STUDY ON FABRICATION AND PROPERTIES OF THE ALUMINUM FOIL/BUBBLE COMPOSITE

Weiwei Wang[1,*], Zhaofeng Chen[1,*], Xinyang Zhang[1] , Lihe Chen[1] and Shengnan Guan[1]

[1] International Laboratory for Insulation and Energy Efficiency Materials, College of Material Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, P. R. China

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ABSTRACT

This paper presents results of a study on fabrication and properties of the aluminum foil/bubble composites（FBCS）. FBCS with aluminum reflective foil and PE bubble layer are fabricated by hot-press at 150~200℃. Properties of composites including tensile strength and thermal conductivity are determined by electronic universal testing machines and heat flow meter method, respectively. The effect of thermal conductivity of composite specimens with different bubble layers and different bubble volume are explored. The damage point is at 0.30 of the stress-strain cure, different bubble layers have little effect on the conductivity of the composite, but the thermal conductivity decreased with the increase of the bubble volume. So, bubble with more volume are more efficient in improving the thermal insulation properties of the composite.

1 INTRODUCTION

With the rapid development of economy, the growing global demand for energy, according to the speculation of the national institute of standards and technology(NIST), by 2040, the global energy demand is set to rise by 40%, with the highest growth expected in developing nations[1].The energy saving and emission reduction has become the issues that all the world concern. Especially in the field of construction and heating pipe has huge potential. A suitable thermal insulation is necessary in these application fields to reduce costs and the emission of CO2 [2-4]. Due to the global need of insulation, the development of more efficient insulating products is necessary [5].

Nowadays, porous materials with low thermal conductivity have been widely used as thermal insulation [6-7], air or inert gas inside the pore of low thermal conductivity to reduce the heat conduction, such as glass and mineral fiber, polyurethane foam, expanded and extruded polystyrene etc. Owning to the high porosity (commonly greater than 80%) [8], the heat conduction can be very low in the materials. In fact, convection and radiation also has important effects on heat transfer[9]. so that the radiative thermal flux may be acknowledged as an important part of the total heat flux within porous materials[10]. The radiative thermal flux in lightweight porous insulation could be up to 30% [11] of total heat flux even at moderate temperatures (300~400K). Therefore, reducing the radiative heat flux is an efficient way to improve the thermal insulation performance of porous materials.

Study shows that reflective insulation, for example gold, silver, nickel, aluminum foil, metallized polyester etc, which consist of one or more low-emittance surfaces[11] can reflect heat back out and reduce heat radiation effectively. Aluminum foil and stainless steel foil has very little radiation coefficient and good ability of antiradiation, which can effectively reduce the thermal radiation. As early as the 1950s, the aluminum foil excellent performance, with many countries in Europe and America, used in the building and industrial to wait as thermal insulation materials.LiuJuan [12]compounds aluminum foil with polyurethane and prepared the polyurethane/aluminum foil composite duct, which is used in central air-conditioning pipe, the results show that polyurethane/aluminum foil composite duct has played a very good noise insulation effect. Su Gaohui[13] studys the influences of pipe insulation with aluminum foil, the results show that when aluminum foil light facing out for package, heat dispersion has been reduced about

5%.Compared with porous materials, the study of reflective thermal insulation material at home and abroad is still limited, a mature research system has not formed yet.

In this paper, a new insulation material (aluminum foil/bubble) which composed of aluminum foil and polyethylene (PE) bubble is introduced. The laminates have low thermal conductivity and environmentally-friendly, which is suitable for industrial or commercial buildings and steam pipelines. Comparing with fibrous insulation, it will not bring discomfort to the human body. While comparing with advanced insulation, such as vacuum insulation panel (VIP) and aerogel, it is easy to be generalized with the advantages of low-cost, high reliability and easy-to-use. The main objective of this study is to fabricate the new insulation material (aluminum foil/bubble), and investigate its tensile strength and thermal conductivity properties.

2 EXPERIMENTAL

Aluminum foil/bubble composites with aluminum reflective foil and PE bubble layer are produced by hot-press at 150~200℃. The aluminum reflective foil layer was composed of aluminum foil, polyethylene terephthalate (PET), chlorinated polyethylene (CPE)as shown in Fig.1(a) and fabricated by composite tape casting technology with lamination temperature at 60~80℃ and lamination pressure at 0.4~0.7MPa using crylic acid as adhesive. The PE bubble layer was made from low density polyethylene (LDPE) whose melt flow rate (MFR) within 0.5~1g/min and prepared on the suction roll with temperature 150~200℃ by extrusion blow molding technology and then composited with aluminum reflective foil layer into a sandwich structure with different PE bubble layers as a core material using hot-press as shown in Fig. 1(b).

