Integrated Propulsion System

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Abstract

In this study an initial concept is described. This shows the possibility of connecting axially an ordinary jet engine, a ramjet engine and a scramjet engine. Furthermore rocket mode is also available in this design. The different modes can be changed by this integrated system as easily as the different modes, or nosecone stages can be changed by ordinary jet engines below and above the speed of sound. Such an engine, with the appropriate fuel can be a great step towards the one stage spacecrafts of the future, due to eliminating the problems of carrying many different engines with different fuels and oxidyzers.

Keywords: jet, ramjet, scramjet, integration, ssto, propulsion, LEO

1. Introduction

One of the greatest problems of present day space activity to carry payload from surface to Low Earth Orbit (LEO) efficiently and economically. In the field of propulsion systems the main direction of present day research is partially substituting the rockets with different kind of jet engines. The MIG-25 Russian fighter aircraft [4] proved to be the best example for the limits of conventional jet engines. The final speed of this plane was limited in 2.8 Mach, meanwhile it was proven that it can reach 3.2 Mach speed. After this record the jet engines had to be changed because of the serious damages (the turbines could not compressed the air, but the incoming high speed air rolled the turbines until they simply burned and seriously damaged). In the 1960ties was sought solution for this problem and it can be said that it was found, although this solution could satisfied only those special demands (Mach 4 maximum speed) of that age. This maximum speed was necessary for high speed reconnaissance, not for space travel, thus the solution did not have to be more sophisticated. The structural materials also strongly limited the further developments. This solution was the jet engine of the SR-71 Blackbird [3], the J-58 jet engine [8].

In our case the examination of the J-58 is important, because it contains promising solutions and shows a lot of important details. Basically this is a "conventional" jet engine, which is surrounded with a lot of auxiliary devices. Considering the scheme of the it - Fig. 1., there can be seen that the jet engine itself is only approximately the half of the whole propulsion system. In front of it is a quite complex tool, which serve only to provide the necessarily low speed and dense air for the turbines. The giant nosecones, which can be seen on the SR-71 is the most widely known parts of these tools. There is also a possibility to let the air flowing backwards to the nozzle and the afterburner, which can work continuously for a longer time. Despite all of these details the J-58 cannot be considered as a ramjet above 3 Mach.

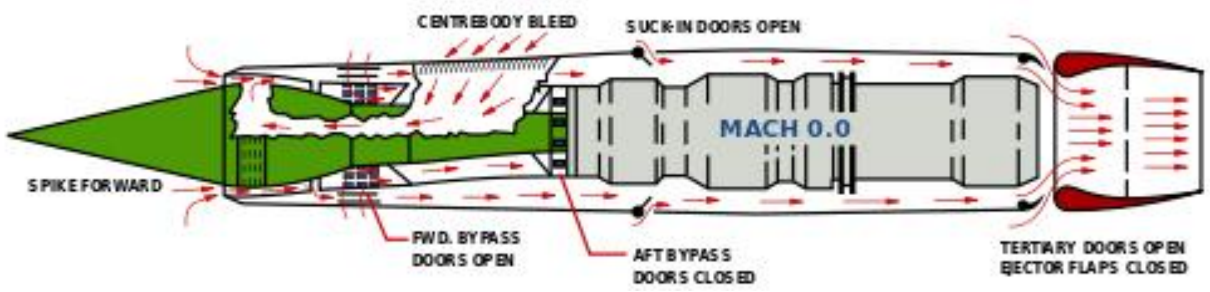

Fig. 1. The scheme of the Pratt & Whitney J-58 jet engine (Fig 1.21 from the SR-71 Flight Manual)

Another important solution from our point of view is the possibility of fuel vaporization into the inlets in case of the Mig-25 – Fig. 2. This was only for increase the power of those engines in hot cases. It can work only for a short time, not permanently during the whole fight. Nevertheless, those Mig-25 pilots, who used it, must be found it very useful for example in case of air-fight situations.

