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Review on Light Weight Foam Composites

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ABSTRACT

Material advancement is nothing but the development of latest technologies. Composite material is one among the advancement of material in replacement for metals and ceramics. In the present era the material is still advanced and had come with new material called light weight material. These high impact light materials have great impact on all engineering applications. Light weight material is formed by addition of light weight hollow filler which is called as Foams. Closed foams are much used in various applications because of its strength, stiffness and insulation. Closed foam which be called as syntactic foams. Few researchers were investigated on various syntactic foams and come up with the better solution as part of application wise. Present study is to focus on the various foam combinations and to reveal the properties, characterization, development, problem facing and applications. This study also helps the researcher to develop the foam for low density applications.

KEYWORDS: *Composite material, Syntactic foams, Microspheres, Mechanical properties*

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1. INTRODUCTION

Particulate polymer matrix composite has realized high potential in structural applications. Weight sensitive components have achieved more attention on marine, aerospace, automotive and structural applications. Closed foam called syntactic foam is known for its low density, high tensile, compression strength and low damage tolerance. Syntactic foam is developed by mixing the light weight filler (microsphere) with the polymer binder. Syntactic foam is used in various applications such as deep submergence vehicles, submarines, Sports accessories, aerospace, automotive [1]. Researchers are developed various syntactic foam combinations and come up with the better properties [2-6]. Polymer matrix syntactic foams gives the better properties in the field of marine and automotive sector rather than with the metallic foams. Syntactic foams also take part in sandwich composites by adding a light weight filler in to the sandwich composites which results as low density, low moisture absorption, high damage tolerant, low thermal conductivity and low dielectric constant properties were in applications like undersea/marine equipment for deep ocean current-metering, anti-submarine warfare, and others use include products in aerospace, automotive and building industries. In comparison to traditional foams syntactic foam is much developed with various combination in various applications with different fabrication technique. Syntactic foam polymer matrix composite plays a key role in development of materials for different applications. The syntactic foam structure is shown below.

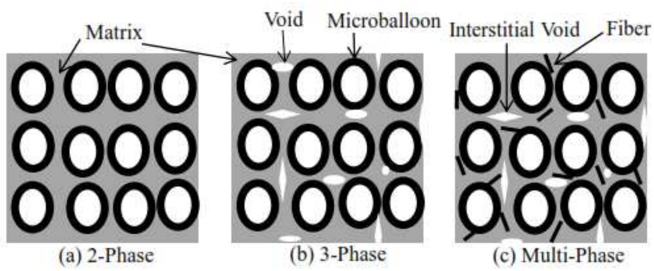

Figure 1. Schematic representation of two, three and multi-phased structured syntactic foams.

2. MATERIALS

Materials are generally required for the development of syntactic foams is microspheres and the matrices. By varying the filler and matrices various combination of syntactic foams are developed. Few literatures it is reveal that the typically used microspheres are glass and fly ash cenospheres which is binded with polymer matrix. The following combination of microsphere and matrices are listed in table 1

Table 1: Microspheres and matrices in syntactic foams

Microspheres	Matrices	Microspheres Diameter	Microspheres Density	Ref.
Glass Microballoon	HDPE	0.45-0.53 μm	0.20g/cc, 0.27 g/cc 0.35 g/cc	[6]
Hollow glass microballoons (HGMs) K20	Nanomer I.28E	25-105 μm	0.2 g/cc	[7]
Hollow Glass Microballoon	Vinyl Ester	0.42-0.62 μm	0.22g/cc, 0.32g/cc, 0.37 g/cc and 0.46 g/cc	[8]
Ceramic hollow microspheres SL75	Potato starch	31–83 μm	0.68 g/cc	[9]
Ceramic hollow microspheres SL300		101- 332 μm	0.80 g/cc	
Hollow glass microspheres (HGM) H20	Epoxy resin	2–150 μm	0.18-0.22 g/cc	[10]
Hollow glass microspheres (HGM) H40		2–100 μm	0.38-0.42 g/cc	
Hollow glass microspheres (HGM) H60		2–95 μm	0.60-0.58 g/cc	
Fly ash cenosphere	Epoxy	63-106 μm	0.92 g/cc	[5]
Cenosphere	HDPE	63-106 μm	0.92 g/cc	[11]
Cenosphere	Aluminium	70-90 μm	0.27 g/cc	[12]
Hollow glass microballoon	Magnesium	11 μm	1.05 g/cc	[13]

3. FABRICATION METHODS

From the past few decades various combination of syntactic foams is developed with different fabrication techniques. Recently the researcher has developed the syntactic foam with the additive manufacturing method. The review of all the various fabrication method is shown below.

