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Paper Session III-A - Prototype Aerogel Insulation for Melamine-Foam Substitute: Critical Space Station Express Rack Technology

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Prototype Aerogel Insulation for Melamine-Foam Substitute: CriticalSpace Station Express Rack Technology

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There is a current lack of environmentally acceptable foams to insulate Long-Duration Human Spaceflight Missions, including the experimental Express Rack for Space Station. A recent 60-day manned test in a sealed chamber at JSC was nearly aborted, because of persistently high formaldehyde concentrations in the chamber. Subsequent investigation showed that the source was melamine foam (used extensively for acoustic insulation). The thermal and acoustic potential for melamine-foam substitutes is evaluated for scale-up to a silica-based foam and aerogel, which is environmentally benign for long duration space flight. These features will be discussed in reference to an aerogel prototype to: 1) assemble material strength data for various formulated aerogels, both silica and organic carbon aerogels; 2) assemble the aerogel into panels of mylar/vacuum-encapsulated rigid boards which can be molded in various shapes and rigidities; and 3) describe a process for space applications for formaldehyde-free, long duration thermal and acoustic insulators.

Melamine foam inside the International Space Station (ISS) vehicle.

A recent 60-day manned test in a sealed chamber at JSC was nearly aborted, because of persistently high formaldehyde concentrations in the chamber. Subsequent investigation showed that the source was melamine foam (used extensively for acoustic insulation). The foam (which is a formaldehyde polymer) was found to emit low (but toxic) levels of formaldehyde continuously at low temperatures (100 F). Recent tests at Rice University revealed significant outgassing of formaldehyde, as follows: a 40 gm. sample at 40 degrees centigrade for 20 minutes released 2.31 ppm with an error of 54 ppBillion (the SMAC for 1 hour which was .4 ppm, and the 24 hour SMAC was .4ppm). For comparison, ambient formaldehyde levels in houses are typically .03 to .04 parts per million. By comparison, typical levels in the smoking section of a cafeteria are 0.16 ppm. Houses with new carpeting can also reach these levels. For home use, the Environmental Protection Agency (EPA) set guidelines which the melamine-based foams violate on space station by a factor of 23. The initial EPA threshold level set for formaldehyde gas was 1.0 part per million (ppm). As testing methods improved, the level was brought down to 0.5 ppm and, eventually, 0.1 ppm. The Space Station Express rack and other space hardware are using this foam for acoustic and thermal insulation. The formaldehyde is formed by foam decomposition, so the rate of formation does not decrease with time (baking, vacuum exposure, etc. are completely ineffective at reducing the offgassing rate).

Toxicologists are particularly concerned about formaldehyde in cabin atmospheres for three reasons: because it is highly toxic; because it is present in appreciable quantities in samples of the Shuttle atmosphere taken during flight (barely acceptable for the short-duration Shuttle missions); and because it is not detected effectively by the standard analytical procedures used with our standard toxic offgassing test. A laboratory study which produced nasal cancers in rats that were exposed to high levels of formaldehyde, increased the concern.

To avoid a build-up of formaldehyde inside the ISS modules, melamine foam should not be used for any internal applications. Although few if any truly satisfactory foams exist for spacecraft applications, reasonable alternatives to melamine are available for all applications. Previous design hardware has accepted the use of fire-retarded polyurethane foam for locker stowage, despite its flammability and limited age-life; polyethylene minicell foam and coated flexible polyimide foam can also be used. Rigid polyimide foam is excellent for acoustic and thermal insulation. Melamine foam is nonflammable, lightweight, and inexpensive, but has very poor durability. Urea-formaldehyde foam insulation suffers from formaldehyde toxicology, and although still extensively used in Europe, has been banned in Canada since December, 1980.

A request was put to halt melamine use on future design work for space station and assess whether Express Rack users have a potential problem with their existing design.

Evaluation of Aerogel Insulating Alternatives:

To meet this lack of critical technology for space station, the use of silica based foams or aerogel is of comparative interest. In some formulations, aerogel is rated as five times better insulation than the nearest large-scale commerically available competitor. Some home insulation studies have rated aerogel as either R-32 to R-64 with near vacuum conditions maintainable in a light vacuum with infrared absorbing carbon aerogels.

Silica aerogel specifications

Apparent density 0.003-0.35 g/cc
Internal surface area 600-1000m^2/g
% solids 0.13-15%
Mean pore diameters ~20 nm
Primary particle diameter 2-5 nm
index of refraction 1-1.05
Thermal tolerance to 500 C
Coefficient of thermal expansion 2-4x10^-6
Poisson ratio 0.2
Young’s modulus 10^6-10^7 N/m^2
tensile strength 16 kPa
Fracture toughness 0.8 kPa*m^0.5
Dielectric constant 1.1
Sound velocity through medium 100 m/s

Encapsulation Technology

As a structural material, aerogel formulation and packaging technologies include mylar coated, vacuum packing of moldable particles, microbeads and contiguous panels. Mechanical strength in compressive modes can be as high as 1000 in strength-to-weight ratio without packaging, but sheer strength is minimal without at least a weak vacuum or further packaging. Recent use of aerogel as a thermal insulator on the Mars rover allowed a 25% reduction in payload weight compared to alternative insulation technologies, or an equivalent 6 pound saving relative to a 25 pound total payload weight.

Conclusions

The study of aerogel-based replacements for space application of formaldehyde releasing foams provides the opportunity to extend and apply previous knowledge gained in high-performance insulation to an innovative and mission-critical area.

References

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