Microstructure was examined by scanning electron microscope (SEM, Quanta FEG 250).Tensile strength, elongation and Yong's modulus of Aluminum foil/bubble composites were determined by tensile test on an electronic universal testing machine at a displacement rate of 200mm/min and 100mm span according to Chinese Standard Methods of Testing (GB/T 1040.3-2006). The size of test specimens cut from Aluminum foil/bubble composites was 200mm×25mm×4.0mm. The thermal conductivity was measured by Netzsch HFM 436 machine using heat flow meter method according to ASTM C 518 standard. The size of testing samples was 300mm×300mm×4.0mm.

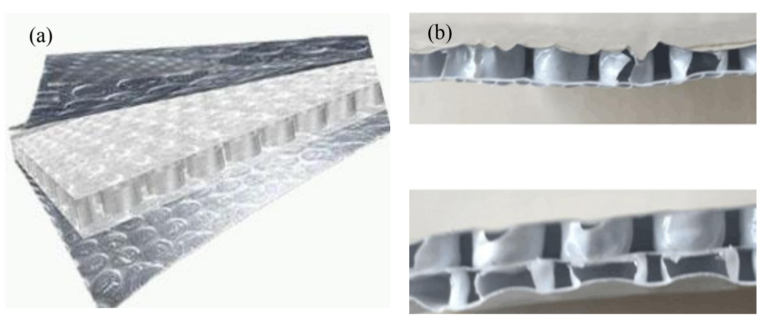

Fig. 1. Aluminum foil/bubble composite: (a) surface; (b) cross-section.

3 RESULTS AND DISCUSSION

3.1 Tensile Strength of Aluminum Foil/bubble Composites

Fig. 2 shows the stress-strain curve of Aluminum foil/bubble composites. The values for tensile strength, elongation and Yong's modulus were 1.66MPa, 30.00% and 37.02MPa, respectively. The curve could be divided into three stages: elastic stage, plastic stage and fracture stage. In elastic stage, stress increased almost linearly with the increase of strain and the laminates' deformation was about 3.02%. In plastic stage, the stress reached maximum value and the deformation was about 26.67%. Then the laminates came into fracture stage, in this stage, the stress decreased with the increase of strain and the laminates suddenly broke while the deformation was 30.00%.

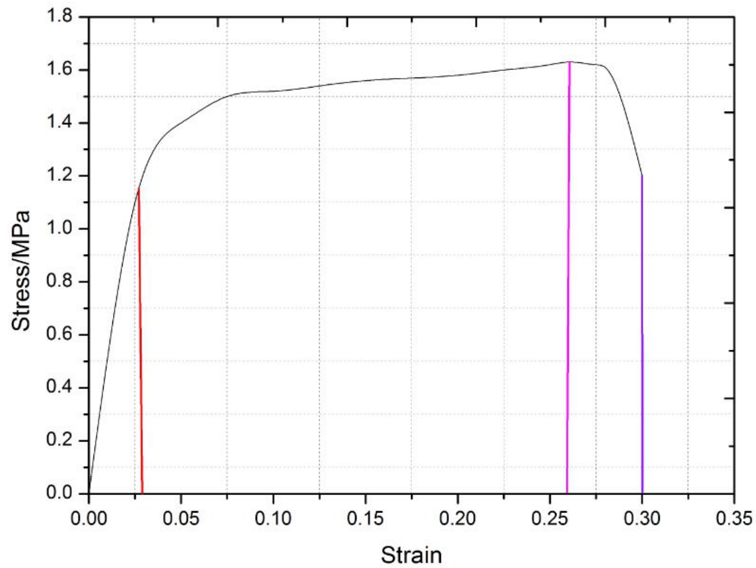

Fig. 2. Stress-strain curve of the laminates by tensile.

Fig. 3(a) is the photo of samples after tensile test. The material deformed severely and curled into the surface of CPE. It indicated that the tensile property of Al, PET, CPE and LDPE were different and then led to the deformation of these material in different degrees. For Aluminum foil/bubble composites, the aluminum foil belonged to metal material, structure defects such as point defects existed in it; PET, CPE and LDPE are kind of crystalline polymer; the four materials existed not only the deformation damage, but also the damage deformation in bonding interface between layer and layer. Under ideal condition, the damage first occurred in the structure defects of the substrate or in the weak connection area of bonding interface. But in actual cases, the various accidental patterns on the surface could also affect the tensile property of the laminate. Fig. 3(b) shows the SEM micrograph of the surface of the laminate before tensile test. It indicated that there were some defects on the surface of the laminate. The area with defects was the region of stress concentration. When the laminate went into plastic stage, multiple stress concentration fields were formed on the edge of the laminate and the aluminum foil cracked first, forming lots of crack points and spreading around. Fig. 3(c) shows SEM micrograph of the fracture surface of Aluminum foil/bubble composites after tensile test. It indicated that layered fracture occurred obviously after tensile test. During test, the unbroken film and the fracture film formed tension field, the force on the one side was transferred to the whole unbroken film matrix on the under surface and the force on the other side was transferred to the broken surface and aluminum foil layer, forming peel force. At the interface between the fractures, when the load was over the maximum capacity of bonding layer, the broken layer separated from the unbroken layer. The LDPE had good flexibility and high elongation; the PE bubble had been stretched after test as shown in Fig. 3(d).

