ISSN:2153-182X, E-ISSN: 2153-1838
Vol. 17 No. 02 (2023)

ENHANCING PERFORMANCE AND SUSTAINABILITY THROUGH ADVANCED MATERIAL BLENDING IN HYBRID COMPOSITE DESIGN

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Abstract: Engineering and manufacturing are domains where material layout and selection are crucial. This procedure entails a thorough assessment of the materials, taking long-term viability, affordability, and property considerations into account. Making the best material choices is crucial to achieve durability, aesthetics, and functionality while reducing their adverse effect on the planet. Furthermore, there are advantages and disadvantages for different industries associated with the growth of composites that are hybrids, especially when it comes to the incorporation of plastics with additional components. The importance of material selection as well as design is emphasized in this abstract, along with how they affect the product performance and sustainability. Creative thinking and business actions are going to be shaped by future developments in material science and design.
Keywords: Material layout, design, growth of composites, hybrid composites with polymers, product performance, sustainability, material science,

I. INTRODUCTION

A. Project Specification

Materials are one of the crucial properties of an object which defines the structural properties and other factors of an object. The design procedure of an object very much depends on the materials that are selected to build the object. The selection of materials is the initial and one of the crucial steps to give the desired structure of the object. Composite material is one of the widely used materials in manufacturing industries. The use of composite materials in building an object is beneficial compared to the other materials types. Multiple materials having different properties compared to each other are used to create a composite material. The use of a combination of multiple materials in an object allows the object to show effective performance in different weather conditions and scenarios

ISSN:2153-182X, E-ISSN: 2153-1838
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B. Aim and Objectives

Aim

The main aim of the project is to select the most appropriate materials in the design by comparing different crucial factors.

Objective

- To identify the factors that are important for material selection
- To highlight on the application of different crucial factors related composite materials and designs.
- To determine the uses of hybrid composites and designs.
- To evaluate the important properties of material design.

C. Research Question

1. What are the factors that define the selection of materials in building an object?
2. What are the material properties that affect the design process?
3. What are the properties of composite design and optimization?
4. What is the use of hybrid composite materials in the manufacturing industry?

D. Research Rationale

What is the issue?

The properties of material selection and design that are used to build objects in manufacturing industries. The selection of materials and design methods are one of the crucial factors in building the desired object.

Why is the issue?

If the selection of materials and the selected design methods are not suitable for the desired object, the manufacturing industry fails to recreate the object accurately.

What is the issue now?

The use of composite materials and composite design is very costly and increases the annual cost of building the object. The objects which are built by using composite materials are easily damaged.

II. LITERATURE REVIEW

A. Research Background

Material selection and design with materials are crucial aspects of metallurgy and other engineering fields. Product development is the most important stage of using materials. A comprehensive review is given for the types of materials from the sides of fundamental principles to advanced techniques [1]. Hence the research background on several types of materials is discussed with the existing body research of material selection and design [2]. Material selection is the first stage of material design, impacting the product's performance and environmental concerns [3]. A lot of seminar works are provided to clear the concept of material selection charts to make a systematic design with all measurements of compounds based on multiple criteria, including mechanical, thermal, electrical, and economic properties [4]. Recent technologies are improved to monitor the material selection process and its design methods with computer-aided tools and databases [5]. Software packages such as CES Edupack and Granta Material Intelligence have become indispensable in academics and industries [6]. Data-driven decisions

ISSN:2153-182X, E-ISSN: 2153-1838
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are taken for the ultimate decision of material characteristics and the tools enable the operations of materials [7].

Fig. 2.1: Design of Materials

Another important part of this research is the design of materials and the entire development process of materials. Several methods are researched for the ultimate optimizations of designs from the classical design of modern technical approaches [8]. Design thinking is imported for a better design of multiple materials. The sustainability of environmental and ecological factors has been added as a significant part of material designs [9]. The concept of eco-design aims to the main development process of materials by minimizing the influence factors in design procedures [10]. A multidisciplinary approach has been also taken for collaborative and strong engineering designs [11]. Design constraints are functioned for early consideration of materials and the materials ' main properties and it encourages cross-functional collaboration in the designs and material selection techniques [12]. This literature review has briefed the diversities of material selection and designs by adopting classical theories to cutting-edge technologies.

B. Critical Assessment

The field of metallurgy has significant advancements in design and production techniques. A critical review is made here to make a clear decision on the strengths and challenges of material selection and design [13]. The workers in the metallurgy domain have great contributions to improving decisions on material selections and designs [14]. Some areas require further attention and development of materials and their systematic functions. The strengths and challenges are discussed below in detail.

