FLAMMABILITY IN ADDITION TO CLAY PROCESSION PERFORMANCE OF TODDLER UNLIMITED COMPLIMENT THREAD NON-BREAKABLE EPOXY COLLECTIVE

Mr. M. Sakthisaravanan Research Scholar (PT), Department of Computer Science, Defence Institute of Advanced Technology, Pune - 411 025& Assistant Professor, Department of Computer Science, Ayya Nadar Janaki Ammal College, Sivakasi- 626 124.
Dr. Dinesh Senduraja Ph.D Research Associate (RA), MED & COS, Defence Research & Development Organisation (DRDO) Pune- 411 021 & Lecturer, Department of Computer Science ,Government Art and Science College ,Veerapandi, Theni -625 534
R. Syed Ali Fathima , Assistant professor, Department of computer Science and Engineering Kalasalingam Academy of Research and Education, Krishankoil-626 126
Mr. S. Sundara Moorthy Research Scholar (PT), Department of Computer Science, Defence Institute of Advanced Technology, Pune - 411 025· & Assistant Professor, Dep.of Computer Science, Arulmigu Kalasalingam College of Art & Science Krishnankoil – 626 126

***Abstract*:**
This study investigates the effects of soil funeral and flammability on sugar palm fiber (SPF) (*Arenga pinnata (wurmb) merr*)-reinforced epoxy fussed. In order to determine the flammability and biodegradability properties, experiments are conducted in accordance with ASTM standards. The hand lay-up method was used to fabricate fused sampleswith two different burden ratios amid epoxy and SPF, which were 70:30 and 50:50. Biodegradability and flammability properties were inspect using Parallel ablazetests, Restrictive oxygen index (ROI), Conduit calorimetric, and soil funeral. It was found that theEpoxy/SPF-50 was the fused that exhibited the fastest degradability at 0.81%/week.The result of the Parallel ablaze test showed that the addition of SPF reduced the ablaze rate but slightly amplified it at 50 wt% because the ratio amid epoxy and SPF exceedsthe optimum fiber loading. The Epoxy/SPF-50 exhibited a better ROI value at 23.3 than pure epoxy (control), which were 19.8. From the Conduit calorimetric test, it was observed that thetime to ignition (TTI) and total heat release (THR) values were dwindled when the quantity

Keywords:
Biofussed, Conduit calorimetric, flammability, soil funeral, sugar palm fiber

Prologue

Over the last decade, the escalating use of natural fibers in polymer fussed has momentously reduced millueal impacts. Owing to their biodegradability, availability, simplicity of processing, low cost, substantial features, and trivial, lignocellulosefiber-reinforced polymer fussed are suggested for use in erection, automotive and stuff diligence (Song et al., 2023; Alaseel et al., 2022; Ibrahim et al., 2012; Jawed & Abdul Khalil, 2011; Sanjay et al., 2018; Tarique et al., 2021). Sugar palm trees could fabricate diverse harvests, including palm sugar, fruits, and fibers (Aworinde etal., 2021; Ilyas et al., 2018; Khan et al., 2021). The SP tree is a jungle lodge that was formerly secret as a Palmae folk's limb but now belongs to the subfamily Arecoideae as well as the tribe *Caryoteae* (Alaaeddin et al., 2019; Atiqah et al., 2018; Ilyas et al., 2020; Tarique et al., 2021). The SP is as well a fast-growing palm that can accomplish ripeness in as little as ten years (Mogea et al., 1991). Indo-Malay province, South Asia, and Southeast Asia are covered by the ecological circulation of SPs (Atiqahet al., 2019; Tarique et al. et al., 2021). Still, by expROIt SPF, plant waste canbe cast-off. Still, SPF is widely vacant at a low cost and is easily handy. Bachtiar et al. (2009) appraise the perfunctory behavior of SPF and establish it to have Young's modulus of 3.69 GPA, a tensile muscle of 190.29 MPA a strain to failure of 19.6%, and a density of 1.26 kg/m^3.
Due to their terrific perfunctory, thermal, and electrical characteristics, modified