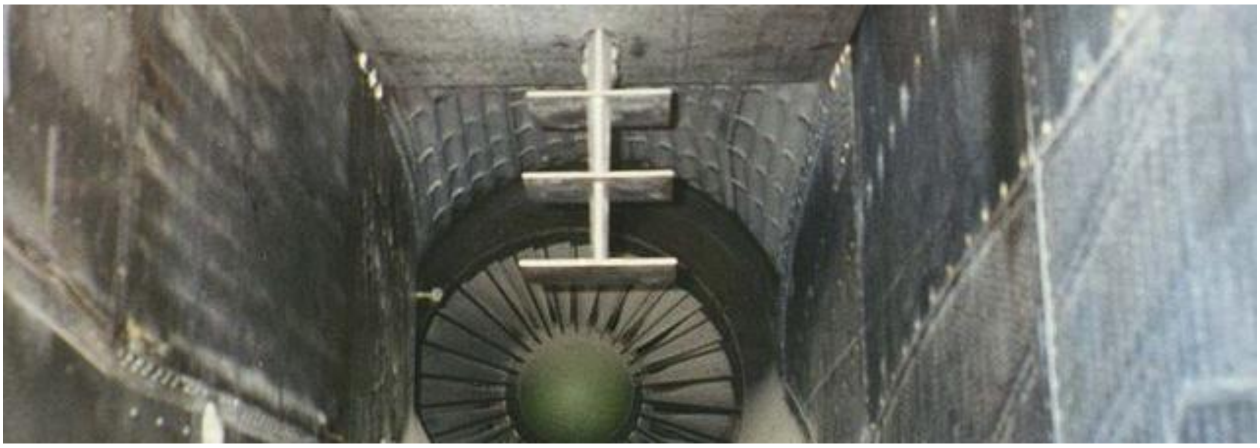

Fig. 2. The water-methanol vaporizer in the inlet of the MIG-25.

Here must be emphasized the main difference between the flight characteristics of spacecrafts and aircrafts. The aircrafts usually reach their normal flying height (10-30 km high) and are flying there with a cruiser speed (800-3300 km/h) for hours. During these hours the engines have to work continuously. Despite, in case of a space travel the engines have to work only for minutes. After reaching the necessary height (100 km or higher) and speed (8 km/s or higher) the engines are shut off (and usually they do not have to work again during the rest of the mission). It must be noted that the stress on the engines is extremely higher in that short work time on the spacecraft engines, than that of on the aircraft engines. Thus, such solutions, like the fuel vaporization into the inlets in case of the Mig-25, the basic concept of afterburning [7] and the hybrid rocket/jet propulsion system of the Canberra experimental aircraft in the 1950ties [2] can be very promising in case of spacecraft engine development, where high thrust is necessary, but only for a relatively short time. These solutions and the J-58 are those which are worth to be further developed.

2. The structure of the integrated propulsion system

The scheme of the integrated propulsion system is the following: The core of it is a conventional cylindrically shaped jet engine - Fig. 3. There are two specialities in its construction. The first is the nosecone and the air inlet. In the forward stage the nosecone hermetically blocks the airflow, thus the whole jet engine can act as a huge nosecone by the ramjet mode and it slows down and compress the incoming air flow. The other speciality is the nozzle construction. In this case not only the nozzle aperture can be changed, but the nozzle can absolutely close and insulate the conventional jet from the combustor of the ramjet - Fig. 4.

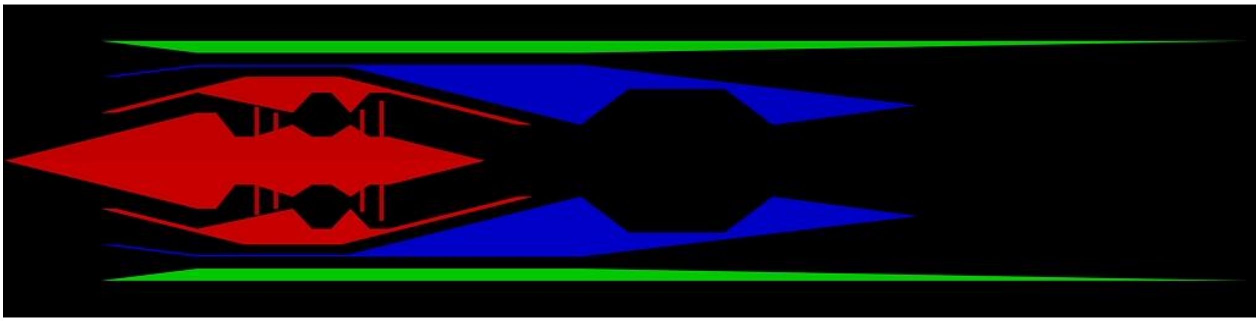

Fig. 3. The scheme of the propulsion system in jet mode. Red colour represents jet engine, blue represents ramjet engine and green represents scramjet engine. In jet mode there is a continuous afterburning in the ramjet combustion chamber.

