SABRE Rocket

Naoufal Chiguerch, Marvin Raupert, Josef Sen and Quentin Fourcoual
TMAL02, Linköping University, 2018

Introduction

The technology of SABRE stands for "Synergistic Air-Breathing Rocket Engine" and is a concept under development by "Reaction Engines Limited", based in Oxfordshire (England). This unique rocket engine concept makes it possible to fly directly into orbit and return in a single stage with a taking off and landing on a runway. All components of a certain aircraft would be completely reusable. Otherwise it is possible to reach the opposite side of the world in under four hours. Reason for that is the design of the hypersonic precooled hybrid air-breathing rocket engine. The technology is still in development, but various test trials show successful results. [4] [5]

Functionality

The technology of SABRE could operate in two different modes. It utilizes both jet turbine for lower speed (taking off) and rocket technology for higher speed. Both modes generating thrust using the rocket combustion and the nozzles. The construction of a SABRE rocket is shown in figure 1. [4]

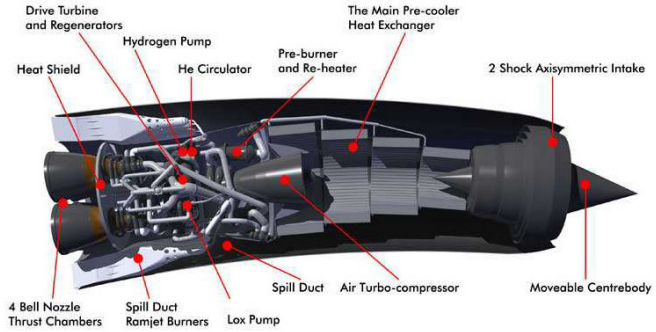

Figure 1: Construction of the SABRE rocket [1]

During the air-breathing mode in the lower atmosphere the oxygen component of its fuel is drawn in from the air like a normal jet engine. In fact of this, the amount of oxygen that needed to be stored is reducing and the thrust-to-weight ratio of the aircraft is increasing. At a certain speed the engine converts to full rocket mode. During this mode the engine uses only its own stored supplies (hydrogen and oxygen). [1] [4]

The reason that these two technologies have not been combined until now is that the incoming air into the engine could not be cooled down quickly enough during the compression. Accordingly, normal existing jet engines cannot provide enough thrust to get into space without overheating.

The new cooling system of SABRE overcame this hurdle. Now it is possible to cool the air entering the engine from 1000°C to -150°C in a hundredth of a second. The scientists have also made it possible that no ice forms during the cooling process. [4]

In figure 2 the way of the air and the circulation of helium in the engine is shown. The airway can be divided into three sections.

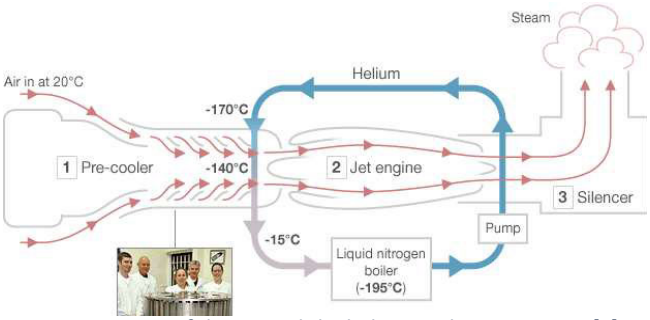

Figure 2: Way of the air and the helium in the test engine [2]

The first section is the pre-cooler. During the flight hot air enters the pre-cooler and with the help of cold condensed helium the temperature drops down very fast. In the jet engine (second section) the chilled oxygen is compressed and burnt with fuel to provide thrust. For keeping the helium chilled, it is pumped through a nitrogen boiler. In this third section, called the silencer, water is used to dampen the noise from the exhaust gases. The third section only exist in the test model. [2]

A closer look at the pre-cooler reveals the special structure, shown in figure 3.

