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Exploration of Blunt Nose Cone with High Temperature Ceramic Composite TPS Materials

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Abstract:A new nose cone concept that promises a gain in performance over existingconventional nose cones is discussed in this paper the term nose cone is used to refer tothe forward most section of a rocket, guided missile or aircraft. The cone is shaped tooffer minimum aerodynamic resistance.In this study a natural nose cone with specific ultra-high Temperature (UHT) ceramic composite TPS materials like Hafnium diboride (HfB2) and zirconium diboride (ZrB2) is analyzed and when compared for its strong protection towards switch of warmness into the constitution. A naval model is designed for from the standards of blunt nose cone and analyzed with the commercial program. A normal quad 4 node aspects is adopted to participate in thermal evaluation in ANSYS program and the simulated outcomes are validated with numerical solutions. Present ablative materials like SLA-561V, SIRCA and AVCOAT are having the warmth flux levels up to an110W/cm^2 and temperatures ranging as much as 2000˚C and want of recent substances and its reliability are focused in this research.

Keywords-Thermal Protection System, Thermal stability, blunt nose cone, UHT ceramic Composite.

I. INTRODUCTION

Current warfare techniques include many technical advances. In the news, one regularly hears of "smart"bombs, satellite TV for PC communications, GPS (Global Positioning System), radar, and guided missiles. A guidedmissile is an unmanned explosive-wearing vehicle that movements above the earth's floor in a flight coursecontrolled by using an external or internal supply. There are many varieties of guided missiles, however, all have the equalremaining function: wreck enemy "objectives", i.e., personnel, tanks, motors, airplanes, ships, and guns,together with attacking missiles. In current utilization, a missile is a self-propelled precision-guided munitions' device, asopposed to an unguided self-propelled munition, referred to as a rocket (despite the fact that those too also can be guided).Missiles have four device additives: targeting and/or missile steerage, flight device, engine, and warhead.Future fighter aircrafts can have supersonic cruise and high attitude of assault and capability to maneuver within theflying route. New missiles ought to be evolved, that is greater maneuverable and have much less static margin thanthose are in use. A missile with much less aerodynamic resistance could be used. The nose manage, as the namesuggests, is realized by using angular deflection of a segment of or whole of missile's nose inside the drift area of themissile's centerline to create a stress difference between the windward and leeward aspects of the nostril. Thedesign of the nostril cone phase of the missile to journey over a compressible fluid medium and essential troubleis the determination of nose cone geometrical shape and cloth used to it for maximum overall performance. Suchobligations require the definition of the stable of revolution shape that reports minimal resistance to rapid movementvia any such fluid medium, which includes elastic particles. This difference produces aerodynamic manage forces and moments relative to missile's mass center to allow the missile to achieve a positive attitude of assault, it's farsuperior because of its better aerodynamic characteristics, shorter reaction time and extended effectiveness andmaneuverability. Moreover, the manipulate forces and moments produced by nostril deflection boom rapidly withMach number growing, which makes it a super method for controlling supersonic and hypersonic missiles. Anidea of transportable nostril and tail for actively steering aircraft, in particular, rocket-craft beneath exclusiveatmospheric and operating situations. In the current yr's space motors like rockets, reentry vehicles regardlesstheir unique designs needed manipulate surfaces at hypersonic speeds. Low-radius leading edges are difficulty toa great deal greater aerodynamic heating than blunt edges, consisting of those on the Space Shuttle, and that they therefore will attaintemperatures that could exceed 2000°C all through re-access.

Their total thickness is estimated on the base of the supposed heat fluxes and temperature which the vehicle has to withstand. Most ablative TPS materials are made of reinforced composites employing organic resins as binders. When heated, the resin pyrolysis producing gaseous products (mainly hydrocarbons) that percolate toward the heated surface and are then injected into the boundary layer.

II. LITERATURE SURVEY

UHTCs originated in the early 1960s. Some of the earliest and most thorough work to date was performed thenby the company ManLabs, under a research program funded by the Air Force Materials Laboratory (AFML)6-7 Workon UHTCs was initiated to meet the need for high temperature materials that would allow the development ofmaneuverable hypersonic flight vehicles. Since then, despite research progress, several significant challenges remainin the use of UHTCs, and these materials have yet to be widely implemented.

