A CRITICAL REVIEW ON THERMAL PROTECTION SYSTEM IN AEROSPACE SHUTTLE

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ABSTRACT

This paper is focused on thermal protection material and its application .The Space Shuttle design presented many thermal insulation challenges. Space vehicles that enter a planetary atmosphere like the Space Shuttle Orbiter require the use of a thermal protection system (TPS) to protect them from intense aerodynamic heating. The aerodynamic heating is generated at the surface of an entering object due to the combination of compression and surface friction of the atmospheric gas. The thermal protection systems used on the Space Shuttles are reinforced carbon/carbon (RCC) at the nose and wing leading edges, high and low temperature reusable surface insulation (HRSI, LRSI)used.

Keywords: Airbrething, Tps (Thermal Protection System), Obiter, Rcc, Space Shuttle

I. INTRODUCTION

The development of thermal protection systems (TPS) for winged flight vehicles originated with the breaking of the sound barrier in 1947 by the Bell X-1 vehicle [1]. Since then, research in hypersonic vehicles has progressed at a rapid pace, from the X-2 supersonic research aircraft flying at a maximum speed of Mach 3.2, to the Apollo capsule at Mach 36, and the Space Shuttle at Mach 27. During this time, it became evident that TPS is a critical component of any hypersonic vehicle and it is often one of the limiting technologies in Severe aerodynamic heating during high-speed flight induces elevated temperatures in the vehicle that adversely affect the structural components by degrading the material properties. This also induces time-dependent changes in material properties, including potentially complex effects such as creep and chemical reactions. The increase in temperatures also induces thermal stresses and strains, which influences the buckling and aero thermo elastic behaviors. Thus, it is critical to maintain the temperatures of the load bearing structural components of hypersonic vehicles within operational limits to avoid catastrophic failure – this is role of TPS hypersonic vehicles design.[2]

II. WHAT IS THERMAL PROTECTION MATERIAL

All the orbiters were covered in TPS materials which protected the shuttles from the heat of re entry and also cold temperature experienced when in space , a temperature range of -121 to -1649°C. There is a complicated array of materials which comprise the TPS to help keep the astronauts and payload safe during flights.

The nose cap aera between the nose cap and the nose landing gear door arrow head of the nose landing gear door and the outer edges of the wings are produced from a reinforced carbon-carbon (RCC) composite. The tiles used were based on work carried out by the lock head missiles and space company who had a patent disclosure which described a reusable insulating tile made from ceramic fibers which could be used during re – entry as a guard against high temperatures. A reusable insulation system that could be directly bounded to a light weight aluminium airframe was very attractive to NASA and so the focus of the generation of the TPS was diverted towards using tiles.The large portion of TPS is comprised of high temperature reusable surface insulation low temperature reusable surface insulation.

The main difference between high reusable surface temperature and low reusable surface temperature is the surface coating used on them.[3]

III. DIFFERENT SOURCES OF HEAT AND TPS

Aerospace engineers face different types of thermal protection challenges as they design spacecraft. One type occurs when a spacecraft moves through the atmosphere at extreme speeds, during both launch and re-entry to the atmosphere. Without proper thermal protection, atmospheric friction generates enough heat to damage or, during re-entry, even destroy a spacecraft.

A different type of challenge occurs in the vicinity of the engines during launch. Here, the fuel lines, electronic components, and structural elements in the base of the vehicle near the engines can be damaged or destroyed by the extreme heat in the exhaust plume of the engine. As the vehicle speeds through the atmosphere, plume to plume interactions or plume/free stream air interactions create high pressures that recirculate some of the hot plume gases forward toward the base. These hot gases are prohibited from entering the engine compartment by a heat shield across the base. This heat shield is a type of thermal protection system. In addition, a tremendous amount of heat from the plume of combustion gases is radiated back toward the area of the engines. This problem is particularly severe with solid rocket boosters, because those plumes are filled with hot particles that increase the amount of radiated heat.

