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Analysis of Voids and Porosity and Its Influence on The Quality of Syntactic Foam Composites

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Abstract

The syntactic foam composite possesses both light and strong qualities. Syntactic foam composite is commonly employed as a buoyant lighting material in amphibious aircraft due to its excellent foaming capability. Composite syntactic foam is utilized because of its ability to efficiently support material drying while maintaining excellent structural strength (mechanical characteristics). In order to ascertain the syntactic compound density, one can determine the composite density based on the ASTM D790 standard. This involves evaluating the porosity calculation and doing a literature review to establish the characteristics of the void. The density of a syntactic foam composite is determined by the density of the filling matrix (microballoon k15), the percentage of porosity, and the identification of voids. The use of the K15 microballoon material will reduce the overall density of the composite because of its substantial structure. The number of small cavities within the composite syntactic foam is indicated by the porosity ratio.Nevertheless, not all apertures present in syntactic foam composites can be classified as k15 microballoon structures, as the composite manufacturing process may result in the formation of air bubbles that become trapped within the composite. The function has no return value. The excessive presence of voids can significantly reduce the density and mechanical strength, leading to a drop in the overall quality of the syntactic foam composite. Porosity analysis is crucial for assessing the quality of drying in syntactic foam composites. The study involved assessing the composite density of syntactic foam with varying concentrations of 0-50% w/w of the k15 microballoon material, following the ASTM D790 standard. The porosity value of the foam was subsequently determined and studied. The findings of this study can serve as a robust point of reference for analyzing the correlation between the density of the reference material and the composite syntactical foam's relative density in different variations.

Keywords: Porositas, Void, Komposit Syntactic Foam

INTRODUCTION

During the era of Industry 4.0, technology is extensively utilised, necessitating the employment of materials that possess a high level of strength, stiffness, and lightweight to adequately support the process. The design of composite materials has shifted its attention towards lightweight properties and cost-effectiveness. These designs can be accomplished through the use of slender structures and more robust materials, or by decreasing material density while yet maintaining the threshold of mechanical strength (Rajan, 2022).The strong composite material has garnered attention due to its exceptional qualities and its contribution to the advancement of robust materials, corrosion resistance, thermal insulation, and electrical conductivity. Syntactic foam composite is a type of composite material that is in high demand in many industries such as maritime, automotive, and aerospace. It possesses lightweight qualities, which contribute to the reduction of material weight and can consequently lead to decreased fuel consumption.

The construction of syntactic foam composite comprises a polymer matrix and a filler (Rui Li et al, 2021). Syntactic fillers Foam composites consist of microspheric bubbles, similar to microballoons, which serve to decrease the weight of the composite and enhance its overall rigidity. The syntactical foam composition possesses a distinct structure that imparts strength, dryness, and excellent thermal insulation due to the utilisation of a robustly structured tiny ball filler. The matrix employed in the syntactic foams composite is an epoxy resin, which serves as a reinforcing agent and enhances the material's rigidity. Microballoons are utilised as a filler for microspheres due to their enclosed cellular composition, lightweight nature, exceptional durability, water repellency, excellent resistance to corrosion, and low thermal conductivity. These properties enable them to survive vibrations in automobiles. The term "floater" is frequently employed in the aerospace and chemistry industries. (Rui li and colleagues, 2021) The incorporation of microballoon material leads to a reduction in material weight due to the presence of empty fillers that are mechanically dispersed within the polymer matrix. These fillers exhibit excellent chemical resistance during the mixing process. The quantification of microballoons is a crucial aspect in the design of composite flow characteristics. It is important to note that the maximum allowable volume fraction of microballoons in composites is 64% v/v of the total material volume. (Ullas et al., 2019). Thus, the set of independent variables consists of the k15 microballoon material with a potential variation of up to 50% v/v.