The main strength of this research is to make evaluated decisions on materials based on computer-aided tools and selection charts. Optimization of designs is technically made here to provide a solid foundation for material designs [15]. Gradually development of metallurgical science and engineering has been the greatest strength in developing the materials and thus helping for huge amounts of productions [16]. This interdisciplinary perspective helps to identify the complex relationships between material designs and sustainability. Some limitations are also found here while executing research on a variety of materials [17]. There is a serious issue of maintaining the quality and quantity of material data using software tools. Ensuring the material property information is a big challenge here for emerging materials and related applications [18]. Additive manufacturing techniques have superimposed the integrating technologies of material selections and designs with no new possibilities of production.

C. Linkage to Aim

This project aims to evaluate the criteria for selecting and designing the materials with multiple constraints and considerations of environmental and industrial parameters [19]. The criteria of material properties and composites are evaluated here for multiple designs based on interdisciplinary design approaches and decision-making processes [20]. Properties of materials are identified here with the help of material selection charts. Design processes of a variety of

ISSN:2153-182X, E-ISSN: 2153-1838
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materials are typically discussed here for the concerned project. Composite design procedures of materials are evaluated here by the software packages related to material designs [21]. Manufacturing and production systems of materials are enhanced in this project to give a better perspective on this project [22].

D. Theoretical Framework

Theoretical Framework has been discussed through this research to describe the fundamental operations required in material selection and design [23] s. This provides a structural representation of the understanding of the principles and concepts of materials that guide the decision-making processes. Several key theoretical perspectives are prominently discussed here for better visualization of material properties and considerations for the design techniques [24]. Material Selection Charts are the critical framework for the designs of materials [25]. The categorizing of materials is based on the properties and relationships between several materials and the main technologies are the main discussions based on the selection charts of materials [26]. The principles are relied on here for material selection procedures and making informed decisions by means of engineering development [27]. Decision analysis is a crucial part of this project to make the considerations of the material selection process [28]. Hence MCDA approach is used to judge multiple criteria based on materials and their design procedures.

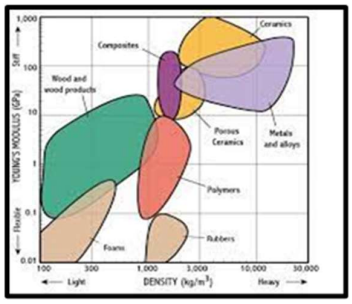

Fig. 2.2: Material Selection Chart

Analytical Hierarchical processes and TOPSIS solutions are MCDA methods for material selection and design to quantitatively weigh the importance of several criteria such as cost, performance, environmental impact, etc [29]. Sustainable designs are the plus points of this theoretical framework approach for maintaining the ecological balance and the life cycle assessments are done for integrating the decisions on sustainable designs of materials [30]. There are multiple environmental impacts which need to be minimized to ensure long-term sustainability in design and manufacturing processes. In recent times, the framework for additive manufacturing systems has evolved for multiple critical designs of materials by exploring unique design possibilities. Some theoretical considerations such as lattice structures, geometric optimization, and material compatibility are included here. The thinking of design encourages multiple designs based on interdisciplinary collaboration with user-centric designs and iterative problem-solving skills [31]. Integration of theoretical frameworks has majorly developed the material selection and design procedures by evolving a set of principles and tools with complex decision-making principles [32].

E. Literature Gap

Significant advancements have progressed in this project for material designs. However, there are several limitations to this project which are included in this literature gap section. The usage of unconventional materials has to be increased in this project for the enhancement of

ISSN:2153-182X, E-ISSN: 2153-1838
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production levels [33]. The influence of cultural and sociocultural factors needs to be reduced for material choices and design choices.

III. METHODOLOGY

A. Research Philosophy

The manufacturing industries give very much importance in the process of material selection. The material selection process is one of the crucial factors in a manufacturing project. The entire manufacturing process depends on the selected materials [34]. These are three main factors which define the materials selection process,

Performance requirements

The performance of the final products is one of the important factors[35]. The performance of the final object very much depends on the materials of the object [36]. The selected design method is another crucial factor for the performance of the object, but the design process also depends on the selected materials [37].

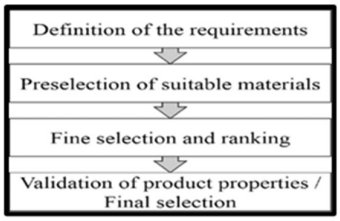

Fig 3.1. Material selection process

Shape, mass and size

The shaping of the object is performed in the design process before implementing it practically [38]. An object has different regions or areas and the shape of these areas of the object can be different. The used material must adopt the shaping nature of the object [39]. So, the section of materials is performed based on the show of the object. The mass and size of the object are also defined by the material of the object.

Cost requirements

The final cost for building an object is one of the important factors which depends on the material selection. The materials of the object must be collected based on the cost of the project. The cost of the materials is one of the covers a large amount of cost in a project so it is very much important to select the materials based on the project budget.