3.1. Hand Layup processing

Rizzi E. et al. [14] fabricated the Glass microballoon reinforced epoxy matrix material shows an improvement in mechanical and thermal properties. Shahapurkar et al. [5] was fabricated the epoxy syntactic foam with fly ash Cenosphere analyzed the better wear properties of the foam. Ashrith [15] fabricated the epoxy syntactic foam with Glass microballoon and analyzed drilling parameters.

3.2. Compression Molding

Jayavardhan et al. [6] Fabricated glass microballoons/high-density polyethylene (GMs/HDPE) syntactic foams observed that varying of filler effects tensile and flexural properties of the foam. Jayavardhan et al. [16] fabricated and analyzed the Glass microballoon/ HDPE syntactic foams shows better compression properties for high density microspheres.

3.3. Injection Molding

Bharath et al. [11] fabricated the Flyash Cenosphere/HDPE syntactic foam composite and observed the improvement in tensile and flexural properties with a variation in filler content by 20 -60 vol.%. He also analyzed the improvement of quasi static property of the syntactic foam.

3.4. Additive manufacturing

Balu patil et. al [18] fabricated the cenosphere/ HDPE syntactic foam composite by 3D printing technology. Initially blends of Cenosphere / HDPE is prepared and cut in to pellets later fed through 3D printer and develop the Closed cell foam composite. The tensile property of the 3D printed foam is compared with injection molded sample and reveal that 3D printed sample has better tensile property. Tensile property is improved with increase in filler content.

4. PROPERTIES

From past studies syntactic foams shows the wide applications in all engineering sectors due to its better properties. The properties of syntactic foams are tailored in respect to variation of filler content and matrix. Porosity and the filler distribution in matrix shows the significant affect to the property of the foam. Figure 2 shows the SEM images of the interfacial adhesion and particle distribution including porosities and voids [19]. Matrix porosity can be calculated using Eq. (1) [19].

$$V_{p,gm} = V_{gm} \times V_{c,gm} \qquad \textit{Equation 1}$$

Where, V_{gm} *is the volume of glass microballoon ,* $V_{c.gm}$ *is the volume cavity* $V_{c,gm} = \eta^{3}$, η is the radius ratio.

$$\eta = \left(1 - \frac{\rho_{sf}}{\rho_g}\right)^{\frac{1}{3}}$$

Where, ρ_{sf} *is the true particle density of syntactic foam and* ρ_g *density of the microsphere*

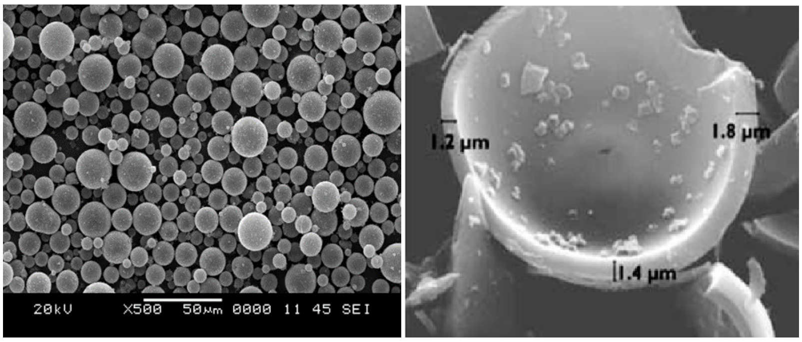

Figure 2: A SEM showing (a) Particle distribution of filler (b) Cut section and porosity of GMB

Density of the syntactic foams is calculated by dividing the mass by volume of the syntactic foams. Volume of the syntactic foam is measured by rule of mixtures Salleh et al.[20]. using Eq. (4).

$$V_f = \frac{W_f}{W_f + (1 - W_f)\frac{\rho_f}{\rho_m}} \qquad \text{Equation 2}$$

Where, W_f is the weight of the filler, ρ_f is the density of the filler ρ_m is the density of the matrix.

