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A NUMERICAL INVESTIGATION OF SCRAMJET ENGINE AIR INTAKES FOR THE 14-X HYPERSONIC VEHICLE

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This work is part of the research and development, at the Institute for Advanced Studies (IEAv), of the first Brazilian hypersonic vehicle prototype, the 14-X airplane. It presents CFD results and performance calculations of the air intake section of some scramjet engine configurations under several operating conditions assuming 2D planar geometry (Fig. 1).

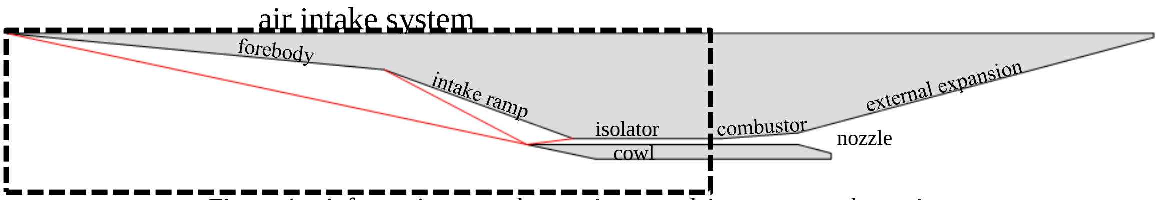

Figure 1 - A frame-integrated scramjet propulsion system schematic.

The reference case considers the vehicle flying at Mach 7 and zero angle of attack at an altitude of 30 km. In this case, air compression is achieved by two ramps, one of which is the vehicle forebody itself and the other is a scramjet inlet compression ramp, and the engine cowl which satisfies the "shock-on-lip" condition. From this reference case, several other cases were simulated varying vehicle operating conditions such as altitude, velocity and angle of attack. Besides these, calculations were made for different configurations of the scramjet inlet compression geometry by varying the inlet compression ramp angle, as well as the number of inlet compression ramps. The airflow in the intake is calculated numerically with the commercial Ansys Fluent software, considering the air as a calorically perfect gas for inviscid flow. For the intake performance analysis, several parameters characterizing the intakes have been calculated and compared as shown in Tab. 1 for the variation in flight parameters.

Table 1 – Performance parameters and airflow properties at the isolator exit when varying flight operating conditions.

	Case 1 (M=7)	Case 2 (M=8)	Case 3 (M=6)	Case 4 (AoA +4)	Case 5 (AoA -4)	Case 6 (H=35 km)	Case 7 (H=25 km)
Total pressure recovery	0.358	0.221	0.404	0.312	0.285	0.358	0.358
Kinetic energy efficiency	0.965	0.956	0.959	0.960	0.955	0.965	0.965
Air capture ratio	1.000	1.000	0.841	0.923	0.971	1.000	1.000

Static pressure ratio	74.19	91.04	60.86	114.57	43.95	74.19	74.18
Static temperature ratio	4.580	5.655	4.177	5.388	4.230	4.580	4.579
Mass flow (kg/s.m)	7.56	8.64	5.45	9.23	5.00	16.63	3.53
Mach number	2.60	2.70	2.19	2.24	2.79	2.60	2.60
Velocity [m/s]	1681	1922	1352	1568	1727	1662	1721
Pressure [kPa]	86.9	106.7	71.3	134.3	51.5	189.1	41.6
Temperature [K]	1038	1282	947	1221	959	1015	1089

At this stage of the numerical studies, the model was based on the assumptions of 2D geometry, calorically perfect gas and inviscid airflow, which is still capable of providing relevant information on the intake system compression capability and on the losses related to the non-isentropic process that exists in this region. The analysis showed how off-design operation, such as Mach number and angle of attack, modifies the flow structure and affects mass capture and airflow condition entering the combustor. Also, the two inlet compression ramp geometry yielded basically the same mass capture and compression capability as the reference geometry with even higher efficiency, so this geometry should also be considered for future analysis.

Although the present modeling is useful for providing a first insight on the intake performance, some phenomena which might alter significantly the airflow in the intake from the one calculated with this modeling, can only be studied with more realistic models which consider, for instance, viscous flow, non-adiabatic walls, 3D geometry, high temperature effects, and so on. Therefore, future works on the air intake of the scramjet propulsion system for the 14-X vehicle should certainly consider such models.

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