International Journal of Scientific Research in Mechanical and Materials Engineering
© 2021 IJSRMME | ISSN : 2457-0435

Manufacturing of Aluminium Composite Reinforced With Silicon Dioxide and Bagasse Ash and Characterization and Investigate the Mechanical Properties

Senait Menbere[1], Prof. Shanta Kumar[2], Mr. Henok Yilma (Phd)[2]
[1]Department of Mechanical and Industrial Engineering Addis Ababa institute of technology, Ethiopia
[2]Department of Mechanical and Industrial Engineering (AAiT), Addis Ababa, Ethiopia

Article Info
Volume 5, Issue 4
Page Number : 55-76

Publication Issue :
July-August-2021

Article History
Accepted : 10 Aug 2021
Published : 20 Aug 2021

ABSTRACT

Silica sand and sugarcane bagasse-ash (BA) consuming as reinforcement in manufacturing of an Aluminum alloy (Al-2024) based matrix hybrid composites. The Aluminum matrix hybrid composites; fabricated by stir-casting method at 750 °C. Casting was performed in induction graphite crucible furnace and stainless steel stirrer having circular slots of diameter of 10mm and length of 500mm also the stirring blade at the end of the steel with 2mm thickness 40mm length and 20mm width. Addition of SiO2 and BA as reinforcement with nine compositions proportions, in the first case 5%, 10%, and 15% BA with Al2024. In second case 5%, 10%, and 15% Silica sand with Al2024. In third case 5%, 10%, 10% BA and 5%, 10%, 10% silica sand with Al2024. The fabricated composite was solution heat-treated (T3). The influence of the reinforcement has identified through different mechanical and microstructural tests. The mechanical properties measuring performed with Rockwell hardness and tensile strength, bending/flexure with universal testing machine. Samples have been prepared as per the ASTM E10, E8 and E290 standards respectively. The selected application of aircraft fuselage structure data used for the result as a sample. The application modeled and analyzed with SOLIDWORK 2017 and ANSYS 2020 R2. The Result shows that there is bigger outcome of reinforcing bagasse-ash with different composition in aluminum matrix reinforced and heat-treated composites. On the third case more improved mechanical properties have been achieved as compared to case one and two of BA & SiO2 combination. It shows that the selection of BA & SiO2 as reinforcement has one of the most significant criteria for the fabrication of aluminum matrix reinforced composites.

Keywords : Al-2024, silica sand/bagasse ash, ASTM, ANSYS 2020 R2.

I. INTRODUCTION

Recently, composite materials are largely uses in the area of structures, high performance racing cars, automobile, and helicopters most recently for the application of commercial airplanes. Composite materials are usually a mixture of dual or extra unlike constituents have different characteristics which is called as matrix & reinforcement are used together to develop and achieve best or new set of characteristics properties of materials. Most frequently used reinforcements are like ceramics, ashes etc. as a type of fiber, whiskers or as a particles uses in metal matrices. Common types of matrices are Al, Ti, Mg, and Cu. Some of commonly used ceramic reinforcements are SiC, Al_2O_3, BC, SiO_2 and WC etc. Among several discontinuously dispersed solids used, the waste ash (which consist high amount of silica & alumina) is the most low density & low-cost reinforcement accessible in massive amounts as a dense unwanted byproduct.

As a General here is three categories of known composites are namely Metal Matrix composite (MMCs), Polymer matrix composite (PMCS) and ceramic matrix composite (CMCs). From the last couple of decade metal matrix composite, have found worldwide application with a significant class of weight and design proficiency for structural material, which are assigned in every range of engineering applications. MMCs are composite materials always having at least two or more material one is metal and another is unlike metal or material. As mentioned above the most common type of matrixes Al, Ti, Mg, Cu. Mostly, matrix material mixed with the metal or material to increase the mechanical characters like strength, hardness, corrosion resistance, wear resistance and so on[1]. Therefore, composites with ash as reinforcement expected to beat the cost problem for broad uses in small engine and automotive applications.

Metals alloys like Titanium, Magnesium, and Aluminum are a good lightweight, very high temperature performance, which make them suitable to structural application. In these days, most researches are in such applications areas mostly focused on aluminum matrices composite material since it largely uses in structural application of aerospace industry. The Al-alloy reinforced by many ceramic particles to develop the mechanical and tribological property. Such properties to be improved are lower density, reduced weight ratio, high strength, better malleability, good machinability, good corrosion resistance, increased wear resistance, better hardness, good thermal & electrical conductivity[2][3] These MMCs fabricated by liquid (solid) state method, to fabricate MMC the process selection also shows a very important role. Liquid state method is mostly in expensive way for producing MMCs ,in general stir casting of liquid state technique is engaged because of its homogeneousness mixing & inexpensive method of casting compare with other methods [4]. In this paper the composite, which produced with stir casting method, give various mechanical properties like the strength of tensile, flexural & hardness properties. The Al2024 reinforced with silica sand and Bagasse ash particle with the volume fraction ratio (5%vf, 10%vf & 15%vf) produced. The investigational result shows that the identical dispersion of reinforcements in the matrices of Al2024 leads to increase in the composite mechanical strength as the reinforcement increases by the volume fraction ratio.

II. Method and materials

Aluminum 2024

Aluminum alloy 2024 is an aluminum alloy, with copper as the primary alloying element. It is uses in applications demanding high strength to weight ratio, as well as good fatigue resistance. It is weldable only through friction welding, and has common machinability. Because of its poor corrosion resistance, it is often clad with aluminum or Al-Zn for protection, although this may decrease the fatigue strength. Due to its high strength and fatigue resistance, 2024 is widely used in airplane structures, especially fuselage and wing structures under tension.

The aluminum 2024 material collected from Ethiopian airlines as a sheet metal form.

Table 1 chemical composition of Al2024

No.	Al	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Pb	Sn	Ti	V	Zr
Avg	93.06	0.028	0.168	>3.33	0.441	>2.67	0.014	<0.005	0.151	<0.01	<0.005	0.011	<0.001	<0.002

Reinforcement preparation

- **SiO_2**

- The silica sand material collected from Addis Ababa bottle and glass manufacturing Share Company. And it filtered with sieve at < 63μm. Then before it mixed with the molten metal it preheated at 700 ^{0}c for a better result on strengthening the composite. The material used in this work was al2024 alloy the SiO_2 as reinforcement particulates with Different volume fraction ratio. The SiO_2 particulate used as a second phase reinforcing particle in the alloy matrix added on the liquefied al2024 by different weight portion such as 5%, 10%, and 15%. The mesh size of silicon dioxide particulate is < 63 microns.

- **Bagasse ash**

The bagasse, which is a waste material of sugarcane, collected from wonji sugar factory, located 110km far from Addis Ababa.

Preparation of bagasse ash

First, the bagasse washed with water to remove the dust and other deposits. In addition, it dried for 4 days with direct sun light until it gets fully dry [5]. Next, it burned at room temperature and it form bagasse ash. Then it sieved at < 63μm particle size.

Table 2 chemical composition of silica sand and bagasse ash

Compound name	SiO_2	Al_2O_3	CaO	Fe_2O_3	Na2O	MgO_2	K_2O	P_2O_5	MnO	TiO_2
Avg. SiO2 Composition by %	93.92	3	0.07	2.01		0.13	0.09			
Avg. BA Composition by %	78.07	9.05	2.437	3.27	0.41	0.9	3.69	0.95	0.13	0.39

Additives

Magnesium powder were added to the composite in small constant amount to each cast because of the property of magnesium which gives the better wettability to the molten composite and good machining performance to the metal matrices composite. it also reduces the surface rigidity and at hand avoids the rejection of the particles from the melts. Though, the interaction of the particles of an Aluminum composite would change with adding Mg that could damaging to the mechanical properties of the composites [6]. Wettability and reactivity determine the quality of the bonding between the constituents and, thereby, greatly affect the final properties of the composite material[7].