Previous study shows that syntactic foams are known for the better compression properties as well as improvement in tensile and flexural strength with the filler damage in the matrix. Fracture of filler material increases the strength and decreases the modulus of the foams Jayavardhana M L et. al [2]. Furthermore, the material structure also affects the property of the syntactic foam. Bharath et. al [17] investigated that breakage of flyash cenosphere in the matrix increases the strength of the material more the filler breakage decreases the strength.

Moisture absorption and the water absorption are the most important parameter for marine applications. Part research is conducted on water absorption and moisture absorption and had come with positive results. The results of the various studies are shown in Table 2.

Table 2: Various syntactic foams investigated results

Syntactic foams	Results	Ref.
Flyash Cenosphere + Epoxy Resin	Syntactic foam is developed by hand layup technique. Investigated the increase in filler content increases the modulus. E40 gives the better properties compared to E60.	[21]
Cenosphere+ HDPE	Syntactic foam is developed by 3D printing technique. Investigated the tensile and flexural properties and compared with injection molded samples. 3D printed sample showed the better properties compared with the injection molded sample.	[18]
GMB+ HDPE	Syntactic foam is developed by compression mold technique. Investigated Quasi static compression gives the better properties compared to the normal compression rate 5mm/sec.	[16]
Cenosphere+ Epoxy	Functionally graded samples are developed by hand layup technique. Investigated the compressive property in which the functional graded sample shows the increase in compressive strength compared with plain foam.	[22]
HGM+ Epoxy resin	Matrix porosity reduced the compressive strength of the syntactic foam.	[10]
GMB+HDPE	Flexural modulus and particle fracture increase with increasing glass microballon while tensile strength decreases with the increase of glass microballon.	[6]
FAC+clay matrix	Processing conditions optimize the development of foams. Compressive strengths do not show clear tendencies.	[24]
Flyash Censosphere/HDPE with a silane treatment	Inclusive of silane treatment to the flyash cenosphere shows the improvement in mechanical properties.	[25]

5. APPLICATIONS [1]

Syntactic foams have first initiated for marine structures as buoyancy material which holds good low moisture absorption and high compressive strength. Later due to the thermal insulation it has been used as insulation for oil pipelines in oil and gas industries. Syntactic foams have spread in all engineering sectors in the few decades. It is also used as a construction material in Remotely operated vehicles (ROVs) and human-operated vehicles (HOVs) used in deep-sea exploration. Syntactic foams used in Boeing and Airbus in the interior of the aircraft. Due to the thermal insulation property, it is used as a space shuttle application and also due to the low coefficient of thermal expansion it is used in space mirror. Syntactic foam is also explored in sports equipment's because of its light weight. Additionally, syntactic foams are used in furniture's, food containers, composite tooling and vacuum forming plug assists, radio equipment's, Blast protection, Fire protection, Electromagnetic Interference (EMI) Shielding/ Electromagnetic Compatibility (EMC).

6. DIFFICULTIES IN SYNTACTIC FOAMS PREPARATION

Syntactic foams showed a better property compared to the conventional material. Researchers faced difficulties in development of syntactic foams. The survival of the microsphere and the microsphere distribution is the main challenge in fabrication of the syntactic foam. Researcher Bharath et.al [17] developed the Flyash cenosphere/HDPE syntactic foam faced difficulties in uniform distribution of filler in matrix and the filler failure. He had come with the optimum solution to retain the filler unbreakable and uniform distribution of filler in matrix. Jayavardhan et al [6] developed the syntactic foam using the compression molding technique, he had come with optimized parameters in which than fifty percent more the microsphere survived and had given a better result. Comparatively he also suggested that injection molding technique is better compared to compression molding. Properties like elastic stiffness, strength, and energy absorption has great effect on heat treatment [25]. Moisture of the microspheres will also lead to the difficulty in fabrication of the syntactic foam.

7. DISCUSSION

The above study reveals the discussion on materials (microspheres and matrix), fabrication technique, applications, parameters which affect the properties and applications of the syntactic foams. The showcased outcome is shown below. a) Researcher are more focused on the selection of filler and the matrix. Polymer and ceramic foam are more focused compared to metallic foam. b) Filler percentage is the most prominent factor in fabrication of the syntactic foam. A past study showed the maximum filler percentage for the proper distribution of filler in a matrix is 60 weight percentage. c) Fabrication technique should be properly selected based on thermoplastic and thermoset matrix. d) Type of Filler and filler percentage have direct influence on the mechanical, thermal and the physical properties of the foam.

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