Hypersonic Flight

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ABSTRACT

The main areas of focus within hypersonic flight were hypersonic propulsion and re-entry vehicles. Findings of the study states, self sustained hypersonic flight need an advanced engine that can function through all Mach regimes. Aerodynamic design of re-entry vehicles require a different approach compared to atmospheric hypersonic flight.

1 Introduction

The first man-made object to fly hypersonic, Mach greater than 5, was the WAC Corporal in 1949, a rocket developed in the United States. It was part of a multi-stage rocket, made to achieve high velocities and altitudes. The WAC Corporal was ignited when the first stage, a V-2 from Germany, had achieved a velocity and an altitude of 1500 $[m/s]$ and 161 $[km]$ [1].

Russia sent the first human flying hypersonic early 1961. The Russian made Vostok I, a spacecraft, achieved Mach 25 during re-entry into the atmosphere. The United States sent a human flying hypersonic, late 1961 in X-15, a rocket powered aircraft that achieved Mach 5. The first aircraft to exceed 1609 $[km/s]$ (one mile per second). In 2004 the first sustainable hypersonic flight was made by the Americans with the X-43, a flight that verified predictions based on wind-tunnel experiments as well as data from CFD. The X-43 was a multi-stage aircraft that, after releasing it's booster rocket, reached Mach 10 with a scramjet engine [1].

One clear difference between hypersonic and subsonic, supersonic aircraft are the integration of components. For regular aircraft, that is subsonic and supersonic, the different parts that they consist of are distinct and easily identifiable. For a modern hypersonic aircraft all the main parts are integrated in each other, ending up in what seems to be a flying wing [1]. The hypersonic technology vehicle as seen in Fig. 1 clearly shows the resemblance of a flying wing.

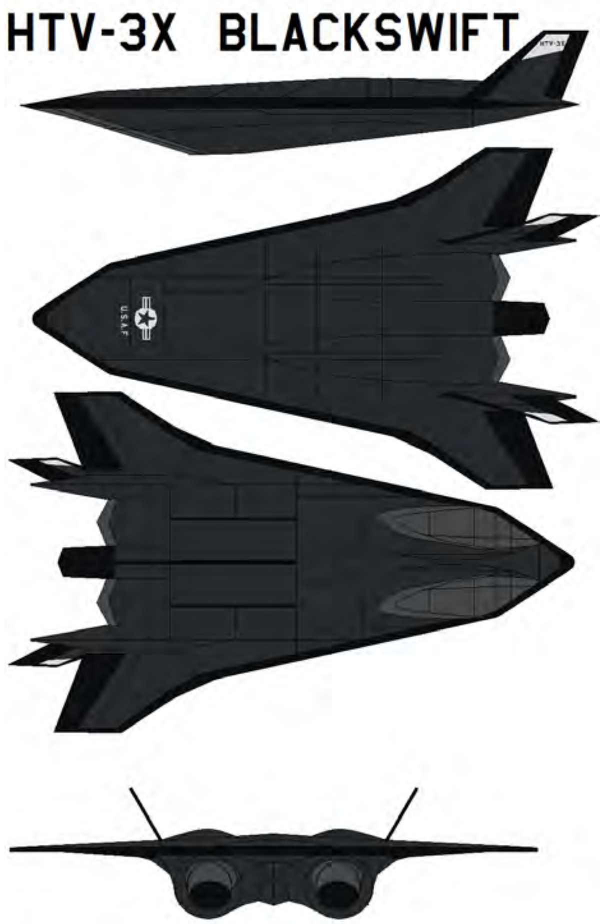

Fig. 1 Lockheed HTV-3X Blackswift, available at [2] under the Creative Commons Attribution 3.0.

2 Hypersonic Propulsion

Scramjets (Supersonic Combustion Ramjet) are used to fly hypersonic through the atmosphere where combustion occurs at supersonic velocities. A scramjet uses the speed of the aircraft to compress the air before combustion of the fuel to give the desire thrust. The only downside to scramjet propulsion is the requirement of assisted take off to initially accelerate the aircraft to hypersonic velocities [3].

Fig. 2 shows the different power plants used by aircraft in different Mach regimes, (a) represents a typical turbo jet engine where the Mach number is subsonic throughout, (b) represents a ramjet engine where the flow speed is reduced to subsonic before combustion and (c) represents a scramjet engine where the flow is supersonic throughout the engine.

