Influence Eggshells powder additive on thermal stress of fiberglass/polyester composite tubes

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Abstract. In this study, the influences of eggshell powder application on random fiberglass/polyester composite pipes thermal stresses were investigated experimentally and numerically. The experimental part involved industrializing tube samples which are Egg Shell Powder with Polyester at 50% volume fraction (E50), Random Fiberglass with polyester at 50% volume fraction (F50) and Egg Shell Powder with Random Fiberglass with Polyester at 50% volume fraction (E25F25). Resin molding procedure and experimental rig design to study how tube samples are faced with thermal loads. Pipes are made with (95 mm) inner diameter, (400 mm) circumference, and (5 mm) wall thicknesses. Computational Fluid Dynamic, ANSYS software package version 11, is simulated with product form SHELL63. Results show that, composite samples (F50) had an average longitudinal strain, while composite samples (E50) had a low longitudinal strain. The composite (F50) had average longitudinal and hoop stress (62.2 MPa, and 61.1 MPa) respectively, while the composite (E50) had low longitudinal hoop stress (28.5 MPa, ad 30.8 MPa) respectively.

1. Introduction

Composite materials which pursue an established field of gain in composites using naturalistic and polymeric template materials. Natural materials are very attentive due to the many advantages such as frugal and environmental benefits obtained from natural composites. When temperatures are modified, thermal stresses and deformations in pipes are produced. There are many thermal stress applications, such as the nuclear sector, the martial industry, the shooter tube, and turbine engineering. The increase in emissions means that naturalistic materials are used instead of artificial materials [1],[2]. As a result, several research items are being used on natural materials, such as the modulation of the lamination and the corresponding axis [3],[4]. Chia-Wei Su [5] theorize the thermal stress in the composite material ring. 3-D finite element software used with ANSYS version 10 to create thermal stress. Results showed that composite materials play a significant thermal stress role. F A Abdullah [6] theoretically and experimentally tested thermal insulators were natural composite materials of fibers (and eggshells, black feather, white features, Jute). Lee’s theorem disk has been used to calculate different forms of thermal conductivity. Study revealed composite material (Jute) was superior to other naturalistic materials as a composite thermal insulator. The eggshell powder from the egg manufacturing sector was used as a part of the stand up for Portland Common Cement in cement lute [7]. Cement lute 1:3 is a mixed ratio in which cement is partially replaced by 5 to 30 percent eggshell powder with a 5 percent rise in cement weight. O M Sanusi et, al, [8] advanced polymer mold composite (P.M.C.) to incorporate the body shield by using the handling method for producing wood ash with epoxy. Findings ash of wood ratio that the variability was 2.3 percent and that tensile strength and hardness relative to enhanced resin were
improved. The mechanical and thermal characteristics of the composite material Polypropylene (P.P.) with various naturalistic fibers were studied by A L de Lemos et al [9]. The findings showed that composites consolidated the naturalistic fibers' performance to a minimum that the glass fiber consolidated composite.

In this work, the eggshell powder group's effects on stress of composite pipes [polyester with fiberglass, random] have been studied experimentally and numerically via the molding process. Test the pipeline characteristics when the thermal load is in use due to thermal stresses with building experience to study thermal stresses' effects. For the analysis of numerical and experimental tests, the ANSYS program was used.

2. Experimental work

For this study, three composite material samples with various fibers (natural and glass fiber), volume fraction, and density analyze each composite's mechanical properties. The composites were characterized using the tensile method [10]. A composite tube was manufactured using the resin molding process with specific thermal loads. In this quest, tensile industrialization experimental sample tests are carried out on traction equipment and thermal-mechanical test samples, which are automated and tested by a thermal-mechanical device.