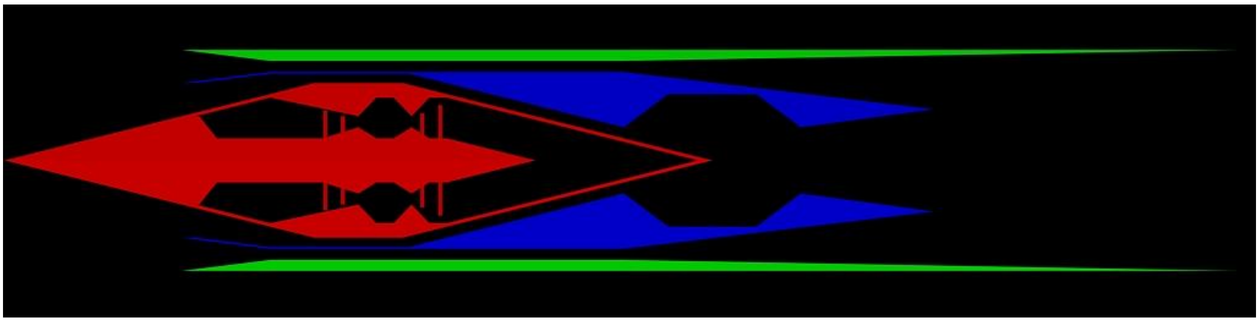

Fig. 4. The scheme of the propulsion system in ramjet mode. The nosecone in forward stage in the front and the nozzle at the rear absolutely insulates the jet engine.

Thus the insulated jet engine act in ramjet mode as ramjet nosecone, behind it is the combustor of the ramjet, which gets high pressured air from the airflow around the insulated jet engine. In the combustor can be vaporized the fuel in ramjet mode. This is already very advantageous in jet mode, because in that mode the combustor of the ramjet acts like the afterburner of the jet. In jet mode here is continuous afterburning, furthermore the airflow around the jet engine also gets into this combustor, which are both increasing the conventional jet thrust.

The great nosecone, which is basically the insulated jet engine can be also moved inside the ramjet engine (or it can be considered as the ramjet engine can be slipped backwards on the jet engine). Similarly to the previous case in the forward stage the great nosecone (the insulated jet engine) absolutely blocks the incoming airflow and turns the jet engine and the ramjet engine together a much greater nosecone, which can pressurize the airflow for the scramjet engine - Fig. 5.

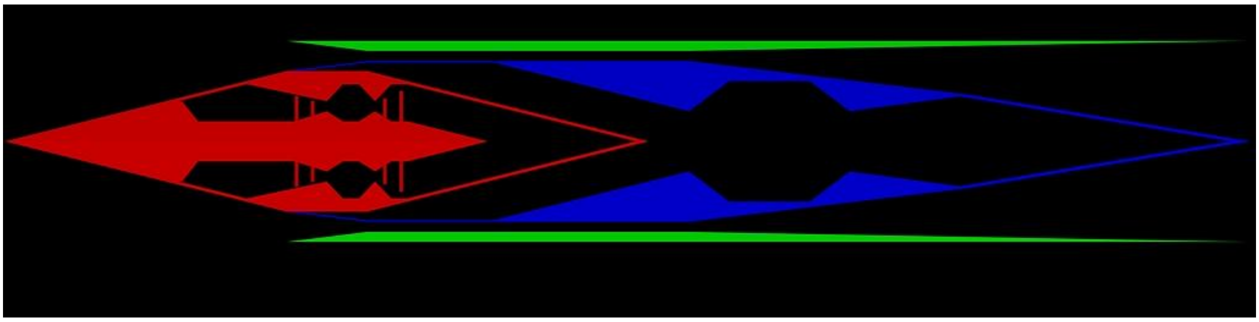

Fig. 5. The scheme of the propulsion system in scramjet mode. The whole insulated jet engine unit moves forward and the nozzle of the ramjet closes, thus the jet-ramjet unit is absolutely insulated, the whole system works like a typical scramjet engine.