But in the process of making syntactic foam composites, we often find unpredictable abrasions. Designed syntactic foam composites have a balanced resistivity and strength in which their resilience does not weaken structural strength when applied to automotive fields or floaters on amphibious aircraft. There's air coming in as the mixing process becomes a weak point in the strength and desiccation of the synthetic foam composite material. Based on the above problem, we aim to analyze void and porosity on syntactic foam composites with variables free of variation of addition microspheres.The calculation data in the analysis of void & porosities are obtained from data of composite density syntactical foam empowered with void identification with SEM-EDS analysis. In this analysis we will link the variable density composite syntaxic foam with voids and Porosity that will affect the material drying where the inconsistent drying of material is characterized by the presence of a plethora of voids in the composite Syntactic Foam. The data and analysis in this article is expected to be an important evaluation in making formulations and treatments in minimizing the presence of voids that are expected to make a lightweight syntactic foam composite fabrication with structural strength

METHOD

Materials

The materials used in this study are Microballon K15, Epoxy Resin Bisphenol A-Epichlorohydrin, Epoxydardener EPH 555 Cycloaliphatic Amine, Silicon Rubber RTV 4. The physical values of the materials used in the composite are shown in table 4.2

Research Step

The research process consists of three primary stages: composite synthesis/fabrication, composite analysis, and calculation of analysis outcomes. The analysis employed is based on the density and morphology of SEM-EDS. The calculations employed include composite density, void percentage, and porosity. A qualitative scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS) test can be used to identify void topologies in foam syntactic composites. During the research process, we utilised the independent variable, which refers to the micrisphere fraction of the k15 microballoon, and the dependent variable, which represents the practical density as the outcome of the research. The predetermined parameters are determined according to the ASTM D790 (for composite manufacturing) and ASTM D792 (for density measurement) standards. These parameters include a milling time of 24 hours, an operational conditioning period of 48 hours, a temperature of 23±2°C, a relative humidity of 50±5%, and a mixing speed of 100 rpm.

Synthesis and Fabrication Methods

Method of synthesis and manufacture of syntactic foam composite in accordance with ASTM D790 standard. In this study, composite manufacture was performed with a variation of % volume of the microballoon versus % volume and resin matrix with variations of 0, 10, 20, 30, 40, and 50% V/V.

For example, a fraction of 50% of the microballoon represents 50% of total sample volume is a microsphere of the residual weight of a resin matrice where the resin Matrix weighs 2/3 of the epoxy resin and 1/3 of the poxy hardener. The size of the samples of the syntactic foam composite according to ASTM D790 standard with a sample width of 12.7 mm, a length of 125 mm, and a thickness of 3.2 mm with each variation requires 5 samples as a data uncertainty requirement.

1. The initial procedure involves determining the combined volume of syntactic foam composite specimens and the weight of epoxy resin material, Epoxy Hardener, and Microballon k15 on each individual syntactic foam compound specimen. The standard test method for flexural properties of unreinforced and reinforced plastics and electrical insulating materials is ASTM D790. The calculation of material weight can be achieved by multiplying the density data with the fractional volume fluctuations of the microballoon.
2. In the second step, utilise a digital scale to measure the weight of the resin matrix, the hardener matrix, and the k15 microballoon microsphere. When weighing, make sure to choose a weight measurement that is equal to or more than the weight of the material, taking into account the empty space in the composite.
3. The third stage involves utilising the DLAB Overhead Stirrer Digital LCD gadget to carry out the mixing operation. The initial blending occurs at a velocity of 100 revolutions per minute for a duration of 10 minutes, involving the combination of microballoon microspheres and the epoxy matrix. Subsequently, the second mixing procedure is conducted for a duration of 4 minutes at a speed of 100 revolutions per minute, combining the microballoons and epoxy resin from the initial mixing process with the epoxy hardener. During this second mixing stage, a polymerization reaction occurs, resulting in the solidification and fracturing of the three-dimensional polymer structure. While mixing, ensure that each part of the glass is evenly distributed and take care to prevent the creation of air bubbles.
4. The fourth stage involves the process of solidifying the composite by forging it from a liquid state. The blended outcome is introduced into a mould made of a 250C syntactic foam composite specimen and left for a duration of 24 hours. To prevent the creation of air bubbles and ensure proper moulding, it is important to avoid inserting the mixture into the mould at an inclined table position. After a duration of 24 hours for the moulding process, extract the composite from the mould and place it into the conditioning cabinet
5. Step 5 involves stabilising and improving the adhesive bond between the microsphere and the matrix resin, decreasing moisture, and eliminating any remaining effects of the welding on the syntactic foam compound. The syntactic foams composite is subjected to conditioning at a temperature of 230C ± 20C and a relative humidity of 50% ± 5% for a duration of 48 hours. Once the conditioning process is finished, place the composite in the container and label the sample with its composite label and variation.