IV. DIFFERENT LAYER IN THERMAL PROTECTION SYSTEM

The Corrugated sandwich MTPS used for the present study consists of: (i) top face sheet, (ii) bottom face sandwich, (iii) truss-core and (iv) thermal insulation. Metallic sheets are used for the first three items. Ceramic insulation in the form of fibers is filled inside the truss core space and the sandwich core to block the heat flow from top to bottom face sheet as shown in the figure(1) the MTPS is of one storied construction. The main design constraint of MTPS is back wall temperature of Sandwich structure should be less than 375K for all re-entry space vehicles at a required duration of 1000s of the flight during the re-entry phase and this can be achieved by filling “SAFFIL” like insulation material inside the truss core.

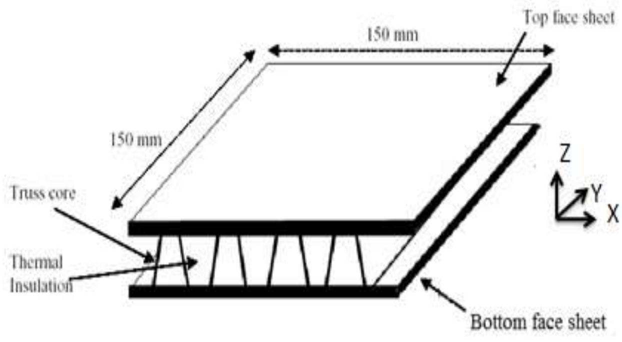

Fig.1 Geometry of MTPS

The structure is symmetric with respect to vertical plane (Z-plane).So one unit cell of 37.5 x 37.5 x 20 mm is considered to obtain the thermal field data. The one unit cell of corrugated sandwich MTPS is shown in Figure (2).

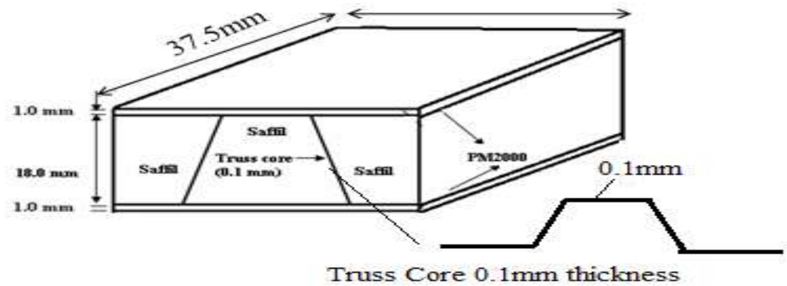

Fig.2 Unit cell of MTPS

The panel is constructed of three materials (i) PM2000 for top face sheet (1.0 mm thick), truss Core (0.1mm thick) and bottom face of top sandwich (1.0mm thick). This model is made by fixing corrugated web to the top and bottom face sheet by the process of brazing.

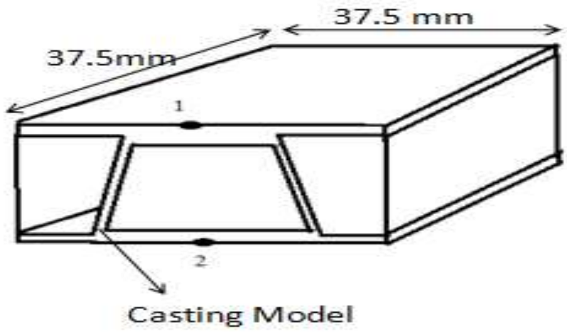

Fig.3 Casting Model

The figure (3) shows a casting model. In this model the web portion is made by casting with TFS and BFS as single volume. In casting model Back wall temperature is very high. [4]

V. HOW THERMAL PROTECTION SYSTEM WORK

The launch cost for the space shuttle increases by about $10,000 [5] for every pound of launch weight. So to keep space expedition economically viable in 21st century we need to decrease the cost of launching a space craft. One of the most expensive systems of a space vehicle is the Thermal Protection System (TPS), which protects the vehicle from the high thermal loads during re-entry; therefore it deserves some special attention. TPS are designed to protect the structure of atmospheric space vehicles from the extreme temperatures arising due during atmospheric re-entry [6].