From the structural point of view the scramjet is very simple, it is just jacketing this much bigger nosecone, which consist of the jet and the ramjet engine. The nozzle of the ramjet can be hermetically closed similarly to that of the jet engine, thus the scramjet mode can be easily provided after reaching the necessary speed. In case of leaving the atmosphere the scramjet cannot work anymore. In this case the nozzle of the ramjet opens, moreover an inner insulation creates a rocket combustion chamber from the ramjet combustion chamber. The fuel and the oxidizer will be vaporized into it and burns, thus the ramjet engine will act as a rocket engine in the final stage of the flight - Fig. 6.

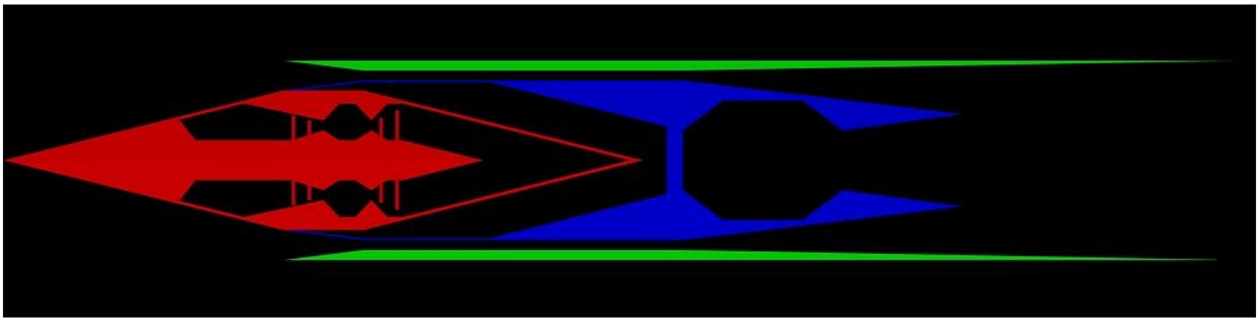

Fig. 6. The scheme of the propulsion system in rocket mode. Nozzle of the ramjet opens, an additional insulator wall creates a rocket combustion chamber from the ramjet combustion chamber, so it works as a rocket in this mode.

3. Questions of geometry and fuel

It must be noted that only the jet and the ramjet is a real structural unit, the insulation of their inlets and nozzles provided, and the ramjet can act as a rocket, as it was described previously. The scramjet can be integrated into this system much more flexibly. This means that there is possible to make the scramjet with a different geometry (not even cylindrical). As it can be seen in case of the X-43 [1] and X-51 [6], the under shape of them from the nose to the tail is a part of the scramjet engine. This is possible in case of the usage of such integrated propulsion system, integrating the jet-ramjet/rocket unit into the shape of the hypersonic plane - Fig. 7. Necessarily, this feature, the shape of the whole vehicle is determined by the scramjet mode, because in that mode are the greatest the aerodynamic and thermal effects.

Considering the scramjet mode, the fuel injection is still a problem [9], but there can be several solution, i.e. usage of solid fuel [10]. The fuel consumption and the appropriate fuel type are questions of detailed planning. To be able to find the exact geometry further studies and simulations must be made. After finding the exact geometry can be measured the fuel consumption, which is strongly dependent on the flight future. Such a propulsion system can be used primarily for reaching LEO with a single stage space vehicle, but it is also possible to use it for simply intercontinental/transcontinental travel, which requires far less fuel by the same engine design.

