Improvement of Polyester Blanket Thermal Insulator Properties Using Phenolic Aerogel

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Abstract

Blanket insulators which can reduce heat transfer through reduction of solid conduction, gas convection and radiation, would be the most appropriate insulation materials. Due to the importance of insulating issues, especially in terms of energy saving, properties improvement of this blanket is considered. To improve the thermal properties of the insulation blankets, aerogel as a super insulator material that has a nano metric structure, low density and high specific surface area demonstrated exceptional properties added to blanket. As a result of this work, the thermal properties of polyester mat blanket insulator were improved by embedding in sol of aerogel materials. The thermal diffusivity ($\alpha$) and thermal conductivity ($K$) are obtained $2.45 \times 10^{-7}$ (m$^2$/s) and 0.04238 (W/m.K) for aerogel blanket insulator, and these coefficients for the polyester mat blanket are $9.26 \times 10^{-7}$ (m$^2$/s) and 0.0676 (W/m.K).

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1. Introduction

Nowadays, in order to optimize energy consumption, use of thermal insulation is one of the most attractive issues in different industries. Heat transfer mechanisms include conduction, convection and radiation. Therefore, blanket insulators can reduce heat transfer through all above mechanisms due to highly porous structure. Blanket insulators cover a wide range of materials including fiberglass, rock wool, synthetic polymers such as polyester and natural blankets. Blanket insulators have wide application in various industries such as petrochemical, aerospace industry, construction, transportation and textile, cryogenic industry and so on. Polyester mat is considered as one of the common blankets as reported in Aspen Aerogels study (2014). Hajizadeh et al. (2014) discussed Novolac type phenolic resin aerogel that has a nanostructure, low density and high specific surface area was used to thermal properties improvement of the polyester blanket. However, aerogels production problems such as dangerous and expensive CO$_2$ super critical drying method are an obstacle to their use. Wang et al. (2012) and Aegerter et al. (2011) investigated Preparation of the aerogel by solvent vapor saturated sol-gel method and ambient drying solve these problems. The manufacture of polyester mat based insulator with in-situ synthesis of phenolic aerogel in mat porosity reduces prices and production costs.

In this work, In-situ sol-gel polymerization of novalac aerogel at solvent saturated atmosphere in macro porous polyester mat was used to improve thermal insulator performance of polyester mat.

2. Experimental

In this work, polyester mat (Bibaft Co. Iran) with a thickness of 1.5 mm was purchased. To produce the gel structure, the novolac resin (IP 502 Resitan Co. Iran) and 2-propanol (Dr. Mojallali Co. Iran) were used to prepare novolac sol. Hot plate method was used to thermal conductivity measurement of very low thermal conductivity samples. This method is presented in Miller (2011) study. To study the microstructure of samples, SEM technique was adopted.

Naseri et al. (2014) used a new way to synthesis Novolac aerogels. So, for preparation of aerogel blanket insulator, the solution of novolac resin in 2-propanol with different weight concentrations were prepared. The solutions with the required polyester mat were placed in the polypropylene mold and it was placed in the autoclave. Before putting the mold inside the autoclave, 50 cc of 2-propanol solvent was poured into the autoclave. In fact, there was the bath solution in the autoclave. After these steps, the autoclave door was closed and the sealed completely. Then, the autoclave was placed in the oven for 5h at 120° C. After that, the oven was turned off and slowly reached ambient temperature inside the oven. Finally, samples were removed from the mold. The novolac gels prepared on the polyester mat substrate were dried in ambient conditions to prevent cracking of samples because of rapid withdrawal of large amounts of solvent. Then, to cure and bring out the entire the solvent simultaneously, the samples were placed in the oven for 24h at 90°C and 24h at 120°C. The polyester blankets with different mass fractions of aerogel (0, 10, 15, 20, 25 and 30) are labeled as PEm, PEm 10, PEm 15, PEm 20, PEm 25, PEm 30, respectively. Fig. 1 shows a sample of the aerogel blanket.

![Fig. 1. A sample of the aerogel blanket.](image-url)
3. Result and discussion

In Table 1, the composition and thermophysical properties of aerogel blankets is given. The blankets properties with concentrations of novolac resin higher than 30% excluded due to lack of flexibility.