Salt (Duge) The salt added to deoxidize the molten composite and to remove the slag from the molten composite

Table 3 Composition by volume fraction ratio

Composite	Volume fraction ratio of materials
1	Al2024
2	Al2024 + Bagasse ash 5%
3	Al2024 + Bagasse ash 10%
4	Al2024 + Bagasse ash15%
5	Al2024 + Silica sand 5%
6	Al2024 + Silica sand 10%
7	Al2024 + Silica sand 15%
8	Al2024 + Bagasse ash 5% + Silica sand 10%
9	Al2024 + Bagasse ash 10% + Silica sand 5%
10	Al2024 + Bagasse ash 10% + Silica sand 10%

Sand mold preparation

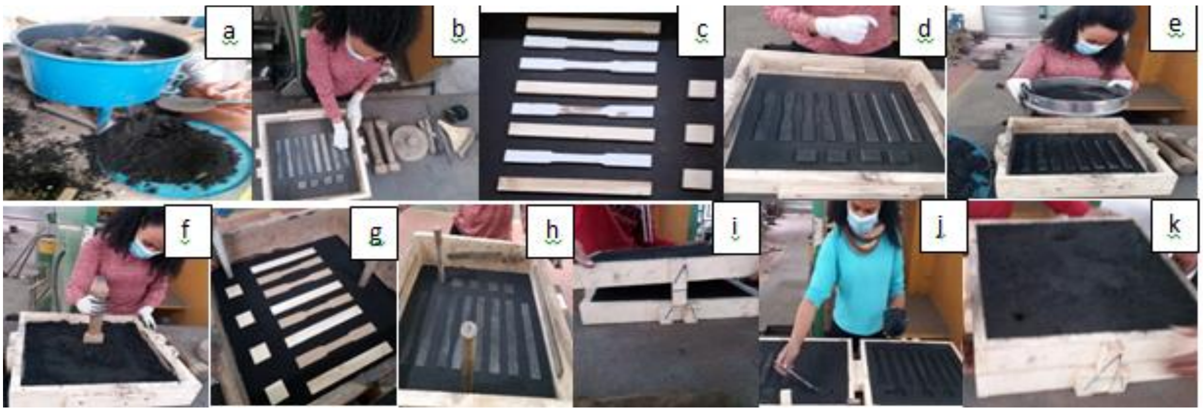


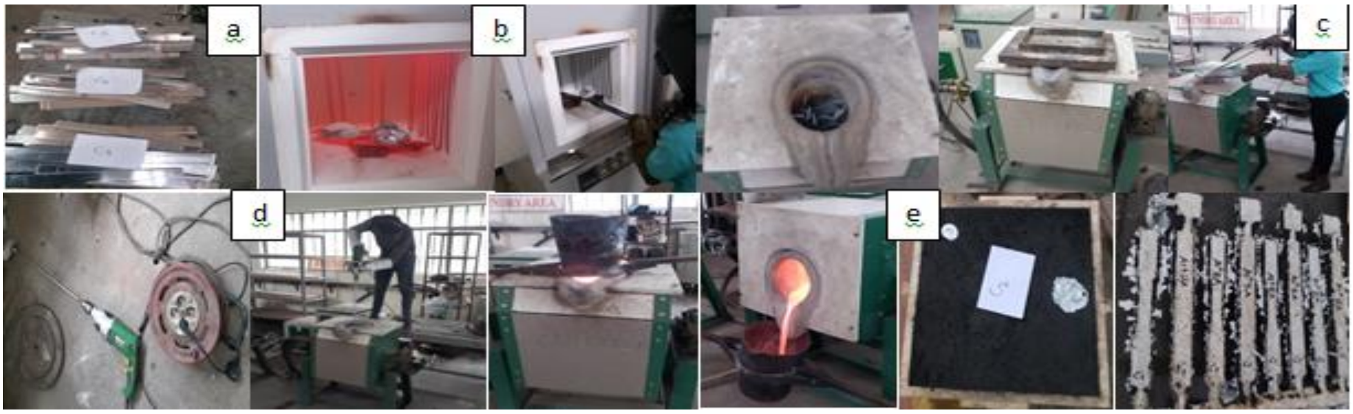
Figure 1: a) Mixing the sand with needed proportion in mixer

b) Full instruments to make sand mold
c) The fabricated wood pattern, of the desired part and split it down inside the mold.
d) Screening graphite on pattern to avoid attachment of wet sand and the patterns
e) Filtering smaller sand for the best front phase smoothness
f) Place the bottom half of the pattern, called the drag, in a box called a flask.
g) Apply a release coating to the pattern, fill the flask with sand and then compact the sand by ramming.
h) Risers and a sprue are then installed in the cope half of the flask.
- The sprue is where liquid metal enters the mold.
- The risers are essentially reservoirs for liquid metal that keep the casting supplied with liquid metal as the

metal shrinks and contracts on freezing.
i) After installing the spru and raiser, the cope half then packed with sand and rammed.
- Turn the drag half of the mold over and place the top half of the flask on top of it.
- The top half of the pattern cope is then place over the drag half of the pattern and release coated.
- Then Create ventilation holes by thin metal.
j) The two halves separate and the remove patterns.
- If hollow sections are required, a sand core placed in the drag half of the mold.
- In addition, gating system cut into the sand on the cope half of the mold.
- Then, painting by graphite and molasses with brush for a better surface of specimen after casting.
k) After 3 days of drying, the two halves are reassembled and clamped or bolted shut for casting.

Aluminum 2024 alloy reinforced with SiO_2 and BA Casting process procedure

- Stir casting method performed according to [8][9]



a) Al2024 cut in to pieces
b) Preheating the reinforcement in heat treatment furnace
c) Mixing the reinforcement into molten aluminum alloy
d) Adding salt and pure magnesium into the composite and removing the slag Stirring the reinforcement with the molten alloy by stainless steel stirrer
e) Pouring the molten composite into the mold and taking out after 3hr

Figure 2: a) – e) the full steps in manufacturing the composite test specimens

Heat Treatment - T3

Heat Treatment Process (temper T3 heat treatment) of cast specimen's offer rise in hardness and other mechanical properties, which is often necessary for many uses. The T3 heat treatment has a three-step process. The castings first allowed heating solution at 5000c for 9hr and then immediate quenching (w temper) at cold-water media. Next, it cooled at room temperature for 3days[10].

Figure 3: Heat treating and immediate quenching with cold water to the specimen at Ethio-Chaina engineering collage lab.

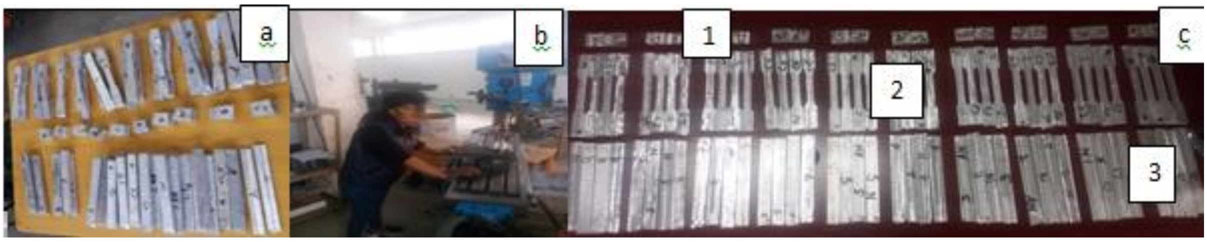


Figure.4: a) test specimens before machining

c) Specimens machining with drill mill machine at Ethio-China engineering college

b) Test specimens after machining

1) Hardness & optical microscope test specimen 2) tensile test specimen 3) flexural test specimens

Tensile Strength Test

Tensile testing is a basic materials science test during which a sample subjected to a controlled tension until failure it also known as tension testing. The results from the test usually used to choose a material for associate application, for quality control, and to predict how a material can react under very different forces. The tensile test [11], was followed while preparing the tensile test specimens for aluminum composite material test. Properties that obtained from this test are Ultimate tensile strength, maximum elongation and reduction in area. Properties like young's modulus and yield strength also are determined from these measurements.

For tensile test, the prepared specimens (rectangular cross section 57 x 3 mm^2 & length 200 mm) carried out utilizing Universal Testing Machine. Four specimens tested in this machine.

Figure 5: (a) typical specimen under tensile strength test and Specimens of tensile test

Flexural bending test

Flexural bending test (3-Point bending test) is one of the simplest bending tests used to determine flexural strength of a material. Flexural strength is the ability of the material to resist bending loads applied perpendicular to its longitudinal axis. The stresses causes by the flexural load are a combination of tensile and compressive stresses. Bending test were tested in the UTM machine exist in Defense University Engineering Collage Lab. ASTM B290, was followed while preparing the 3-point bending test specimens for aluminum composite material test. According to this standard, the dimension of each specimens was 2.5 mm thickness, 20 mm of width and 200 mm overall length. Four specimens tested in this machine.

Figure 6: (a) Typical specimen under bending test on UTM, and Specimens of bending test.

Hardness test

Hardness test measurement carried out on the base metal and composite samples by using standard Rockwell hardness test machine. The Rockwell scale is a hardness scale based on indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. Rockwell hardness measurements carried out in order to investigate the influence of particulate volume fraction on the matrix hardness. First, the specimen surface polished until it get smooth surface. For each specimen, tests taken at different point like two times of the diameter of the other test point. The applied Load was 100 kg and ball indenter used was 1/16' as the Aluminum Rockwell hardness test standard. Advantages of the Rockwell hardness method include the direct Rockwell hardness number display and fast testing time.

The hardness of unreinforced and reinforced Al2024 composite was determined according to ASTM E10at room temperature of 20 ^{0}c.

Hardness test Rockwell scale B, indenter 1/6” ball Pmajor 100kg

HRX = Rx = M- $\frac{(h2-h1)}{0.002}$

Where M = 130 for B, E, M, R etc. scales

Figure 7: Rockwell hardness test

Micro structural analysis

The optical microscopy test performed to analys the morphology of the base metal and the composite. Before testing the specimen hade to polished in different glass paper (abrasive paper). The polishing process was continiud untill the specimen get the clear face (like mirror). The materials used to polish in different step are 120,150,180, 220,CC400,1/0, 2/0 electro coated waterfroof abrasives. After applied those polising steps the specimen washed by MP-2B grinder polisher with the addition of water and by using grade II, III abration gel. Finally the specimen washed by sodium chlorid and get dry for optical microphg test.

