MiniSShot

ProtoSShot-M Mark III

Testing of Potential Rocket Motor Casing Thermal Barrier Materials

Rev. 2009/04/20

Purpose

This documents describes testing that was performed to assess various common materials that could potentially serve as a thermal barrier to reduce heat damage to the inner walls of the motor casing for the *MiniSShot ProtoSShot III* rocket motor.

In previous firings of the *MiniSShot* motors, and the associated *Short Stack* firings, thermal damage was regularly observed at either (or both) ends of the fiberglass/epoxy motor casing. Although the thermal damage was relatively minor, affecting only the protective epoxy liner (which is 0.025" or 0.64mm thick), the more serious concern relates to associated heat-up of the motor casing in the affected regions due to heat transfer. Such heat-up can reduce the structural capacity of the motor. It is believed that the observed heating is a result of hot combustion gases flowing around the grain assembly during motor startup, when pressure equalization occurs.

To reduce the thermal damage and heat transfer, a simple and lightweight solution was sought in the form of installation of a barrier material that would line the casing interior.

Specimens and Test procedure

Three materials were selected as potential thermal barriers..

1. Aluminum tape, *Nashua* brand, 0.004" (0.1mm) thickness (Specimen #2).
2. Aluminum "insulating" tape, *Nashua* brand, 0.004" foil thickness with a 0.004" butyl adhesive layer (Specimen #3).
3. Stainless Steel (type 321) foil sheet, 0.002" (0.05mm) thickness painted on one surface with one coat of insulating paint (Specimen #4).

Each material was bonded to a sample of 3.5"*Ameron* fiberglass tube, identical to that used for the motor casings, cut to a length of 3 inches (7.6 cm), then cut lengthwise into equal quarter sections. Specimen #1 was left bare. The insulting paint used for specimen #4 was a blend of latex primer paint with glass microballoons and phenolic microballoons to the following mass fractions (wet):

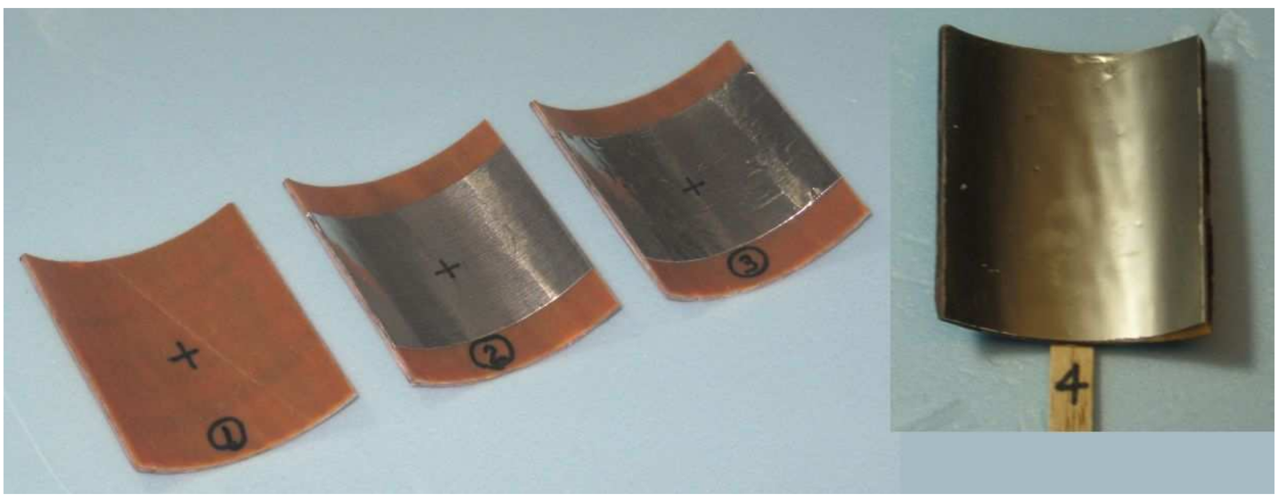
Latex paint	0.934
Glass microballoons	0.034
Phenolic microballoons	0.033

Specimens #2 and #3 were cleaned with lacquer thinner and a strip of foil tape material was then applied to the inside surface. For specimen #4, a piece of stainless steel foil was cut to match the size of the quarter section. One coat of insulating paint was then applied to one side of the foil with the paint being allowed to fully dry between coat applications. The foil was then bonded under clamping pressure, paint side down, to the quarter section using a minimal amount of *West System* epoxy. The purpose of the epoxy adhesive was strictly to ensure intimate contact between the foil material and the quarter section of fiberglass. It is not anticipated that such bonding would be used in an actual application.