Table 1. Composition and feature of aerogel blankets.

| Sample code | Solvent (%) | Novolac (%) | Density (g/cm³) | Porosity (%) | Thermal conductivity (W/m.K) | Thermal Diffusion (m²/s)×10⁻⁵ |
|-------------|-------------|-------------|----------------|--------------|-------------------------------|-----------------------------|
| PE₅₀        | 0           | 0           | 0.074          | 93.59        | 0.0676                        | 0.926                       |
| PE₅₀ 10     | 90          | 10          | 0.137          | 88.29        | 0.04617                       | 0.0337                      |
| PE₅₀ 15     | 85          | 15          | 0.173          | 85.29        | 0.04238                       | 0.0245                      |
| PE₅₀ 20     | 80          | 20          | 0.22           | 81.37        | 0.04752                       | 0.0216                      |
| PE₅₀ 25     | 75          | 25          | 0.263          | 77.79        | 0.08048                       | 0.0306                      |
| PE₅₀ 30     | 70          | 30          | 0.315          | 73.47        | 0.09261                       | 0.0294                      |

Resin concentration in the initial solution is a very important parameter which strongly influences the thermal and mechanical properties of the aerogel. According to Table 1 with increasing concentration of resin in sol, the density is increased. To justify this phenomenon it should be noted that, by increasing the concentration of the resin, the mass of the gel will be increased and because of constant sample volume the density increase significantly. It also shows, first of all, by increasing resin, aerogel blankets porosity is reduced.

Thermal conductivity is one of the key properties of thermal insulators (Fig. 2). With thermal conductivity decreases, the insulation properties of aerogel blanket are improved.

![Fig. 2. Thermal conductivity and thermal diffusivity of samples.](image-url)
In Fig. 2, the thermal conductivity was determined using hot plate, Miller et al. (2011) method and by α = K /cₚ ρ, coefficient of thermal diffusion was calculated as reported in Manoj study (2012). According to this Figure, the lowest thermal conductivity belongs to the sample of 15 wt.% resin in initial sol (PEm 15) and minimum thermal diffusivity belongs to the sample of 20 wt.% resin in initial sol (PEm 20).

To investigate the microstructure of the samples, the SEM images are given in Fig. 3. As shown in this figure, with increasing concentration of resin in sol (aerogel in blanket), the particle size is reduced and microstructure clustering is constructive and also the particles sinking is more and more seen on the surface.

![SEM images of samples](image)

Fig. 3. SEM images of samples:

(A) PEm; (B) PEm 10; (C) PEm 15; (D) PEm 20; (E) PEm 25; (F) PEm 30.

4. Conclusion

To select the optimal concentration of resin in initial sol which was embedded in polyester mat insulator, criteria of lightness, flexibility, thermal conductivity, and thermal diffusivity are very important. With novolac aerogel mass fraction in insulator increase, insulator will become heavier and its flexibility will decrease. So the samples with concentration of resin in initial sol less than 20 wt. % are appropriate. Thermal conductivity plays an important role in choosing the adequate thermal insulator which is appropriate for PEm 15. Based on this research, because of having good thermal properties, the PEm 15 sample has an optimal resin concentration in initial sol.

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References

Aegerter, M. A., Leventis, N., Koebel, M. M., 2011. Aerogels Handbook. Springer, 2011. New York.
Aspen Aerogels, 2014. Inc. Available from: http://www.aerogel.com/products.htm.
Hajizadeh, A., Bahramian, A. R., Sharif, A., 2014. Investigation of the effect of sol concentration on the microstructure and morphology of Novolac hyperporous. Journal of Non-Crystalline Solids, 402: p. 53-57.
Miller, R. A., Kuczmarski, M. A., 2011. Method for Measuring Thermal Conductivity of Small Samples Having Very Low Thermal Conductivity. NASA Glenn Research Centre Cleveland, Ohio.
Manoj, B., Kunjomana A.G., 2012. Study of Stacking Structure Amorphous Carbon by X-Ray Diffraction Technique. International Journal of Electrochemical Science, Vol 7(1): p. 3127-3134.
Naseri, I., Kazemi, A., Bahramian, A. R., Razzaghi, M., 2014. The effect of solvent on drying shrinkage of novolac xerogels. In Advanced Materials Research. Trans Tech Publ.
Wang, J., Chen, M., Wang, C., Wang, J., Zheng, J., 2012. A Facile Method to Prepare Carbon Aerogels from Amphiphilic Carbon Material. Mater. Lett. vol. 68, pp. 446-449.