Figure 8: a) Grade II & III Polishing gel b) MP-2B Grinder Polisher Engineering Collage Lab. c) Optical microscope measuring instrument d) performing optical microscopy test

Application Specification/dimension

Analytical data

Considering the fuselage structural part fuselage skin and standing from this the aim of this research paper to design, static analysis, and testing properties based on the experimental test results. The experimental test specimens were prepared as per ASTM standard. The aluminum ceramic matrix composite fuselage skin designed with SOLIDWORK 2017 software, which is compatible with ANSYS 2020**R2** and imported to FEA, which will have a high strength to weight ratio and lower stress than that of the current Al2024.

Structural Analysis: Hoop Stresses

Hoop stresses are the result of cabin pressure loads acting on the fuselage skin and frames. This pressure force is a byproduct of the pressure differential between atmospheric pressure and internal cabin pressure, taken into account when sizing the skin, and frames. Using the pressure load, radius of the fuselage, and the thickness of the skins, the hoop stress calculated using Equation 1.

Types of load, which are, applied on the fuselage structural parts

According to [12] the fuselage dimension and the applied force calculated to analysis the von-mises stress and deformation of fuselage skin. The Calculation of force a differential pressure from 20psi – 110psi considered for the current case. Due to the internal pressurization of fuselage passenger cabin, the hoop stress would develop in the fuselage structure. The tensile load developed inside the fuselage of the skin corresponding to pressurization considered for the linear static analysis of the skin. The cabin pressure converted into force and analyzed in this cases.

The corresponding pressure value in SI unit is N/m2. The calculated load tabulated in table 4.

$\sigma hoop = \frac{pd}{2t}$ ……………………………………………………………………………………….eq. (1)

Where, P = the load in N/m2,

d = the diameter, and

t = was the thickness of fuselage skin.

Substituting P from above, d = 5.64m, and t = 0.005m we find the hoop stress values. The hoop defined as,

$\sigma hoop = \frac{F}{A}$……………………………………………………………………………………………….eq. (2)

Where, F = the force value which has to be entered for analysis, and

A = the area.

A = (Length of fuselage * Thickness)

= (15 * 0.005) = 0.075m2

$F = \sigma hoop * A$……………………………………………………………………………………eq. (3)

The applied force derived from hoop stress equation.

Table 4 calculated load (N)

Pressure (psi)	Pressure($N/m^{2)}$	Load (N)
20psi	137,895.145864	5,832,964.67
30psi	206,842.718796	8,749,447.005
40psi	275,790.291728	11,665,929.34
50psi	344,737.86466	14,582,411.675
60psi	413685.437592	17,498,894.01
70psi	482633.010524	20,415,376.345
80psi	551580.583456	23,331,858.68
90psi	620528.156388	26,248,341.015
100psi	689475.72932	29,164,823.35
110psi	758423.302252	32,081,306.542596

Table 5 Mechanical properties of Al2024 and Al2024/ Silica Sand/Bagasse Ash composite

Materials	AlCu T3		AlCu/SiO2/BA	
Mechanical properties	Values	Units	Values	Units
Density (ρ)	2.6555	g/m3	2.56	g/m3
Young modulus (E)	70.887	GPa	78.894	GPa
Poisson's ratio (v)	0.33		0.3	
Tensile yield strength (σy)	214.22	MPa	392.67	MPa
Ultimate tensile strength (σt)	320.22	MPa	560	MPa
Behavior	Isotropic		Isotropic	

For Aluminium, alloy 2024-T3 we have Yield strength = 214.22 MPa

Factor of safety considered = 2

Therefore, Allowable stress = 214.22/2

Allowable stress = 107.11 MPa.

- Also for Al2024/SiO2/BA –T3 We have Yield strength = 392.67 MPa

Allowable stress = 392.67/2

Allowable stress = 196.335 MPa.

Mathematical Modeling

The mathematical modeling is a crucial task to understand or predict the real situation of the designed components. In this case, pressure load, which would apply on the fuselage skin structure, could consider.

According to the literature stated in chapter two of this thesis, the main common mechanical stress, which affects the life of the fuselage structure, is the tension, bending, etc., produced by static loading, by internal and external pressure, high fatigue and stress. In this case, the fuselage is loaded a static load and during analysis consider this type of loading. For the analysis of the fuselage skin material properties the selected material composition is 10% silica sand and 5%bagasse ash reinforced aluminum matrix. The selected materials have a good tensile strength to density ratio, good flexural strength and hardness properties than the other compositions. In addition, as the microphage result shows, it has uniformly distributed structure; which make it to give a better result. The young modulus and Poisson ratio also calculated from the selected material property.

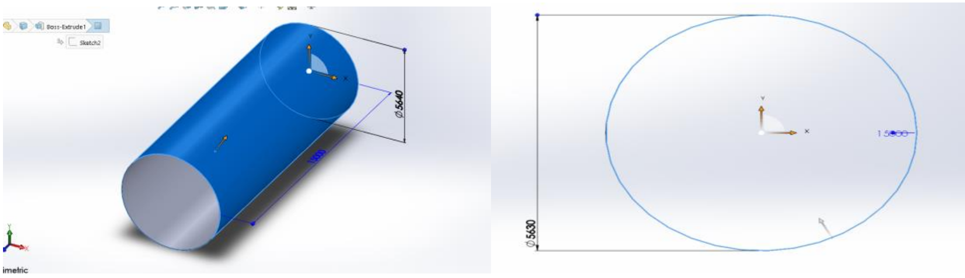


Figure.9 Trimetric view of fuselage skin and 2D drawing of fuselage skin using SOLIDWORK 2017

Static analysis of Al2024 and Al2024/SiO2/BA composite fuselage skin

Define Engineering Data

This completed by selecting the Engineering Data from the analysis tab of the ANSYS Workbench and inserting the corresponding values.

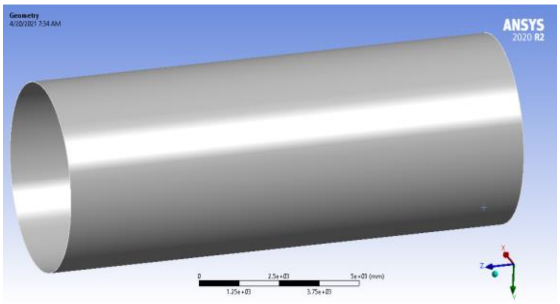


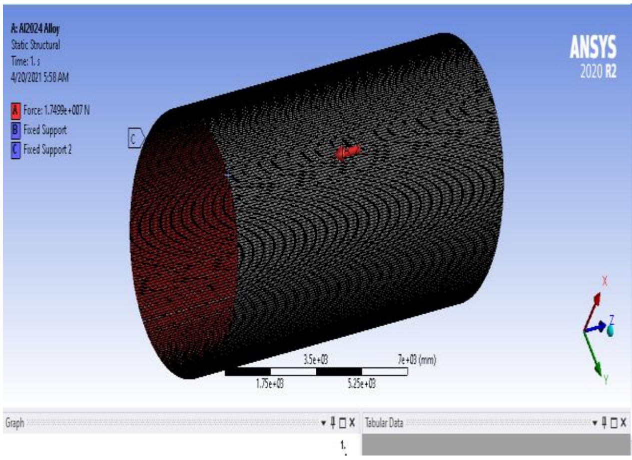
Figure.10 : The browsed 3D model of Al2024/SiO2/BA & The browsed 3D model of Al2024

Apply Mesh Controls/Preview Mesh

After transferring the CAD geometry into the FEA software, the structure meshed using the coarse mesh setting. Using this setting, ANSYS constructs a mesh containing 133280 elements and 534800 nodes. While a finer mesh is possible, it significantly increases the required computation time, with little improvement in overall accuracy.

Apply Loads and Supports

In order to attain the accurate stress analysis for any application, the support and the load should define. This will ensure that the solution incorporates to support of the domain. The place where the fuselage skin mounted at the center of fuselage structure considered as fixed support applied on both of skin face and static load is applied inside the fuselage along Fx direction as shown in the figure 11 and 12. For this analysis, the applied load is 17499KN for both Al2024 and Al2024/silica sand/bagasse ash composite.



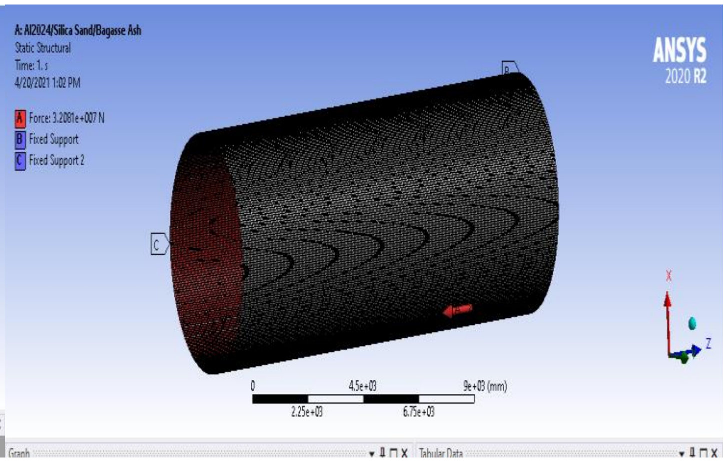


Figure.11 : Boundary condition and applied load of Al2024 Figure. 12: Boundary condition and applied load of the Al2024/SiO2/BA

Generate solution

In this step, the solution generated from the above input parameters of the research. The total deformation and equivalent (Von Misses) stress are the basic variables to solve by this software analysis.