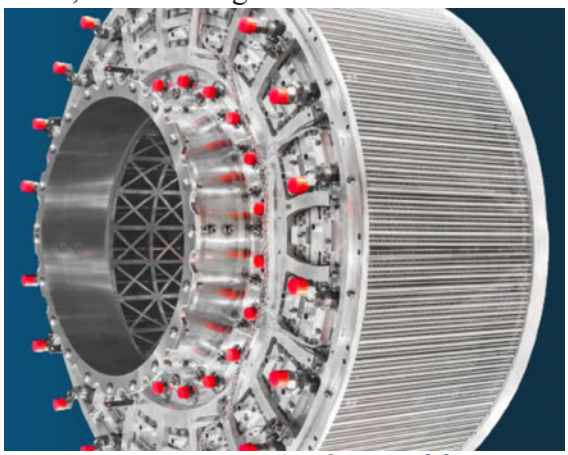

Figure 3: Pre-cooler of a SABRE [3]

The hot air flows around an array of thin pipes filled with condensed helium. All in all, the pipes have an overall length of hundreds of kilometers. The resulting high surface, also shown in figure 4, is the reason for the cooling. The technology behind the not possible icing remains a company secret. [3]

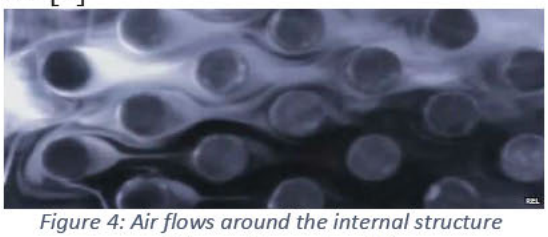

Figure 4: Air flows around the internal structure of the cooling system [2]

Next to the cooling system the figure 5 shows in simplified form the complete SABRE cycle. The air (blue) from the intake is going through the pre-cooler and the turbo-compressor. The compressor provides a high-pressure air supply to the combustion chamber which allows operations from zero forward speed on the runway and during ascent up to Mach 5,5 in air-breathing mode. At higher altitude with lower density the engine switches to the rocket mode to get the orbital velocity (Mach 25).
The air is cooled with helium (green) that has been itself cooled with the liquid hydrogen fuel (purple) by using the HX4 (heat exchanger). After the pre-cooler the helium is further heated in HX3 by the product of the pre-burner. This energy could drive the turbine and the liquid hydrogen pump (LH2). [2] [6]

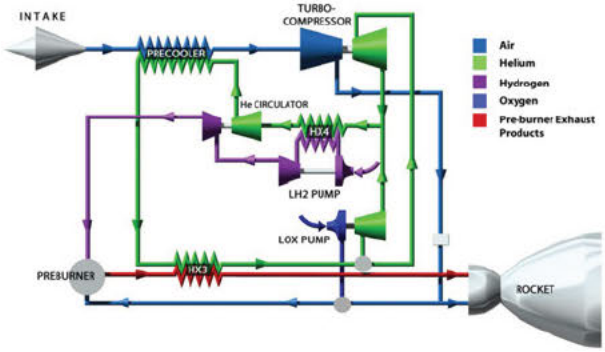

Figure 5: Simplified SABRE cycle [6]

If the engine changes to rocket mode the energy to drive the LH2 pump and the liquid oxygen pump (LOX) is completely produced in HX3.

This way of reusing the heat increases the engine efficiency. As the figure 5 shows, the use of lightweight heat exchangers is required and the key technology to develop SABRE engines. [6]

Conclusion

This technology is the biggest breakthrough in aerospace propulsion since the invention of the jet engine. It has the potential to dramatically lower the cost of space flight in fact of the completely reusable space vehicle and reduce fuel burn by 5-10 % while enabling aircraft-like access to space. Also, the better thrust-to-weight ratio makes the engine so potentially valuable. To make the final version of the engine, the scientists of "Reaction Engines Limited" need more money. [2] [4]

Authenticity and Plagiarism

By submitting this report, the author(s) listed above declare that this document is exclusively product of their own genuine work and that they have not plagiarized or taken advantage from another student's work. If any irregularity is detected, the case will be forwarded to the University Disciplinary Board.

REFERENCES:

[1]https://web.archive.org/web/20141018192749/http://www reactionengines.co.uk/news_updates.html

[2] https://www.bbc.com/news/science-environment-23332592

[3] https://www reactionengines.co.uk/sabre/pre-cooler

[4]https://en.wikipedia.org/wiki/SABRE_(rocket_engine)

[5]https://web.archive.org/web/20121207125042/http://www reactionengines.co.uk/press_release/PRESS%20RELEASE%20-%20THE%20BIGGESTBREAKTHROUGH%20IN%20PROPULSION%20-%2028%20November%202012.pdf

[6]https://web.archive.org/web/20141009122504/http://www reactionengines.co.uk/sabre_howworks html