Composite Density Test Method

The density of syntactic foam composites is determined through the use of the ASTM D-792 standard. Prior to measuring density, it is necessary to determine the temperature of the water being tested.Subsequently, the specimens to be examined are measured in the atmosphere, with a weight ranging from 1 to 10 grammes. Arrange the wire and sample in a manner that allows the sample to be suspended above the container at a specific distance. Immerse the wire, which already holds the sample, into the container while ensuring that the wires do not touch the wall. Determine the mass of the wire with the sample while it is submerged in water at the identical depth as the previous step. Observe the weights of the wires and samples when they are immersed in water (this is done to measure data on the samples). Conduct test procedures on each specimen as necessary based on the test needs or requirements. For optimal validity of the test outcomes, it is advisable to utilise two specimens for each sample. Assess the test outcomes by juxtaposing them with the theoretical outcomes in order to establish their accuracy. If the initial test results do not satisfy the specified degree of rigidity, further testing with a larger number of specimens may be necessary to achieve the needed level of accuracy

Theoretical and Practical Density Measurement Methods

Theoretical density refers to the calculated and estimated density derived from the composition of raw materials, such as microspheres and resin matrix, with proportions of each component determined according to established mixing standards (Ullas et al., 2020). The computation of theoretical density can be performed using the following formula:

$$\rho_t = \rho_{HGM} * \phi_{HGM} + \rho_{epoxy\ resin} * \phi_{epoxy\ resin} + \rho_{repoxy\ hardener} * \phi_{epoxy\ hardener}$$

The variables in question are as follows: ρ_t represents the theoretical density value, ρ_{HGM} represents the density of the microballoon k15, ρ_{epoxy} represents the density of the epoxy resin matrix, ϕ_{HGM} represents the volume fraction of the microballoon k15, and ϕ_{Epoxy} represents the volume fraction of the epoxy resin. In the aforementioned computation, there are two distinct types of resins: epoxy resin, which serves as a polymer matrix, and hardener resins, which function as a composite hardener. The reduction in density can be attributed to the low density of the k15 microballoon. (Ullas et al., 2019).

The practical density refers to the density value that is determined following the production of syntactic foam composites. The practical measurement of density is conducted according to ASTM D-792, utilising the following formula:

$$\rho_e = \frac{\text{W composite in air} * \rho_e \text{ of liquid}}{\text{W composite in air} - \text{W composite in liuid}}$$

The variables in question are as follows: ρ_e represents the experimental density value, W composite in water refers to the weight of the syntactic foam when measured in air, ρ_e of solvent represents the density of the solution employed, and W composite in liquid represents the weight of the compound in the ethanol solution.

Composite Morphology Analysis with SEM-EDS

An examination of the surface morphology of a syntactic foam composite is conducted to detect the presence of trapped air on the fractured surface of the composite. Composite fractures are derived from the outcomes of flexural mechanical tests conducted on composites. Invariably, air bubbles trapped inside the compound are consistently discovered at the core of the composite. Syntactic foam composite specimens can be effectively dried and coated with Au/Pd metal to minimise the charge filling effect when the sample is placed in a vacuum environment for scanning electron microscopy (SEM). The use of a conductive coating facilitates the transfer of electron charge, hence mitigating the phenomenon of charge accumulation. This study employs the SEM-EDS JEOL JSM-6510LA instrument. One indication of air infiltration into the syntactic foam composite is the presence of amorphous black dots, which will be thoroughly examined in the analysis and research section.