III. Result and discussion

Result

The analysis performed by using analytical analysis, experimental analysis and numerical analysis. The experimental analysis is to determine the material property of aluminum ceramic reinforced composite as per ASTM standard to verify with the theoretical calculated aluminum ceramic reinforced composite materials and the finite element model consists of the static analysis to determine the von-mises stress and deformation of the fuselage skin for both materials. Finite element analysis is performing on both Al2024 and aluminum ceramic reinforced composite fuselage skin, although the geometry and load application are the same for both fuselage skin. The most important step of finite element analysis procedure is the physically realistic interpretation of the results by the analysis. Since finite element analysis procedures always accompanied by an extensive output of data, it is extremely important that we interpret the results correctly.

Experimental Results

Tensile Test

For tensile strength evaluation, there were four specimens of aluminum ceramic reinforced composite with matrix/reinforcement particle ratio (Al202485%, SiO2 10%vf and BA5%vf) tested. while the typical UTS and composite vol. fraction ratio of aluminum ceramic reinforced composite specimens under tensile is presented in figure 3.12, and each of the four specimens result showed a small difference among their result output.

Therefore the maximum tensile strength and tensile modulus of the Al2024 85%, SiO2 10% & BA 5% of particle reinforced isotropic aluminum ceramic composite material are 560 MPa and 78.849 GPa respectively.

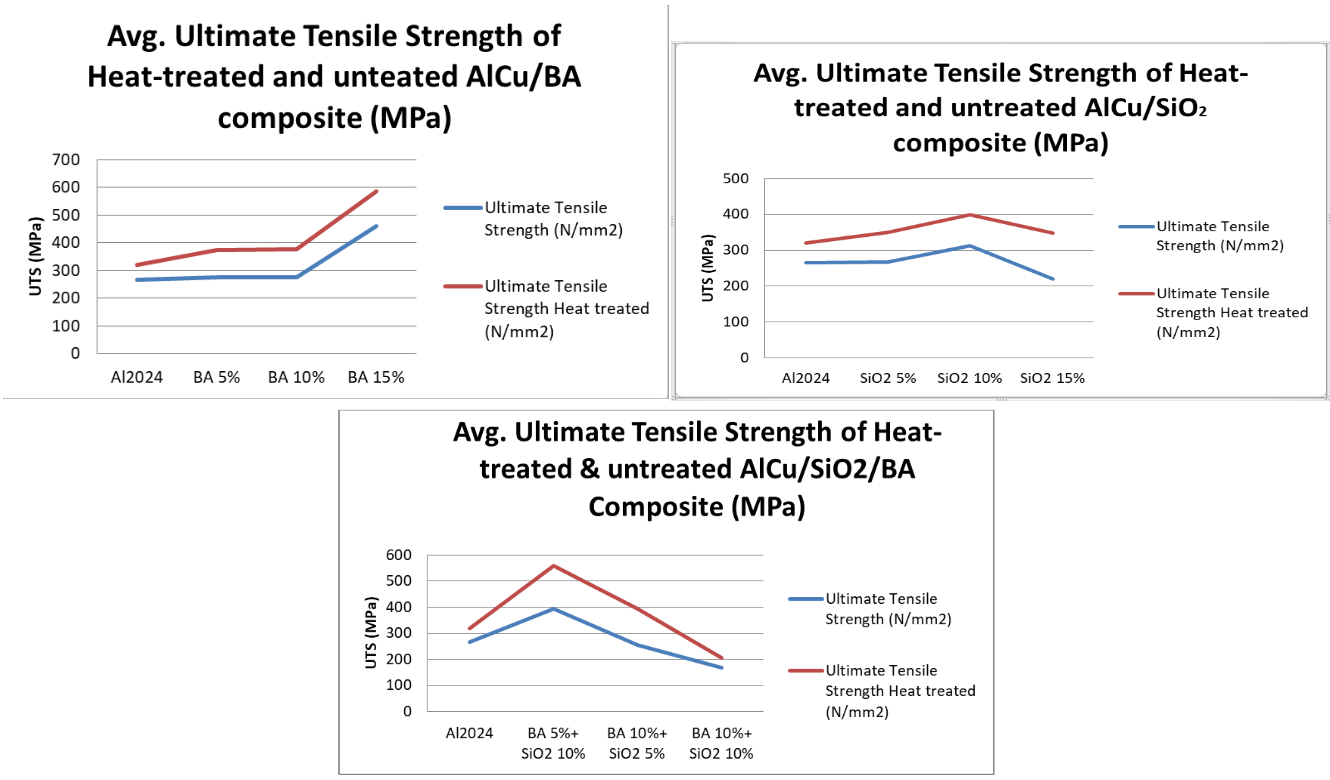


Figure.13: Tensile strength of AlCu/BA, AlCu/SiO2 & AlCu/SiO2/BA composite, respectively.

Hardness Test

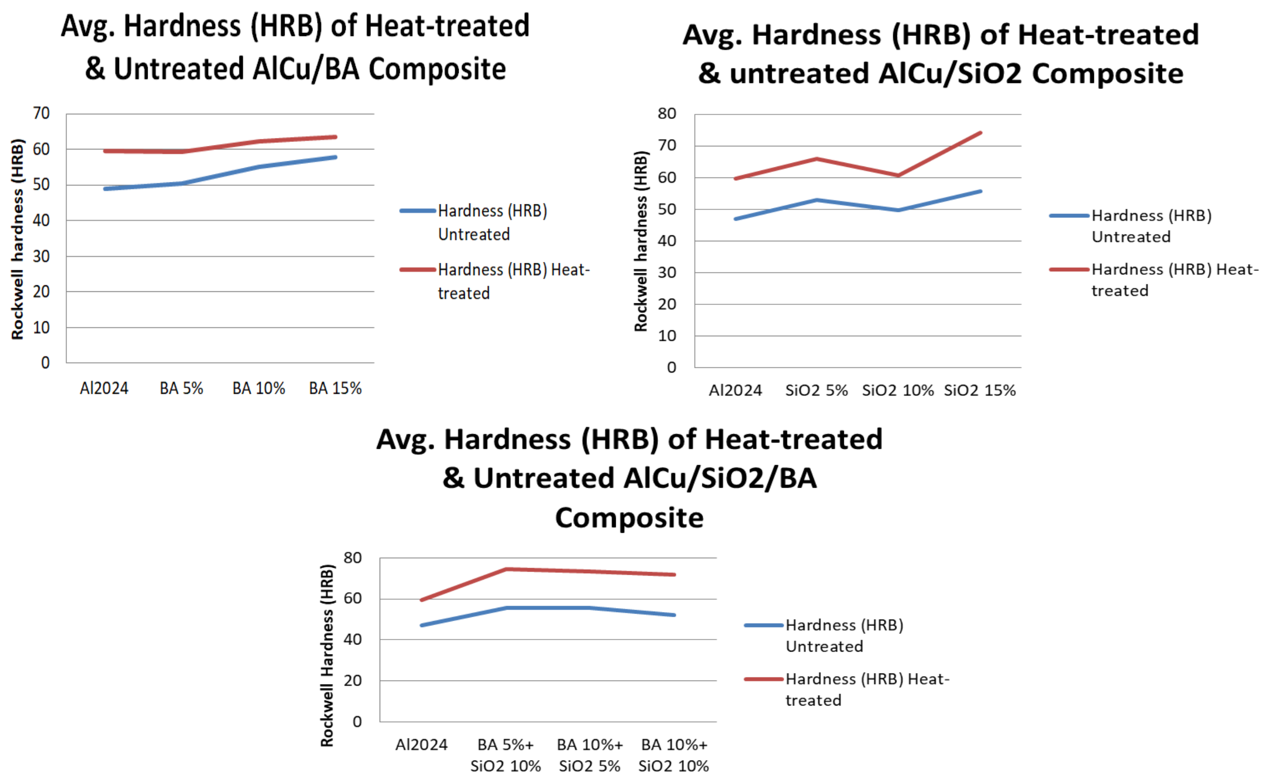


Figure.14: Rockwell hardness results of AlCu/BA, AlCu/SiO2 & AlCu/SiO2/BA composite, respectively.