The table below shows the density of the various materials.

Specimen material	Areal density (gram/sq.metre)
1. Aluminum tape	276
2. Aluminum/ butyl tape	385
3. Stainless steel foil/ paint	403

Figure 1 illustrates the four completed specimens.



<u>Figure 1</u> – Specimens #1 through #4 (left to right)

The method of testing the materials was essentially the same as used for earlier ablative materials testing. A type-k thermocouple was mounted to the backside of the specimen using a piece of aluminum tape. A camcorder was set up to record the temperature readings. The specimen was then mounted vertically in a jig that accommodated a propane torch a fixed distance from the specimen. A metal shield was initially placed between the torch and the specimen. The propane torch was fired up and with the aid of a countdown timer, the shield was removed allowing the flame to impinge on the specimen for exactly 5 seconds. Readings were recorded over a ten second period (5 seconds during flame-on, another 5 seconds afterward). A water spray gun was then used to cool the specimen to preserve its condition for examination.

The setup is shown in Figure 2.

<u>Figure 2</u> – Setup for application of flame heating to specimens

Results and Discussion

The results of the temperature recordings are shown in Figure 3. The condition of the specimens is shown in Figures 4 and 5. When the aluminum foil was peeled off specimen #1, a sticky, hard-to-remove adhesive remained. It was found that removal of the aluminum foil from the butyl adhesive of specimen #3 was difficult, and removal of the butyl was exceptionally difficult. It appeared as though the tubing material was not in any way visibly affected, unlike the other three specimens which showed some degree of scorch marks. The aluminum tapes showed some localized melting at the location of flame impingement.

