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Gas film/regenerative composite cooling characteristics of the liquid oxygen/liquid methane (LOX/LCH4) rocket engine

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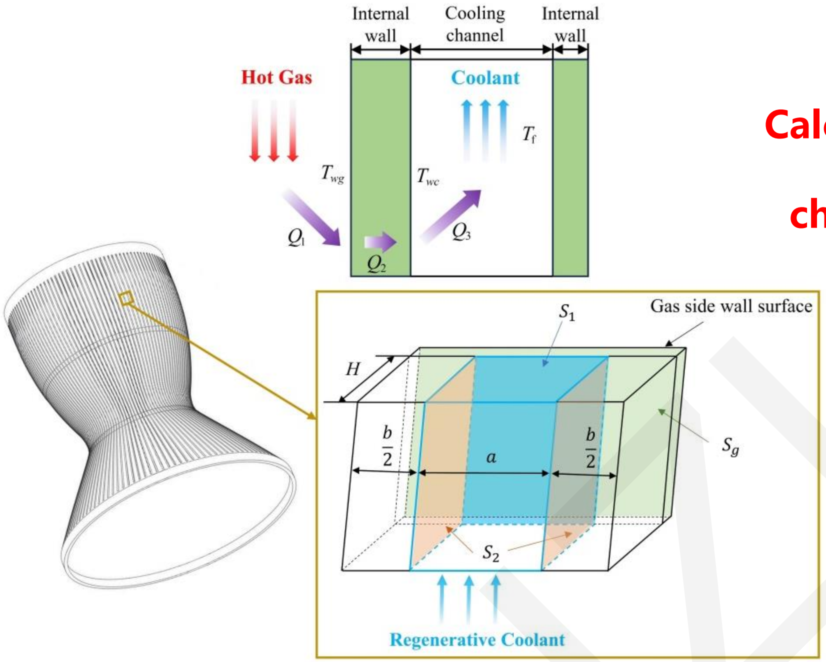
The one-dimensional composite cooling model



