PEAK OF FLIGHT
NEWSLETTER

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Making an Ablative Nose Cone for Supersonic flights

Cover Photo: *When Pigs Fly...* The Pigasus rocket kit at lift-off. Get your own at: www.ApogeeRockets.com/Rocket_Kits/Skill_Level_3_Kits/Pigasus

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Thermal Ablative Experiments for the Sugar Shot Nose Cone

By Vicente Alvero Zambrano

This report describes experimentation that was performed to test potential ablative materials ("ablator") for use as the tip of the Extreme Sugar Shot (ESS) nosecone. The ESS vehicle will reach hypersonic velocity while it traverses through the upper atmosphere on its way to Space. Aerodynamic heating of the nosecone tip will require it to be made of suitable heat-resistant material.

The goal of the Sugar Shot to Space rocket is to reach 62 miles with sugar propellant (see: sugarshot.org)

It has been calculated, that at an altitude of 13,000 meters the ESS rocket will have reached a speed of Mach 5, causing a temperature of stagnation on the tip of the nosecone of over 927 °C (1700 °F, over 4 times the oven temperature that we normally have in our homes.

At this is a frightening temperature, it is vitally important to have a thermal shield on the rocket nosecone.

Introduction

This report describes an experiment that was performed on various ablator to ascertain their effectiveness in providing thermal protection of rocket motor components. An "ablative material" is a polymer with inherently low thermal conductivity which slowly pyrolyzes (decomposes through heating to a high temperature) layer-by-layer when its surface is intensely heated, leaving a heat-resisting layer of charred material.

The intention of studying various materials was to come up with a simple, readily available and inexpensive ablative for use in amateur rocket motors. The immediate need is for an ablative that will serve to insulate a newly-designed nozzle and bulkhead, such that the temperature is kept sufficiently low to minimize heating of a composite motor casing under development. More so than metal casings, composites are susceptible to loss of strength and stiffness at elevated temperature.

Besides the aforementioned basic requirements, three specific requirements of a practical ablative are being sought:

- Provide effective protection against severe thermal loading. In other words, the part being protected must be kept below a certain maximum temperature.
- Be readily moldable, machineable and possessing good bonding characteristics. It is envisioned that an ablative material would be applied to the part requiring protection, perhaps with the aid of a mould, then machined to a final thickness or desired profile.
- Resistance to "flow deformation" under a combination of exposure to heating and high velocity gas. To this end, it was felt that a filler material may be beneficial, integrated into a resin matrix.

Samples	Nº	RE	RP	MF	TiO2	Al2O3	Cork	Latex	x	X	FV
Avcoat	8	42		30							25
Avcoat +TiO2	9	42		30	5						25
Marshall + Al2O3	10	83				10	9				8
Epoxy + Al2O3	11	60				40					
SS2S	12	65		15							20
Phenolic microballoons	13	85		15							
SS2S + x	15	65		15					x		20
SS2S + X	16	65		15						X	20
SS2S + Al2O3	18	65		15		20					20
Polyester	19		100								
Latex	20			50				50			
Latex	21			70				30			
Phenolic microballoons	23	50		50							
SS2S + TiO2 + Al2O3	22	85		15	10	10					20

Table 1: Ablative Materials Tested

All numbers shown in Table 1 are percentages

RE = epoxy resin; RP = polyester resin

MF = phenolic microballoons; FV = glass fibre (strands)

x= 5% titanium dioxide , X = 10% titanium dioxide

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Conducting Themal Ablative Experiments

Photo 1: The slurry of ablative material before it was applied to the aluminum test sheet.

