

THERMAL ANALYSIS OF VSB-30 ROCKET PAYLOAD

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Abstract. Space vehicle payloads are subjected to diverse heat sources during the flight, which can lead its temperature to surpass the limit of operation. During the mission planning, a previous analysis of temperature evolution of the payload shall be performed in order to assure that the systems will operate under the limit. In this paper, the transient thermal analysis of the payload of VSB-30 sounding rocket is presented. The computational simulation via a FEM software provides the local temperature evolution of the payload, allowing to determine the maximum temperature points, and to propose solution to reduce temperature peaks where it surpasses the limit.

Keywords: FEM, Thermal analysis, Rocket payload.

1. Introduction

Sounding rockets are extensively used to provide microgravity environments for scientific experiments. The Institute of Aeronautics and Space (IAE) of Brazil has designed, built and launched hundreds of rockets along the past 40 years. In order to assure to proper working of the electronic systems and experiments on board, the prescribed temperature limit for the internal environment of the payload must be respected. Such limit is commonly assumed as 60° C.

In this paper the thermal analysis of the payload of VSB-30 sounding rocket in a typical mission is performed. VSB-30 is a two-stage unguided solid propellant rocket used by the Brazilian Space Agency (AEB) and by the European Space Agency (ESA) (Machado and Pessoa Filho, 2007). Figure 1 shows a schematic representation of VSB-30. It has a total length of 13m and a diameter of 0.6 m. It is equipped with two solid propellant motors, namely S31 and S30. S31 acts as a booster during its 15s burning time, whereas S30 burns for about 30s, reaching an apogee of 250 km, for a payload mass of 400 kg. VSB-30 structure is built with composite material (nose top) and aluminum (the rest of payload). The objective is to assure that the payload will operate under the temperature limits during the flight.

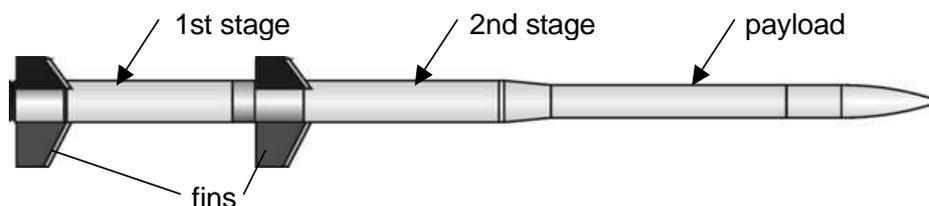


Figure 1: VSB-30 sounding rocket.

2. METHODOLOGY

A 3-D payload model was built and applied to simulate the heat exchange during flight via ABAQUS software (Simulia 2013), a commercial FEM package, which included transmitters, batteries and all other electronic devices onboard that generate heat from electric power dissipation, according Figure 2. A hexahedric mesh was generated with 10,982 nodes and 6,620 elements, Fig. 2. Two layers were used for the modulus wall.

Although the temperature limit for the internal environment is 60° C, the temperature limit for operation of the electronic devices was considered 85° C, according to the datasheets of these elements (Machado, 2013). As seen on Figure 3, the batteries, transmitter and other electronic devices are given by numbers, which the characteristics of every element were shown in Table 1.