Flexural Test

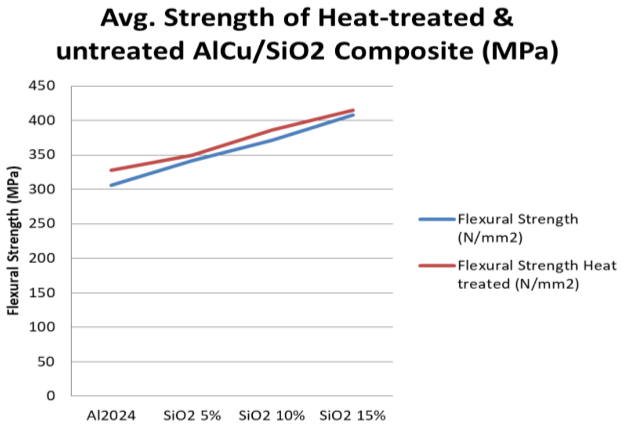
The flexural test measures the load required to bend a beam in three-point loading conditions. The data records frequently used to select elements for parts that will maintain loads without inflection. Flexural modulus is used as sign of a material's stiffness once inflection. Three-point bend test carried out in an UTM machine in accordance with ASTM B290 standard to measure the flexural strength of the aluminum ceramic reinforced composites. For specimens prepared for repeatability. In addition, each of the four specimens result showed that there is no big difference among their result output. Bending test performed with Bending test DIN 50110 Under three points bending when the load P is applied at mid span of a rectangular specimen of span L between two rollers, the highest flexural strength (σ_{bf}) is determined by:

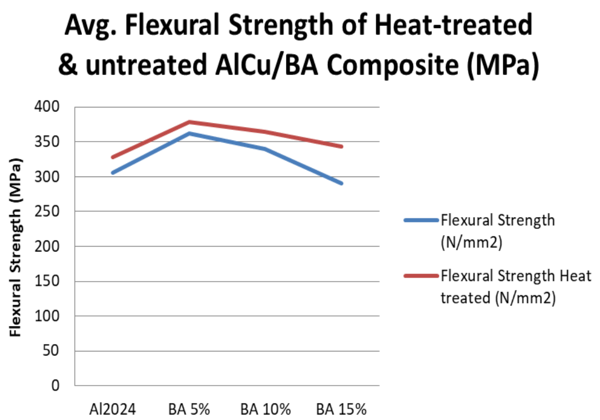
$$\sigma bf = \frac{3LP}{2(bd2)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{eq. (4)}$$

Where: P = load at a given point on the load- deflection curve, N L= support span of specimen, mm

b = width of the specimen tested, mm and

d = depth of the specimen, mm





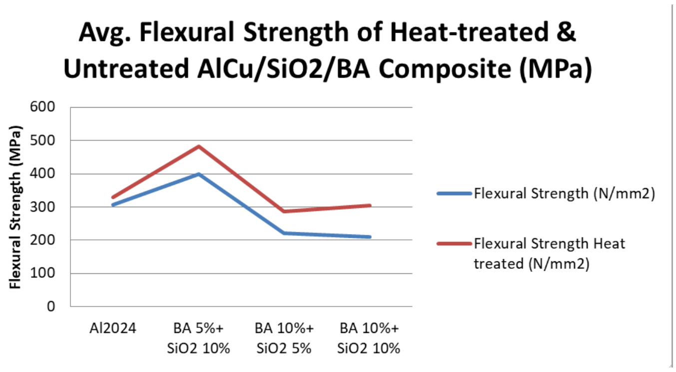
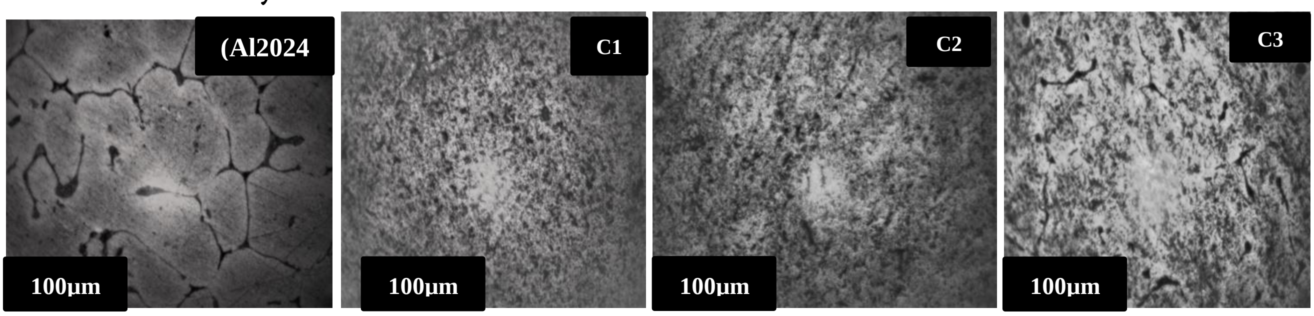
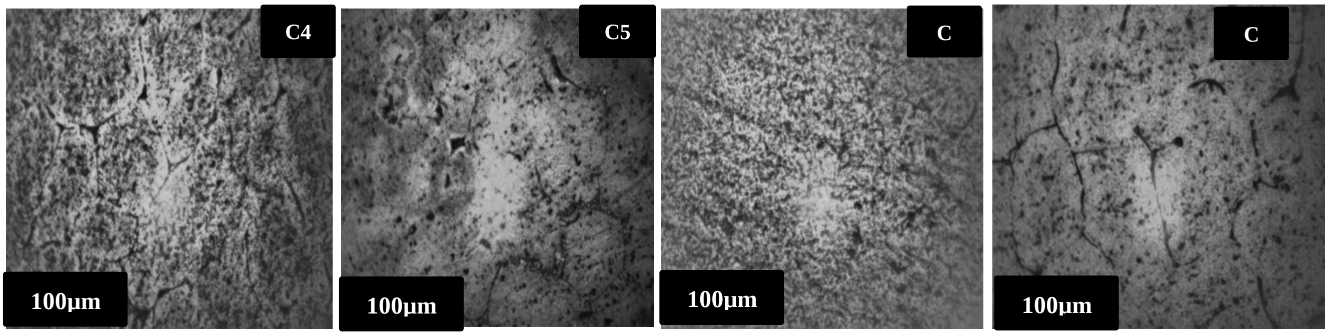


Figure.15: Flexural strength of AlCu with SiO2, BA and AlCu/SiO2/BA composite, respectively.

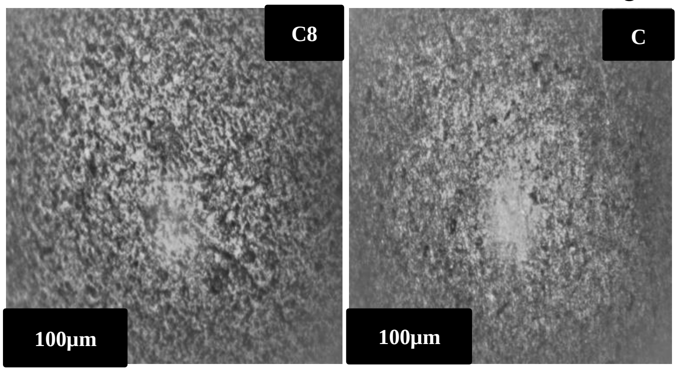
Micro structural analysis



a) Al2024 b) Al2024 95% and BA 5% c) Al2024 90% & BA 10% d) Al2024 85% & BA 15%



e) Al2024 and SiO_2 5% f) Al2024 & SiO_2 10% g) Al2024 & SiO_2 15% h) Al2024, SiO_2 10% & BA 5%



i) Al2024 85%, SiO_2 5% & BA 10% j) Al2024 85%, SiO_2 10% & BA 10%

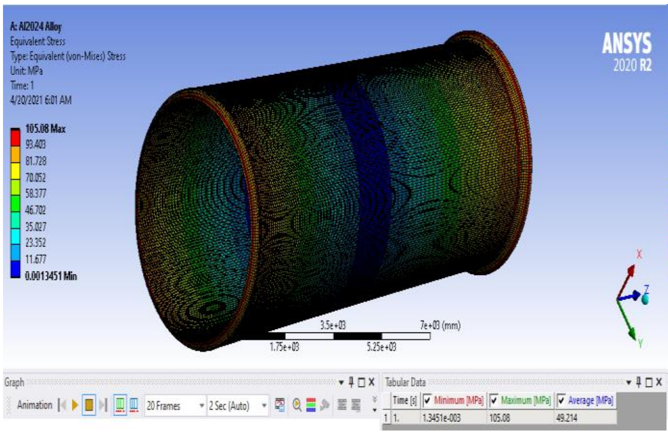
Figure 16: (a-j) optical microphage of reinforced and unreinforced aluminum composite

Static Structural Analysis Result

Stress defined as the average force per unit area that some particle of a body exerts on an adjacent particle, across an imaginary surface that separates them.

a) Equivalent (von- mises) stress (MPa)

The equivalent (Von Misses) stress values of both the Al2024 and reinforced matrix of FEA respectively looks like in the following figures.