Calculate within a thrust chamber unit

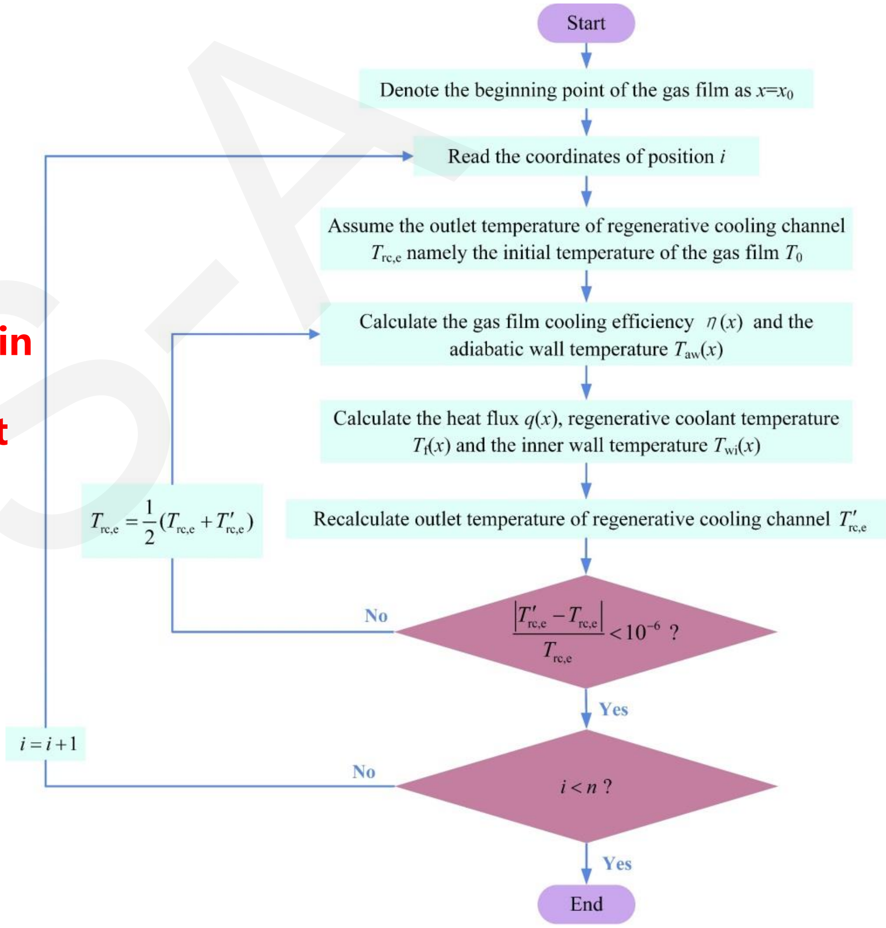
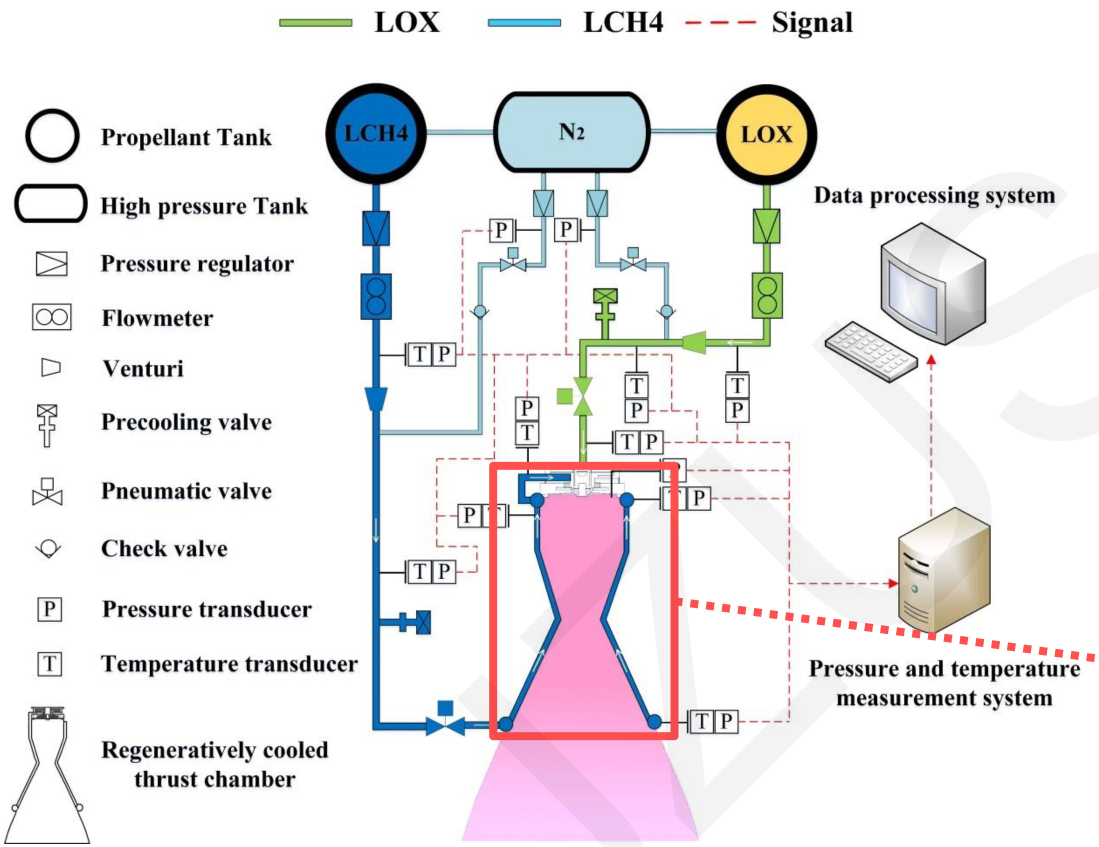
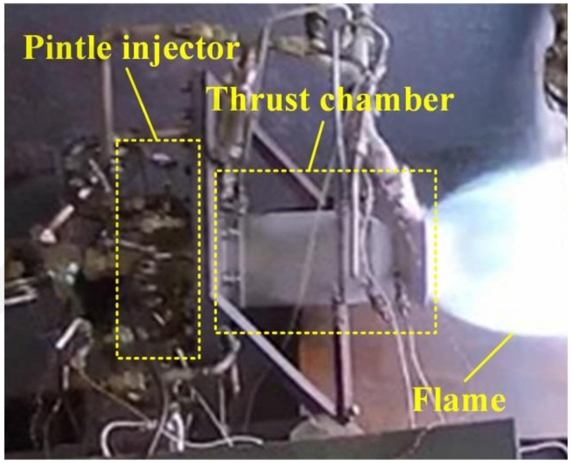


Fig. 1. The schematic diagram of the composite cooling heat transfer calculation process