Void Measurement

A composite is a substance composed of multiple components that combine to create unique features. Variations in material composition will also impact its physical characteristics, specifically its density. Theoretical density, a mathematical equation formula, can be used to calculate the density differences of epoxy resins, epoxy hardener, and microballoons. The density of syntactic foam composites can be accurately determined using the ASTM D-792 standard. Theoretical density estimates and empirical test findings demonstrate a decline as the volume percentage of the microballoon increases. Void fractions refer to the disparities between density data that has been theoretically calculated and data that has been experimentally tested. The citation is from Afolabi et al. (2021). Void and porosity are deemed unfavourable as they might result in a reduction in the modulus and strength of the composite. Additionally, larger void percentages of density contribute to heightened moisture absorption and diffusion in composite constructions. The void and porosity investigation in this research use analytical and quantitative descriptive methods, utilising formulae from literature to perform calculations. The outcomes of these calculations are then explained based on pertinent and current scientific sources. The void content can be determined by subtracting the experimental density from the theoretical density using the following equation:Komposit adalah suatu bahan yang terdiri dari dua atau lebih bahan yang menghasilkan sifat baru. The difference in materials will also affect their physical property, namely density. The difference in density between epoxy resin, epoxy hardener, and microballoons can be calculated using a mathematical equation known as theoretical density. The density testing of syntactic foam composites can be calculated practically using

ASTM D-792 standards. Theoretical density values and experimental test results indicate a decrease in tandem with an increase in microballoon volume fraction. The difference between theoretical density data and practical testing is referred to as void fraction (Afolabi et al, 2021). Void and porosity are considered undesirable since they can cause a decrease in modulus and strength in composites. Higher void fractions than density also contribute to increased moisture absorption and diffusion in composite structures. The methods employed in this study for calculating void and porosity analysis are analytical and quantitative descriptive. These methods utilise formulas derived from literature sources to calculate and explain the results based on relevant and up-to-date scientific references. The calculation of void content can be determined by calculating the difference between the theoretical density and the experimental density, as shown in the equation below:

$$\mathrm{Vv} = \frac{\rho_{th} - \rho_e}{\rho_{th}}$$

The variables used in this equation are Vv for the volume of unoccupied space, ρ_e for the actual experimental density, and ρ_{th} for the theoretical density. The void content is determined by comparing the theoretical density and the measured density of the composite, and is expressed as a percentage of the theoretical density.

Regarding the absence of content, the derivative data refers to the relative absence of content, and this relative absence of content is a measure of the percentage of voids in relation to the volume of sodium material. (Tagliavia et al., 2009). Relative void content refers to the measurement of empty space or pores within a composite material relative to its mass. This parameter has a direct impact on the mechanical properties of the composite. The relative void percent of the composite syntactic foam can be determined using the following equation:

$$\phi_p = \frac{\mathrm{Vv}(\frac{\rho_{th}}{\rho_m})}{1 - \phi - \mathrm{Vv}(\frac{\rho_{th}}{\rho_m})}$$

Where the value ϕ_p is a relative void value, Vv is a composite void, ϕ is a variation of the addition of the microsphere to the composite, ρ_{th} is the theoretical density, and ρ_m is the measured density that is measurable during the practicum.

Porosity Measurement

The primary distinction between porosity and void is in their definition as empty spaces. Porosity specifically refers to the failure of the resin matrix to fill the microparticles in a syntactic foam composite, resulting in the formation of voids. These voids can be considered as true vacuums due to the entry of air into the composite. Porosity is the measure of the amount of vacant space within a material compared to its overall volume. For the sake of greater clarity, let us examine the equation used to calculate porosity:

$$\text{Porosity} = \frac{V_v}{V_m} x\ 100\ \%$$

The value V_v represents the volume of empty space, often known as the volume void, while V_m represents the total volume of material.The V_v data is derived from table 1, whereas the total volume of the composite material is calculated according to the ASTM D792 standard by calculating the difference in weight between the composite in air and in a solvent (alcohol).