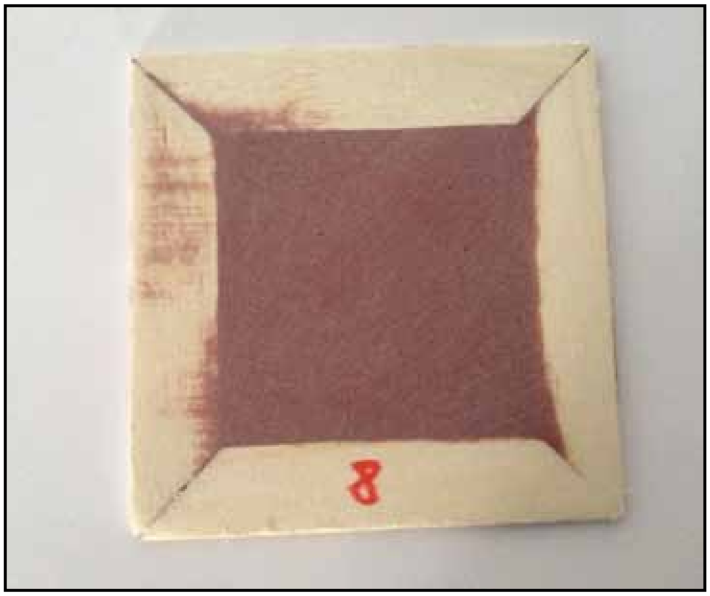

Photo 2: The ablative material was formed into a sheet of 2.4mm thickness

Preparation of specimens

All specimens were prepared in an identical manner. The ablative has joined an aluminum sheet 10 cm x 10 cm. To help adhesion, the surface is left rough with 400 grit sandpaper and then cleaned with alcohol and a BB gun. To help ensure a uniform thickness of the ablative layer, the substrate was defined by a frame made with wooden oral depressants (see Photo 2). The resulting size of the sample of ablative was 6 cm x 6 cm.

The different samples were prepared by carefully weighing the components, mixing thoroughly and then applying to the substrate using a spatula. All samples were degassed in a vacuum chamber at a pressure of -1 bar for at least 10 minutes. After curing for 24 hours at room temperature, the samples were post-cured in an oven at a temperature of 70 ° C for one hour. Then, the surface was sanded to leave a smooth and constant thickness of about 2.4 mm. The thickness of each specimen was carefully measured with a caliper and scored.

Test setup and procedure

A conventional cooking butane torch was used to heat the samples. The samples are attached vertically to a base plate, which also had a support for the torch nozzle, arranged such that the distance between the nozzle tip and the sample was consistently 75 mm. The heating time for each sample was 11.5 seconds, which was controlled by LabQuest, to which is also connected a K-type thermocouple for temperature readings, with a sampling rate of 3 samples/sec.

The test setup is shown in Photo 3.

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Conducting Themal Ablative Experiments

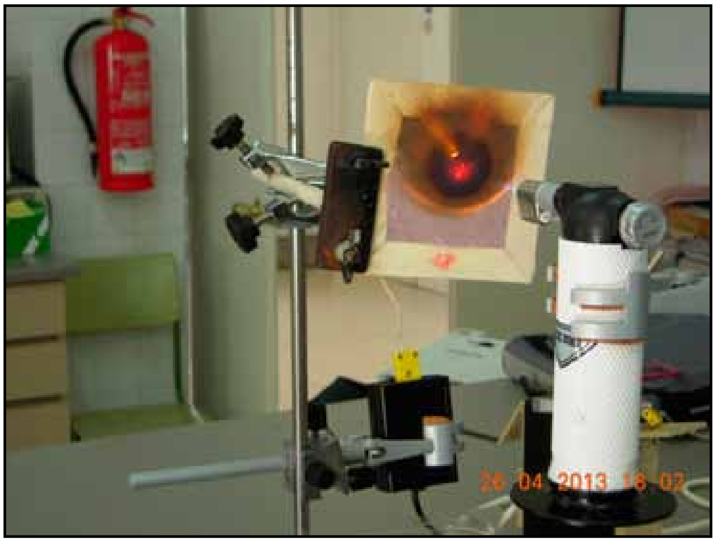

Photo 3: The material was heated with a Butane torch for 11.5 seconds.

The test procedure was as follows:

• Turning on the torch.

• Placing the torch flame directed to the center of the sample and start of data collection by the LabQuest.

• At the end of 11.5 seconds, quickly remove the torch and cool the sample with a spray.

• Cooling of the thermocouple by a fan until reaching room temperature.