Thrust chamber hot fire test verification





Thrust chamber hot test

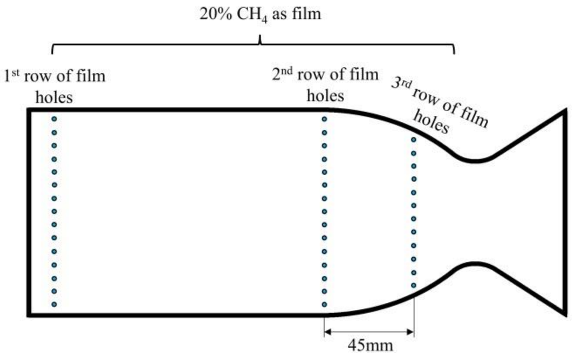
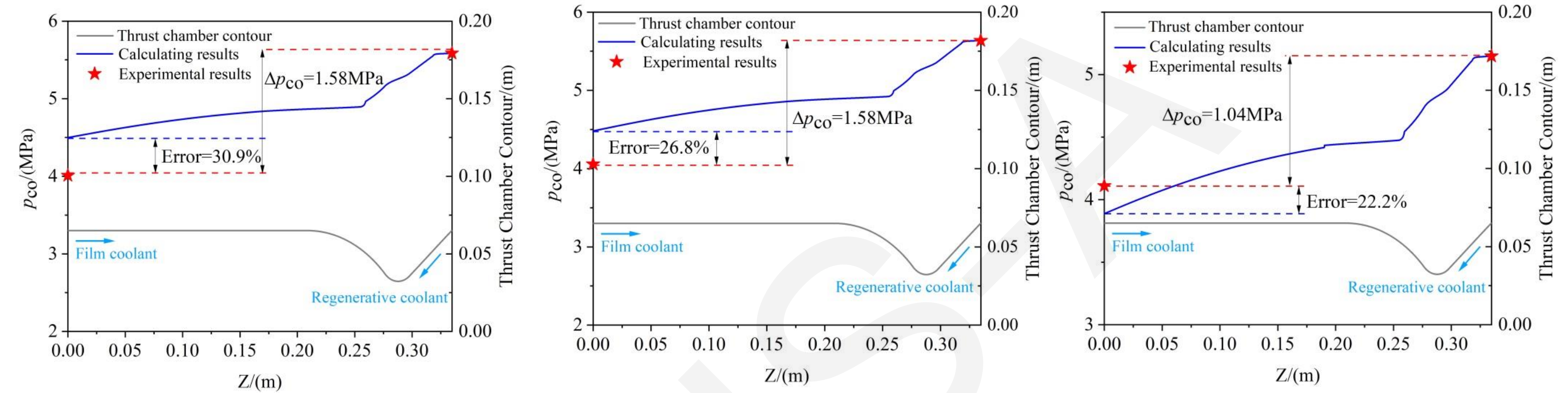


Diagram of composite cooling thrust chamber

Fig. 2. Schematic diagram of the composite cooling thrust chamber hot test system.

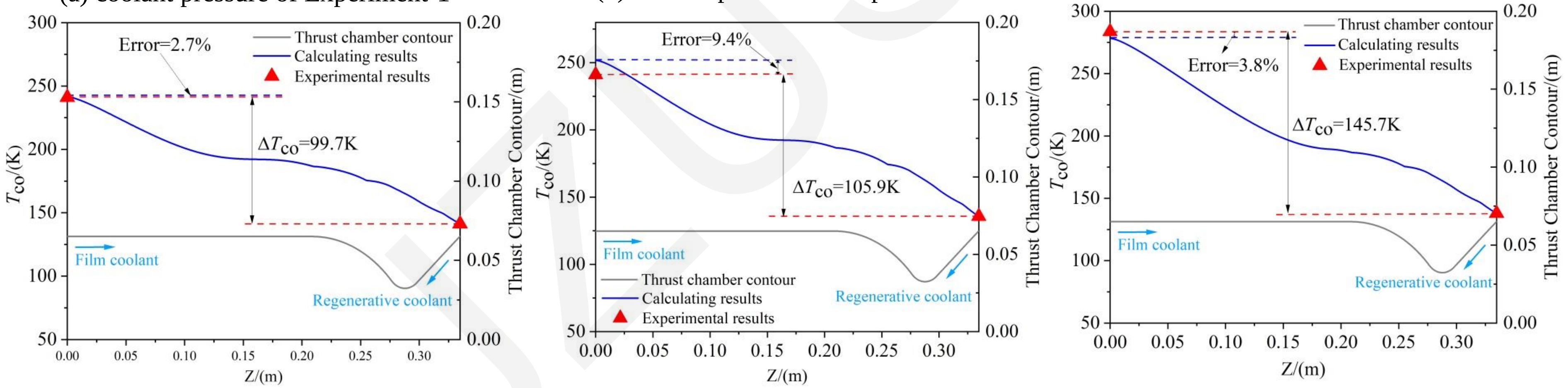
Thrust chamber hot fire test verification