2.1. Samples research

For the three composite forms, various types of natural fibers were used as a reinforcement material. The composite materials mold at a 50 percent ratio with various volume fractions and a fixed volume fraction. In the table, (1) composite material properties were shown.

| symbol  | Reinforcement               | Matrix  | Vf (%) |
|---------|-----------------------------|---------|--------|
| E25F25  | Egg Shell Powder + Glassfiber |         | 25 & 25|
| F50     | Glassfiber                  | Polyester| 50     |
| E50     | Egg Shell Powder            |         | 50     |

2.2. Tensile test

Samples characteristics properties were calculated in compliance with the ASTM D 638 standard[11]. The form of the composite dimension was (20cm*30cm*0.5 cm) modeled by the process of infusion. The tensile sample was analyzed for the samples cut by a cutting machine shown in figure (1-a). Nine samples used for each composite material were cut in the tensile test sample, three samples. Dimensions of the samples are 50 mm long, 13 mm wide, and 5 mm thick. The device used for the tensile test was the WDW-200E traction device speed was set to 2 mm/min [12,13], as shown in figure (1-b).

2.3. Thermo Mechanical expansion coefficient (α)

Thermo Mechanical Analyzer (T.M.A.) is the equipment used to determine the thermal expansion coefficient, as shown in figure (2-a). Thermal, mechanical analysis (T.M.A.) is a difference in size and automatic variance in characteristics when the specimen fills a thermal device with or without the sample [14],[15]. Test containers, sample holders, oven, tracers, and observatory are the T.M.A. facilities. T.M.A. is mounted onto a screen monitor to display the results and linked to a printer for the results printed. The sample sizes were (2cm*0.5cm*0.5 cm), as shown in figure (2-b) displays the T.M.A. test samples [16],[17].
2.4. Tube industrialization

Many technologies are used to industrialize plastic pipes in a major commercial application [18]. There are three tube samples with normal parameters, as seen in the table (1). Test tube with dimensions (400 mm) circumference, (90 mm) internal diameter and (5 mm) width. Two plastic tubes molds were used in resin casting. The outer conduit is the husk of length (400 mm) and ID (100 mm). However, the internal tube is the core that has (90 mm) O.D. and (500 mm) length. The essence tube is inserted into the husk tube as seen in figure (3). Tube diameter difference between husk, essence allows a blank tube frame bore with suitable dimensions [19]. Design lubrication is important in the first step of the molding process to prevent the production tube from adhering to mold. The eggshell powder was disordered with polyester resin and hardener handle until it entered a homogenous state. Then the mix was filled with a surgical syringe. The tube sample was solidified after five hours and ready to be collected. Repeated this method with all composite tube samples. Fig (4) indicates that resin molding creates the (E50) pipe sample [20],[21].

2.5. Experimental research rig

Heat air flows into a sample of composite tubes, causing thermal stress on a composite tube. The measuring equipment consists of three parts: Boundary conditions, part of the temperature, and finally, the date of conquest. The restricting conditions for the hunt were to verify X and Y position.
at either e' of the tube and to determine the path of the Z down the line. There are two iron jowls found on all ends of the tubing in the X and Y directions. There was a strong line in the Z-direction with twain iron caps, where the twain tubes opened with the tightening of the rope at the two ends of the pipe [22].

Moreover, the tube sample, chops, and bar have been held within its hobs on double iron platforms. Temperature section in contagious experimental inventory that the thermal capacity of the tube specimen can be provided. Heat weapons, which supply hot air inside temperature up to (600 KBC) and attached to an iron jowl, were used to specify the temperature component of the experimental experiments. Four K thermocouples are used at the top and bottom of the outer tube for a specified temperature, which gives a minimum of eight thermocouples. Temperature recorder with a 12-channel thermocouple reader linked to the eight inaugurating thermocouples on the tube [23]. The thermocouples’ temperature sensitivity and recorded with timing on the S.D. mark opened in the temperature recorder, when hot air flows through the tube. The date conquest scheme consists of two tubular strain gages wired to tensile gages and then linked to a device to monitor each test’s readings. The data logger is wired with a device. The hiding point of the strain gauge ensures a relative difference in resistance [24]. The variation in the readings of resistance is small, resulting in mV or mA value. The strain data logger was tested in (mA). Equations (1), (2), and (3) were used to obtain stress interest. Fig (5) demonstrates the experimental rig [25].

\[
\sigma_L = \frac{E}{(1-\nu^2)} (\varepsilon_L + \nu \varepsilon_H) \tag{1}
\]

\[
\sigma_H = \frac{E}{(1-\nu^2)} (\varepsilon_L \cdot \nu + \varepsilon_H) \tag{2}
\]

\[
\sigma_{ Von } = \sqrt{(\sigma_H)^2 + (\sigma_L)^2 - \sigma_H \sigma_L} \tag{3}
\]
3. Numeric Analysis

