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COMPARATIVE ANALYSIS OF DIFFERENT COOLING METHODS OF THE LIQUID PROPELLANT ROCKET ENGINE NOZZLE

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Key words: rocket engine, nozzle, ablative cooling, regenerative cooling, film cooling.

The exhaust gases of the rocket engine are very hot, provides a risk of nozzle melting during long time operation. That's why it is important to find methods that would not only improve the structure, but also increase airworthiness and economic efficiency.

First possible way in order to prevent melting is making the walls of chamber so thick that even hot gases cannot heat all the metal to the melting temperature level, e.g. could be used a heat-resistant alloy Inconel.

Ablative cooling. Ablative cooling is one of the most simple and effective ways of cooling of the engine. It is a special technique which utilizes latent heat of evaporation and predominant chemical reaction. The carbon composite alloy as an ablation material is attached to the combustion chamber and acts as insulators since the thermal conductivity of ablative materials is very low. When combustion gases flow they are having high temperature and they start vaporizing the liners of ablative materials the material will carry heat with it. For example, the SpaceX Falcon 1 with Merlin 1A engine carbon composites were used as ablative cooling. The rate of combustion of the carbon composite layer depends on the technical specification and design of the rocker engine.

Regenerative cooling is a common option. The method involves allowing a certain amount of fuel to flow through the walls of the combustion chamber and nozzle, absorbing heat before it reaches the injectors. In order to do this, channels are cut into the walls to allow the liquid to flow through, and the interior of the chamber must, firstly, withstand high temperature stress, and secondly, be a good conductor of heat from the walls to the channels. Here, a composite material made of carbon fibers impregnated with a carbon matrix or thermally conductive polymers can be used, all of which meet the conditions mentioned above. The coolant liquid through the channel can be either fuel or cryogenic fuel, i.e. an oxidizing agent, which means that the outside of the rocket nozzle will be extremely cold, while the inside is the opposite. On the other hand, there is an increased chance that the fuel will boil over. In this case, the energy transferred from liquid to gas can be used to rotate the turbine and run the engine pumps.

Film cooling requires the injection of liquid between the combustion chamber or nozzle surface and hot combustion products. This creates an artificial boundary between the wall of chamber or nozzle and hot gases, which acts as thermal insulation removing the excessive heat. The easiest way to provide this liquid film is to arrange bigger amount of fuel or oxidizer injectors on the outer perimeter of the injector face. This way it can be created a ring of extra fuel flowing around the outer perimeter that won't have enough amount of oxidizer needed to burn. Such liquid ring can stop the heat transferring from the main combustion gases to the walls and flow it away. Additionally that fuel will be used later in the combustion process but it already has grater temperature which increases the efficiency of engine [1].

Conclusion

It is completely inefficient and impractical to make the walls of the nozzle thick due to a sharp increase in the weight of the structure and the price. It is much easier to use the ablation cooling method, it has no moving parts and self-regulating, although in this case the engine cannot be used again due to the wear of the walls of the ablation chamber. In film cooling, there is a risk of coolant leakage from the system, which can lead to loss of thrust or damage to the nozzle. Although the design is complex, it involves complex systems for supplying the coolant, as well as ensuring a higher wall pressure than in the combustion chamber – the regenerative cooling method is widespread among modern rockets, such as SpaceX Falcon 9 and Blue Origin New Shepard etc.

References:

1. Everyday Astronaut https://www.youtube.com/watch?v=he_BL6Q5u1Y&t=0s

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ANALYSIS OF POSSIBLE SOLUTIONS FOR MOST COMMON SPACESUIT DESIGN PROBLEMS

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Key words: Spacesuit, shoes, knapsack, gloves.

The design of modern spacesuits has several disadvantages: the bulkiness of the gloves, the too short time of using the knapsack, a large number of layers of materials, which in turn makes the design bulky and heavy. The high probability of throwing an astronaut away from the station is also a big problem. Therefore, it is worth considering options for solving these problems.

Shoes for spacesuits must protect the feet from mechanical damage, cooling and overheating and various other external factors. Spacesuit boots for walking in zero gravity have a simple design, since astronauts do not normally walk on the surfaces of space objects, but they must be comfortable, quick and easy to put on and take off. Already for staying on space objects, shoes must be more carefully thought out, for example, for landing on the moon or Mars. Another problem is