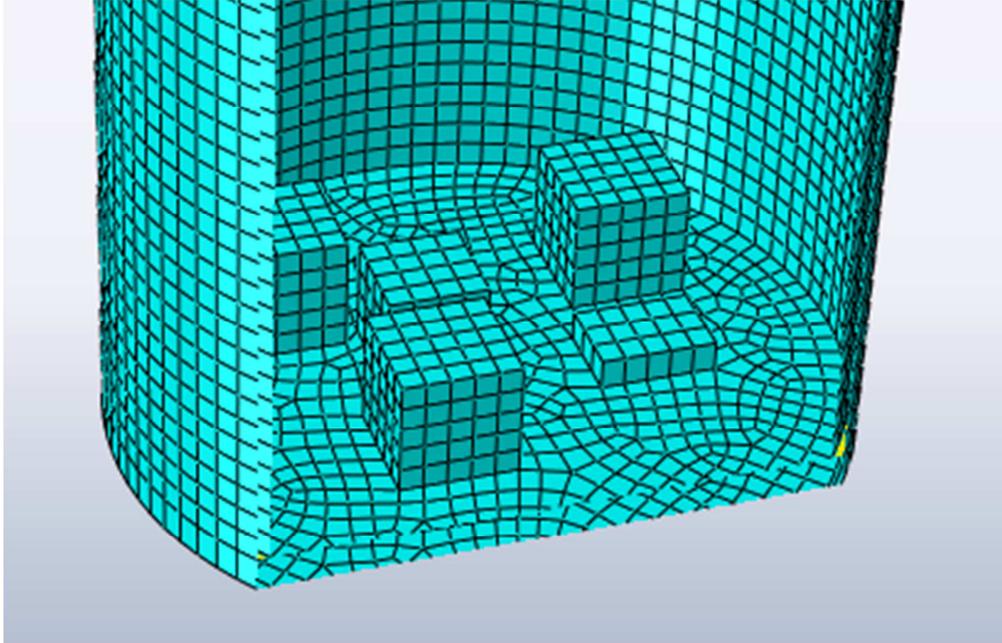


Figure 2: FEM mesh used for discretization.

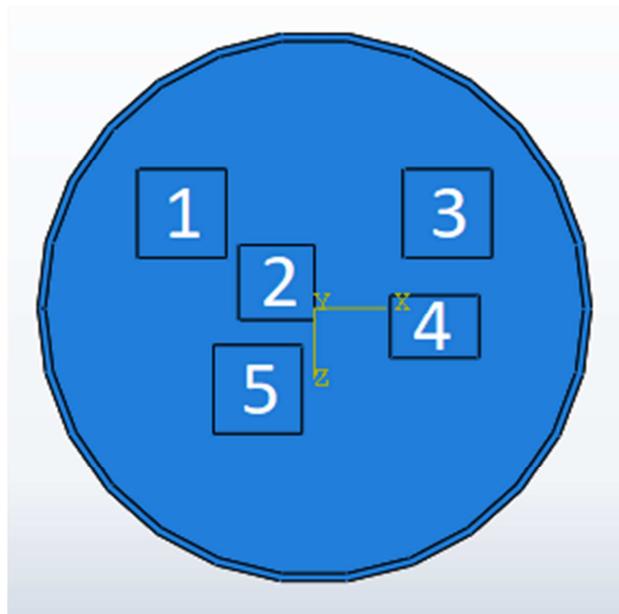


Figure 3: Heat sources placement in the payload transversal section.

Table 1: Characteristics of elements.

Number	Name	Mass	Power dissipation
1	Battery	0.2 Kg	11 W
2	MCE	0.9 Kg	46 W
3	Battery	0.9 Kg	11 W
4	Transmitter	0.585 Kg	46 W
5	PCM	0.585 Kg	46 W

The aerodynamic warming was also accounted as an external boundary condition for the payload wall (Machado, 2008). The trajectory used to estimate the warming parameters is shown in Fig. 4 (Machado 2008). The possibility of longitudinal and radial spinning of the payload during the reentry was considered (Machado, 2012). The resulting heat convection coefficient and recovery temperature at the stagnation points are shown in Fig. 5. The average of those parameters was applied to the external payload wall.

