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Experimental Investigation Of Mechanical And Water Absorption Properties Of Waste Cassette Disc Powder As A Filler In Woven Natural Fiber Composites

Immanuel Durai Raj. J[1,a*], Arivazhagan.M[2,b], Prabhuram.T[3,c], Sibi silvesta. J[4,d]
[1*,2,3,4]Department of Mechanical Engineering, St. Joseph's Institute of Technology, Tamil Nadu, India, 600119 , [a]immanuelje74@gmail.com, [b]arivazhaganm138@gmail.com, [c]prabhuram.t@gmail.com, [d]ajsibisilvestar@gmail.com

ABSTRACT
The world currently acknowledges that e-waste is the waste stream that is expanding at the quickest pace. If not properly managed, the toxic chemical components of e-waste can have a detrimental impact on the health of individuals and ecosystems. This represents an imminent impediment to the realization of sustainable development objectives. Waste cassette discs are an example of electronic waste that is not biodegradable and contains numerous hazardous components that pose environmental hazards. This work implements an alternative method for the safe disposal of e-waste materials. In this study, waste cassette discs are pulverized and impregnated into pine apple-woven natural fiber composites in the ratios of 0%, 5%, 10%, 15%, and 20% by weight of fiber. A vacuum bagging method hand lay-up process with epoxy resin is used for the fabrication of composite boards. An analysis of the composite board's mechanical, water absorption, and surface roughness properties was conducted. Experimental results demonstrated that the addition of waste cassette disc powder, with an optimal weight percentage of 5%, enhanced the mechanical properties of the composite. This experimental work highlights the potential of waste cassette disc powder as a cost-effective and environmentally friendly filler material for improving the mechanical properties of composites and also paves the way for the safe disposal of e-waste.
Key words: *pine apple woven fiber, e-waste disposal, vacuum bagging process, water absorption test, waste cassette disc powder.*

INTRODUCTION

Electronic waste is a term that describes wasted electronic devices. A variety of electronic gadgets, such as laptops, video cameras, CDs, DVDs, remote controls, hard drives, televisions, as well as e-cigarettes, dishwashers, and solar panels, are included in this category[2]. These devices are no longer desired by their owners, have stopped functioning, or have become obsolete in comparison to new technologies that are emerging [1]. As a result of product failure or obsolescence, several million electrical as well as electronic gadgets end up in landfills each year. When not disposed of or recycled properly, these obsolete electronics represent a risk to human and environmental health [4,5, 6]. Worldwide, e-waste production reached an expected 62 million metric tonnes in 2022. In 2030, it will reach 82 million metric tonnes, an increase of 32 percent. Formally collected and recycled materials, are accounted for only 22.3% of the total[3]. Waste cassette discs (WCD) and digital video discs (DVD) are two of the e-waste materials that are going to become obsolete nowadays. A billion CDs and DVDs are made annually, but millions are discarded. Many of them end up in incineration and landfills, which negatively impact the environment, waste energy, and deplete useful materials. CDs don't break down easily, so landfills aren't a beneficial way to get rid of them. Over time, CDs can leak out Bisphenol A (BPA), which can be harmful to people's health. Burning CDs releases toxic fumes into the air, and single-stream bins cannot recycle them without a special process. Experts estimate that a CD will require over a million years to completely decompose in a landfill. BPA is considered a dangerous chemical due to its effects on fertility, eye damage, skin allergic reactions, and respiratory irritation. Endocrine disruptor BPA can also disrupt hormone function. Therefore, we need to find an alternative method for the safe disposal of WCD. A novel way is proposed in this research work by converting WCD into micro sized filler and reinforced with pine apple woven fiber composites along with epoxy resin.

