Approach of designing the thrust chamber for the liquid rocket engine

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I. Introduction

The thrust chamber is the beating heart of any chemical rocket engine, serving as the crucible where propellants are mixed, ignited, and expanded into high-velocity exhaust to generate thrust. As the primary source of propulsion, it embodies the convergence of multiple physical disciplines—fluid dynamics, thermodynamics, combustion science, heat transfer, structural mechanics, and acoustics—making its design one of the most complex and critical challenges in aerospace engineering. Whether powering a small satellite's attitude control system or enabling humanity's return to the Moon, the performance, reliability, and efficiency of a rocket engine hinge on the careful orchestration of processes within this compact, high-energy device.

II. Mission requirement

To establish a systematic methodology for selecting the most suitable rocket engine architecture (cycle type, scale, key parameters) based on mission-driven thrust requirements, thereby defining the foundational design parameters such as chamber pressure, nozzle geometry, and complexity envelope.

A. First stage

The rocket engine installed on the first stage is the key that determine whether the launching mission can be accomplished successfully. To overcome the gravity that lifting the rocket out of the atmospheric of earth

As a result, high thrust to weight ratio is mandatory.

B. Second stage

With the lifting up by the first stage up to near space, the lack of atmospheric drag, the initial velocity from the first stage enables it to overcome the gravitational force from earth. while the majority of weight intense on the first stage of the rocket, the propellant can be carried by the second stage must be less than the first stage. given by the reduced propellant, the impulse stands for the higher position in this case.

As a result, To gain the orbital velocity for the rocket, high impulse with moderate thrust is required for this stage.

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III. Engine Cycle Selection

The engine cycle is actually depends on the pressurisation system of the rocket. The Squeeze-type and pump type. Engine cycle is actually the operating condition of the pump type. Cycle include both open and close cycle of the rocket engine.

A. Open cycle

The engine that apply the Open cycle exhausting the exhaust gas out of the thrust chamber, after being applied to drives the turbine of the turbo pump. Gas generator cycle is the widely applied and well known cycle of rocket engine. The effect of reducing the propellant effiency is significant on the high thrust engine. therefore, the high thrust engine, must apply the close cycle pressurisation system.

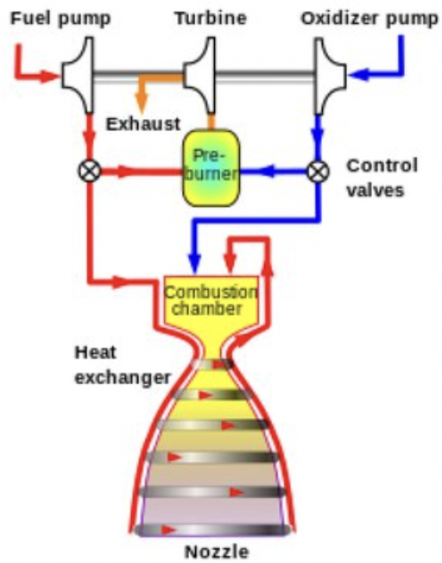
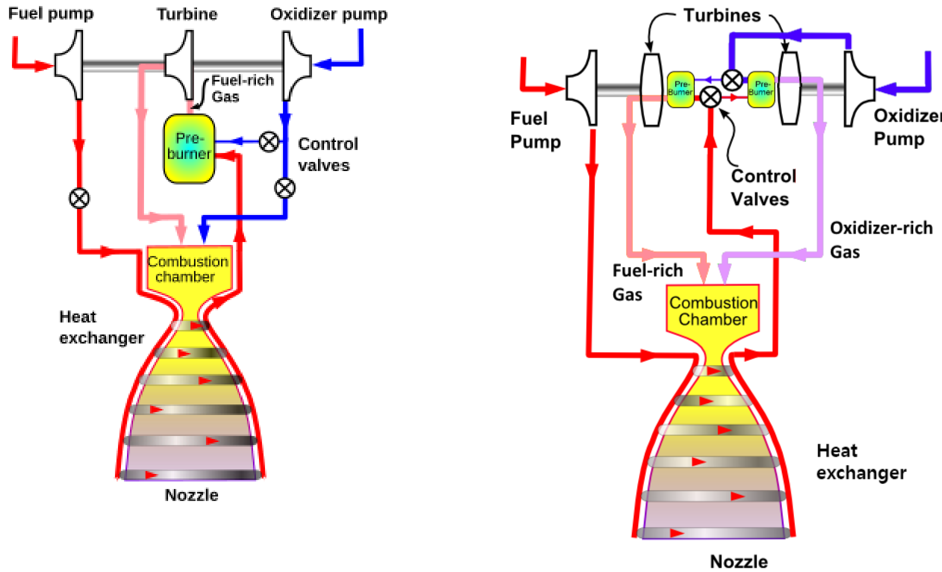


Fig. 1 The gas generator cycle rocket engine

B. Close cycle

Close cycle reuse the exhaust gas from the pre-burned into the thrust chamber for the secondary combustion, for a much complete combustion and also preventing the waste of propellant. this include the expansion cycle, staged combustion cycle , and Full Flow Staged Combustion Cycle (FFSCC).

The staged combustion cycle can be classify into the partially and full flow staged. the partially staged applying the **either rich or lean** combusted exhaust gas at the pre-burner that drives the turbine of fuel and oxidizer pump, and apply pump into the thrust chamber. The full flow staged takes **both fuel rich and fuel lean** on driving the fuel and oxidzier pump. after that, both of the rich lean air injected into the combustor.



(a) Staged Combustion Cycle rocket engine (b) Full Flow Staged Combustion Cycle rocket engine

Fig. 2 The schematic diagram of staged combustion cycle rocket engine

IV. Cycle Selection to Core Parameters

A. Thrust

As mentioned in the previous section, the impulse is essential on the high thrust rocket engine. Therefore, typically the thrust are applied in the following range.

Table 1 The selection of engine cycle with thrust

Cycle	Thrust, N
Gas generator cycle	100k to 1M
Staged combustion cycle	100k to 7M

The pump type cycle is the pressuarizatiopn method is that provide sufficient presusre supply to the engine, while the pressure feed type only apply on the upper stage under microgravity environment. It is widely applied for the staged combustion cycle on the high thrust rocket, but it also avliable on the engine on the medium small size rocket

B. Chamber pressure

The chamber pressure depends on the cycle directly, since this determine whether the pump is avliable on continuously providing the cycrogenic propellant to the chamber.

C. chamber geometry

Insert tables and figures within your document; they may be either scattered throughout the text or grouped all together at the end of the file. Do not insert your figures in text boxes. Figures should have no background, borders, or outlines. In the LaTeX template, use the "caption" command to type caption text. Captions are bold with a single tab (no hyphen or other character) between the figure number and figure description. See the Table 1 example for table style and column alignment. If you wish to center tables that do not fill the width of the page, simply highlight and "grab" the entire table to move it into proper position.

V. Case Study: An staged combustion cycle Engine for a 200 kN First Stage

VI. Conclusion

Appendix

References