Epoxy resins are now utilized to fabricate natural fiber-reinforced fused (NFRCs) and create various industrial harvests. Natural fiber integration is also the most intriguingapproach to altering epoxy resin. innate fibers as fortification in polymers have seena rise in concentration and use in recent years in engineering as well as research expertise (Mohammed et al., 2023; Alamri & Low, 2012; Farhana Mat Nasir et al., 2020; Low et al.,2007; Shih, 2007; Tarique et al., 2022). Das and Biswas (2016) inspect the impact offiber length on the perfunctory behaviour of coir fiber-reinforced epoxy fussed, finding that tensile muscle attained its ceiling value at 12 mm fiber length. Venkateshwaran et al. (2011) examined the estimate of optimal fiber length for banana epoxy fused, finding that escalating fiber length and burden ratio enhanced tensile muscle and modulus, likely a 15 mm fiber length. Aji et al. (2011) inspect the effect of fiber length on tensile self of epoxy resin fused reinforced with kenaf/PALF fibers, finding that a fiber length of 0.25 mm provided the best utmost tensile muscle, although a fiber length of 2 mm reduced tensile modulus property owing to weak interface bonding amid the milieu and reinforcement.

In addition, the perfunctory chattels of epoxy fussed based on a stacking series of Cyperus pangorei and jute fibers were studied by Vijay and Singaravelu (2016) when compared to the other three fussed, the perfunctory muscle of one fabricated with *C.*

Pangorei as the core and jute fibers as the skin deposit was shown to be enhanced. Adhere et al. (2017) lay bare that the scrutiny of sugar palm fibers' usageas rope and habitual formation material stimulated them to explore the likelihood of employing them as a fused fabric. The fibers are warped to the apt spanbefore being woven into rope. The fibers must endure wind loads and give guard from rain and humid sun to be used as habitual roofing in rural tropical conditions becausesugar palm fibers have adequate endurance. Previous research on tensile as well as flexural properties of sugar palm epoxy fussed has focused on the use of woven roving, longrandom, and chopped random fiber fussed, with the results showing that the woven roving sugar palm epoxy fussed gave better properties than the long random and chopped random fiber fussed (Shaba et al., 2016). However, all the samples execute poorly compared to glass fiber epoxy fussed, meaning fiber conduct was essentialfor improving the materials.

Several studies have verified that natural fiber can increase biofuels' resistance to ignition. By reinforcing twill woven hemp fabric with epoxy fussed, Kozłowski and Władyka-Przybylak (2008) found that the flammability of the base milieu fussed was lowered, as measured by higher Restrictive oxygen index (ROI) valuesand a reduced heat release rate of 25%. Moreover, fussed' static and dynamic perfunctory properties from the modified fabric were superior. Bharuch et al. (2014) report that treated fussed performed better in fire and blaze resistance tests (UL94 V and UL 94 HB) and had lower rates of blaze propagation and mass loss. Treated sisal fiber (SF)-reinforced recycled polypropylene (RPP) fussed' flammability was evaluated using a Parallel ablaze test with UL-94 (Gupta et al., 2012). In lightof issues about safety, waste disposal, and the decline of nonrenewable resources,researchers and scientists are also concentrating on using renewable resources (Alas eelet al., 2022; His ham et al., 2011; Liu et al., 2006). Numerous research activities have been done on reinforcing natural fibers that could replace synthetic fibers (glass and carbon fibers) in fused applications, such as coir, date palm, bamboo, oil palm empty fruit bunch (OPEFB), hemp, sisal, flax, jute, and others (de Violoncellos et al., 2014; Doe & Zachary, 2010; Mahout et al., 2014; Mishra & Biwa's, 2013; Skid etal., 2013; Youssef et al., 2012).

Because the existing scenario concerns using logically abundant material to surrogate

Synthetic material, this research deals with NFRCs and using innovative plant fibers to reinforce polymer fused. However, to our knowledge, studies dealing with SPF/Epoxy fussed have not been performed. As a result, the primary purpose of this research was to inspect the biodegradability and flammability characteristics of epoxy-based fussed reinforced with SPF.

