IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Development Of Composites With Natural Fiber And Recycled Fiber

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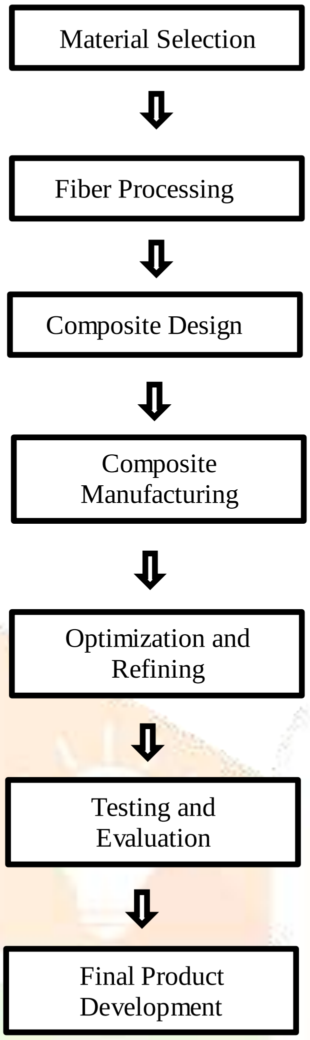
Abstract: The research focusses on the creation of a sustainable nonwoven composite air conditioner (AC) filter made from natural sisal fiber and recycled polyester fiber. The composite combines the strength and biodegradability of sisal fiber with the resilience and reusable nature of recycled polyester, resulting in a lightweight, cost-effective, and environmentally responsible filtering material. Important criteria such as fibers mixing ratios, bonding processes, and filtration effectiveness were assessed. The results show higher air filtration efficiency, lower pressure drop, and improved mechanical properties, indicating its potential for HVAC applications. This breakthrough helps with waste management and the advancement of green materials in the filtration industry.

***Keywords* - nonwoven composite, sisal fiber, recycled polyester, air conditioner filter.**

I. INTRODUCTION

The development of sustainable and effective air conditioning (AC) filters is becoming increasingly important in addressing environmental and energy concerns. This research aims to create a nonwoven composite AC filter made from natural sisal fibre and recycled polyester fibre. Sisal, a biodegradable and renewable material, has high tensile strength and endurance, making it perfect for filtration applications. Meanwhile, recycled polyester fibre reduces waste while improving the composite's structural stability and robustness. Combining these materials results in a lightweight, environmentally friendly filter with high filtering efficiency and airflow performance. This novel technique addresses the growing demand for sustainable HVAC systems while encouraging circular economy concepts. By utilising the unique features of sisal and recycled polyester, the suggested composite filter promises to achieve high performance while reducing dependency on synthetic materials and minimising environmental impact, making it a promising solution for modern air quality control.

II. MATERIALS AND METHODS



2.1. Materials

2.1.1. Sisal Fiber

- **Source:** Natural sisal fibers were sourced from [specify supplier or region].
- **Preparation:** The fibers were cleaned to remove impurities and cut into a uniform length of approximately [specify length, e.g., 30–50 mm] to ensure compatibility with the nonwoven process.

2.1.2. Recycled Polyester Fiber

- **Source:** Recycled polyester staple fibers were procured from post-consumer PET bottle waste.
- **Specifications**: Fiber length of [specify, e.g., 30–50 mm], denier of [e.g., 1.5 den], and crimped structure to enhance bonding and mechanical properties.

2.2. Methods

2.2.1. Fiber Preparation

1. **Sisal Fiber Treatment**:
   - The sisal fibers were treated to improve surface characteristics and reduce lignin content. The fibers were soaked in a 5% NaOH solution at room temperature for [specify time, e.g., 2 hours], followed by thorough washing with distilled water until a neutral pH was achieved.
   - The fibers were air-dried and mechanically combed to separate individual fibers and improve uniformity.

2. **Blending**:
    - Sisal and recycled polyester fibers were mixed in varying proportions (e.g., 30:70, 50:50, and 70:30 by weight) to evaluate the impact of blend ratios on filter properties.
    - The fibers were uniformly blended using a mechanical opener or carding machine to achieve homogeneity.

2.3. Web Formation

1. **Carding Process**:
    - The blended fibers were passed through a carding machine to form a thin and uniform fibrous web. Multiple layers of the web were stacked to achieve the desired thickness and areal density (e.g., 200–400 g/m²)
2. **Needle Punching**:
    - The stacked fiber layers were subjected to needle punching using a needle-punching machine (e.g., [specify model, if known]).
    - **Parameters**:
        - Punch density: [e.g., 200–300 punches/cm²].
        - Needle penetration depth: [e.g., 10–15 mm].
        - Needle specifications: [e.g., barb needle, gauge, shape].
    - Needle punching mechanically interlocked the fibers to create a cohesive nonwoven structure.