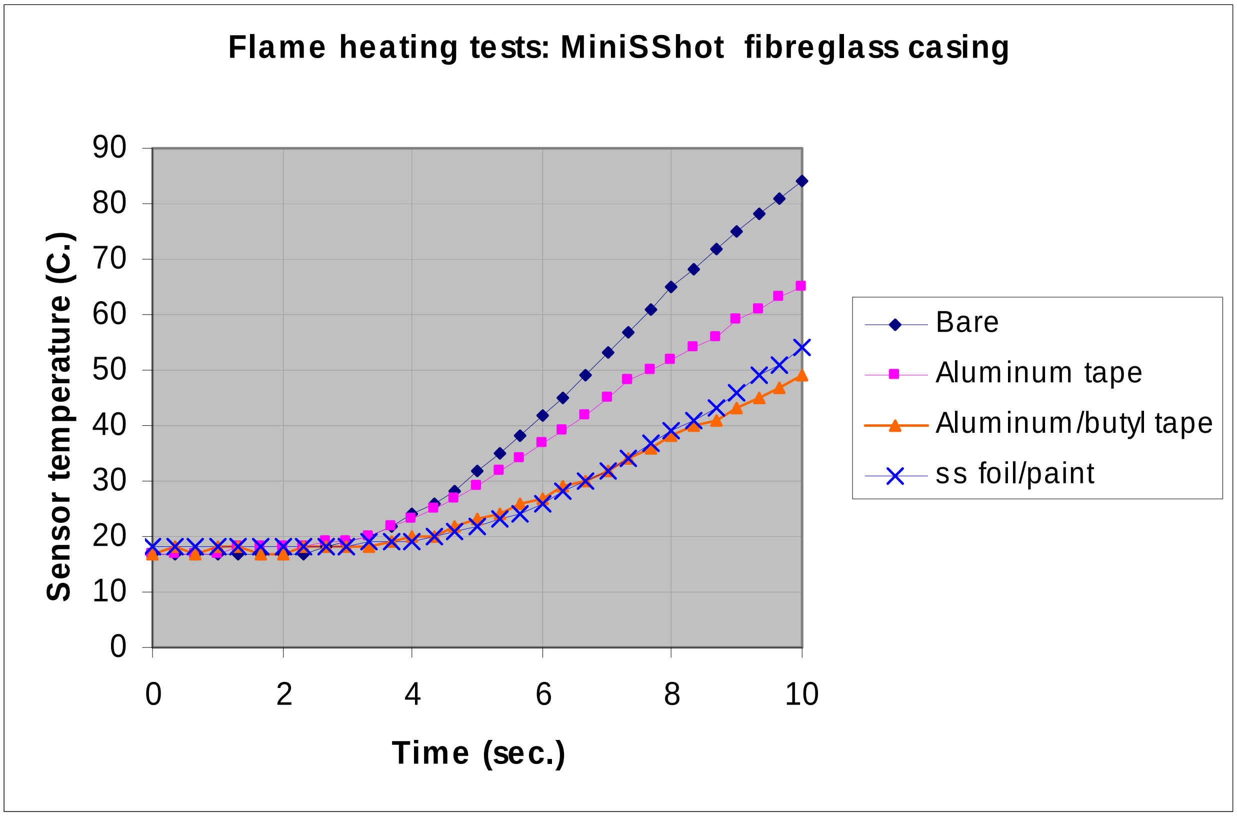
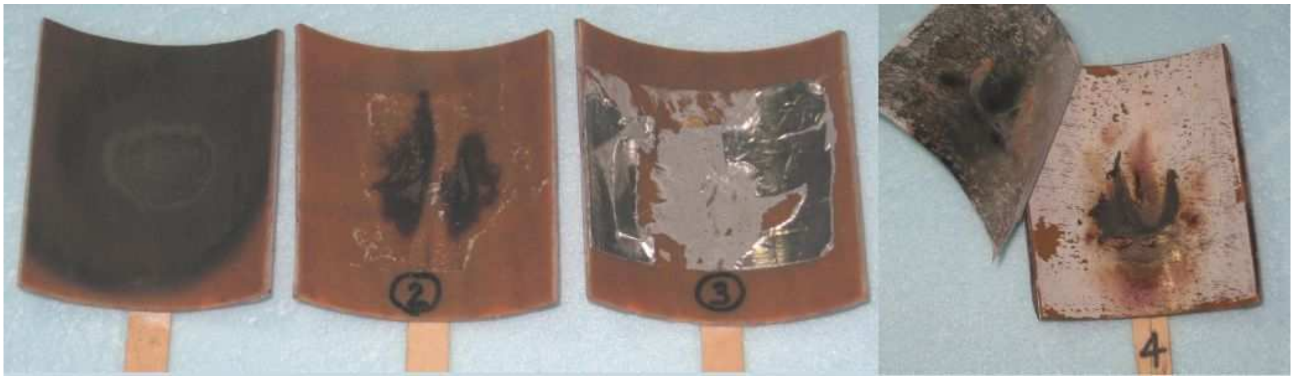


Figure 3 – Results of temperature sensor readings

Figure 4 – Condition of specimens after exposure to flame (#1-4, left to right)



<u>Figure 5</u> – Condition of specimens after exposure to flame and with metal foil peeled away (#1-4, left to right). Note specimen # 3 has only part of foil peeled away.

It is readily apparent from the graph shown in Figure 3 and from the condition of the fiberglass material shown in Figure 5, that even the use of aluminum foil tape provides a notable degree of thermal protection, both from a heat transfer perspective, and reduction in scorching damage. The aluminum tape/butyl and the stainless steel foil with insulating paint both provided similar and significant thermal protection. Both the aluminum tape materials had a major disadvantage of leaving a sticky residue that was very difficult to remove even with the use of solvents that could cause damage to the fiberglass casing.

Conclusions

The use of a simple and lightweight barrier such as metal foil provides value-added thermal protection to the fiberglass motor casing. The aluminum tapes did have a serious drawback, leaving a sticky, hard to remove residue. As such, such material would be good for single-use motor applications, but not for the *MiniSShot* motor where re-usability is a necessity. The stainless steel with insulating paint provided good thermal protection without this drawback, making it a better choice.