Bulk UHTCs are fabricated at temperatures ranging from 1900–2100 °C and pressures of 60–100 MPa by hotpressing in either resistance- or induction-heated furnaces, using graphite dies — in processes that have not changedmuch since the 1960s. High melting temperatures make consolidating pure samples by conventional hot pressingextremely difficult. Work by ManLabs found that additives could eliminate billet cracking and make dense, fine-grained microstructures achievable.6 In particular, adding SiC from 5–30 volume percent improved UHTCdensification and oxidation resistance.

During initial stage upward flight to the ionosphere, the speed of the missile is not great enough to pose anyserious thermal problems. However, at the altitude of 50 miles, the absolute pressure begins to increaseprogressively during descent, until the earth's surface is reached. At the present time, missiles reentering the airlayer during downward flight, attain speeds equal to Mach 5 or 3700 miles per hour, and in the near future,missiles are expected to be designed which will attain speeds as high as Mach 18, equivalent to approximately13,000 miles per hour. These heating rates being produced by the high temperature of the air boundary layerahead of the missile resulting from the compression of air, which temperature can be as high as 12,000 F. at11,000 Mph. It is seen, therefore, that a challenging problem in the design of intercontinental missiles is thetendency of the atmosphere to burn them up as they descend towards the earth. At the extreme speeds withwhich the missiles descend through the atmosphere, they suffer aerodynamic heating and abrading due to theextremely high skin temperatures developed in and by the air boundary layer immediately encompassing themissile, and this condition is increasingly critical and greatly aggravated at high Mach numbers as to constitutea serious thermal barrier. It is obvious that the missile must have a low drag-to weight ratio during its upwardflight through the atmosphere. Reentry into the its descent towards the earth, a high drag-to-weight ratio isrequired to reduce the speed of the missile and consequently its heating rate. However, the downward speed ofthe missile must not be reduced to the point where it can be intercepted. for that purpose blunt nose cone isuseful for hypersonic speeds .blunt cones are less drag resistance and produced less shock waves at high speedranges.

III. METHODOLOGY

The co-ordinates for the development of blunt cone profile is taken into consideration with respect to the tangency point and in which the basic size of the nose cone is given in key points as (11.55,0), (76,0), (76,37), (13.7833, 7.66), (10.95, 4.3), (76,38.5), (10.95,5.8), (9.75,4.3), (10.55,0). Base material for the nose cone is carbon epoxy and the TPS materials are Hafnium diboride (HfB2) and zirconium diboride (ZrB2) and their properties are as listed in Table: 1 [4] for performing the analysis. A layer of 1.5 mm is taken for the analysis purpose for each of the TPS material.

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Table: I Material properties

	Carbon epoxy composite	Hafnium diboride (HfB2)	Zirconium diboride (ZrB2)
E (N/mm^2)	1.81e5	0.75e5	4.2e5
1/m	0.36	0.37	0.34
ρ (kg/mm^3)	1.7e-6	10.5e-6	6.085e-6
α (°k^{-1})	2e-6	7.6E-6	8.3e-6
k (W/mm-K)	7e-3	62e-3	70e-3

The FEM model is generated from the key points as furnished in the problem description. In the context of the model theactual model follows the steps of operations like from points to lines, lines to areas and free meshing methodologiesavailable in the software. An axisymmetric model is chosen for the better approach to the solution as the time and datastorage can be promisingly minimized with such model. The end boundary conditions are chosen based on the realistic nosecone structure of hypersonic vehicle and later thermal analysis is performed.

IV. MATHEMATICAL MODELING

A simple mathematical model is adopted for the validation of the actual conditions of the composite structure for its thermal analysis from the fundamentals of FEM procedures. A cantilever beam with two materials is an acceptable model to satisfy the problem. The governing equation for this condition with an isotropic body with temperature-dependent heat transfer has the form of global equations for the domain can be assembled using connectivity information. Shape functions Ni are used for interpolation of temperature inside a finite element as per equation (1) is given by[6]

$$T(x) = N_1(x)T_1 + N_2(x)T_2 \ldots\ldots\ldots\ldots\ldots (1)$$

Where T(x) is the temperature at the required position, N1 and N2 are the shape functions which will be defined in terms of temperature, T1 and T2 are the temperatures at that locations. To simplify the above equation in mathematics, evaluate the shape functions as per equation (2) is given by

$$N_1 = 1 - \frac{x}{L} \text{ and } N_2 = 1 - \frac{x}{L} \ldots\ldots\ldots\ldots\ldots (2)$$

Where L is the length of the element and x is the distance from the reference point.

