Nanotube-reinforced Graphite Foam

Witold Kowbel[1], C. Bruce[1], J.C. Withers[1], Khalid Lafdi[2], and Roland Watts[3]

1. MER Corp., Tucson, AZ 85706
2. UDRI, Dayton, OH
3. WPAFB, Dayton, OH

Kowbel@MER Corp.Com

INTRODUCTION

Graphite foam is a next-generation material, which is inexpensive, lightweight, fire-resistant, impact absorbing, and can be highly thermally conducting [1-3]. Graphite foam is applicable to a broad spectrum of commercial, defense, and aerospace markets, and is the enabling technology for a host of next-generation material systems and components that includes heat exchangers. Many enhanced properties of open-or closed-cell foams can be tailored by varying the precursor and the obtained properties of porosity/density/cell size. Graphite high-conductance tailoring, foam structural ligament enhancement, coatings, and other techniques can be used to expand heat exchanger operation to be compatible with all high performance engines, both military and commercial.

EXPERIMENTAL

Multi-wall nanotubes were impregnated into the high thermal conductivity foam using two approaches:

i) In-situ nanotube reinforcement at the pitch precursors.
ii) Post-foam infiltration using a solution of nanotubes.

The high thermal conductivity foam was fabricated using an AR pitch precursor and a final heat treatment temperature of 3000^{o}C. The density was assessed on a geomentric basis. The thermal diffusivity was measured using a laser flash method, while specific heat was measured using Differential Thermal Calorimetry. Compressive strength was measure using 1.5 cm foam cubes. The foam anisotropy was examined using a polarized light optical microscope.

RESULTS AND DISCUSSION

Figures 1 – 2 show the effect of in-situ nanotube reinforcement on the properties of the high thermal conductivity foam. The nanotubes were applied by mixing with the starting pitch powder.

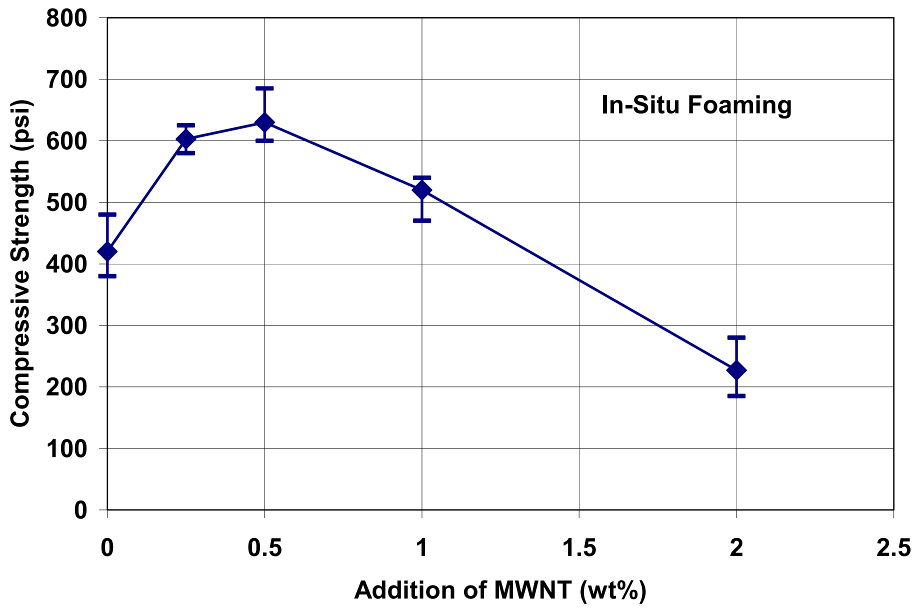

Figure 1. Effect of Nanotube Addition on Compressive Strength of High Thermal Conductivity Foam.

Figure 1 shows the effect of nanotubes on the composite strength. Up to 0.5 wt %, nanotube reinforcement yielded a significant increase in strength. An increase of about 50% (at 0.5 wt % nanotubes) is observed. The strength increase is attributed to the high strength of the nanotubes and their alignment within the foam ligaments. Further increase in the amount of nanotubes resulted in a progressive decrease of the compressive strength, due to a decrease in the foam density (Figure 2).