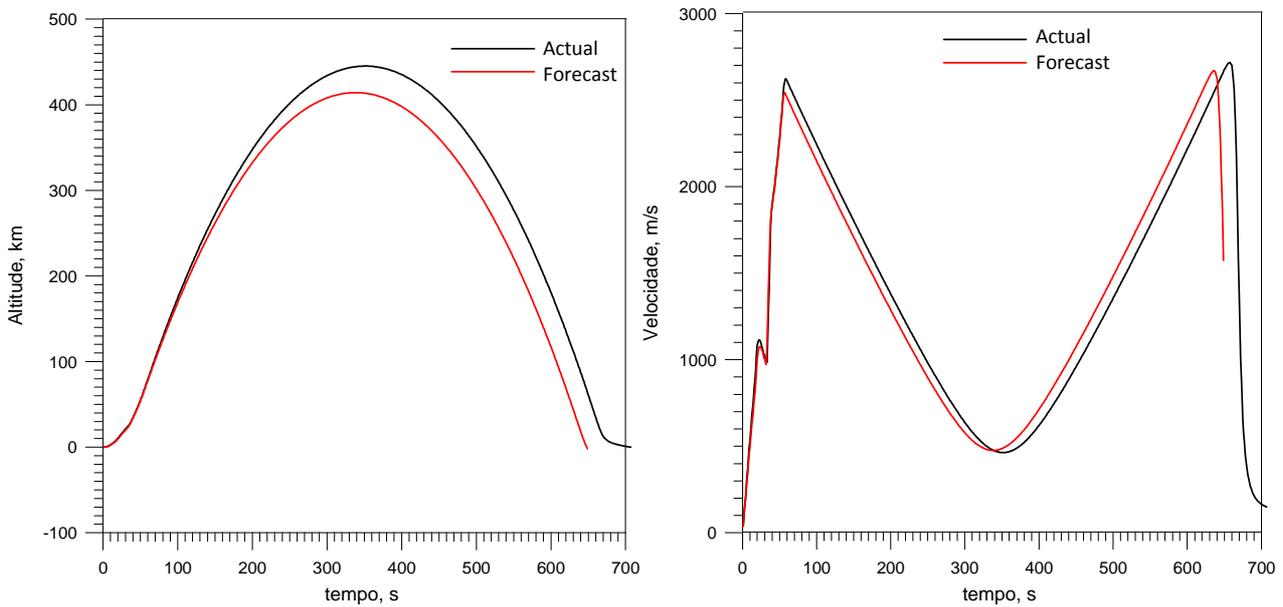


Figure 4. Trajectory of VSB-30 – altitude and velocity maps.

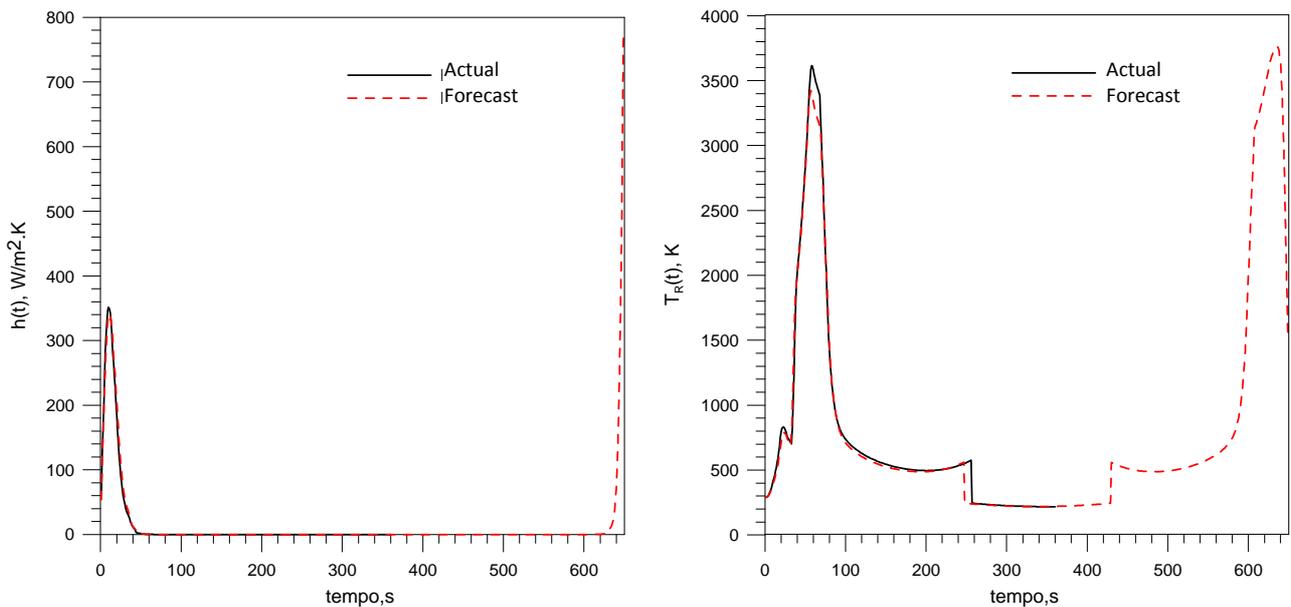


Figure 5. Recovery temperature and convective heat transfer coefficient at stagnation point, during VSB-30 trajectory.

Natural convection was considered in the internal environment, with a temperature of 300 K and a heat transfer coefficient of $6 \text{ W/m}^2\text{K}$. The power dissipation was converted in volumetric body heat fluxes for all elements.

3. RESULTS

The simulation was performed to accomplish the total flight period, and the temperature distribution was extracted for the whole payload, Fig. 6. Two cases were simulated: case 1- a perfect contact between the transmitter and basis; case 2- addition of an aluminium structure with 2.6 cm thickness between the basis and the transmitter. The temperature evolution with the time for the transmitter is showed in the Figs 7.a,b for cases 1 and 2, respectively.

