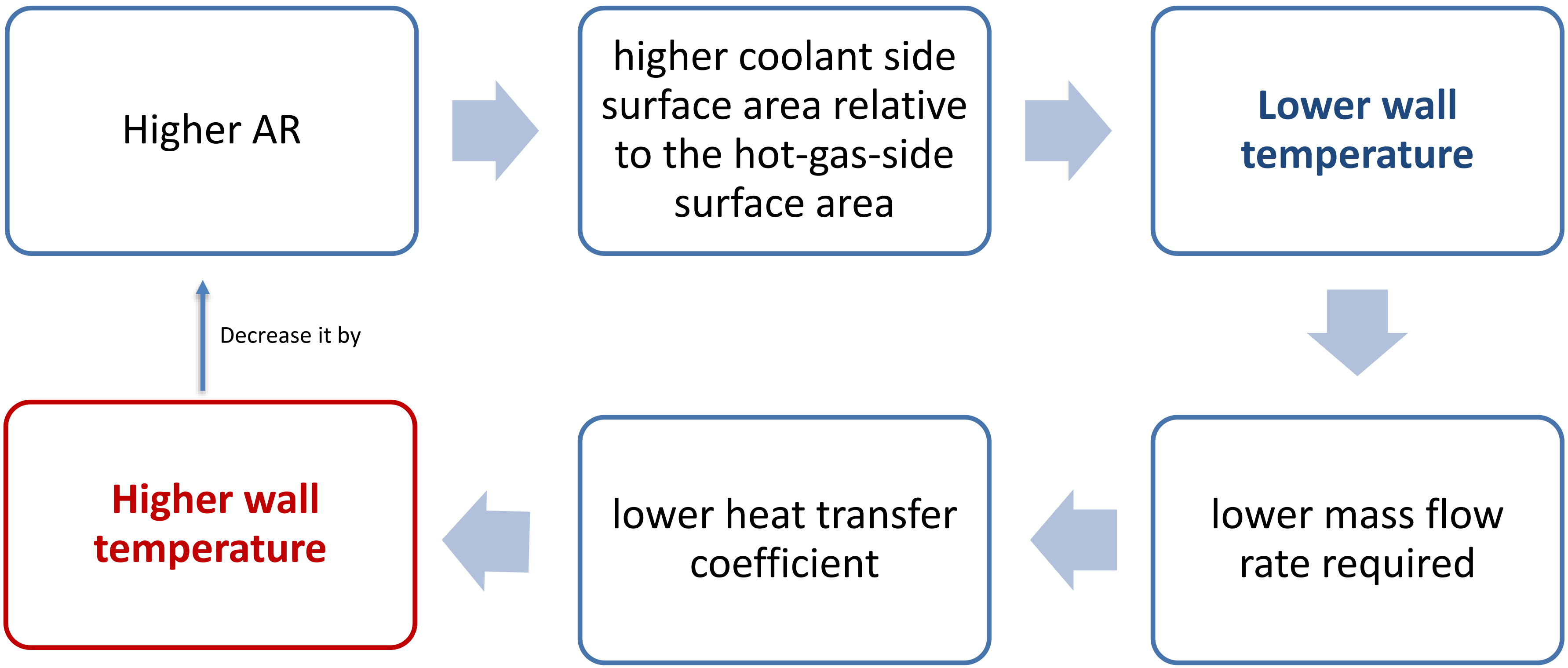
Key Equations and Concepts

- **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 [2]

- Cooling jackets outlet pressure: 5.6 Mpa
- Wall temperature < 880K
- Coolant is subsonic in the cooling channels