RESULTS AND DISCUSSION

Conducting a study on the correlation between density analysis and porosity in syntactic foam composites, utilizing the fundamental data shown in the table below :

Table 1. Density and Void Data of Syntactic Foam Composite

Sample Code	Theoritical Density	Experimental Density	Volume (mL)	Void Content	(%) Porosity	Relative Void Content
MB15-0%	1.1000	1.1529	0.80414	-0.0481	-4.5881	-0.0440
MB15-10%	1.0050	1.0310	0.94216	-0.0259	-2.5203	-0.0245
MB15-20%	0.9100	0.9313	0.95778	-0.0234	-2.2856	-0.0226
MB15-30%	0.8150	0.8230	0.94092	-0.0098	-0.9734	-0.0099
MB15-40%	0.7200	0.7346	1.0851	-0.0203	-1.9901	-0.0207
MB15-50%	0.6250	0.6311	0.48438	-0.0097	-0.9640	-0.0105

Note: MB15-0% refers to Mikroballon K15 (the type of microballoon used) and the microballoon fraction in the syntactic foam composite is zero percent.

Table 2. Data Sheet Physical Properties of Syntactic Foam Composite Assembly Material

Material	Density (gram/mL)	Another Physical Properties		
Mikroballon K15	0.150	Wall thickness (µm) 0.70	Microballoon size (µm) (mean diameter) 43.6	Isostatic crush strengh 2 MPa
Epoxy Resin	1.15	Cure Time (23 °C) 24 hours	Viscosity (mPa*s/25 °C) 900	Storage (sealed, at 15 °C) 12 month
Hardener	1	Flexural strength 130 MPa	Processing time for 100 g mixture 90 minutes /20 °C	Storage (sealed, at 15 °C) 12 month

Density Analysis of Syntactic Foam Composite

The syntactic composite density is determined by various factors, including the density of the resin matrix, the density of the k15 material in the microballoon, the amount of voids, and the mixing factor during specimen preparation. The composite syntactic foam is characterised by two distinct densities: the theoretical density and the actual density. (trial). Using the data from table 1, a straight line graph was constructed to determine the regression of linearity and the disparities between the theoretical and practical density. The graph is displayed below:

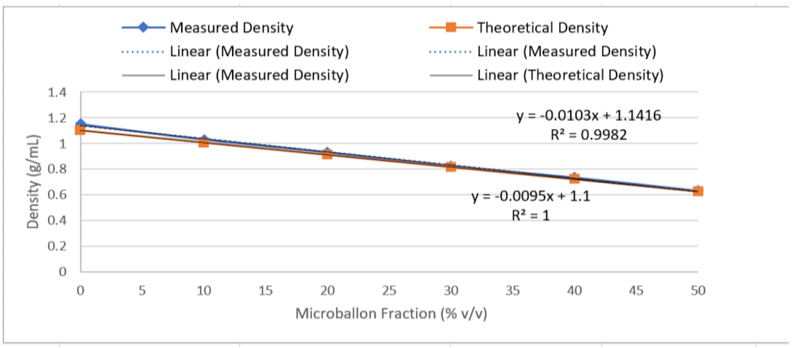


Figure 1. Graphic Value of Density Theory and Practice of Syntactic Foam Composite

The graph above illustrates a significant disparity between the actual density and the theoretical density. In theory, the practical-density values should be similar to or slightly lower than the theoretical density. Theoretical density values are higher than practical density values because theoretical densities are derived solely based on mathematical formulas, without considering the presence of voids and porosity. Experimental density drop, in comparison to theoretical density, is typically attributed to the high presence of void air content and the agglomeration between the resin matrix and the k15 microballoon filler.

However, in reality, the practical density exceeds the theoretical density. In the investigation conducted by Li et al. in 2020, a higher practical density was observed compared to the theoretical density. Pollution during the synthesis and composite manufacturing process, excessive compression procedures, and mass retention in syntactic foam composites can generate imbalances in density data. Additional factors contributing to the issue include the presence of porosity in the molecular foam compounds and the occurrence of mechanical melting processes that result in the fracture of the polymer microsphere (k15 microballoon). (Li et al., 2020). The causes of abnormalities in density data will have an impact on the porosity data discussed in the following section.