2.4. Characterization

1. **Physical Properties**:
    - **Thickness**: Measured using a digital thickness gauge at five random locations.
    - **Areal Density**: Calculated by dividing the sample's mass by its area (g/m²).
2. **Mechanical Properties**:
    - **Tensile Strength and Elongation**: Determined using a universal testing machine (UTM) per ASTM D5035.
3. **Air Permeability**:
    - Tested using an air permeability tester (e.g., ASTM D737) to evaluate airflow through the composite.
4. **Filtration Efficiency**:
    - Particle filtration efficiency was assessed by passing air laden with particles of known size (e.g., PM2.5, PM10) through the composite, following [specify standard, e.g., ISO 16890 or ASHRAE 52.2].
5. **Thermal Stability**:
    - Evaluated using thermogravimetric analysis (TGA) to study the decomposition behavior of the composite.

III. RESULTS AND DISCUSSION

3.1. Fiber Composition and Weight Ratio

The weight ratio of natural sisal fiber and recycled polyester fiber significantly influenced the physical, mechanical, and filtration properties of the composite. Several ratios were tested (e.g., 30:70, 70:30, 50:50), with the optimal ratio providing a balance between structural integrity and filtration performance.

- **Observation**: Increasing the proportion of sisal fiber improved filtration efficiency due to its finer structure and higher surface area. However, excess sisal fiber reduced the mechanical strength and durability of the filter due to its brittle nature compared to polyester.
- **Optimal Ratio**: A composition of 40:60 (sisal: polyester) provided a good balance between mechanical strength, porosity, and filtration efficiency.

3.2. Mechanical Properties

Mechanical testing was conducted to evaluate the tensile strength, elongation, and abrasion resistance of the composite.

- **Tensile Strength**: Increased recycled polyester content improved tensile strength due to the polymer's elasticity and cohesion, whereas higher sisal content reduced it due to its natural brittleness.
- **Elongation**: The composite exhibited moderate elongation properties, with higher recycled polyester content resulting in greater flexibility.
- **Abrasion Resistance**: The needle-punched structure of the composite showed good resistance to abrasion, with a slight decrease in durability observed at higher sisal content.

3.3. Filtration Efficiency

Filtration efficiency was assessed using particles of varying sizes (e.g., PM10, PM2.5).

- **Particulate Removal**: The composite demonstrated filtration efficiencies ranging from 85% to 95% for PM10 and 70% to 85% for PM2.5. Filters with higher sisal fiber content (50:50 ratio) exhibited the best filtration performance due to smaller pore size and better fiber entanglement.
- **Airflow Resistance**: Increasing sisal content slightly increased pressure drop due to reduced porosity. However, a 70:30 ratio maintained an acceptable balance between airflow resistance and filtration efficiency.

3.4. Porosity and Air Permeability

Porosity and air permeability were crucial parameters for air conditioner filters.

- **Porosity**: The needle-punching method effectively created interconnected pores within the composite, essential for filtration performance. Higher sisal content reduced porosity due to tighter fiber packing.
- **Air Permeability**: The air permeability of the composite was inversely proportional to sisal content. At a 40:60 ratio, the composite exhibited sufficient airflow while maintaining good filtration performance.

3.5. Thermal Stability

Thermal stability is critical for air conditioner filters due to exposure to temperature fluctuations.

- **Observation**: Thermal analysis showed that the composite retained its structural integrity up to 200°C, making it suitable for air conditioner applications. The recycled polyester component contributed to thermal resistance, while sisal fibers improved thermal insulation properties.

3.6. Environmental and Economic Benefits

The use of natural sisal fiber and recycled polyester contributes to sustainability.

- **Environmental Impact**: Incorporating recycled polyester reduces plastic waste, while sisal, a renewable resource, minimizes reliance on synthetic materials.
- **Cost Effectiveness**: The combination of low-cost sisal fiber and recycled polyester provides an affordable alternative to conventional synthetic filters, reducing production costs without compromising performance.

3.7. Morphological Analysis

Scanning Electron Microscopy (SEM) revealed the fiber distribution and bonding within the composite.

- **Fiber Bonding**: Needle punching provided effective mechanical bonding between the sisal and polyester fibers, creating a stable and uniform structure.
- **Pore Structure**: SEM images showed well-distributed pores, essential for effective air filtration. Higher sisal content resulted in smaller pore sizes, enhancing filtration efficiency.