To protect against the heat of friction, engineers use special insulating blankets, foams, and tiles on the skin of the spacecraft. The heat shield or thermal protection system (TPS), which protects against the heat from the engine exhaust plumes, is a more local system that is installed near the throat of the engine nozzles in the base of the vehicle.

Think of other heat protection "systems" you may have seen or used, such as a potholder, a thermal bottle, or a fireman's special coat. These are doing the same job as the TPS on a spacecraft. Some of these, such as the potholder, provide local protection, which just needs to protect your hand from the hot handle of a baking dish.

Others, such as a thermal bottle, protect the whole surface from absorbing heat or losing heat, depending on whether you have a cold drink or a hot drink in the bottle.

Different methods can be utilized to enable a TPS to keep heat from reach-ing the inside of the spacecraft. One method is to use a covering material that will absorb the heat and radiate it back into space, away from the spacecraft. All materials radiate heat when they get hot. You can feel this whenever you put your hand near something hot like a radiator, a hot stove, or the coals of a campfire. However, only certain materials can radiate heat so efficiently that the heat does not build up within the material and pass it into the spacecraft or possibly melt the body of the spacecraft.

Another way a TPS works is to let small bits of itself actually burn and fall away from the spacecraft. These materials neither absorb nor radiate much heat, so when the surface becomes very hot, the material starts to burn and erode. The term that describes this process of material being eroded by heat is ablation [7].

VI.TPS IN ROCKET-LAUNCH VEHICLES AND AIR BREATHING VEHICLES

6.1 Rocket Launch Vehicles

The Space Shuttle Orbiter, shown in Figure(4) , utilizes a conventional, skin-stringer aluminum aircraft structure. The structural temperatures are required to stay below 350°F for re-use purposes. To keep the temperatures down to 350°F, re-usable surface insulation tiles are used primarily on the windward surface, and reuseable blankets are used primarily on the leeward surface. For the leading edges and the nose cap, where temperatures are greater than 2,300°F, reinforced carbon/carbon (RCC) is used.

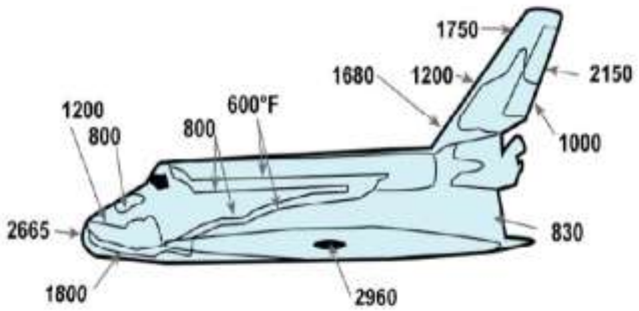

Fig.4 Nominal Maximum Temperatures on the Surface of the Space Shuttle Obiter

TPS for Air-Breathing Hypersonic Vehicles [8]

6.2 Air breathing Vehicles

For an air breathing vehicle, the aerothermodynamics, propulsion system, and airframe, including much of the TPS and hot structures, are highly integrated, as shown in Figure 15 where the entire under side of the vehicle is part of the propulsion system. This is very different from most rocket-based systems. The differences between rocket-based and air-breathing vehicles have significant impacts on the airframe structures.

The differences in rockets and air-breathers Figure (5) impacts how thermal management and TPS are handled. Rockets accelerate, but do not cruise, while in atmospheric flight, and are usually launched vertically [9].

Fig.5 Typical Rocket and Air-Breathing Vehicles

VI. CONCLUSION

Several types of Thermal Protection system materials were used on the orbiter. These materials included tiles, advanced flexible reusable surface insulation, reinforced carbon-carbon, and flexible reusable surface insulation. All of these materials used high-emissivity coatings to ensure the maximum rejection of incoming convective heat through radiative heat transfer. NASA faced a greater structural design challenge in the creation of numerous unique tiles. It was necessary to design thousands of these tiles that had compound curves, interfaced with thermal barriers.

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