Void Identification Using SEM-EDS Morphology Analysis

The composite syntactic foam contains two distinct types of pores, which are found within the microspheres and the matrix resin (Li et al., 2021). The pores present within the micro-sphere, which are enclosed within the structure, are anticipated to decrease the density and facilitate the drying process of the composite material. Furthermore, the presence of unwanted pores in the matrix resin leads to a decrease in the composite density in an irregular manner, resulting in a reduction in the mechanical strength and the high voltage concentration point of the syntactical foam. (Tagliavia et al., 2009). The matrix resin has void pores, which are generated during the mixing process between the microsphere and the resin. This allows air to enter the resin matrix and subsequently form air bubbles within it. This results in a reduction in the actual density compared to the theoretical density, as air becomes trapped inside the matrix material during the mechanical mixing process of microballoons in a resin matrix, creating voids. Figure 2 illustrates a void that is present in the syntactic foam composite.When the theoretical density is lower than the practical density, its value is negated. The value of the void can be observed in table 1. The detection of voids in this study is accomplished using SEM analysis, as depicted in images 2a and 2b.

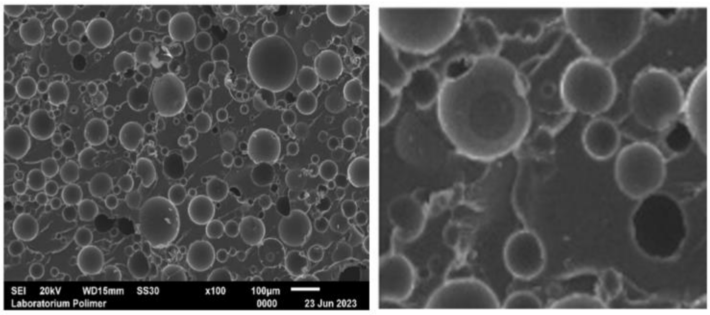


Figure 2a. Surface morphology of SEM 100x on composite variation of foam 30% V/V (left) **2b**. Void identification magnification of composite (kanan)

Detection of empty spaces using the surface morphology technique The purpose of SEM is to examine the surface characteristics of the sample with a high level of detail, allowing for the visualisation of microspheres, resin matrix, pores, and voids present on the surface of the syntactic foam composite. The composite fraction sample of syntaxic foam is subjected to SEM analysis in order to reveal the condition of cracks on the material surface (Tagliavia et al, 2009). In Figure 2a (left), the SEM examination reveals the morphology of resin matrices, which exhibit a smooth and uniform surface. The SEM also shows the existence of microballoons, which appear as small spherical structures. Additionally, voids are observed as empty spaces on the composite surface. (Ullas et al., 2020).

On figure 2b is a manual magnification of figure 2a which aims to clarify the presence of void in a syntactic foam composite. Void tends to be seen with black dots with irregular shapes and positions where a black dick indicates the absence of filling material on the compound. A void will increase the material's fragility thereby decreasing the composite's mechanical strength. In morphological analysis, identified misrospheric dimensions on syntactic foam composites have values ranging from 4.60 mm to 5.00 mm with an ellipsoid shape, the k15 microballoon microsphere has a white phase where more and more variations of microballons make the syntaxic foam compound white, and more microballon fractions of k15 will increase uniaxial stress causing increased elastic deformation. (Qiao et al, 2022)

Investigation of the absence of material and the presence of empty spaces in syntactic foam composites

The left side of Figure 2.a illustrates the existence of a void within the material matrix, which is then expanded by the void component depicted on the right side of the image. Figure 4.2 on the right depicts a void with an irregular yan shape and a black hue. This figure also illustrates that the void is consistently dispersed across the matrix that surrounds the microballoon material. The information presented in table 4.2 can be visualised as a graph illustrating the impact of including the micro balloon microsphere k15 on the voids and relative void content, as depicted in the figure below :