Resources AND techniques

Resources

The SPF was calm from sugar palm trees at Kampong Kuala Employ, Nigeria Sembilan, Malaysia, as shown in Figure 1. The epoxy resin and hardener, namely Epoxy HL002 TA/B, are supplied by ZKK SD. Bud, Cheraw, Kuala Lumpur, Malaysia, were used in thefabrication process of the fussed.

Fabrication of SPF/Epoxy Fussed Trying Illustration

The SPF-reinforced epoxy fussed was fabricated at room warmth using a hand lay-up practice. SPF was assorted into the milieu with a stirrer with 500 RPM to fashiona milieu and filler fusion; as a result, a harmonized fusion of milieu and filler was formed. The resin is a colorless, viscous liquid with a viscosity of 5500–1000Cps at 30°C, while the hardener has a gumminess of 30–20Cps at 30°C. The ratio of epoxy resin tohardener was 2:1. Table 1 lists the opus of the SPF-reinforced epoxy fussed. A thin plastic sheet is put to the bottom and top of the mound to accomplish a smooth surfacefor the fussed. The epoxy was mutual with the SPF before being placed into the 300 mm × 300 mm × 3 mm mound. The mound was cured at room warmth for 24 hrs.,after which fused samples be aloof.

Table 1

The formulations of the SPF-reinforced epoxy fussed

Name of fussed	Epoxy Resin (wt. %)	SPF (wt. %)
Pure Epoxy	100	0
Epoxy/SPF-30	70	30
Epoxy/SPF-50	50	50

Portrayal of amalgamated Sample

Soil Funeral Test. A soil funeral test was talented to appraise fussed' biodegradability. Varieties were primed with four replicates of each sample and engraveto the subsequent magnitude: 10 cm (L) × 4 cm (W) × 0.3 cm (H). 4, 8, 12, and 16 weekswere used for the biodegradability test. Varieties were buried 10 beneath the exterior inmoist soil in a polybag. During the test epoch, the polybags were al fresco. After a specified time the varieties were taken out of the soil and dirt free with purify dampen. Using Equation 1, the burden loss, L_{oss} (%), was calculated.

$$W_{loss} = \frac{W_{initial} - W_{final}}{W_{initial}} \times 100\% \quad (1)$$

Parallel enthusiastic Test. The flammability test was carried out in a Parallel position.The varieties had dimensions of 125 mm × 13 mm × 3 mm when ready, according to ASTM D635-18 (2018). Two indication lines were pinched as preliminary and dying pointsat 25 mm and 100 mm intervals. The sample was clamped parallels at the end, creationboth allusion lines visible using a retort stands. The case was lit from the other end,and the timer was ongoing as rapidly as the blaze was 25 mm away from the trial. The test was run in triplicate, and it was noted how long the blaze took to move ahead 100 mm. Equation 2 was used to establish the sample's ablaze rate.

$$V = L\ t \quad (2)$$

Where V, L, and t represent linear ablaze rate (mm/min), burnt length (mm), and time (min), respectively.

Restrictive Oxygen Index (ROI)

The ASTM D2863-09 (2010) is used to evaluate the ROI. This conduct test intended to spotthe lowest oxygen content of the mock-up detonation. The varieties had the Subsequent dimensions: 100 mm × 6.5 mm × 3 mm. The varieties was placed perpendicularly in the hub of a glass cavity and lit for 10 seconds until detonation. Ten replicate varieties were used in the test until the last five varieties, which were tested, had an oxygen concentration deviation of 0.2 vole%. Equation 3 calculated ROI based on the last five testvarieties that burned.

$$LOI\ (\%) = C_{ff} + kd \quad (3)$$

Where C_u is the final oxygen value concentrations, in volume % to one decimal place forthe previous five measurements, d is the interval difference amid oxygen concentrationlevels in percent dimensions, and k is a dynamic derived from tentative values.

Conduit Calorimetric

The Conduit calorimetric testing was conducted Subsequent ISO 5660-1 (2002). The varieties had dimensions of 100 mm × 10 mm × 3 mm. The varieties was wrapped in aluminumfoil on the sides and underneath before being placed Parallels on the varieties holder. The varieties' surfaces were spark-ignited and irradiated with a 35 kW/m^2 heat flux.