Finally the conduction and convection problem solution may also be able to be taken the form as,

$$[k^{(e)} = \frac{k_x A}{L}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} + \frac{hPL}{6}\begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \ldots\ldots (3)$$

The forcing function can be written as

$$\left\{f_h^{(e)}\right\} = hPT_a \begin{Bmatrix} \int_0^1 N_1 dx \\ \int_0^1 N_2 dx \end{Bmatrix} = \frac{hPT_a L}{2}\begin{Bmatrix} 1 \\ 1 \end{Bmatrix} \ldots.(4)$$

and finally the problem solution can takes the form

{k}{T}={f}……………… (5)

V. RESULTS AND DISCUSSIONS

A 2D model is analyzed for its steady state heat transfer analysis by using Newton Raphson model at Mach number 10 for hypersonic environment and the surface temperature is taken as 2478°k and boundary temperature of 298°k [3]. A total number of 1157 elements are taken for its final solution convergence.

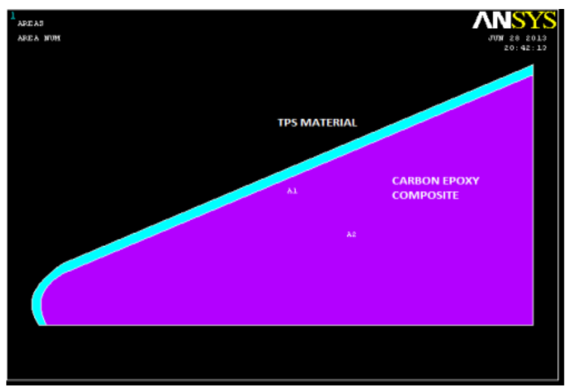

Fig. 1 A typical blunt nose cone 2D profile with TPS Layer

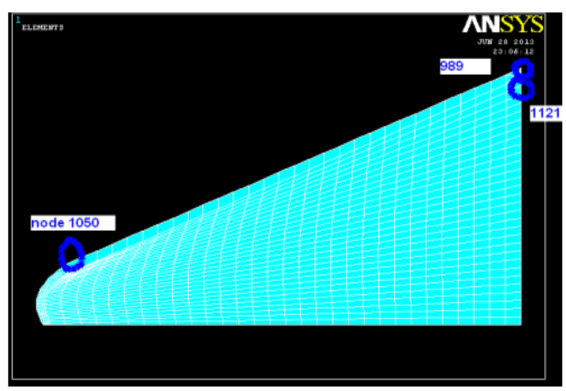

Fig. 2 Node 989,1050 & 1121 locations

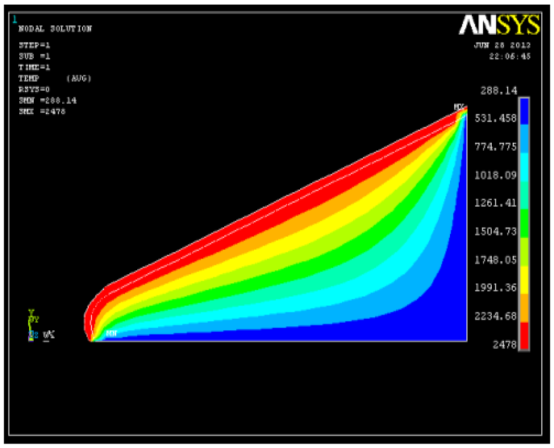

Fig. 3 Temperature distributions for HfB2 material

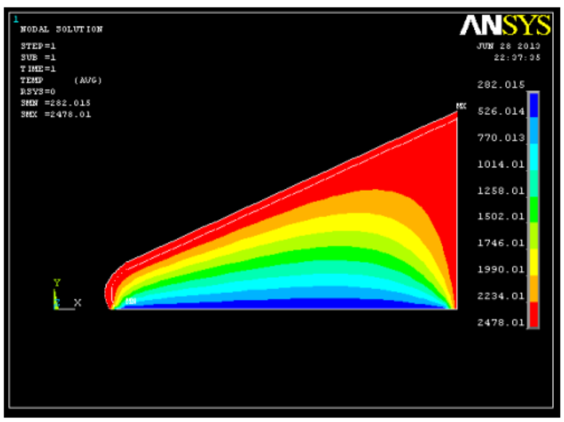

Fig. 4 Temperature distributions for ZrB2 material

Table II HfB2 material results

At Node numbers	Temperature in °K	Thermal gradient (°k/mm)	Thermal Flux (W/mm^2)
1050	2478	-10.755	0.627
1121	1196.36	-250.790	4.496
989	2411.58	-81.905	-2.141

Table III ZrB2 material results

At Node numbers	Temperature in °K	Thermal gradient (°k/mm)	Thermal Flux (W/mm^2)
1050	2478	-7.438	0.6258
1121	2478	-0.0021	-0.0018
989	2478	0.0055	-0.000315

The node numbers are chosen for mathematical solutions at 1050, 989 and 1121 at the radii of the nose cone 5mm, 37mm and 38.5 mm respectively and the solutions were compared.