1.1 Selection of fiber

Natural fibers are a renewable resource offering a superior solution for sustainable supply due to their low cost, low density, minimal processing expenses, absence of health concerns, and enhanced mechanical and physical qualities. The primary disadvantage of natural fiber is its moisture absorption, necessitating the alteration of its surface properties through chemical treatment. Synthetic fiber-reinforced polymers were pricey and had an influence on the environment [7]. Because of their high cellulose content, pineapple leaf fibers have outstanding mechanical qualities, and as a result, they are utilized in the construction of buildings and automobiles across the world [8]. The chemical components of PALF (pine apple leaf fiber) include cellulose (70-82%), hemicellulose (11-18%), lignin (5-12%), and ash (1.1%) [9]. Pineapple (PALF) possesses exceptional mechanical qualities and can be utilized in the production of sustainable textile products. The density of PALF is comparable to that of other natural fibers, however, its textile modulus is significantly high, and its tensile strength is the highest among related natural fibers [10]. Pineapple leaf fiber (PALF) possesses a more delicate texture than all other vegetable fibers. The fiber exhibits a silky gloss, a pure white hue, is finer than jute, and possesses excellent antibacterial qualities. At now, products utilizing natural fibers are increasingly sought after due to their renewable characteristics, superior biodegradability, and environmentally benign manufacturing processes [11]. The tensile mechanical test of woven fiber specimens showed a very comparable tensile strength that is 17.1% greater than those that have not been stitched [12].

Table.1 Physical and Mechanical Properties of pine apple fiber [15-16]

Diameter (μ)	Density (kg/mm^3)	Tensile strength (MPa)	Young's modulus (GPa)	Failure strain (%)
50	1540	1020	71	0.8

Table.2 Calculation of filler % addition by weight of PALF fiber

Laminate	Amount of WCD filler used (%)	Weight per layer (gm)	Amount of filler (gm)
PA1	0	31+32+30+31+31=155	0
PA2	5	32+31+31+31+32=157	7.85
PA3	10	31+31+32+31+32=157	15.7
PA4	15	32+32+31+31+32=158	23.7
PA5	20	31+31+31+32+31=156	31.2

2. MATERIALS AND METHODS

2.1 Preparation of WCD filler

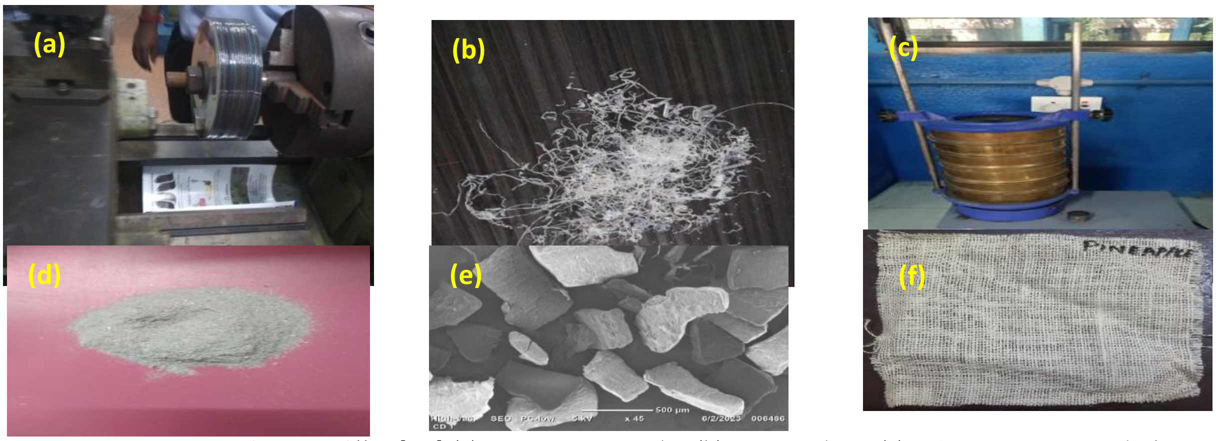


Fig.1 Preparation of WCD filler [13] (a) Turning in Lathe (b) WCD chips (c) 75 microns sieve shaker (d) Micro sized filler (e) SEM image of WCD filler (f) Pine apple woven fiber