B. Research Approach

The quantitative research approach is adopted in this study to evaluate the materials selection process and the design techniques in the manufacturing industry. Multipole types of materials of different nature act as a single material in composite material [40]. Different types of materials are combined to create a composite material. The properties and nature of composite material are beneficial for creating the desired product or object. The composite materials can be shaped easily which is one of the benefits of using this material. The composite design process is easy and short compared to the material design processes.

C. Research Design

The composite design process is used significantly by the design and manufacturing industry. It is seen from research that the manufacturing industry uses multiple types of materials such as plastic, irons, metals etc. Composite materials are one of the material types that have been used by the manufacturing industry significantly in the past few years. The designing of an object is

ISSN:2153-182X, E-ISSN: 2153-1838
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easy in the composite design process compared to the other design processes. The products are designed effectively by using the composite design process [41]. This process allows the use of multiple materials
to build the object. Since Composite materials can be easily shaped it decreases the length of the design process and optimizes the energy consumption.

D. Data Analysis and Collection Methods

Hybrid composites are one of the widely used composites in the composite design process. Multiple types of fibres are used to create a hybrid composite material. Bone and oyster are one of the hybrid composite materials which are mostly used by the manufacturing industries as the main material in composite designs. The use of these materials increases the strength of the campsite structure.

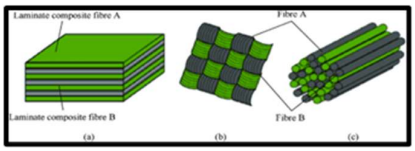

Fig 3.2. Hybrid composite material

These materials gain the strength of the bonds between the soft tissue and the inorganic blocks of the objects. These are differences between the composite material and the hybrid composite materials. One of the fundamental differences between these two materials is that composite material deals with the physical level of an object but hybrid composite materials deal with the molecular level of an object [42]. The strength of the object gains significantly when hybrid material is used as the main material in an object.

E. Ethical Consideration

Multiple research papers are studied to evaluate various processes of metrical selection and material design. All the studied research papers are based on the material and the design processes used in manufacturing industries. All the data are taken from authentic sources. These data help to evaluate the material properties, especially for the composite and hybrid materials. The difference between the design processes of these two materials is also identified by using the data on the material properties of these two materials.

IV. RESULTS AND DISCUSSION

A. Critical Analysis

Engineering and manufacturing both depend on the design and material selection process. This demands a thorough knowledge of the characteristics, viability, and affordability of various materials. Making decisions requires making compromises between efficiency, design, and environmental impact frequently [43]. The composites that are hybrids, such as plastics combined with other substances, and optimization of composite materials present prospects for creativity, they also pose difficulties in terms of production feasibility and structural integrity. In order to create goods that are useful, sustainable, and appealing to the eye, material choice and design are crucial. The complex interactions between material qualities, specifications for design, and cost efficiency must be carefully taken into account during this process.

B. Findings and Discussion

Theme 1: Material Selection Criteria

Selecting materials for a project is complex, engineers and designers consider a wide

ISSN:2153-182X, E-ISSN: 2153-1838
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range of factors. In order to make sure that the material satisfies the project's unique functional needs first the evaluation of the material's physical characteristics, such as durability, toughness, and thermal insulation are monitored [44]. Economic factors are crucial since materials must be economical and adhere to spending limits.

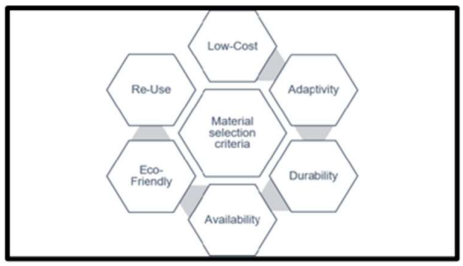

Fig. 4.1: Material selection criteria

Examining a material's ecological impact, recyclability, and general eco-friendliness is necessary due to sustainability's growing importance. In order to prevent delays and guarantee a seamless supply chain, this is also crucial to take procurement and material availability into account. Another crucial factor is interoperability with currently used manufacturing techniques since this influences the viability of production [45]. Designers and engineers have to consider many different aspects, such as material qualities, cost efficiency, long-term viability, accessibility, and industrial compatibility. This process is known as "Material Choice Criteria" and it is complex. The general efficacy of the substance selection and design procedure depends on the effective choice of components that meet these requirements.

Theme 2: Composite Design and Optimization

A crucial component of substance selection and construction in design and manufacturing is composite construction and optimization. The specified qualities and functions are achieved by multiple materials selection and combination throughout the composite's design procedure [46]. This necessitates giving careful thought to elements like materials compatibility, methods of production, and cost efficiency.

