Ultra Low Weight Composites - Microsphere Syntactic Foam

Dr. Lee Ching Hao

INTRODUCTION

Composite material is not a novelty term for many people nowadays. Tailorable properties to fit specific purpose or working environment is one of the most attractive feature of composite material. Wherefore, polymer matrix composites can be designed as low density but high-performance materials. Reduction of structural weight has been demanded in transportation industries. Vehicles or public transports with lower weight could increase fuel efficiency as well as load capacity; likewise, low weight aerospace materials resulted in higher flight distance, higher passenger capacity, and lower carbon footprint. Syntactic foam was established with many promising properties like high thermal stability, high compressive strength-to-weight ratio, low dielectric constant and high impact properties. It is one type of composite materials and fabricated by hollow particle fillers insertion in matrix [1-4]. Initial applications of syntactic foam were designed for marine structures due to its outstanding buoyancy properties and later applied on aircraft, sport equipment, furniture [5].

Some frequent used polymer matrix includes epoxy, phenol and vinyl ester. Epoxy syntactic foams are the most widely studied syntactic foam. On the other, hollow particles played important role for the properties of syntactic foams and sometimes referred microballoon [6] or microspheres [7]. Hollow glass microsphere (HGM) is the most famous fillers in syntactic foams because of its lower density with high compression strength [8]. Other famous microsphere has been used in syntactic foams are made by carbon, fly ash cenospheres, ceramics and polymers. The figure of microspheres syntactic foams is shown in figure 1. The hollow particles can be characterized based on their wall thickness (w) and it can have related to a parameter named radius ratio, η, with equation as below

$$\eta = \frac{r_i}{r_o} \qquad (1)$$

Where ri and ro are the internal and outer radii of hollow particles, respectively. Diversity of wall thickness in a constant microsphere's size are shown in figure 2. The parameter η is then related to the microspheres which using the equation as below,

$$\eta = (1 - \frac{\rho_{ms}}{p_g})^{\frac{1}{3}} \qquad (2)$$

Where ρ_g and ρ_{ms} is the density of microsphere's material and density of microsphere, respectively. It is reported that smaller wall thickness for microsphere diameter has lower density value as well as poorer strength properties. Inclusion of thin wall thickness microsphere reduced the strength and modulus of composite because part of the stronger phase is replaced by a weaker phase [9]. Besides, Zhu (2012) has studied four types of HGM, having different density, inserted in epoxy syntactic foams. The results shown a deteriorated thermal conductivity trend for higher HGM content or lower HGM density in (Figure 3), which showing that the performance of the syntactic foam is mainly contributed by properties of HGM [10]. This findings was agreed in many previous studies [11, 12]. On the other hand, Panteghini (2015) reported the dependence of the effective compressive strength on microsphere volume contents can be predicted very well by using modelling of the relation between the matrix defectiveness and the filler mechanical response [13].

Crushing of HGM is an important failure mechanism for compression performance. Therefore, study on compression failure mechanism of syntactic foam was done by Huang (2015) [14]. In the syntactic foam with low volume fraction of microspheres, the distance between microspheres is far and most of the micro-cracks are near to the top and bottom of the microsphere when being pressed. After that, the micro-cracks propagate almost in the longitudinal direction (Figure 4a) where stress loading is applied. By joining the neighbouring voids (crushed microspheres), the micro-cracks become a macroscopic longitudinal crack in the foam, which can be seen on the specimen surface. On the other hand, higher microsphere fillers content in the syntactic foam (Figure 4b) creates more voids in the matrix because more microspheres are crushed in compression. The stresses in the matrix concentrate not only near the top and bottom of the microspheres but also in the connection between the microspheres. Therefore, there are more micro-cracks forming in the matrix in all possible directions. As the foam is deformed, the macro-crack propagates crack in the preferred diagonal direction on the surface.

As conclusion, previous studies show that a diverse set of applications exists for syntactic foams ranging from deep sea vehicles to space vehicles. It is found that the modulus of syntactic foams can be higher than that of the matrix resin, which enables their load bearing structural applications. Applications of syntactic foam are grow rapidly as the research studies continues to explore.

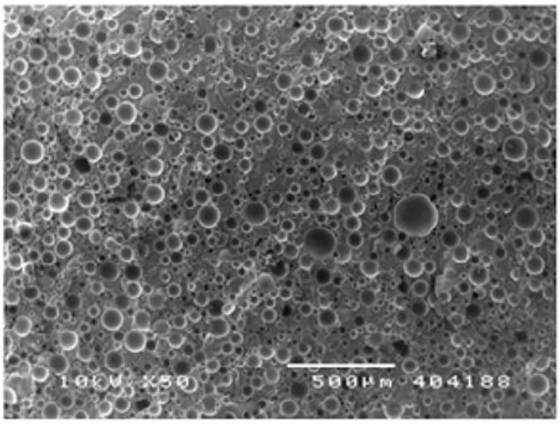

Figure 1: Microspheres syntactic foams

Figure 2: Diversity of wall thickness in a constant microsphere's size (increasing wall thickness from left to right [9].Figure 1: Microspheres syntactic foams

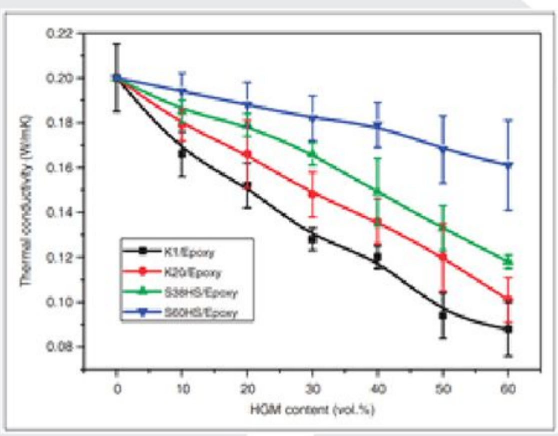

Figure 3: Thermal conductivity of the composite as a function of HGM content at average temperature of 40oC [10].

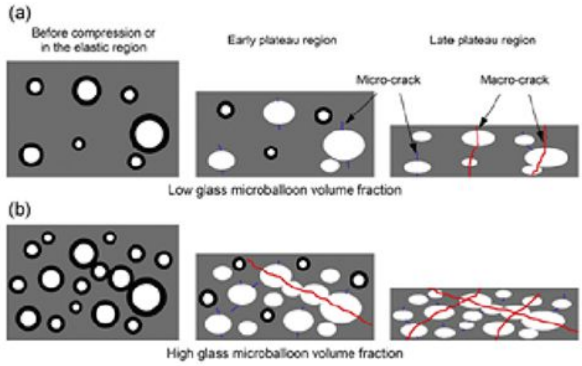

Figure 4: Schematic of the microstructural change in syntactic foams at the elastic and plateau regions during uniaxial compression: (a) low and (b) high glass microspheres volume fractions [14].

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Author :
Dr. Lee Ching Hao
Post-Doctoral

Laboratory of Biocomposite Technology,
Institute of Tropical Forestry and Forest Products (INTROP),
Universiti Putra Malaysia, 43400 UPM Serdang,
Selangor, Malaysia.
Email : leechinghao@upm.edu.my