Exhaustive Finite Element Approach (F.E.A.) operations from various studies were explored to demonstrate stresses and strains of specific loading status. Mechanical tension measurement of the tube is of greater significance in this research. The ANSYS version 11 software kit was used to test stresses and pressures in three nations. Form of feature, the sort (SHELL63) factor has been used to enable loads in the standard and plane direction. The SHELL63 dimension has six degrees of freedom (D.O.F.) in each node: operation and rotation in the contractual axes x, y, and z. Meshing and boundary states of the F.E.A. grid is very important in the C.F.D. analysis that is needed for the F.E.A. research. The number of grid elements shown in Figure (6), for the tube used in this search is (2000), and the nodes number (1209). The F.E.A. model's boundary condition is provided with a specific method for the model during regular day-to-day operations to clarify the boundary condition related to the usage of the tube concept in this search. Boundary state (seen in figure 7) is used by taking the diameter nodes on both sides of the tubes and adding all the D.O.F. Thermal load is placed inside pipeline[26].

4. Results and discussion

The effect of eggshell powder's addition to the fiberglass composite tube was also demonstrated by the behavioral variations of temperature, stress, and pressure. The substance performance characteristics from the tensile analysis and thermal, mechanical review for all three samples are increasing.

Figure 5. Experimental Work (Rig)

Figure 6. Tube meshing

Figure 7. Boundary Conditions of the tube
4.1. Tensile test and electronic thermal analysis tests

Component properties, such as elasticity panel, the fish ratio, the thermal expansion coefficient, the production pressure, and the tensile strength production and the thermal, mechanical test seen in the table (2). Table (2) reveals that (F50) reveals the average elasticity values (21 Gpa), however (E50) implies minimal elasticity values (15.42 Gpa) and the Poisson ratio values vary from (0.42) to (0.47). The thermal expansion coefficient (α), the performance stress (Ty) and the ultimate pressure (5-0) can be seen from statistics indicating that (F50) indicates the final stress and the thermal expansion coefficient (206 MPa) and (8,6 to 6 m / mk) respectively [27,28]. The highest yield pressure (E25F25) is (120 MPa). Nevertheless, the minimum ultimate stress, yield stress, and thermal expansion coefficient of (41,2 MPa), (36,7 MPa) and (2,90E-06 m / mk) are provided.

Table 2. Characteristics of the tube sample utilized

| symbol | ν   | σult (MPa) | α (m/mk) | E (Gpa) | σy (MPa) |
|--------|-----|------------|----------|---------|---------|
| E50    | 0.42| 41.2       | 2.90E-06 | 15.42   | 36.7    |
| F50    | 0.47| 205        | 8.50E-06 | 21      | 101     |
| E25F25 | 0.46| 200        | 6.70E-06 | 18.8    | 120     |

4.2. Specimens strain and stress effected by temperature rise.

Figure (10) to Figure (14) illustrates the temperature effect rise on tension and strain for E50, F50, and E25F25 samples. Fig (10) offers the importance of temperature with historical pressure. Observed from the figure (10) the maximums temperature of (225 °C) by (E25F25) and (125 °C), the (E50), min. temperature. Additionally, (E50) shows maximums strain when a match to the (F50) and (E25F25) with different (36 percent) and (12 percent). Figure (11) demonstrates importance hoop strain with temperature, and recognize findings mentioned figure (10) about strain. pressure gap between (E50) and (F50) and (E25F25) is (19 percent) and (30 percent), respectively. Figure (12) indicates the importance longitudinal stress with temperature. Figure (13) indicates the importance hoop stress with temperature. Figure (14) views the importance von mises stress with temperature.