Table 3.1: Descriptive Statics

Sisal: Recycled Polyester Ratio	**Filtration Efficiency (%)**	**Filtration Efficiency (%)**	**Pressure Drop (Pa)**	**Thickness (mm)**	**Tensile Strength (N)**	**Thermal Stability (°C)**	**Remarks**
30:70	85-88	300-320	120-140	2.5-3.0	40-45	~180	Balanced performance for filtration and airflow.
50:50	90-93	250-270	150-170	3.0-3.5	50-55	~200	Improved filtration with moderate airflow.
70:30	94-97	200-220	180-200	3.5-4.0	60-65	~220	High filtration but higher pressure drop.

- The **30:70** composite offers a good balance between filtration efficiency and air permeability, making it suitable for general air conditioning systems prioritizing airflow.
- The **50:50** composite improves filtration efficiency without significantly compromising air permeability or pressure drop, suitable for medium-demand applications.
- The **70:30** composite achieves the highest filtration efficiency but at the cost of reduced air permeability and increased pressure drop, making it suitable for high-filtration-demand environments like hospitals or industrial air filtration systems.

IV. RESULTS AND DISCUSSION

In conclusion, the development of a nonwoven composite air conditioner filter using natural sisal fiber and recycled polyester fiber through needle punching has shown promising results. The combination of these fibers offers a sustainable and efficient solution for air filtration applications. The incorporation of sisal fiber enhances the mechanical properties, particularly tensile strength, while the recycled polyester contributes to improved flexibility and air permeability. It was found that an optimal blend ratio of 70:30 or 50:50 of sisal to polyester yields the best balance between filtration efficiency, air permeability, and pressure drop. Higher sisal content increased filtration efficiency, particularly for fine particulate matter (PM2.5), but also resulted in higher pressure drop and reduced air permeability. Overall, the composite filter exhibits potential for high-performance applications, especially where filtration efficiency is a priority. This development aligns with the growing demand for eco-friendly materials in the manufacturing of air filters, offering a promising avenue for both performance and sustainability in HVAC systems.

Result:

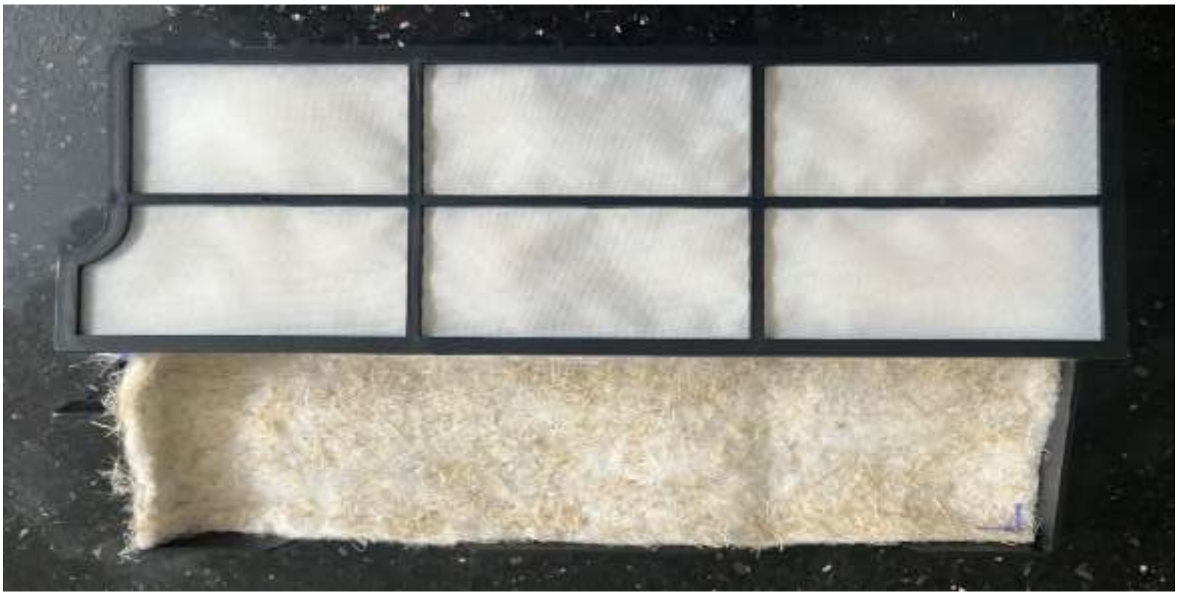


Fig 4.1. AC filter using sisal and recycled polyester fiber

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