RESULTS AND Debate

Soil funeral

Soil funeral testing for SPF-reinforced epoxy amalgamated was done for 16 weeks. It was observed that the burden loss of an epoxy resin was raised in the innate soil milieuafter the fortification of SPF. As expected, loss of burden loss of fused was more momentous with an augment in funeral time in soil. The burden of pure epoxy had lost 3.55% of its innovative burden by the end of week 16, while the burdens of Epoxy/SPF-30 and Epoxy/ SPF-50 had lost 9.74% and 12.88%, respectively. The average degradation rates for pureepoxy and Epoxy/SPF-30 are 0.22%/week and 0.61%/week, respectively. Epoxy/SPF-50had the premier usual degradation rate of 0.81%/week. Figure 2 illustrates the trend of burden loss (%) of SPF-reinforced epoxy fussed as a function of biodegradation timeafter soil funeral analysis.

Pure epoxy indication a minimal burden loss because the polymer milieu is not easy to degrade. It was noticed that escalating the quantity of SPF amplified the degradability rate. Epoxy/SPF-50 indication the highest rate of degradability. The existence of cellulosein SPF allows water molecules to easily absorb. Due to its hygroscopic nature, cellulose in SPFs can absorb water from the milieu and swell. The escalating hygroscopic properties of fussed enhanced microbial activity, resulting in burden loss (Ilia's et al., 2020; Minh et al., 2019). The mechanism of biological degradation comprises water

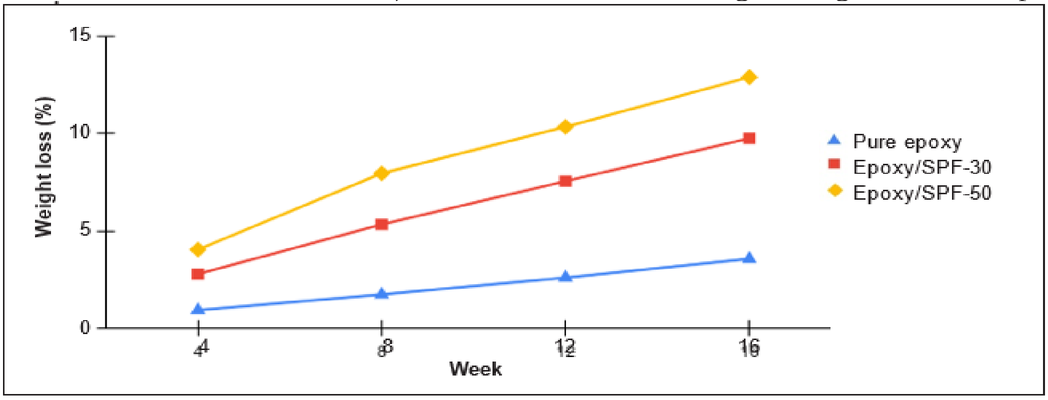


Figure 2. The trend of the sample's burden loss (%)

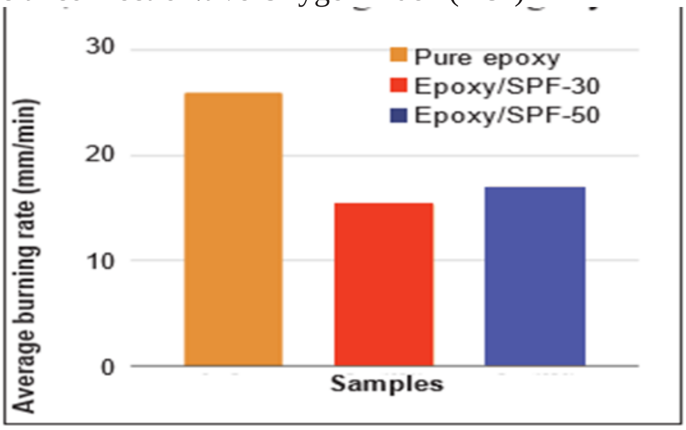
molecules trenchant the material, strong covalent bonds breaking, and microorganisms degrading the hemicellulose and cellulose.

