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Assessment on Reusability of Space Shuttle External Tank

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Abstract—**The main aim of this paper is to introduce the concept of reusing the external tank of a space shuttle. This is achieved by using a Thermal Protection System (TPS) in conjunction with a High Temperature Heat Shield (HTHS).**

This paper reviews the design and development performed so far during the last few years along with further applications for future space missions.

Index Terms—**External Tank, Space Shuttle, Thermal Protection, High Temperature Heat Shield.**

I. Introduction

One of the most important and the only non-reusable part of a space shuttle is its External Tank (ET). There is a need to recreate the ET for every new space mission. This is primarily because of the fact that the ET cannot withstand the high temperature during re-entry and hence it breaks up and disintegrates over a remote ocean. Making the ET reusable has definitive economic benefits.

Here the authors are introducing the use of a TPS using a combination of aerogels and HTHS. The idea is to concentrate the weight on the nose end of ET, by strategically placing a retractable HTHS. Soon after the jettisoning of ET from main shuttle, the heat shield is extended thereby preserving the rest of the body, which is coated with aerogels.

II. Review on Current Developments

The major improvements that have been made to the ET are at the forward bipod fitting area, liquid hydrogen tank to intertank flange area and the liquid oxygen feed line bellows. These are discussed below [1].

A. Forward Bipod

The new bipod design eliminates the insulating foam ramps of the original design in favor of electric heaters. In the original design the ramps help to prevent the ice buildup. Now the new bipod redesign will allow the tank to fly with the fittings exposed without the insulating foam ramps. The redesign also adds four rod heaters placed below each fittings in a new copper plate to prevent the formation of ice while the shuttle sits on the launch pad loaded with the cryogenic fuel [1].

B. Liquid Hydrogen Tank/Intertank Flange

The inter tank is the ripped cylinder structure that joins the liquid hydrogen and oxygen tanks. The flanges at both the ends are insulated with foam. But there was a development of voids or spaces while these foams are sprayed. To reduce the number of voids, and enhance closeout, or finishing, procedure has been implemented that includes improved foam application to the stringer area of inter tank ribbing and to the upper and lower area of the flange [1].

C. Liquid Oxygen Feedline Bellows

Normally the feedlines are insulated with foam but since they must allow for movement they are not insulated. So the lack of insulation on the bellow means the moisture can turn to ice as the surface is cold because of the cryogenic liquid oxygen. So to prevent ice from forming the bellows thermal protection system is being reshaped to include a drip-lip that allows condensate moisture to runoff [1].

III. Surface Protected Flexible Insulation

Surface protected flexible insulation (SPFI) is aimed to protect vehicles against high heat fluxes against earth atmosphere reentry. The SPFI was developed by DaimlerChrysler Aerospace AG [2], to extend the application of fibrous insulation material to the windward side of the reentry body.

To make the fibrous insulation applicable to the windward surface of the reentry vehicle, aerodynamic smoothness of the surface combined with certain pressure tightness has to be provided to avoid hot gas penetration. In the case of SPFI, this is achieved by a thin sheet of ceramic material (Ceramic Matrix Composite) attached to the outer surface of the insulation [2].

The SPFI is aimed to be:

1) Light weight.
2) Low cost.
3) Simple to assemble.
4) Easy to integrate and maintain.

The SPFI has undergone several tests that are very important for any reentry vehicles, like the thermal shock cycle test, plasma erosion/catalicity test, arcjet reentry test, structural test etc. and have been proved to be successful [2].

The thermal design of the SPFI has been proved that it can withstand a temperature of around 1200 - 1400 ^{0}C. Also there is a coating system that is developed based on the ceramic

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components which exhibits high emissivity throughout the temperature range, excellent adhesion to the ceramic cover, and extremely low catalycity [2].

IV. Reusability of ET Using SPFI

The external tank gets detached from the orbiter shortly after the main engine cutoff just before orbital velocity is reached. Upon re-entry it burns up and disintegrates over a remote ocean. Using an HTHS made from SPFI may prevent this. The authors suggest the use of this heat shield as shown in Fig. 1. The proposed design acts as a blunt body, by having a high angle of attack. Therefore a hot shockwave is created in front of the ET, which deflects most of the heat and prevents the ET surface from directly contacting the peak heat. Therefore re-entry heating is largely convective between the shockwave and the shield's skin through superheated plasma [3].

Additional aerogel coating may be employed to protect rest of the body, owing to its lightweight and low thermal conductivity. Silica aerogels has the capacity to withstand a temperature up to 1200 ^{0}C [4] and hence a good candidate for this purpose.

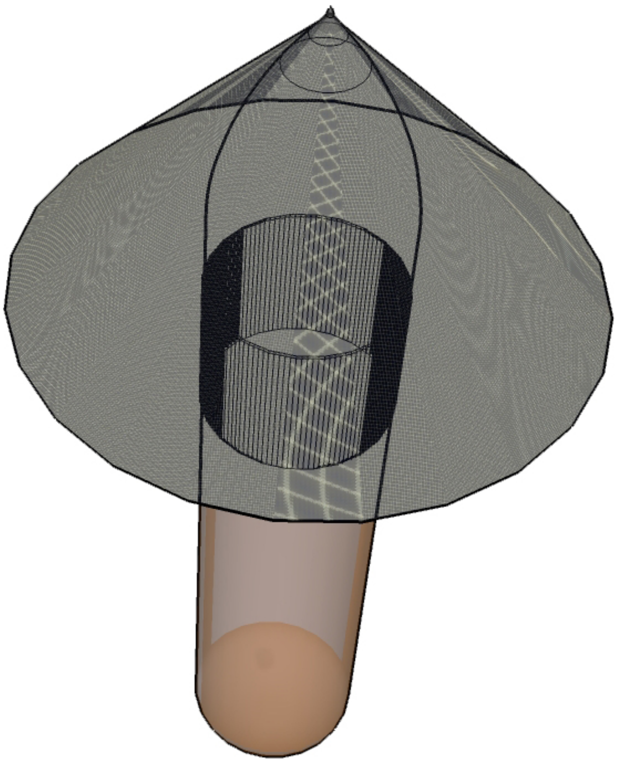

Figure 1: The proposed HTHS design for the ET

V. HTHS Design

Soon after the separation, we may orient the ET, in a similar fashion to the space shuttle re-entry. This can be achieved by proper guidance using the technology based on the OMS (Orbital Maneuvering System). As we are having a near vertical fall with nose pointing down, we can have a conical retractable heat shield as shown in Fig. 2.

Figure 2: ET with the extended HTHS during re-entry

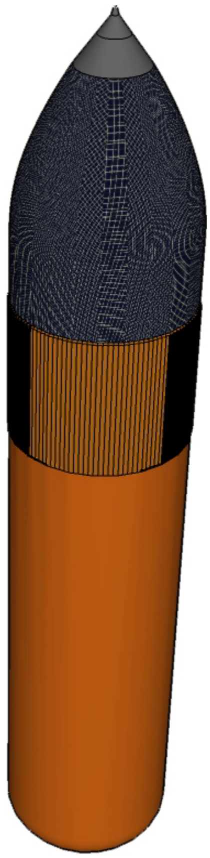

Figure 3: ET with HTHS retracted

VI. Conclusion

An idea to re-use the external tank is presented. As the shuttle program gets to its final phase, and with the development of Ares launch vehicles, the same principle could be applied to this class of launch vehicles.

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