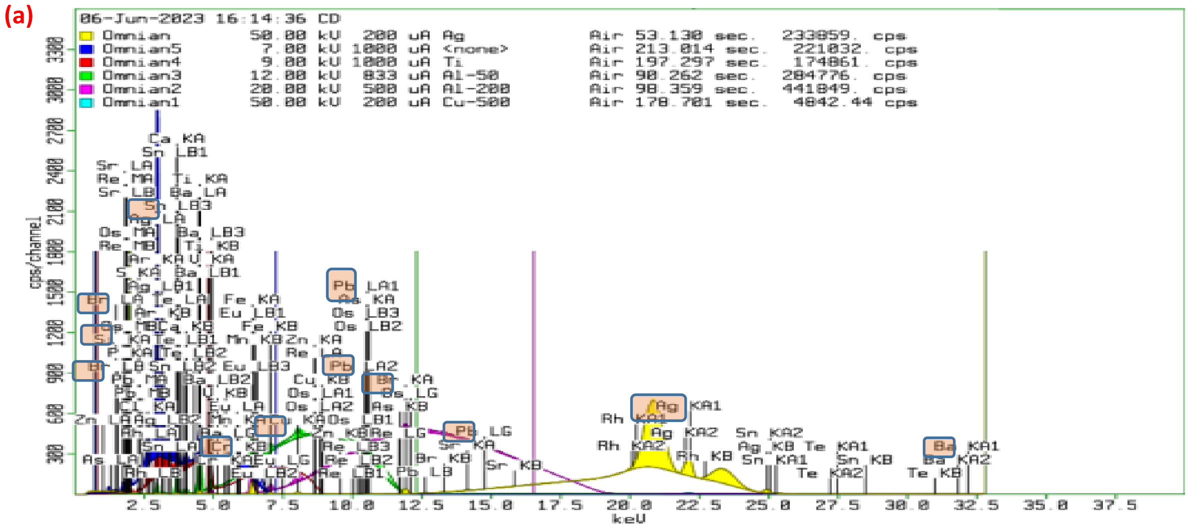


Fig. 2 XRF analysis of WCD filler [7]

Table. 3 XRF elemental composition of WCD filler [7]

Compound	SnO_2	BaO	CuO	P_2O_5	PbO	SrO	ZnO	Br
Wt. (%)	30.8	29.3	12.7	11.6	3.6	1.9	2.01	7.6

Waste compact discs (WCD) and digital versatile discs (DVD), which were collected from waste scrap dealers along with the labels of the discs. It was fed into the lathe for the turning operation (Fig. 1). Then it was grinded and sieved to 75 microns. XRF (X-ray fluorescence) graph analysis (Fig. 2) shows the presence of various hazardous elements like tin, barium, copper, phosphorous, lead, zinc, and bromine, etc. Table 1 shows the weight percentage of hazardous elements present in WCD filler.

2.2 Composite board preparation

WPCB fillers and WCD fillers are taken in the proper proportion of 5%, 10%, 15%, and 20% by weight of fiber. WCD filler particles are combined in a 10:1 ratio with epoxy resin LY 554 and the hardener amino hydrocarbon. Epoxy resin is chosen since it possesses superior flexibility and strength and is frequently employed as the primary constituent, serving as both adhesives and matrices [14]. The sonication process properly mixes fillers with epoxy resin. The hand layup process is used for the fabrication of laminates. To remove the air trapping, the vacuum bagging technique is used. In order to meet the ASTM testing requirement of a thickness ranging from 4 to 5 mm, an overall of five layers of fiber had been applied. Every layer is organized in a uniform orientation. The vacuum was sustained at a pressure of 0.1 bar for a duration of three hours utilising a vacuum pump. A minimum period of 24 hours is required to ensure adequate drying. The board was subsequently extracted from its mold. Five laminate boards were fabricated. One without the addition of fillers. Another 4 laminate boards with 5%, 10%, 15%, and 20% addition of WCD fillers with respect to the fiber layer weight of different fibers. Samples to conduct mechanical and thermal tests were prepared by the water jet machining process. Required samples are marked with dimensions as per the requirement from the ASTM standard for different tests to be conducted.