Each strength value corresponds to the average of 6 – 8 data points. The scatter in the data varies from about 50 – 100 MPA.

Figure 2 shows the effect of nanotube reinforcement on the thermal conductivity. Up to 0.5 wt% of nanotubes, the thermal conductivity remains constant within the experimental scatter. An increased amount of nanotube reinforcement significantly decreases the thermal conductivity.

In addition, infiltration of pitch containing up to 2% nanotubes has shown up to 70% strength increase (for 2% nanotubes) with a minimum change in the foam density. Figures 3 demonstrates that affect.

Intrinsic agglomeration problems set the 2 wt% nanotubes dispersion limit. The thermal conductivity was 150 W/mK before and after nanotube reinforcement with ± 10^{o}C error.

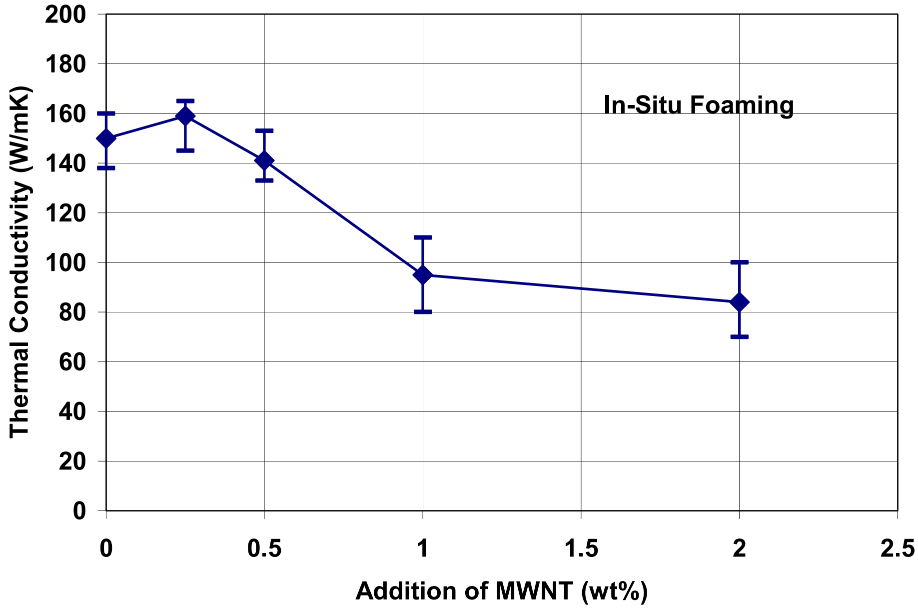

Figure 2. Effect of Nanotube Addition on the Thermal Conductivity of High Thermal Conductivity Foam.

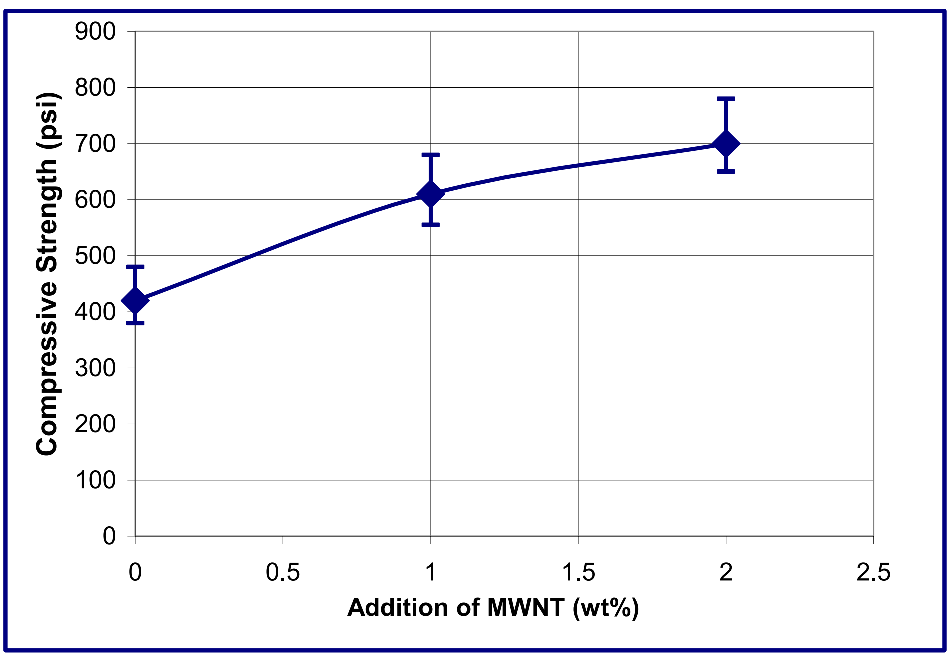

Figure 3. Effect of Nanotube Infiltration on Strength.