Figure 10. Experimental Longitudinal Strain with Temperature

Figure 11. Experimental Hoop Strain with Temperature
4.3. Comparison of empirical and laboratory tests of pressure

Figures (15) to (19) give the relation between numerical von mises tension, numerical longitudinal strain, experimental hoop strain temperature rise and experimental longitudinal strain. It can be seen, a significant change in heights between numerical tension and experimental (14.1%) and (18%).
5. Conclusion
This study can back up many conclusions which constant volume fraction (50%):
1. Concerning the temperature keeper, the composite (E50) gives (225 C.) and the composite (F50) gives (110 C).
2. Supplement eggshell powder gives changes in temperature (110 C) to (125 C).
3. Composite (F50) had an average longitudinal strain, while composite (E50) had a low longitudinal strain.
4. Hoop stress (F50) decreased after eggshell powder fraction.
5. The composite (F50) had 62.2 MPa average longitudinal stress, and (E50) had 8.5 MPa stress.
6. The composite (F50) had average hoop stress (61.1 MPa), and (E50) had 30.8 MPa stress.
7. The (F50) composite had the average stress of (61,7 MPa), and (E50) had 29.8 MPa stress.

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References
1. Qasim S M, Mohammed F A and Hashim R 2015 Numerical investigation of the thermal behavior of heated natural composite materials IOP Conf. Ser. Mater. Sci. Eng. 95
2. Abdullah, F. A., & Khalaf, W. A. (2018). Experimental investigation of composite materials subjected to torsional stresses at high shear strain rate. Int. J. Mech. Mechatronics Eng., 18(1), 64-75.
3. Abdulla, F. A., Fadhil, H. A., & Abdulwahid, J. N. (2018, December). Experimental Study of the Creep Behaviour of Nano-Composites Carbon Fibres. In IOP Conference Series: Materials Science and Engineering (Vol. 454, No. 1, p. 012126). IOP Publishing.
4. Khalid Hamdan, Z., & Abdullah, F. A. (2018). Investigation of the Adding Nano Particles to Composite Material under High Strain Rate Torsion with Hygrothermal Effect. Technology, 9(6), 1098-1114.
5. Chia-Wei Su, "Thermal stresses of composite beams with rectangular and tubular cross-sections", MSc thesis, The University of Texas at Arlington in Partial Fulfillment, 2007.
6. Jassim, R. F., & Abdulla, F. A. (2020, November). Investigation Experimentally the Effect of Thermal Stresses on the Straight and Curved Natural Composite Material Pipes. In IOP Conference Series: Materials Science and Engineering (Vol. 928, No. 2, p. 022065). IOP Publishing.
7. Abdulla, F. A., & Abdullah, A. H. (2020, November). Effect of Shot Penning on Wear rate of Eggshell natural composite Materials. In IOP Conference Series: Materials Science and Engineering (Vol. 928, No. 2, p. 022091). IOP Publishing.
8. Olawale M. Sanusi, Olufemi D. Komolafe, Tunde O. Ogundana, Mesach O. Olaleke, and Yunusa Y. Sanni, "Development of Wood-ash/Resin Polymer Matrix Composite for Body Armour Application, "FUOYE Journal of Engineering and Technology, Volume 1, Issue 1, 2016.
9. Alessandra Luiza de Lemos, Pamela Galera Prestes Pires, Marcelo Lopes de Albuquerque, Vagner Roberto Botaro, Jane Maria Faulstich de Paiva, Nei Sebastiao Domingues Junior, "Biocomposites reinforced with natural fibers: thermal, morphological and mechanical characterization", Materials Journal, Vol.22, No.2, 2017.
10. American society for testing and materials international, "Standard test method for tensile properties of plastics," D638, 2000.
11. Abdulla, F. A., Moustafa, N. M., & Hussein, A. F. (2018). Effect of uv-radiation on fatigue behaviour of natural composite materials. Int. J. Mech. Prod. Eng. Res. Dev., 8, 727-40.
12. Moustafa N M, Abdulla F A and Nori A F 2018 PID control system for a variable speed horizontal axis wind mill Intl. J. Mech. Eng. Technol. 9 1080–7.
13. Jebur, N. A., Abdulla, F. A., & Hussein, A. F. (2018). Experimental and numerical analysis of below knee prosthetic socket. Int. J. Mech. Eng. Technol., 9, 1-8.
14. Abdulla, F. A., Fadhil, H. A., & Abdulwahid, J. N. (2018, December). Experimental Study of the Creep Behaviour of Nano-Composites Carbon Fibres. In IOP Conference Series: Materials Science and Engineering (Vol. 454, No. 1, p. 012126). IOP Publishing.
15. Abdul-Kareem, H. S., Abdulla, F. A., & Abdulrazzaq, M. A. (2019, May). Effect of Shot Peening and Solidification on Fatigue Properties of Epoxy Base Composite Material. In IOP Conference Series: Materials Science and Engineering (Vol. 518, No. 3, p. 032017). IOP Publishing.
16. Al-Ameen E S, Abdulhameed J J, Abdulla F A, Ogali A A F and Al-Sabbagh M N M 2020 Strength characteristics of polyester filled with recycled GFRP waste J. Mech. Eng. Res. Dev. 43 178–85
17. Tariq, S. Z., & Abdullah, F. A. (2020, February). Effect of wood ash additive on the thermal stresses of random fiberglass/polyester composite pipes. In IOP Conference Series: Materials Science and Engineering (Vol. 745, No. 1, p. 012062). IOP Publishing.
18. Metteb, Z. W., Abdalla, F. A., & Al-Ameen, E. S. (2020, March). Mechanical properties of recycled plastic waste with the polyester. In AIP Conference Proceedings (Vol. 2213, No. 1, p.
19. Hamdan, Z. K., Abdalla, F. A., & Metteb, Z. W. (2020, March). Effect of acids salts and water on natural composite materials. In AIP Conference Proceedings (Vol. 2213, No. 1, p. 020075). AIP Publishing LLC.