At Node numbers	HfB2 material		ZrB2 material	
	Simulated results Temperature in °K	Mathematical solutions	Simulated results Temperature in °K	Mathematical solutions
1050	2478	2432.9	2478	2432.9
1121	1196.36	1208.1	2478	1208.1
989	2411.58	2398.89	2478	2398.89

Stress deformation

Stress: - The force acting across a unit area in a solidmaterial resisting the separation, compacting, orsliding that tends to be induced by external forces.

Strain: - Change in length of an object in somedirection per unit undistorted length in some direction,not necessarily the same; the nine possible strains forma second-rank tensor.

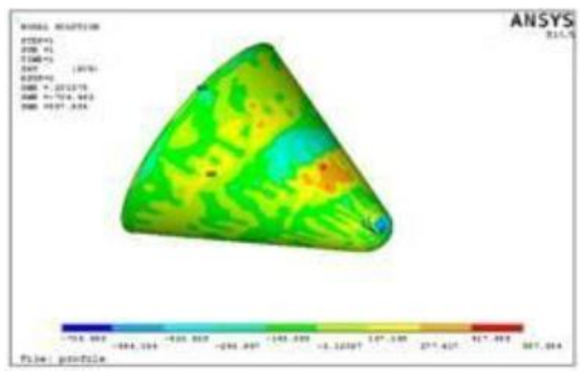

Fig. 5 Stress-X Direction with gravity

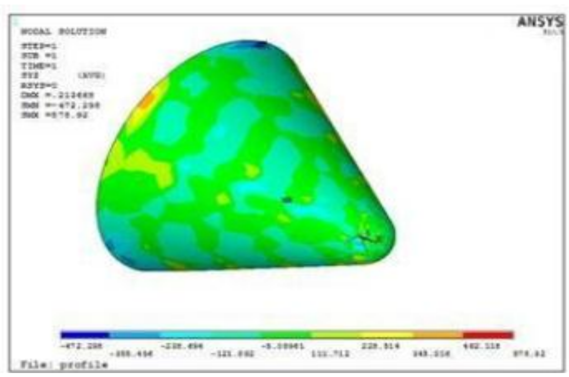

Fig. 6 Stress-X Direction without gravity

VI. CONCLUSION

Simulated options at more than a few nodes are validated with numerical options which can be particularly in excellent understanding and show the feasibility of the difficulty methodology.For the Hafnium diboride material the temperature distribution is from 2478°k to 2411.58°k and the distribution is natural showing the uniformity of the distribution over the entire nose cone. But for the Zirconium diboride material the temperature distribution just isn't identical and its 2478°k at the skin of the TPS layer and indicates the resistance of the material in transferring the temperature for the remaining of the nose cone. From the simulated results the Hafnium diboride material shows the simpler distribution pattern and its heat flux values are also in promising stages than Zirconium diboride material.This can be extra evaluated for the transient thermal evaluation which will have extra options for the outlined drawback.

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BIODATA:

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