We observed two basis textures: highly anisotropic area with very oriented carbon regions (single arrows in Figure 4) less oriented carbon area and rich of nanotubes (double arrows in Figure 4). This well noticeable difference is the result of local agglomeration of nanotubes in a pitch matrix. There is an issue of nanotubes dispersion in the pitch precursor. In some areas the nanotubes seems to be fairly dispersed and in another areas nanotubes are more localized and may form an inclusion with bad surface wetting. From our research study in nanocomposites, unfunctionalized nanotubes tend to agglomerate and form an inclusion that contributes to the mechanical failure of the materials.

At this level of processing, both foams are not fragmented except from one location another when there is large anisotropic area where we observed some cracks parallel to ligaments, an orientation similar to the cracks observed in a needle coke. There is a certain influence of disinclination defects on crack development in highly anisotropic pitch.

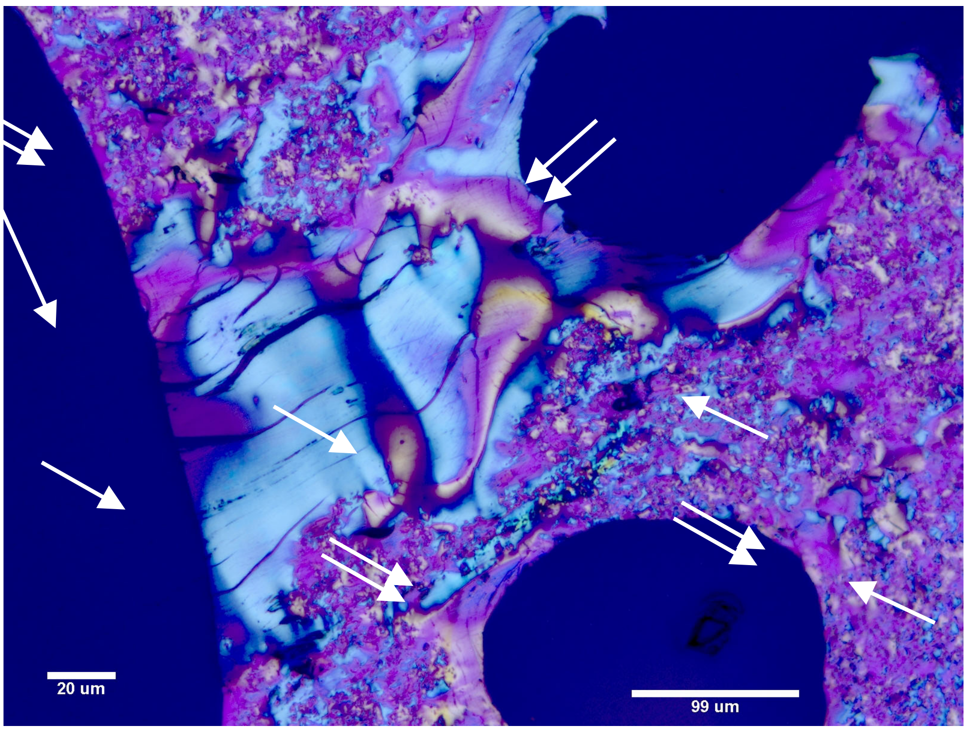

Figure 4. Large magnification optical micrograph of sample 40 showing variation anisotropy variations. Single arrows indicate areas free of nanotubes and double arrows are areas rich of nanotubes.

CONCLUSIONS

1. The use of graphite foam enables the use of surface heat exchanger in the military turbofan applications.
2. Up to 70% strength increase was observed upon nanotube reinforcement.
3. Slight increase in thermal conductivity was observed with nanotube reinforcement.

REFERENCES:

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