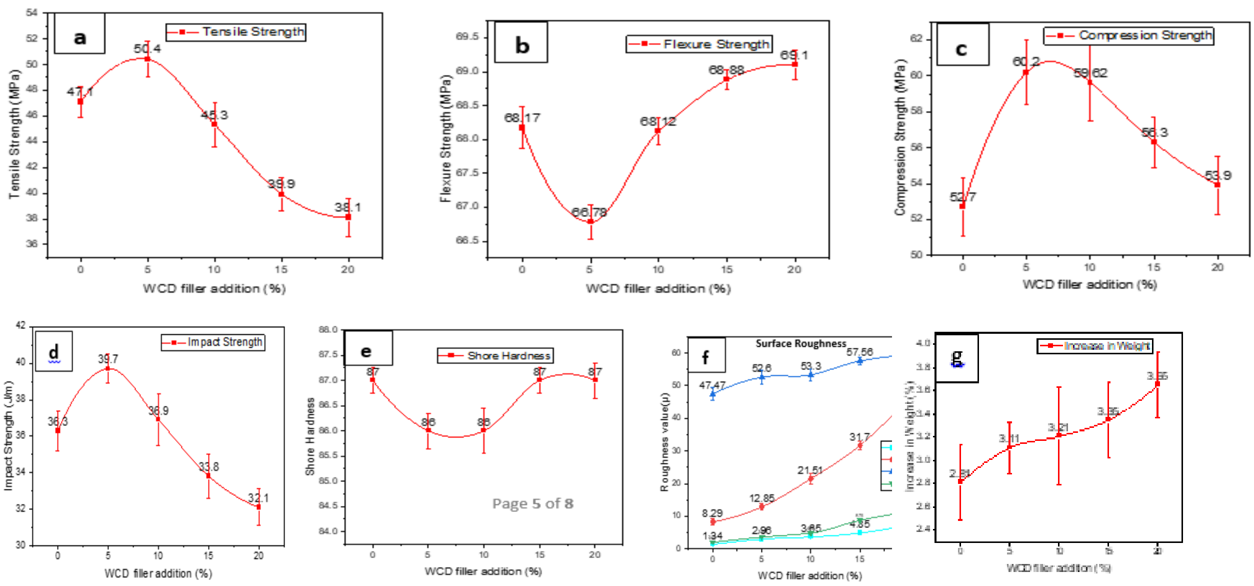
2.3 Experimental methods

Material tensile strength was measured using ASTMD3039 specimens (120 × 20 × 3 mm) prepared using a Dak System Inc. 7200 Series UTM (universal testing machine). For each WCD filler concentration, three specimens were calculated and the average calculated. We used an ASTM D3410-compliant compression testing machine (Dak System Inc., Make, 7200 Series) to compress the fabricated composite samples. Three 120 × 25 × 3 mm samples were tested at 2 mm/min under 100 kN stress. Flexure testing was done in a three-point bending machine per ASTM D-790. The specimens are 125 mm long, 12.7 mm wide, and 3.2 mm thick. The ASTM D256 Izod impact test was used to determine the load-bearing

capacity of the WCD-reinforced polymer composite. A vertically placed pendulum hammer broke composite specimens (64mmx12.7mmx3.2mm) with 10 kJ and measured the impact energy in J/m.
Fiber-reinforced composites are usually tested for hardness using the Shore D test. A shore durometer is used to measure this following ASTM D2240. Zero-to-100 is the reading scale. As value increases, hardness increases. The composite's water absorption ability was examined to determine fiber absorption in water. Slices of 2″ diameter by 0.25″ thickness were taken from each composite specimen to assess water absorption according to ASTM D570 criteria. Samples were dipped in room-temperature water for 24 hours. To assess weight after immersion, the samples were removed from the water and weighed. The percentage of water absorption was calculated by weighing the samples..

3. RESULT AND DISCUSSIONS

Fig. 3 incorporates various mechanical testing results pertaining to pineapple cloth incorporated with WCD filler. Mean values are computed, and error bars are displayed according to the data dispersion. Fig. 3(a) illustrates the variability of sample tensile properties. The tensile strength of the composite increases consistently with the concentration of WCD filler, reaching up to 50.4 MPa [17]. It rises by up to 5% before declining in both tensile values. The incorporation of WCD filler enhances tensile strength. The WCD filler comprises high-modulus polycarbonate particles that function as reinforcing fillers, diminishing matrix mobility and enhancing composite rigidity. The graphical representation indicates that the tensile strength of composites stabilised following the addition of 5 wt.% fillers, as PALF fibers may detach from the matrix under increased loading, hence reducing the reinforcing effectiveness of the fillers [18], as illustrated in Fig. 3(i) as well as Fig. 3(j).
The compression test data also indicates that the composite compressive strength of WCD filler is 60.2 MPa, as illustrated in Fig. 3(c), due to the uniform distribution of WCD filler in all openings of PALF fiber. The flexural strength variations of PALF composites are illustrated in Fig.3(b). In bending strength experiments, composites composed of PALF that contain no filler exhibit superior performance. The flexure strength has decreased slightly from 68.17 MPa to 66.7 MPa due to the incomplete homogeneous contact between the fiber and the filling [19].