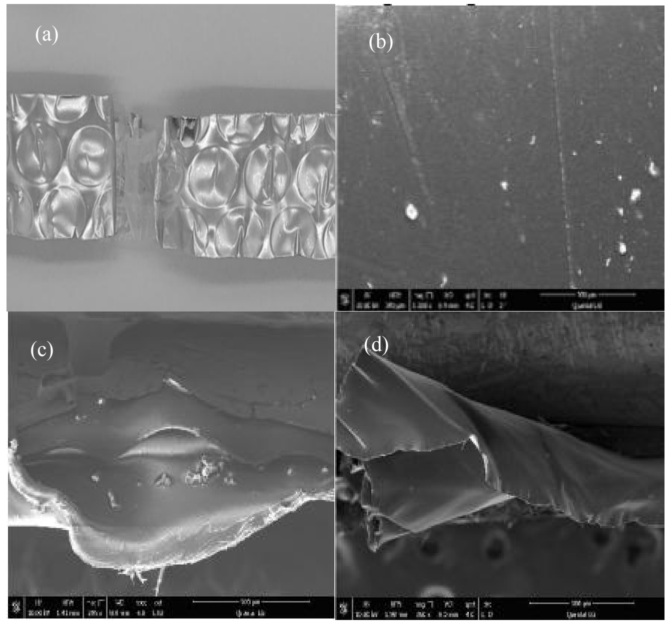

Fig. 3. Aluminum foil/bubble composites: (a) samples after tensile test; (b) the surface of the laminate before tensile test; (c) Al foil; (d) PE bubble.

3.2 Thermal Conductivity of Aluminum Foil/bubble Composites

3.2.1. Effect of Bubble Layers on Thermal Conductivity

The effect of bubble layer on the thermal conductivity of composite was studied with bubble diameter is 10 mm, bubble height is 4 mm .Fig.4 is the results of thermal conductivity with different bubble layers which are measured at room temperature, from Fig.4 shows, thermal conductivity is 0.0392 W/(m K),when aluminum foil /bubble composite with single layer, with the increase of the bubble layers, the thermal conductivity also will increase, and the bubble layers is up to 4 layers, its thermal conductivity is 0.0545 W/(m K).

Two reasons may account for this phenomenon. On the one hand , the bubble layers increase and the bubble layer heat transfer has changed. Bubble layer heat transfer consists of three parts: part of the heat transfer through the gas;Part of the skeleton, by bubble wall of solid heat transfer;There are part of the convection heat transfer through gas.Bubble layer increases, the increase of gas thermal resistance of thermal conductivity, thermal conductivity of composites is reduced.But at the same time, the convection heat transfer of the gas and solid heat transfer for the bubble wall also strengthened, thermal conductivity increases, and the two heat transfer strengthening effect to the bubble layer is greater than the gas thermal conductivity of the heat transfer effect.Finally heat insulation performance of composites reduces, thermal conductivity rises.

On the other hand, thermal conductivity λ、 thickness h and thermal resistance R, has the following relationship: $\lambda = h/R$ .With the increase of the bubble layers, the thickness of the composites increases, which results an increase in solid heat transfer. Different bubble layers have little effect on the conductivity of the composite. Mainly because the aluminum foil bubble composites is not composed of a single component, presents a nonlinear changes between thickness and thermal resistance.