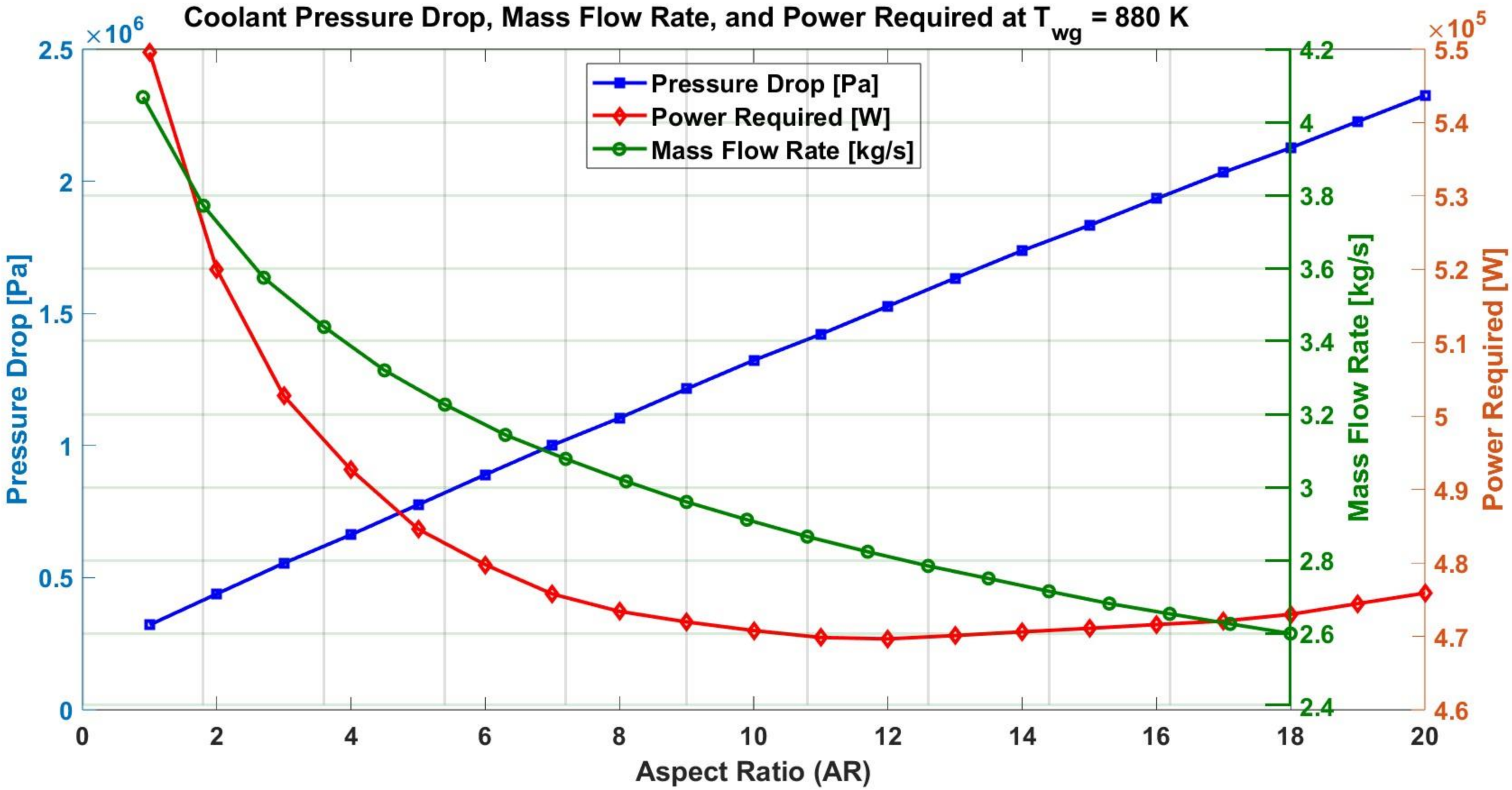
Need for a parametric study



Results Overview

- Minimum pressure drop at AR=1, minimum power loss at AR=12.
- Current RL-10
  - H_2 mass flow rate = 2.7 kg/s
  - Power consumption: 0.50 MW
- Optimized RL10
  - Hydrogen mass flow rate = 2.6 kg/s
  - Power consumption = 0.47 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=12 for minimizing power loss while maintaining acceptable cooling, and subsonic flow in the channels
- **Future Work**: Suggestions for further parametric studies with more variables.

References

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3. Haberbusch, Modeling the RL1O with Densified Liquid Hydrogen and Oxygen Propellants.
4. NASA SP8107, Turbopump systems for liquid rocket engines.
5. Bartz, Technical notes.

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