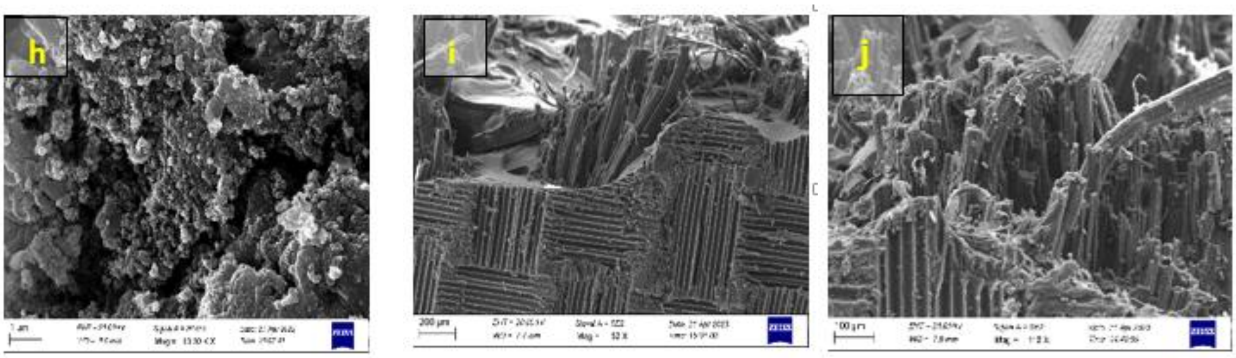


Figure : 3 Mechanical testing results & SEM image (a) Tensile test results (b)Flexure strength results (c) Compression test results (d) Impact strength results (e) Shore D hardness test (f) Surface roughness results (g) Water absorption results (h) WCD filler distribution in Pine apple fiber laminates (i) Tensile test fiber breakage (j) Tensile test fiber de-bonding. The results of the impact test are depicted in Fig. 3(d). A composite is capable of absorbing impact due to the fact that its constituent elements are linked together by a polymeric matrix, which uniformly transfers the force of the impact. At 5%, PALF composites exhibit an enhanced impact strength of 39.7 J/m. The laminates become brittle if additional WCD fillers are added, and the energy-absorbing capability decreases significantly at a 20% filler addition. The impact of the inclusion of WCD fillers with varying percentages on hardness values is illustrated in Fig.3(e). At a 15% filler addition, laminate exhibits a slightly greater hardness value of 87. The surface of the laminate is rendered more durable by the inclusion of fillers. The absorption of water has restricted the practical application of natural fibers as reinforcements. Natural fibers are prone to moisture absorption due to their hydrophilic, cellulose-rich chemical structure. Micro cracks are the result of a fracture between the matrix and the fiber. The water absorption percentage of WCD filler increases rapidly to 3.65% when 20% of the filler is added, as illustrated in Fig.3 (g). This is due to the fact that the fillers' concentration absorbs water, and there will be a tiny void in between the fibers along with the matrix [20]. Fig.3 (f) displays the roughness average (Ra), maximum roughness depth (Rmax), root mean square average of the profile heights (Rq), average maximum height of the profile (Rz), and the readings were taken. The average value is tabulated. The Ra value increases gradually as the density of the filler increases, as the WCD fillers are forming interstitial compounds.

4. CONCLUSION

The mechanical, surface roughness, and water absorption results lead to the following conclusions:

- The tensile strength increases from 47.1 MPa to 50.4 MPa, the compression results show an increase from 52.7 MPa to 60.2 MPa, and the impact strength increases from 36.3 J/m to 39.7 J/m with the 5% addition of fillers. A further addition of filler decreases the strength.
- The flexural strength decreases from 68.1 MPa to 66.7 MPa, while the shore D hardness values drop from 87 to 86 at a 5% filler addition. Additionally, an increase in the average surface roughness value and water absorption capacity is observed as the amount of filler addition increases.
- The SEM image shows the distribution of WCD filler in the PALF composites, as well as the peeling off and tearing of fibers at the fracture point.
- Through this experimental work, it has been found that instead of dumping or incinerating waste compact discs into landfills, they can be used as fillers in natural fiber composites.

AUTHOR CONTRIBUTIONS Immanuel Durai Raj: writing – original draft, investigation, and formal analysis; Arivazhagan: writing –review and editing, and formal analysis; Sibi silvesta : writing – review and editing, and investigation; Prabhuram: conceptualization and methodology.

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