At the final instant, after 720 seconds of flight, the result showed maximum temperatures of $92,3^\circ \text{ C}$ $80,3^\circ \text{ C}$ for cases 1 and 2, respectively. In case 1, the operation limit was surpassed for the transmitter, which means that the device should present malfunctioning during the mission. In the case 2, the addition of the aluminium structure works as a heat sink, reducing the final temperature in more the 12° C and assuring that the transmitter will operate under the temperature limit.

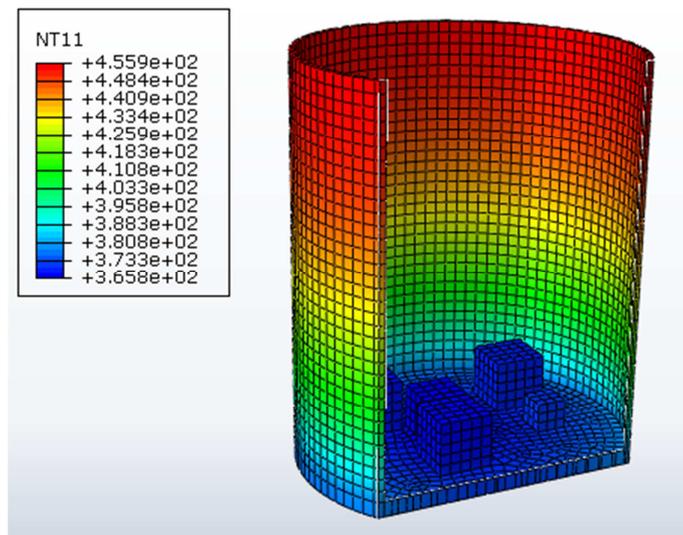


Figure 6: Temperature distribution in the payload at $t = 720$ seconds.

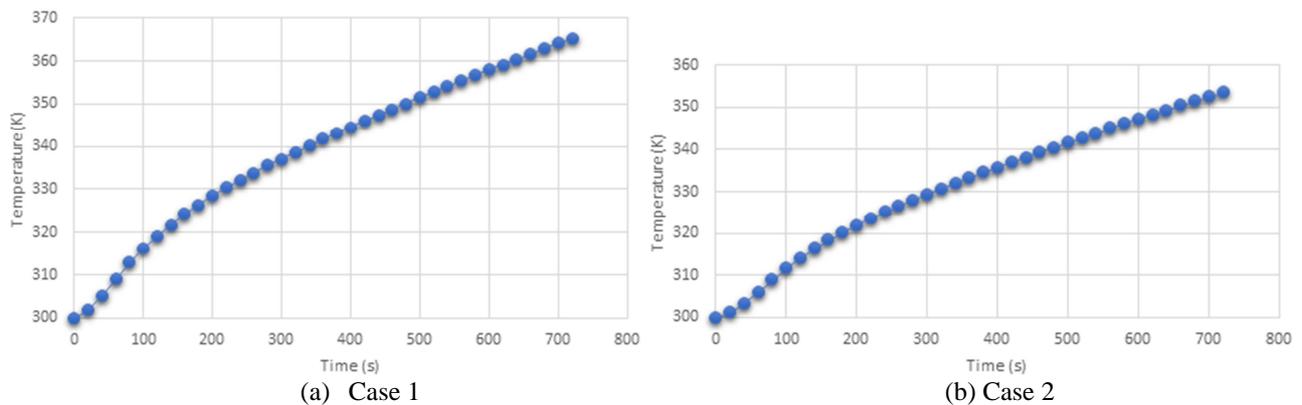


Figure 7: Temperature evolution of the transmitter with the time.

4. CONCLUSION

In this work the thermal analysis of the VSB-30 payload was performed through the FEM method, employing the ABAQUS software. This way of analysis, which is unusual for this kind of problem, was considered useful to determine the individual thermal behavior of the payload elements. Preliminary results showed that without the use of any kind of heat sink, the maximum temperature will surpasses the limit of operation.

Although the use of heat sinks represents a reliable solution for this kind of problem, it should be pointed out that the addition of any mass in the payload implies rising weight and modifies the dynamic characteristics of the whole vehicle, including effects over the trajectory.

5. ACKNOWLEDGEMENTS

This work was supported by CNPq, under the PIBIC program of undergraduate fellowships.

6. REFERENCES

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