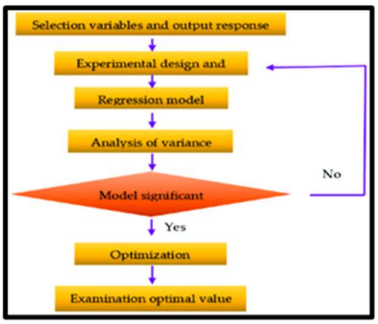

Fig. 4.2: Composite design and optimization

Optimization entails the use of cutting-edge methods and simulation instruments to improve composite frameworks and make sure they satisfy specific performance specifications while using the least amount of weight and materials possible. This also involves dealing with issues with resilience, thermal endurance, and the strength of the structure [47]. The composites design and optimizing trade-offs are frequently balanced because improving one factor may unintentionally worsen another [48]. This emphasizes how composite substances are dynamic and developing in engineering, with ongoing efforts to improve performance [49]. This acts as

ISSN:2153-182X, E-ISSN: 2153-1838
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an illustration of the complex interaction among material characteristics, manufacturing procedures, and design factors that must be meticulously choreographed to generate novel, high-performance, and effective composite substances [50].

Theme 3: Hybrid Composites: Polymers with Other Materials

An important consideration in the design and choosing of components is the "Hybrid Composites: Polymer Compounds with Other Material" subject matter. Science, technology, and manufacturing, hybrid composites which combine plastics with additional materials represent a calculated strategy [51]. These composite substances provide a special combination of benefits and attributes [52]. But for the combination to be effective, manufacturing procedures, performance standards, and structural variables must all be carefully considered.

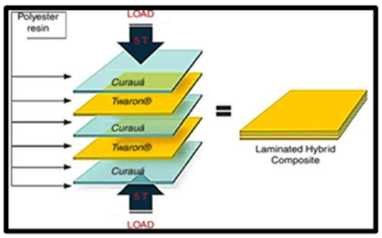

Fig. 4.3: Hybrid composite preparation

The characteristics of several materials are frequently blended synergistically by hybrid composites, improving power, adaptability, and toughness [53]. They are widely used in sectors like buildings, automobiles, and aviation where durable yet lightweight components are necessary. The hybrid composites emphasize how important it is to have an in-depth knowledge of both science and technology and materials science concepts. Finding an equilibrium between price constraints and performance optimization is the challenge. A collaborative effort is necessary for effective hybrid combined design, requiring content researchers, engineers, and producers to work together to ensure that polymers are successfully incorporated with other materials in a variety of applications.

C. Evaluation

The types of composites are indispensable in industries like aviation and cars because of their special qualities, which include increased strength and durability [54]. The incorporation demands a careful evaluation of production procedures and substance harmony. One of the main challenges is still achieving optimal performance within budgetary constraints. In order to ensure the successful integration of plastics with other substances across a variety of applications, effective evaluation necessitates an integrated strategy involving cooperation among content scientists, engineers, and producers [55]. The analysis found its capacity to spur creativity and enhance performance by utilizing techniques of material selection and design.

V. CONCLUSION

A. Critical Evaluation

The importance of substances in engineering and manufacturing is emphasized in "Material the Choice and Design" is crucial. The choice of materials, optimization for composite designs, and integration of mixed composites, that is, plastics with other materials all have a big impact on how well a project turns out. The analysis has brought to light the complex interactions that occur during the decision-making process among performance, affordability, and environmental sustainability. This is evident that to satisfy the demands of various industries,

ISSN:2153-182X, E-ISSN: 2153-1838
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choosing materials and design calls for a careful, interdisciplinary approach. This research offers insightful perspectives on how to develop products and engineering endeavours that are viable, visually appealing, and functional.

B. Research Recommendation

There are a few important areas that research in choosing materials and layout should focus on first. More research is needed to determine whether advanced materials are appropriate for a given purpose, especially in developing industries like gadgets and energy from renewable sources. This research ought to concentrate on creating and improving instruments and processes for composite design optimization that take environmental impact, manufacturing feasibility, and structural integrity into account. A thorough investigation into the bonding methods and compatibility of hybrid composites particularly those incorporating plastics and other materials is necessary. Ongoing research is required to assess and enhance the sustainability of supplies and design decisions, addressing the expanding awareness of the environment in manufacturing and technology.

C. Future Work

"Material Selection and Design" encompasses multiple research directions. Continued research is required to create cutting-edge materials that satisfy changing industry-specific requirements and complement sustainability objectives. This entails improving combined designs and manufacturing processes even more in order to boost output and lessen environmental effects. Further research into cutting-edge testing and modelling methods, as well as innovative approaches to evaluating material properties, will be essential for a more precise and effective choice of material. In order to further propel future advancements in hybrid composites, researchers, engineers, and producers must continue their cross-disciplinary work. By addressing these issues, the field continuously grows and better products and designs can be developed.

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