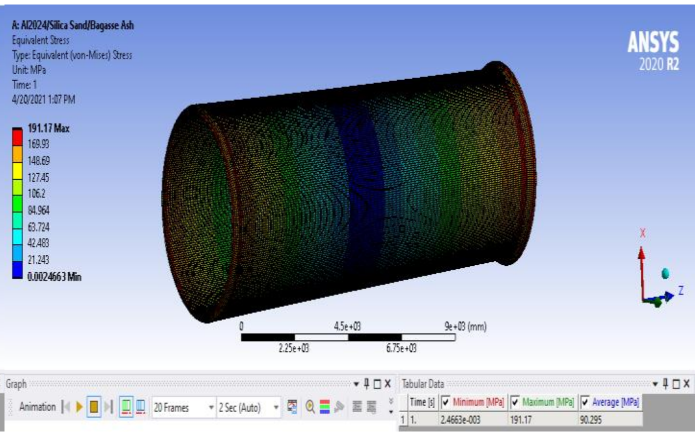
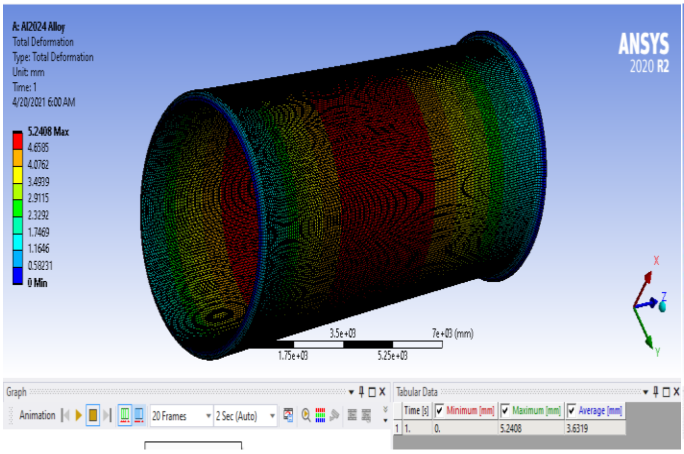


Figure. 17: Equivalent (Von Mises) stress of Al2024 Figure. 18: Equivalent (Von Mises) stress of reinforced metal matrix (Al2024/silica sand/bagasse ash)

As shown in figure 17 and 18, the maximum von - Mises stress is 105.08 MPa for Al2024 fuselage and 191.17 MPa reinforced Aluminum composite fuselage.

Deformation

The deformation values of both the Al2024 fuselage and reinforced Aluminum composite fuselage of FEA respectively looks like in the following figures



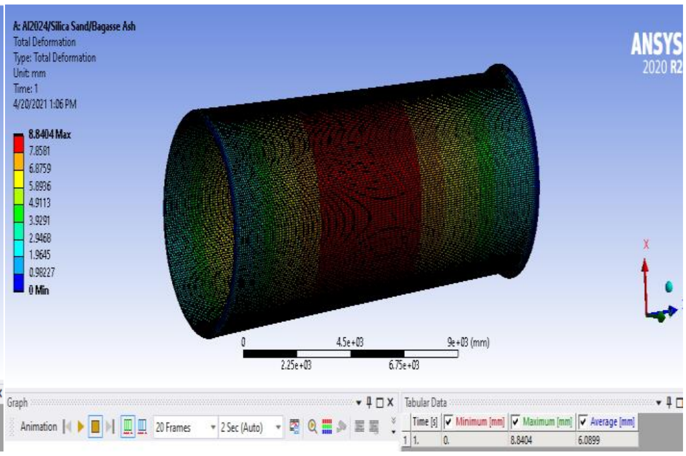


Figure. 19: Deformation of Al2024 Figure. 20: Deformation of reinforced Aluminum composite Al2024/silica sand/bagasse ash

As shown in above figure 19 and 20, the total deformation is 5.24mm for Al2024 fuselage skin and 8.84 mm reinforced Aluminum composite fuselage skin.

IV. Discussion

Experimental result discussion

Tensile Test

The tensile properties evaluated from the tensile test are the UTS (σ), strain (ε), elongation and youngs modulus. As the result shows the tensile strength of the Al2024 basic alloy and the formed composites are increases linearly with the increase in SiO2 10 vf% and BA 5 vf% particle content. Addition of reinforcement in matrix alloy generates a great amount of disorder densities throughout solidification because of the thermal mismatch among matrix alloy and reinforcement particles. Hence, the SiO2 & BA particles reinforcement could productively work as a barrier to dislocation movement. Therefore, it enhances the UTS, younges modulus and yield strength of the produced composites. The best strength is obtained at Al2024/10 vf.% SiO2/ 5 vf % BA AMCs by increasing from 320.22 MPa unreinforced alloy to 560 MPa reinforced material.

Hardness Test

Figure 14 showed the peak values of hardness at the maximum and minimum value for all hardness test specimens. From average values of Hardness specimens, the maximum hardness value 74.36 (HRB) and the minimum value 59.26 (HRB) the output force is 100kg as the Rockwell hardness test indenter scale for soft and Aluminum type material. When the reinforcement added to the matrix, it shows the hardness properties increasing except at the composition of BA 5%. In general, it is concluded that Al2024/SiO2/BA composite material have a higher or improved mechanical properties hardness than the Al2024 unreinforced Alloy.

Flexural test

Figure 15 clarified the highest values of flexural strength and maximum output force for all flexural test specimens. From average values of flexural specimens, the maximum bending strength value 408 MPa in transverse direction and the maximum output force is 24 kN. As it shows addition of volume fraction ratio in the matrix increases the material resistance to bending load, in this experiment the composition of silica at 5%, 10% also silica 5%+ bagasse 10%, silica 10% +bagasse 10% revealed the bending resistance of a material is reduced. It may due to the amount of ceramic particle in the matrix. Here also the best result recorded at cast7 composition, which chosen for the fuselage skin analysis investigation.

Microstructural test

Optical microphage for aluminum composite reinforced with SiO2 and BA represent on the figure 16 it shows the reinforcing particle are visible and uniformly distributed in as a particulate in the aluminum matrices. It also shows there is high volume of particulate spread in the matrices. Most of the microphage result shows a good dispersion of particulate in the aluminum matrices in all composition of composite. This result shows that there was a best result achieved in stir casting method for particulates to get a great uniform distribution in the matrices [13]. The optical microphage investigation showed a reasonably uniform distribution of BA and SiO2 particles and a small macro-segregation of particles in certain spaces. The dispersion of BA and SiO2 particles influenced by the better wettability of the BA and SiO2 by the molten metal and great interfacial attachment among BA and SiO2 particles and the metal matrix material fig. 16.

During the casting it observed that of the composites, increasing the %vl BA and SiO2 particles above 10 vl%, the mixtures fluidity became thick and the flow of the molten matrix composite reduced. The microstructure shows there are small breaks and a reasonably identical dispersion of BA and SiO2 particles in the metal matrix. The silica and Bagasse ash (ceramic) phase revealed as dark points (fig.16, (b-j)). Although the alloy metal phase is white (fig.8, (a)). However, there is a cluster and segregation of BA and SiO2 particles in the micro scale with metal reinforced with 5%vf,10 vf% and 15% SiO2 and BA particle (fig 16, b-j).

The presence of Mg and Cu in the alloy guaranteed the foundation of the essential bonds between the constituents of the compound tested. Interfaces between the particles and the metal matrix, as free from intermediate phases and any precipitates, had an adhesive character of component bonding. In addition, they organized by a high interlinking & strength of bonding. Microstructures of the MMCs clearly display a uniform dispersion of BA & SiO_2 in the matrix with some discontinuities and agglomeration as the vol% additions of the reinforcement is raised beyond 10 vol% faction ratio, figure 16 (c, d, f, g, i & j).

In the composites investigation, no effects of unwanted occurrences observed, which often form the structures of cast composites, such as the residue or fluid out of the reinforcing phase, also the growth of particle agglomerates or gas bubbles formation. This revealed that here is good interfacial bonding among the BA & SiO_2 particles and matrix, this good interfacial bonding may occurred due to the Mg in the matrix, which helps in improving wettability of the ceramic phase in the metal matrix figure (e, f & h). Aluminum alloy based fly ash mixtures. It must well-known that the existence of the ceramic particles in the metal matrix alloy outcomes in a much smaller grain size in the cast composites compared to the matrix alloy as we can see on figure (a) and the rest of composites grain structure. Composite density reduced with rising vol% additions of reinforcement particles.

The density of BA & SiO_2 was 1.77 g/cm3 and 2.197 g/cm3 respectively. The overall density of BA & SiO_2 particle reinforced composites reduced with vol. fraction ratio additions of particles Hardness values improved with an addition vol. fraction of reinforcement particle. This is due to the existence of hard ceramic phase of the SiO2 & BA in the ductile matrix, figure 16 (g, I &j)[14].

As hardness property of composite concerned, adding reinforcement particle in the matrix can raise the strain energy in the boundary of the particles in the medium and propensities may occur by the formation of the disorder at the boundary of ceramic reinforcing particles by change in the thermal expansion coefficient among matrix & ceramic reinforcing particles. The, dislocations produced rising in hardness and residual stress in the mixtures. It is understood that if there is greater the quantity of the ceramic reinforcing particles in the medium, the greater density of dislocation as a result, the greater the hardness in the composite.