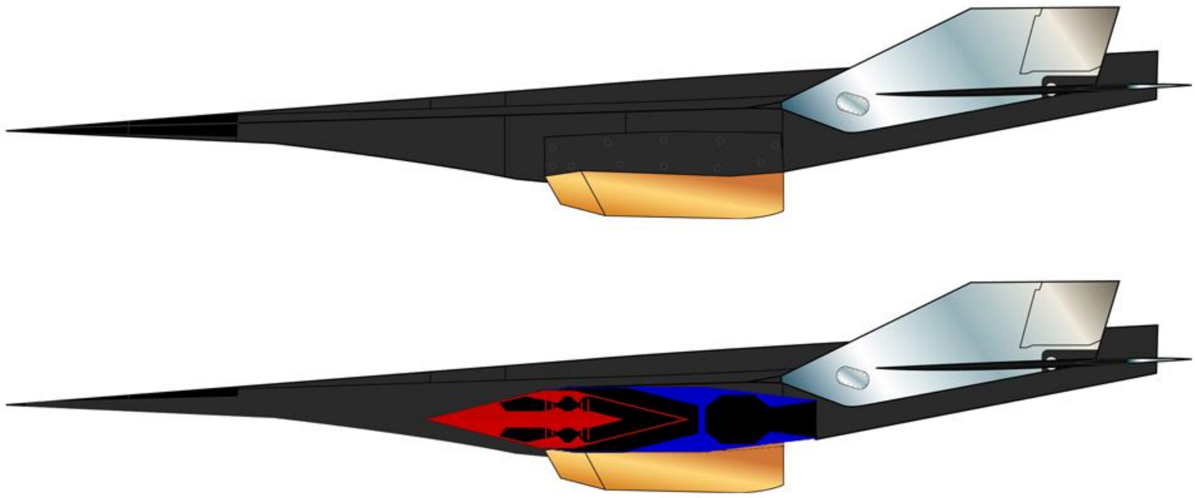

Fig. 7. A possible integration of the jet-ramjet/rocket unit into a different/existing scramjet design.

In case of such an integrated propulsion system choosing appropriate fuel and the oxidizer is very important. The fuel must be used in all modes (jet-ramjet-scramjet-rocket). The structural simplicity, reliability and gentle operation are the main considerations. Thus, it is worth to use kerosene as fuel, and hydrogen-peroxide (or high-test peroxide) as oxidizer in the rocket mode. High-test peroxide is hypergolic with kerosene, it can be used as a monopropellant (in the space), which is very useful in LEO. Furthermore the usage of this oxidizer is the most friendly for the engines [5]. The storage is also very simple, it does not require cooling despite liquid oxygen.

4. Conclusion

There are great opportunities of using such integrated propulsion systems. Even today the only possibility to reach the LEO is using a multi-stage rocket. According to the ongoing developments, this seems to will not be changed in the next decades. There can be expected only that some stages will be substituted, for example there will be used scramjet engines instead of second stage rockets, or carrier airplanes or magnetic acceleration rails instead of first stage rockets. In these systems the propellant, the engine and the given stage of the flight (initial phase, first stage rocket; accelerating phase, second stage rocket; third phase/reaching LEO, third stage rocket) are strongly attached. This means that the whole system in the very first moment of the launch contains usually at least three different rocket engines, usually they using different kind of fuel and oxidizer. Such systems are unnecessarily complex and carrying three engines is a great luxury from the point of view of efficacy. Using such integrated propellant systems there can be realized the single staged spaceships, which can revolutionize the transport between the surface and LEO.

Application

There can be many kind of applications. The main is a single stage from surface to LEO transport system. But there can be mentioned many other uses. Here must be emphasized the modularity of this system. It is possible to use only the ramjet-scramjet, or ramjet-scramjet-rocket combinations, which can revolutionarize the aircraft launched long range guided weapons. It makes also possible that existing high speed aircrafts (for example Mig-31, Su-27 etc.) can launch (at high altitude and at high speed) such projectiles, which contains small satellites, which can be driven on this way on LEO. This would radically decrease the costs of using small satellites, which is the most dynamically improving (economically) section of space industry.

Another interesting opportunity is using only the jet-ramjet combination. For example, using an existing Mig-25 plane, improve its heat resistance (using chrome-cobalt-molybdenum alloys instead of steel) and improving its air inlets similarly to that of the Mig-29. In case of the Mig-29 the main inlets can be closed and there exist fish gill like secondary inlets on the top of the body of the plane. Making a similar structure to the Mig-25, the jet engine can be closed at about 2.6-2.8 Mach, the gill like inlets can provide the necessary airflow for cooling the jet, and the closed main inlet can act as the nosecone of the ramjet. In this case the nosecone pressurized airflow can be directly driven into the afterburner section and the afterburner would act in this case as the ramjet combustion chamber. On this way, there is possible to create a new version of Mig-25, which can reach Mach 4-5 cruising speed at high altitudes (well above 30 km height).

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