After the samples had cooled, the appearance of the burnt area registration was photographed. Then the burned material was scraped carefully and the thickness of the remaining ablator was again measured and recorded.

Besides ablator samples, the same procedure was repeated with a sample of bare aluminum in order to provide data for estimating the rate of heating.

Results

Specimen	Initial ablative thickness (mm)	Final ablative thickness (mm)	Percent ablated	Ablation rate (mm/s)
2	2.88	2	69.44	0.174
3	1.75	0.675	38.57	0.059
5	2.53	1.175	46.44	0.102
6	2.3	1.65	71.74	0.143
7	2.99	0.875	29.26	0.076
8	2.2	0.575	26.14	0.050
9	2.38	0.925	38.87	0.080
10	2.725	0.65	23.85	0.057
11	2.1	1.05	50	0.091
12	2.26	1	44.25	0.087
13	2.87	0.45	15.68	0.039
15	2.51	0.675	26.89	0.059
16	2.42	0.65	26.86	0.057
18	2.26	0.475	21.02	0.041
19	2.76	0.675	24.46	0.050
20	2.31	1.375	59.52	0.120
21	2.25	1.675	74.44	0.146
22	2.3	0.825	35.87	0.072
23	2.25	1.125	50	0.098

Table 2: Raw data after the flame test for the different ablative materials.

Sample	Delta-t (ºc)	Velocity (mm/s)	F
Avcoat	5.3926	0.050	3.7088
Avcoat +TiO2	4.2561	0.080	2.9369
Marshal + Al2O3	8.1010	0.057	2.1656
Resin + Al2O3	12.7198	0.091	0.8639
SS2S	3.8692	0.087	2.9707
Phenolic microballoons	2.7084	0.039	9.4672
SS2S + x	2.3215	0.059	7.3009
SS2S + X	2.3215	0.057	7.5571
SS2S + Al2O3	3.5476	0.041	6.8751
Polyester	4.6429	0.050	4.3076
Latex	2.7084	0.120	3.0768
Latex	6.5539	0.146	1.045
SS2S + TiO2 + Al2O3	2.3215	0.072	5.9827
Phenolic microballoons	3.8449	0.098	2.6539

Table 3: The higher the F value (see Conclusion), the better the ablative material.

Conclusion

A function of F = (1 / (t * v)), the 3 best results are for samples with phenolic microspheres (85% and 15% resin

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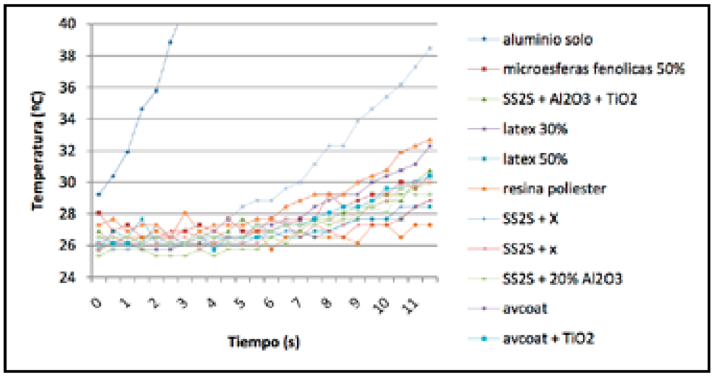
Conducting Themal Ablative Experiments



Graph 1: Temperature rise of the aluminum base plate during the 11.5 second test.

phenolic microspheres) SS2S + x (65% resin, 15% phenolic microspheres, 20% glass fiber plus "x") and SS2S + X (65% resin, 15% phenolic microspheres, 20% glass fiber and "X"). When choosing our best candidate, we opted for the last 2 options, because for a more rigorous analysis, we should have taken into account the density of each sample. But if you look at the 85% resin concentration in the first case and 65% in the second and third cases, the density of the two samples will be considerably smaller.

About the Author:

Vicente Alvero Zambrano is a Student of physical science and lives in Santa Marta de los Barros (Badajoz-Spain). His goal in model rocketry is to make space more accessible. He also enjoys cycling, robotics, electronics, chemistry, physics, and geology.