Parallel Ablaze Test

The SPF-reinforced epoxy fussed' Parallel ablaze test was tested Subsequent ASTM D635 (2018). The fire was stopped when it reached the 100 mm mark of the varieties. Figure 3 shows the average ablaze rate of the samples.

According to the findings, incorporating SPF reduces the rate of ablaze. Epoxy/SPF-30 burned at a lower rate of 15.4 mm min^{-1} than pure epoxy, which burned at 26 mm min^{-1}. The blaze took time to promulgate alongside the Epoxy/SPF-30 sample and fictitious charin chorus. The SPF habitually flows into char during ablaze, providing bonus blaze-retardant fortification (Soriano et al., 2021). This finding indicates that reinforcing the SPF reduced the epoxy fuse's ablaze rate. However, the ablaze rate augmentedslightly in Epoxy/SPF-50 due to the SPF/

EP ratio being more than finest fiber loadings. As a result, the fuse's ability to formulate char is reduced during theablaze process (Xiao et al., 2018; Torque etal., 2022). Compatibility of fiber and milieu is critical for providing the best blaze- retardant characteristics to fuse. The milieu polymer determines a fuse's by their interfacial connection.tive Oxygen Index (ROI)



The ROI is a extensively used fire index for distinguish the flammability of polymer stuff. It describes the lowest oxygen concentrations required to help a material's flammable ignition. The ROI values of varieties are shown in Table 2.
The frontier Oxygen value of pure epoxy is
19.8% and is classified as burnable as its ROI value is lower compared to the oxygencontents of air, which is 21%. Textile withless than 21% ROI value is secret as flammable under the customary ROI criteria. Conversely, supplies are painstaking to be Table 2
The Restrictive oxygen index (ROI) of the samples

Samples	ROI
Pure Epoxy	19.8
Epoxy/SPF-30	22.5
Epoxy/SPF-50	23.3

self-extinguishing if their ROI value is larger evaluate to 21% because, according to the usual air opus, oxygen content in the air is 21%, as materials with a value elevated compared to this cannot support ablaze at room warmth without an exteriorfire spring (Karunakaran et al., 2016). Pure epoxy possessed a low ROI value due to the poor flammability assets of the polymer milieu. According to Prabhakar et al. (2015), polymer matrices are weak against blaze propagation and thermal load. Polymer matrices themselves depend upon corroboration and filler. The Epoxy/SPF-50 indication a better ROI value of 23.3 compared to the Epoxy/SPF-50, which is 22.5. Fussed' flammability is influenced by interactions amid and among its constituent parts. However, the ablazerate of the epoxy/SPF-50 was lower because higher ROI values indicate lower flammability,a lower ablaze rate, and better blaze retardance. Combining them can make the fused less flammable (Gurunathan et al., 2015). However, the ROI value was not momentously amplified amid the 30 wt. % and 50 wt. % of SPF, which may be related to the non-polar behavior of SPF that affects low fiber dispersion.

Conduit Calorimetric

Conduit calorimetric gathers data like TTI, HRR, and THR. Table 3 shows selected data obtained from the Conduit calorimetric test.

TTI portray the time needed for ignition when materials are exposed to a constantheat flux (35 kW/m^2) and in an oxygen-controlled milieu. Thus, the privileged TTI is preferable as well as considered to be less flammable. From Table 4, Epoxy/SPF-50 hasthe lower TTI at 62 seconds, while Epoxy/SPF-30 has the higher TTI at 97 seconds. Thefast ignition of Epoxy/SPF-50 could be due to the high lignin content of SPF. Lignincollapse contributes more to char generation than cellulose and hemicellulose. still,lignin deopus begins at a lower warmth, amid 160 and 400°C (Ali et al.,2021; Fu

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et al., 2017). Therefore, the increase in lignin content will increase flammability.The heat release rate is a crucial and further factor in seminal a material's flammability (HRR). When a material is exposed to fire, HRR is the heat released per unitarea. In addition to being a crucial restriction for describing fire behavior, it also plays arole in defining concepts like a fire hazard. HRR curve for varieties is shown in Figure 4. According to scrutiny, the HRR curve for SPF-reinforced epoxy fussed has two peaks. By forming carbonic char structures, the first peak reflects the charring process. The