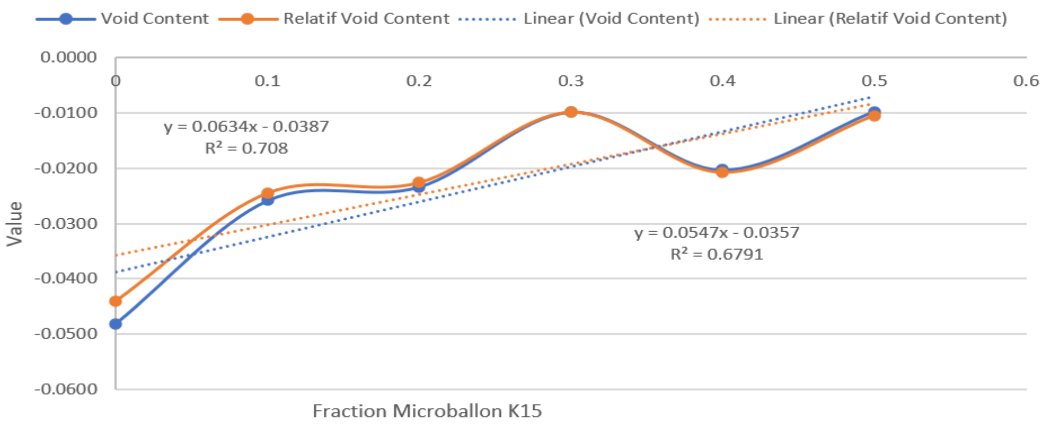


Figure 3. Graphic Effect of the K15 Microbabllon fraction on Void and Relative Void Composite Content Syntatic Foam

Table 1 displays data values for void and void negative content, calculated using formulas from many relevant journals. The progressively higher negative relative void value with increasing microballoon variation indicates that the measured mass of the composite material exceeds the theoretical mass. This shows that a composite material has a lower porosity than what is theoretically predicted. A higher void content relative value can indicate a higher density than anticipated, therefore indicating greater quality. (Tagliavia et al., 2009). This can be attributed to the disparities between theoretical density and practical density, with the practical intensity surpassing the theoretical density (Yang et al, 2018).A scarcity of gaps and cavities may suggest that the materials possess a higher density than intended, hence elevating the overall composite density.

Analysis of Porosity in Syntactic Foam Composites

Porosity refers to the proportion of empty space, or pores, in relation to the overall volume of a composite material.The citation is from Qiao et al. (2022). The presence of pores in the syntactic foam composite can impact the mechanical properties, density, compression behaviour, electrical properties, and moisture absorption capacity of the composite material. The compound's high porosities suggest a significant amount of vacant space, which will serve as the initial site for cracks and material failures during mechanical testing. (rigidity and flexibility). Porosity can arise from various sources, including the particle distribution during the contact between the resin matrix and the microsphere, the mixing process, the combining process, the utilisation of non-homogeneous particles, and the presence of voids within the particles. (Tagliavia et al., 2009). In the event that the connection between the resin matrix and the microsphere is suboptimal, a void will develop between the two. Porosity is characterised by the presence of linear voids, and the greater the voids, the higher the composite porosity. Additionally, the computation of porosity is presented in table 1. Subsequently, a graph illustrating the impact of adding microballoon k15 microspheres on the composite porosities of syntactic foam is shown in figure 4 below:

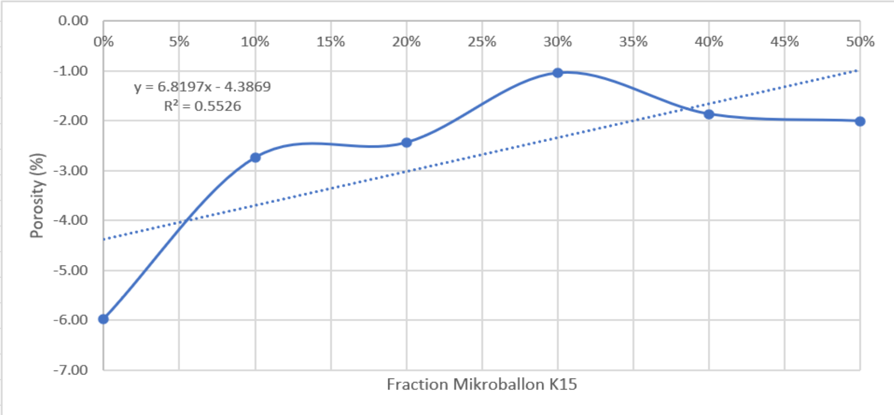
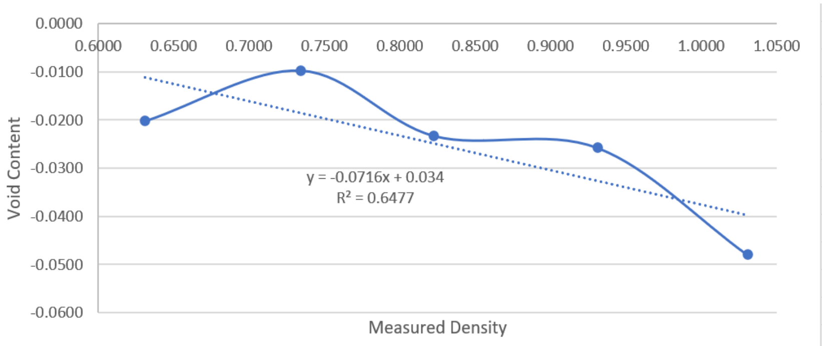


Figure 4. The influence of the K15 fraction on the value of % Composite Porosity

The provided diagram depicts a graph representing the impact of incorporating a microballoon on the proportion of negative porosity, as indicated by the negative trend observed in the void graph of figure 3. The presence of negative porosity in syntactic foam composites indicates that the material possesses a higher density than expected, with a highly compact structure and absence of void spaces (Qiao et al., 2022). Negative porosity readings may arise when the observed density exceeds the theoretical density. This phenomenon might arise as a result of various factors, including inaccuracies in the calculation of theoretical density, inadequate manufacturing of foam syntactic composites, the utilisation of mechanical mixers, and the existence of cracks in the k15 microballoon microsphere (Li et al, 2021). This can lead to a weight gain that will impact the mechanical qualities. Furthermore, the presence of a negative porosity value suggests inadequate loading of the microsphere in the syntactic foam composite, resulting in a denser structure than intended for the composite material.

Practical correlation between density and void content in syntactic foam composites

The density of the syntactic foam composite is directly influenced by the presence of voids. Augmenting the density of the syntactical foam compound will result in a diminished decrease in void within the composite. The graph below illustrates the second phenomenon in this investigation. Investigation of the absence of material and the presence of empty spaces in syntactic foam composites



A direct correlation exists between the practical density and void of the composite syntactic foam, such that a decrease in void results in a decrease in density. According to Yang et al. (2018), the practical density is higher than the theoretical density, resulting in a negative void content. This can lead to adverse consequences, such as the composite type having a larger weight than intended, so diminishing the material's effectiveness as a lighting agent. Conversely, a negative void value enhances the strength and capacity of the material to endure loads (Ferreira, 2011).

CONCLUSION

The mechanical strength and dryness of a material significantly influence the composite quality of syntactic foam. The presence of pores in the K15 microballoon microspheres results in dry syntactic foam composites. However, the density of the foam often experiences an uneven drop due to voids and porosity. Empirical composite density estimates yield higher values than theoretical density computations, making the rupture of pores more predictable. Morphological examination using SEM-EDS reveals the presence of voids in the mixing process, characterized by irregularly shaped black spots. As the data for the variation of a K15 balloon increases, the proportion of voids and porosity also increases. This is due to the existence of empty voids in the resin matrix and the K15 microballoon microsphere. Porosity and void affect practical density values. Positive porosities result in fewer voids than expected and more pores filled with air or gas. Density, void, and porosity influence the drying process of syntactic foam composite materials. If the third variable is not connected, it can result in elastic deformation and reduced mechanical strength. To reduce empty spaces, it is essential to enhance the mixing quality. Uniform mixing processes allow air to enter, affecting the stability of the soil surface during soldering. Ensuring a homogeneous mixing process ensures the evenly distributed non-composite liquid throughout the mould. Hence, the composite syntactic foam possesses a consistent (linear) density that is lower than the theoretical density.

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