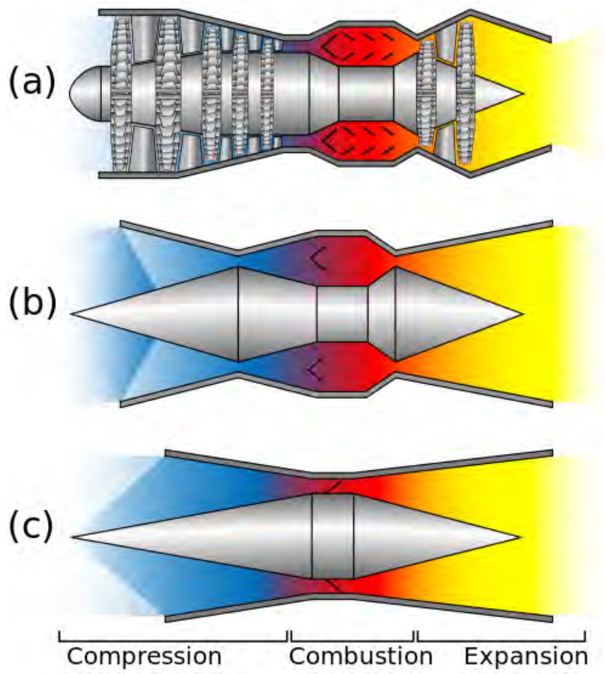

Fig. 2 Various power plants used in different Mach regimes. a) Turbo Jet Engine b) Ramjet Engine c) Scramjet Engine, available at [4] under the Creative Commons Attribution 3.0.

3 Re-entry Vehicles

Hypersonic flight is also applicable to re-entry vehicles, a typical Mach number for re-entry vehicles entering the atmosphere is around 25. At such high velocities aerothermal heating is a significant problem. The air friction accompanied by radiative heat from the shock layers accumulate an enormous amount of heat on the body. In order to manage and dissipate the heat evenly, these bodies are designed with large curvatures rather than sharp edges [5].

Sharp nosed bodies produce less drag and reduce the risk of a normal shock wave in front of the body. Fighter jets and missiles in the supersonic and low hypersonic Mach regime, as in Fig. 1, optimize their designs based on the fact that sharp nosed bodies produce less drag. Applying this design principle to bodies in hypersonic Mach regime has proven to be difficult. The oblique shock waves generated by the sharp edges will generate an immense amount of heat. This heat will be concentrated locally on the edge, eventually melting it. Because of the heat concentrations, heat dissipation is quite often more critical than drag reduction when designing for hypersonic speed. Bodies designed for high hypersonic speeds are thus designed with large round bluff noses in front, as seen in Fig. 3. The blunt nose body will cause a bow shock and increased drag but it will still be more optimized in heat management [5].

Decelerating the module is a also a critical aspect to consider while planning the trajectory. Conventional methods of deceleration using drag devices such as parachutes will fail to work in the hypersonic regime since the air density will be very low at high altitudes. Furthermore, the heat generated will burn the tether line connecting the drag device to the re-entry vehicle [6].

Current methods of hypersonic deceleration in re-entry vehicles involve using the geometry of the module itself. Atmospheric re-entry modules are typically axisymmetric bluff bodies. These bluff bodies will generate drag as well as significant lift when trimmed at an angle of attack. Achieving this aerodynamic lift component for axisymmetric bodies can be achieved by shifting the lateral position of the Centre of Gravity. This will enable the module to trim at the required angle of attack and attain better aerodynamic efficiency (L/D). The lift component will also reduce the loads acting on the astronauts inside the module [7].

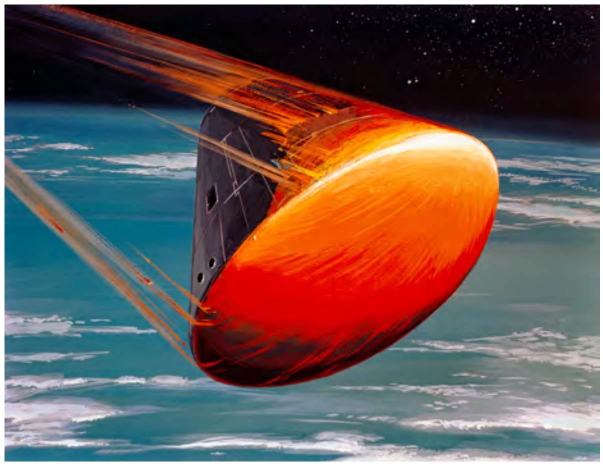

Fig. 3 A blunt nosed re-entry module entering the atmosphere illustrating the temperature difference along the surface [8].

4 Conclusion

Hypersonic flight is limited due to the available engine technology and materials. To fly hypersonic today, aircraft needs at least a two stage propulsion system to be able to reach and maintain sustained flight in the hypersonic Mach regime. Development of engines that can operate across all Mach regimes will pave the way for hypersonic atmospheric flights in the future.

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