Table 3
The selected data obtained from the Conduit calorimetric test

Samples	TTI (S)	pHRR (kW/m^2)	THR (MJ/m^2)
Pure Epoxy	82	706.3	99
Epoxy/SPF-30	97	468.5	79
Epoxy/SPF-50	62	355.1	71

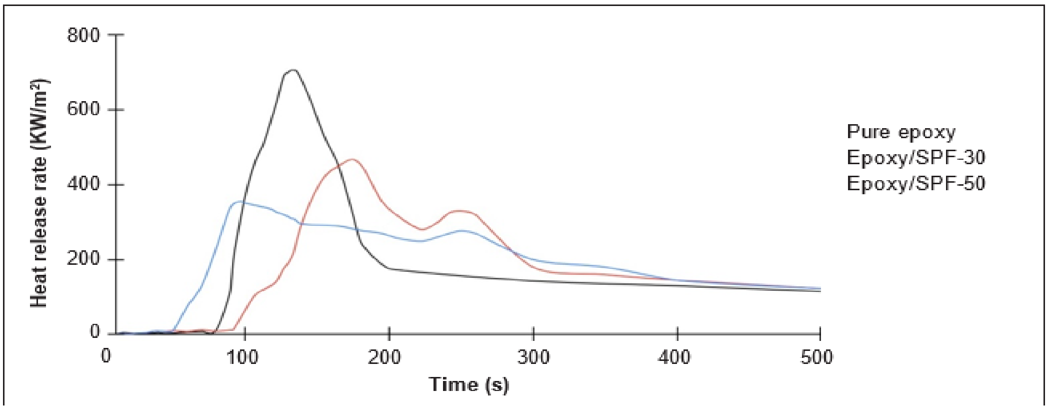

Figure 4. The HRR curves for the samples

Char layer shelter and prevents the society of mass and volatiles from the thick to the gas phase. Hence, after the first peak, the ignition rate dwindles, and a dropin the HRR curve was seen. As the ablaze route goes on, a surplus of fascinated volatiles causes high interior anxiety during the escape, which accelerates the configuration of voids and causes the char residue to crack and humiliate, which further persuade ignition and results in another peak HRR (Cheek et al., 2020).

The ceiling quantity of heat unrestricted during ignition is referred to as the peak HRR (pHRR), and the total quantity of heat released is shown by the area under the HRRcurve (THR). From Figure 4, the pure epoxy reveals the highest pHRR at 706.3 kW/m^2.When the quantity of SPF amplified, the TTI and THR values from the Conduit calorimetric test dwindle. The Epoxy/SPF-30 showed superior thermal solidity than Epoxy/SPF-50. Moreover, char fabrication supports the blaze-retardant struggle of SPF-reinforced epoxy fussed. A momentous diminution of pHRR amid 33% and 50% was seen on the SPF-reinforced epoxy fussed than pure epoxy. The supreme diminution was observed on Epoxy/SPF-50, with a pHRR of 355.1 kW/m^2 and a THR of 75 MJ/m^2. Thediminution of pHRR and THR of the sugar palm fused could symbolize the augment inchar fabrication (Hatanaka et al., 2016).

Finale

This delves into aims to widen an epoxy fused resistant with SPF. The Epoxy/ SPF-30 fused indication the lowest ablaze rate for parallel ablaze at 15.4 mm/ min due to char fabrication from SPF, which amplified blaze-retardant shield. The ROI value increases when the quantity of SPF is amplified. Epoxy/SPF-30 is better than Epoxy/SPF-50 due to the low scattering of fiber when the quantity of SPF is amplified. From the Conduit calorimetric test, TTI and THR values dwindled when SPF amplified. In Accretion, the char gadget helps to raise fireproof resistance of SPF-reinforced epoxy fused. The degradability rate of sugar palm-reinforced epoxy amalgamated was augmented as the magnitude of SPF augmented. After 16 weeks of soil funeral taxing, pure epoxyindication the buck burden loss, 3.55%, and Epoxy/SPF-50 indication the chief burden loss, 12.88%. But, the fruition in this field has enabled the use of natural-fiber-based fussed in a wide variety of diligence, plus edifice, automotive, and aerospace.

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