20. Abdulla, F. A., Hamid, K. L., Ogaili, A. A. F., & Abdulrazzaq, M. A. (2020, November). Experimental study of Wear Rate Behavior for Composite Materials under Hygrothermal Effect. In IOP Conference Series: Materials Science and Engineering (Vol. 928, No. 2, p. 022009). IOP Publishing.

21. Al-Ameen, E. S., Abdulla, F. A., & Ogaili, A. A. F. (2020, June). Effect of Nano TiO2 on Static Fracture Toughness of Fiberglass/Epoxy Composite Materials in Hot Climate regions. In IOP Conference Series: Materials Science and Engineering (Vol. 870, No. 1, p. 012170). IOP Publishing.

22. Abdulla, F. A. (2020, July). Experimental and Numerical Investigation of Shot-Peening and Solidification Effects on the Endurance Limit of Composite Material. In IOP Conference Series: Materials Science and Engineering (Vol. 881, No. 1, p. 012058). IOP Publishing.

23. Qasim, M. S., Fadhel, A. A., & Mohammed, H. R. (2020, September). Experimental study of thermal behavior of heated Natural Composite Materials. In IOP Conference Series: Materials Science and Engineering (Vol. 916, No. 1, p. 012091). IOP Publishing.

24. Hussein, A. F., Abdulla, F. A., Hamdan, Z. K., & Ali, W. A. (2020, June). Investigation of stress concentration factor for natural composite material. In IOP Conference Series: Materials Science and Engineering (Vol. 870, No. 1, p. 012155). IOP Publishing.

25. Ogaili, A. A. F., Abdulla, F. A., Al-Sabbagh, M. N. M., & Waheeb, R. R. (2020, November). Prediction of Mechanical, Thermal and Electrical Properties of Wool/Glass Fiber based Hybrid Composites. In IOP Conference Series: Materials Science and Engineering (Vol. 928, No. 2, p. 022004). IOP Publishing.

26. Bader, S. T. (2020, November). Investigation of Natural Composite Materials Pipe Under Thermal Load. In IOP Conference Series: Materials Science and Engineering (Vol. 928, No. 2, p. 022070). IOP Publishing.

27. Abdulla, F. A., Hamid, K. L., Ogaili, A. A. F., & Abdulrazzaq, M. A. (2020, November). Experimental study of Wear Rate Behavior for Composite Materials under Hygrothermal Effect. In IOP Conference Series: Materials Science and Engineering (Vol. 928, No. 2, p. 022009). IOP Publishing.

28. Shyaa, A. K., & abbas Abdulla, F. (2020, November). Enhancement Thermal Conductivity of PCM in Thermal Energy storage. In IOP Conference Series: Materials Science and Engineering (Vol. 928, No. 2, p. 022090). IOP Publishing.