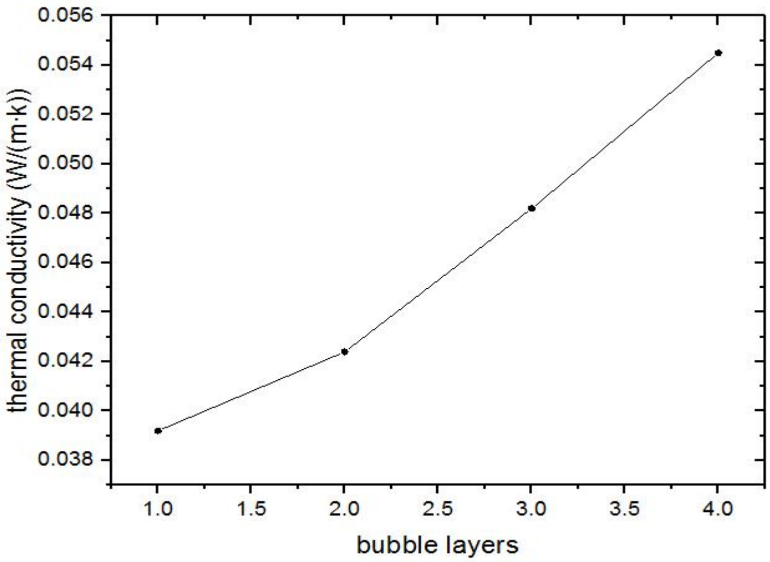

Fig. 4. Effect of bubble layers on thermal conductivity

3.2.2 Effect of Bubble Volume on Thermal Conductivity

The reaserch is by studying the same thickness 4mm , different diameter of the single layer of bubble to figure out the releationship between diamater and thermal conductivity.Fig.5 is the results of thermal conductivity of different bubble vo;ume in room temperature. With the volume increase from 314mm^3 to 1256mm^3, conductivity is decrease slowly from 0.0392W/(m·K) to 0.0355W/(m·K), and the desent rate in volume 706-1256mm^3 is bigger than in volume 314-706mm^3

With the bubble volume increasing, the relative content of polyethylene bubbles in the unit area is reduced. Therefore, in the aluminum bubble/foil composite material, the heat conduction by polyethylene bubbles is relatively reduced, and the heat conduction through the air is relatively increased. Through investigation, the thermal conductivity of LDPE is 0.33W/(m·K), the air is 0.023W/(m·K), so by increasing the bubble volume, can reduce the solid thermal conductivity of the material and increase the gas theraml conductivity, the gas thermal conductivity is less than solid thermal condutivity, so the all thermal conductivity of the whole material is reduced.

It is worth noting that air layers formed by PE bubble has increase the thermal conductivity of the composite material and incerease the bubble vocume, it can increase the theral conductivity of air layer and decrease the thermal conductivity of the material efficiently, but meanwhile, as the middle layer of aluminum bubble composite material, the PE bubble plays as a support role between the two side reflective aluminum foil, so all bubble layer has a certain mechanical properties.Considering the overall mechanical properties of materials and the use of performance, a low thermal conductivity by incerase the bubble volume bindly in the manufacture process should not be pursued.

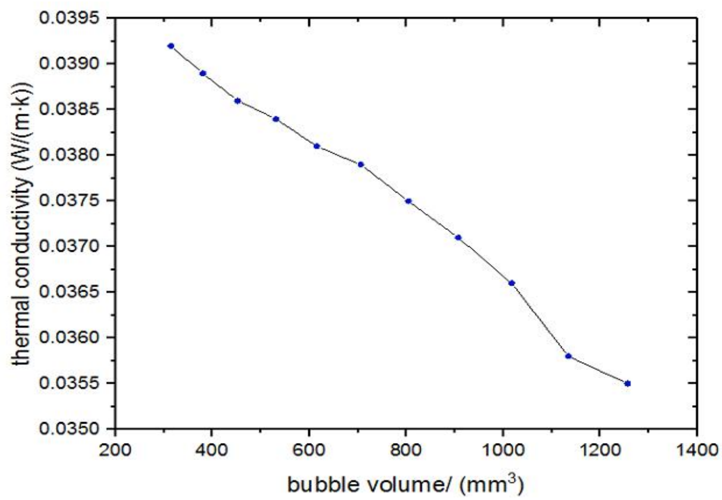

Fig. 5. Effect of bubble volume on thermal conductivity

4 CONCLUSION

Aluminum foil/bubble composites with aluminum reflective foil and PE bubble layer are successful fabricated by hot-press at 150~200℃. Properties of composites including tensile strength and thermal conductivity are analyzed ,respectively.

The damage point is at 0.30 of the stress-strain cure,with the increase of the bubble layers, the thermal conductivity also will increase, the thermal conductivity decreased with the increase of the bubble volume. But bubble with more volume are more efficient in improving the thermal insulation properties of the composite.

The average thermal conductivity of Aluminum foil/bubble composites is 0.038W/(m•K) at room temperature.Material has excellent thermal insulation, waterproof performance, and lower production cost, can be applied to building, heat pipes, and other areas of the heat preservation and heat insulation, be suitable for promotion.

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