(a) coolant pressure of Experiment-1

(b) coolant pressure of Experiment-2

(c) coolant pressure of Experiment-3



(d) coolant temperature of Experiment-1

(e) coolant temperature of Experiment-2

(f) coolant temperature of Experiment-3

Fig. 3. Comparison between calculation results and experimental results

The influence of gas film flow rate on composite cooling performance

Gas film flow rate increases → gas film cooling efficiency increases → gas side wall temperature decrease

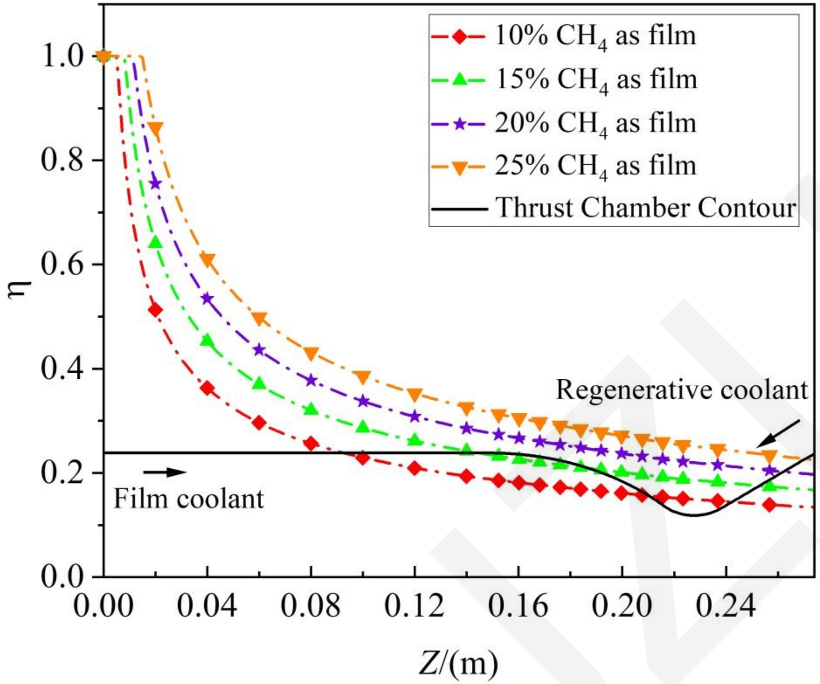


Fig. 4. Distribution of gas film cooling efficiency at different mass flow rates

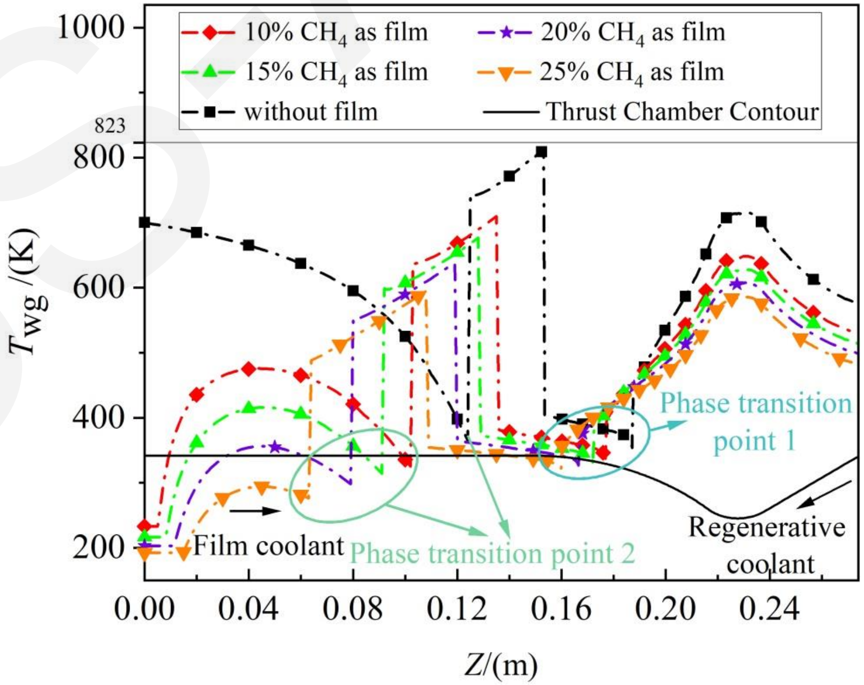


Fig. 5. Distribution of the wall temperature on the gas side at different mass flow rates