The ultimate tensile strength and yield increased with increasing vol. fraction ratio of reinforcement particles additions up to maximum values of and 586.9333 N/mm2 yield strength 15%vf BA addition & the maximum ultimate strength is obtained 347.667 at SiO2 15%vf addition. In the other composition and reduced at the other composition of vol. fraction ratio figure 16 (a-j).

The maximum values for both yield strength and ultimate tensile obtained in this composites at 10% silica sand/5% bagasse ash. As compared with decreased values of these properties at 10% BA + 5% SiO2 and 10% BA + 10% SiO2 addition are attributed to the uniform distribution of the particles at 10%silica sand/5% bagasse ash in the microstructure figure (h) related to the microstructure of composite with 10% BA + 5% SiO2 and 10% BA + 10% SiO2 addition, figure 16 (I & j).

The results indication that Al2024/10% silica sand/5% bagasse ash particle samples have 49.76% and 34.25% rises in ultimate tensile strength and yield than that of unreinforced Al2024 alloy. The percent elongation reduced with rise in volume fraction of silica sand and bagasse ash, figure 16 (h).

Numerical analysis discussion

This section of the paper specifies the result obtained from the ANSYS software carried out by making everything the same for both Al2024, except material properties; i.e. at the same loading type and the same specimen dimension boundary condition and the same method of finite element analysis. The FEA result shows different stress types and deformation due to the applied load on the specimen. Two different materials for fuselage skin namely Al2024 and Al2024/silica sand/bagasse ash composite for fuselage skin compared each other like this.

The Table shows the two material performance of resisting the applied load until it reached their yield tensile strength. It shows that the heat-treated ceramic particle reinforced Al-2024 have the better performance of tensile strength over the unreinforced heat-treated aluminum alloy.

In order to design fuselage structural component such as skin, frame, stringers and bulkhead against the loading and internal pressurization and buckling failure the persuaded Von-Mises stress in the material must be lower than the allowable stress. Therefore, failure load under pressurization condition for skin found to be greater than 60psi or 17499KN for un reinforced Al2024 alloy and 110psi or 32081KN. Due to space constraints the von-misses stress plot and deflection plot are shown only for failure load case.

As shown from table 4, the static analysis result using ANSYS 2020 R2 Workbench software shows the value of allowable stress with different pressurization load. It was analyzed as the result the maximum von - misses stress and deformation are at 17499KN load

105.08 MPa and 5.2408 (mm) respectively if the greater load applied on it its going to fail and create a great damage on materials and lives. In the new designed isotropic metal ceramic composite as shown in the table 4, the maximum von misses stress and deformation are at 32081KN load 191.17 MPa and 8.59 mm respectively. As it seen here, the unreinforced Al2024 tensile yield strength has the lowest value allowable stress for the applied load on the fuselage skin. It fails at more than 17499KN as it compared with the reinforced Al2024/silica sand/Bagasse ash composite. The new composite load resistance is more than 40.7 % than the unreinforced al2024 alloy.

Depending on static analysis results, the equivalent (Von-Misses) stress of the new ceramic reinforced aluminum composite material fuselage skin is the yield strength has a great resistance to one as compared to that of the unreinforced aluminum metal alloy. In addition, the maximum displacements of the Al2024/silica sand/bagasse ash composite material fuselage skin have the lowest deformation value compare with that of the unreinforced one under the same FEM. This indicates that new composite material fuselage skin less stressed less density and has a better performance.

Graphical comparison for load failure of both Al2024 & the new composite

Load Verses Von- misses Stress

The comparison of Load verses von-misses stress of both Al2024 and Al2024/silica sand/bagasse ash composite fuselage skin graph clearly illustrated in figure 21. Load taken on the graph at the x-axis. Whereas:- the stress for Al2024 and composite material is taken on y-axis. Observation of the graph indicates the difference level of stress of two different materials at a given loading condition; this implies that the unreinforced Al2024 alloy is highly stressed than that of the Al2024/silica sand/bagasse ash composite fuselage skin material. Also the due to the less al2024 yield strength it fails sooner than the reinforced one.

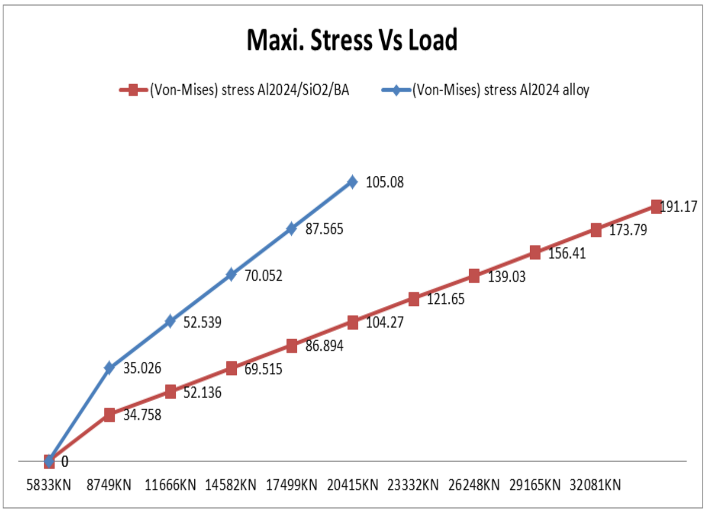


Figure 21 : Comparison Load Verses Von-misses stress of Al2024 & Al2024/SiO2/BA

Table 6 : finite element maximum (von-mises) stress result

Applied load in KN	**(Von-Mises) stress Al2024 alloy**	**(Von-Mises) stress Al2024/SiO2/BA**
	Maximum stress (MPa)	Maximum stress (MPa)
5833KN	35.026	34.758
8749KN	52.539	52.136
11666KN	70.052	69.515
14582KN	87.565	86.894
17499KN	105.08	104.27
20415KN		121.65
23332KN		139.03
26248KN		156.41
29165KN		173.79
32081KN		191.17

Load Verses Total Deformation

The comparison load verses deformation of Al2024 and the new composite fuselage skin shown in figure 22. It shows that the deformation in unreinforced aluminum alloy fuselage skin is higher than the new reinforced composite fuselage skin for the given loading conditions.

Table finite element analysis of deformation result

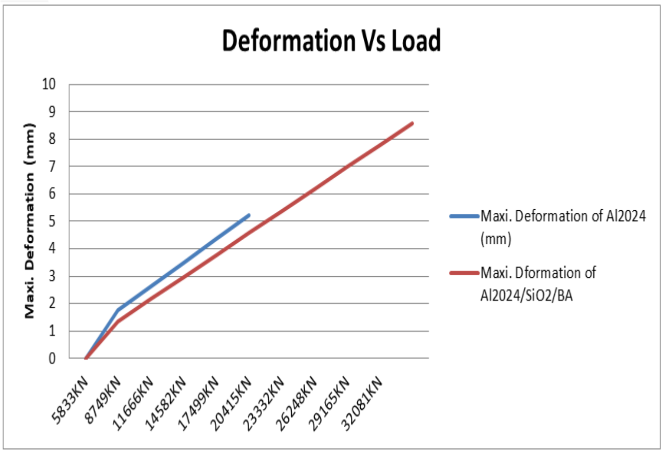


Figure 22 : Comparison Load Verses Deformation of Al2024 and Al2024/silica sand/bagasse ash fuselage skin

Table 7 : finite element maximum (von-mises) stress result

Applied load in KN	(Von-Mises) stress Al2024 Maximum deformation (mm)	(Von-Mises) stress Al2024/SiO2/BA Maximum deformation (mm)
5833KN	1.7469	1.36
8749KN	2.6204	2.16
11666KN	3.4939	2.97
14582KN	4.3673	3.77
17499KN	5.2408	4.57
20415KN		5.38
23332KN		6.18
26248KN		6.98
29165KN		7.79
32081KN		8.59

V. CONCLUSION

The main objective of this thesis is to improve Al2024 mechanical properties by reinforce with the hard ceramic particle silica sand and the agro-waste bagasse ash. The selected application area of the Al2024 is fuselage structure as the alloy currently and mostly uses as aerospace application. The analysis accomplished by using experimental and analytical analysis.

The Al2024/Silica sand/ Bagasse ash manufactured by stir casting method with a different composition ratio and investigated the tensile, bending and hardness of its mechanical performance, also for the characterization optical microscope test performed. Then as the result obtained from the performed tests, the composition of Al2024/with the volume ratio of 10vf silica sand and 5vf bagasse ash gave better results as compared to the other compositions by its hardness and flexural strength performance. Based on the experimental results, the composite selected for the application of fuselage structural part.

The Al2024 and the reinforced composite 3D modeling performed with SOLIDWORK 2017 and the mechanical property analysis of the material result analyzed. In addition, a relative study has made with respect to stresses and deflection between Al2024 and composite fuselage structure. The effect of addition of SiO2 and BA particles and treating with heat by tempering T3 condition on the mechanical properties of the alloys Al-2024 has investigated. Based on the results, the following conclusions are drawn.

- Addition of SiO2 and BA particles increases the hardness property of the matrix alloy by about 25.4%. Significant improvement in the tensile performance of the material with the combination of SiO2 and BA particles at 15%vf SiO2 content. And maximum yield strength obtained at 15%vf BA Addition of SiO2 and BA particles increases the ductility of the matrix alloy up to silicon dioxide 10vf, 5vf BA. However, it decline when the vf of the reinforcements above that.

- Hardness values found to increase with the reinforcement addition and heat-treating. The Al-2024 alloy reinforced with 10%vf SiO2 and 5%vf BA shows a significant improvement in the hardness, tensile and flexural strength compared to other composition percentage. It observed that density reduction as compared to unreinforced Alloy. Moreover, increase its performance by increasing tensile strength 560 MPa, increasing flexural strength 408 MPa, and increasing hardness from 59 to 74.
- Also, in the structural analysis of aircraft fuselage skin it shows a reduction of stress, on von-mises stress the maximum allowable yeild strength stress is 196.17 MPa and maximum deformation 8.59 mm recorded for the Al2024/SiO2/BA composite and the maximum allowable stress 105.08 MPa, the maximum deformation 5.2408 mm for unreinforced Al-Cu-Mg. Hence this combination can be used for light weight & high strength applications.[19]
- As the results, it is clear that composite Al2024/SiO2/Bagasse ash composite aircraft fuselage skin has less stress than the Al2024 alloy with similar dimension and load capacity it also shows the composite material have better resistance for the high amount of applied load as a structural material. As a general, by using, the ceramic particle and agro-west ash's it could achieve improving the current aerospace materials property instead of changing them, it is batter to keep them with their un-replaceable character by other materials.

VI. Recommendations

Other tests such as wear test, corrosion test, thermal and electrical conductivity test etc. should conduct for fully characterize the composites. The interest of a material with lightweight and high performance is increasing in surprising way from time to time. Therefore the properties of composite materials, like high strength to weight ratio and high specific stiffness are attractive for the construction of lightweight, fuel efficient and environmentally, economically safe aerospace and automotive components.

VII. Future work

As a future work a lot of work could considered because of the new Al2024/SiO2/BA, composite shows a great result and create great motivations to work on other industrial and agro-waste as a raw material for high industrial applications. In this investigation a better mechanical properties achieved. such as, density reduction, stress reduction, high strength, increased hardness. The Al2024/SiO2/BA composite material can be used for a different application area based on its material property such application areas would be automotive application with a necessary inspection and more investigation. Based on this perception, regarding to Al2024/SiO2/BA composite material various products can be made and developed in the future, in which this study could not addressed.

- Investigate other mechanical testes to improve the material performance in all aspect.
- Investigate the effect of heat treatment on aluminum ceramic composite.
- Based on the material mechanical property it could implemented on more of automotive parts like break disc, which needs more stress resistance material.

VIII. REFERENCES

[1]. M. Imran, A. R. A. Khan, S. Megeri, and S. Sadik, “Study of hardness and tensile strength of Aluminium-7075 percentage varying reinforced with graphite and bagasse-ash composites,” Resour. Technol., vol. 2, no. 2, pp. 81–88, 2016, doi: 10.1016/j.reffit.2016.06.007.

[2]. I. M. Astika, “Hardness improvement of aluminum alloy 2024 t3 after artificial aging treatment,” IOP Conf. Ser. Mater. Sci. Eng., vol. 539, no. 1, 2019, doi: 10.1088/1757-899X/539/1/012004.

[3]. K. Ravi Kumar, T. Pridhar, and V. S. Sree Balaji, “Mechanical properties and characterization of zirconium oxide (ZrO2) and coconut shell ash(CSA) reinforced aluminium (Al 6082) matrix hybrid composite,” J. Alloys Compd., vol. 765, pp. 171–179, 2018, doi: 10.1016/j.jallcom.2018.06.177.

[4]. H. S. Kumaraswamy, V. Bharat, and T. Krishna Rao, “Influence of Mechanical &tribological BehaviourOf Al 2024 MMC Fabricated by Stir Casting Technique-A Review,” Mater. Today Proc., vol. 5, no. 5, pp. 11962–11970, 2018, doi: 10.1016/j.matpr.2018.02.170.

[5]. A. M. Usman, A. Raji, M. A. Hassan, and N. H. Waziri, “A Comparative Study on the Properties of Al-7%Si-Rice Husk Ash and Al-7%Si-Bagasse Ash Composites Produced by Stir Casting,” Int. J. Eng. Sci., vol. 3, no. 8, pp. 1–7, 2014, Online]. Available: http://theijes.com/papers/v3-i8/Version-1/A03810107.pdf.

[6]. O. F. F. L. Y. Ash, B. A. S. H. Al-mmcs, M. Anas, and M. Z. Khan, “COMPARISION OF HARDNESS AND STRENGTH Comparison of Hardness and Strength of Fly Ash and Bagasse Ash Al-MMCs,” vol. 1, no. June, pp. 88–93, 2016.

[7]. S. Soltani, R. Azari Khosroshahi, R. Taherzadeh Mousavian, Z. Y. Jiang, A. Fadavi Boostani, and D. Brabazon, “Stir casting process for manufacture of Al–SiC composites,” Rare Met., vol. 36, no. 7, pp. 581–590, 2017, doi: 10.1007/s12598-015-0565-7.

[8]. G. Narasaraju and D. L. Raju, “Characterization of Hybrid Rice Husk and Fly ash-Reinforced Aluminium alloy (AlSi10Mg) Composites,” Mater. Today Proc., vol. 2, no. 4–5, pp. 3056–3064, 2015, doi: 10.1016/j.matpr.2015.07.245.

[9]. A. M. Usman, A. Raji, N. H. Waziri, and M. A. Hassan, “Production and Characterisation of Aluminium Alloy - Bagasse Ash Composites,” IOSR J. Mech. Civ. Eng., vol. 11, no. 4, pp. 38–44, 2014, doi: 10.9790/1684-11433844.

[10]. P. Maibusab, H. K. Shivanand, M. M. G., S. H.A., and S. B. G., “Evaluation of Wear Properties of Heat-treated Al 7075/Graphite Powder/Bagasse ash Hybrid Metal Matrix Composites,” Int. J. Sci. Res. Sci. Technol., vol. 6, no. 3, pp. 201–210, 2019, doi: 10.32628/ijsrst1196338.

[11]. ASTM E8, “57,” Annu. B. ASTM Stand. 4, vol. i, no. C, pp. 1–27, 2010, doi: 10.1520/E0008.

[12]. R. Abbishek, B. R. Kumar, and H. S. Subramanian, “Fatigue analysis and design optimization of aircraft’s central fuselage,” IOP Conf. Ser. Mater. Sci. Eng., vol. 225, 2017, doi: 10.1088/1757-899X/225/1/012031.

[13]. O. B. Fatile, J. fedayo AkinruliI, and A. A. Amori, “Microstructure and Mechanical Behaviour of Stir-Cast Al-Mg-Sl Alloy Matrix Hybrid Composite Reinforced with Corn Cob Ash and Silicon Carbide,” Int. J. Eng. Technol. Innov., vol. 4, no. 4, pp. 251–259, 2014, Online]. Available: https://doaj.org/article/3ff98d13a11042498fb5fe293ccaae35%0Ahttp://ojs.imeti.org/index.php/IJETI/article/view/42.

[14]. V. Dardare and S. G. Kulkarni, "Effect of bagasse ash reinforcement on Al356 matrix composite manufactured by two stage stir casting process," Int. J. Curr. Eng. Technol., vol. 8, no. 04, pp. 911–915, 2018, doi: 10.14741/ijcet/v.8.4.3.
[15]. S. Thirumalvalavan and N. Senthilkumar, "Evaluation of mechanical properties of aluminium alloy (Lm25) reinforced with fused silica metal matrix composite," Indian J. Eng. Mater. Sci., vol. 26, no. 1, pp. 59–66, 2019.
[16]. V. S. Aigbodion, S. B. Hassan, G. B. Nyior, and T. Ause, "Effect of Bagasse ash reinforcement on the wear behaviour of Al-Cu-Mg/Bagasse ash particulate composites," Acta Metall. Sin. (English Lett., vol. 23, no. 2, pp. 81–89, 2010, doi: 10.11890/1006-7191-102-81.
[17]. M. Sayuti, S. Sulaiman, T. R. Vijayaram, B. T. H. T. Baharudin, and M. K. A. Arifin, "Manufacturing and Properties of Quartz (SiO 2) Particulate Reinforced Al-11 . 8 % Si Matrix Composites," 2012.
[18]. V. S. Aigbodion, S. B. Hassan, T. Ause, and G. B. Nyior, "Potential Utilization of Solid Waste (Bagasse Ash)," vol. 9, no. 1, pp. 67–77, 2010.
[19]. V. Mahesh Kumar and C. V. Venkatesh, "Effect of ceramic reinforcement on mechanical properties of aluminum matrix composites produced by stir casting process," Mater. Today Proc., vol. 5, no. 1, pp. 2466–2473, 2018, doi: 10.1016/j.matpr.2017.11.027.

Cite this article as :

Sh