Influence of gas film introduction position on composite cooling performance

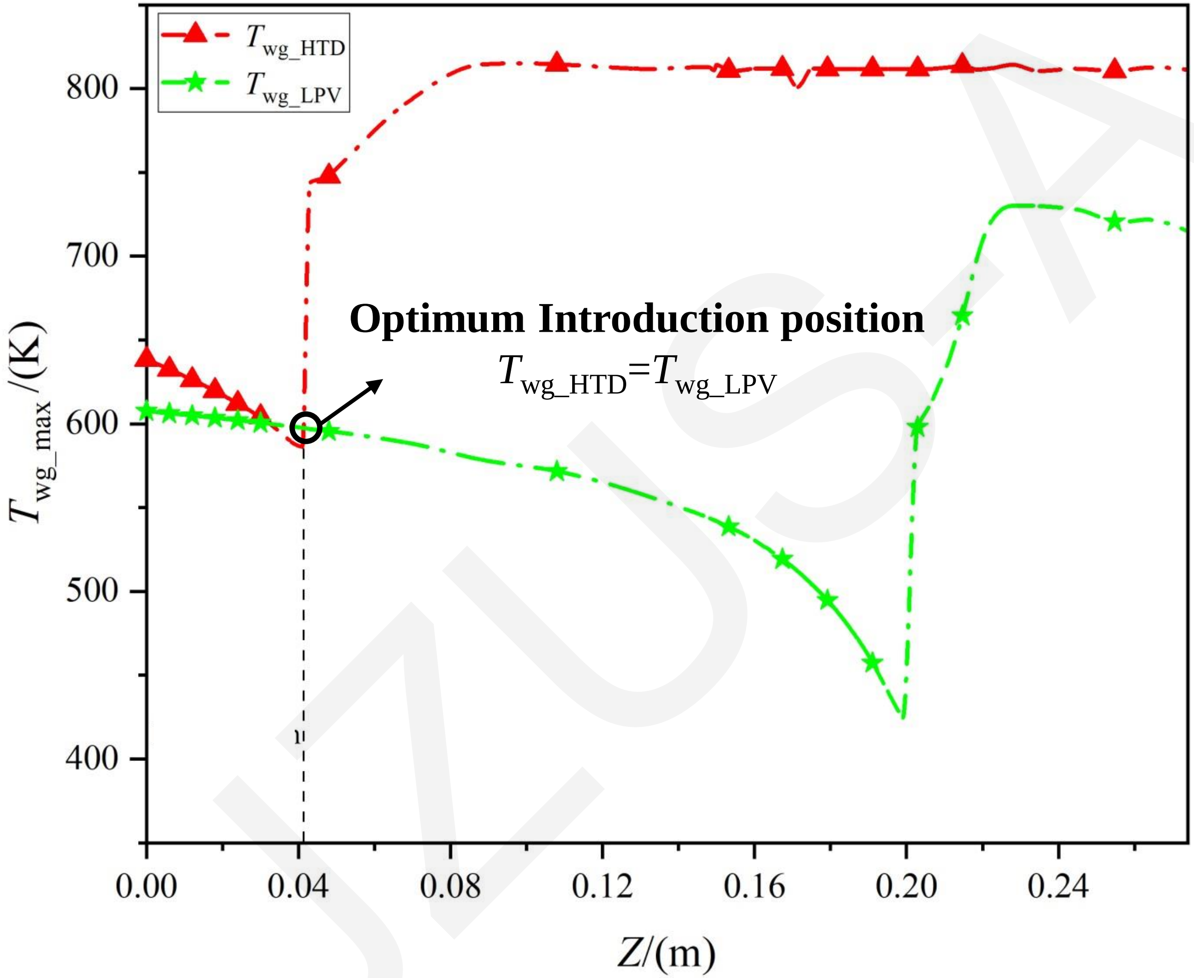


Fig. 7. Variation of the peak wall temperature on the gas side for different introduction positions. T_{wg_HTD}: extreme value in heat transfer deterioration region; T_{wg_LPV}: extreme value in liquid-phase region

Conclusions

- The one-dimensional composite cooling heat transfer model offers the advantages of low computational cost and higher accuracy. Compared with the experimental results, the temperature rise error of coolant is less than 10%.
- Increasing the gas film flow rate strengthens the cooling effect. At a gas film flow rate of 25%, the peak wall temperature is only 595 K, which is far lower than the material temperature limit.
- The optimal introduction position is achieved when the gas film is introduced by a single row of holes, allowing the gas-side wall temperature to be distributed more evenly and lowering the peak value. At a gas film flow rate of 20%, the ideal introduction position is Z=0.043 m and the peak wall temperature is 596 K.