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Optimizing The Selection Of Material For Polymeric Composite Bumper Beam For Enhancing Performance And Durability

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Abstract:
By 2020, it is predicted that there will be 76 million cars produced worldwide annually. Automobile manufacturers are being forced by new legislation, such the Endpoint of Life Vehicle (ELV) rules, to think about the environmental effect of their manufacturing and maybe switch from the usage of synthetic components to agro-based products. Currently, only non-structural and semi-structural automobile components may employ agro-based materials due to poor mechanical qualities and some production restrictions. The mechanical characteristics of natural fibres can be enhanced above those of natural fibres alone by hybridization with glass fibre. This study focuses on a kenaf/glass fibre hybrid to improve. The price of petroleum-based goods will likely rise in the near future due to limited petroleum resources. According to estimates, a 25% weight reduction in cars would save a total of 250 barrels of oil a year. Given that using low-density natural fibres might reduce weight by 10 to 30 percent [2], it's feasible that manufacturers would think about incorporating more natural fibre into their new goods. Additionally, the EU laws (ELV) on recycling are requiring industries to think about the environmental effects of their manufacturing and maybe switch from based on petroleum to agro-based products. Natural fibre composites provide excellent prospects for using sustainable, recyclable, and biodegradable materials all at once [5]. Natural fibre composites are inexpensive, have low tool wear rates, and need less energy during manufacture. They also show no splitting function, which is suitable in some applications. They also demonstrate outstanding formability, acoustic qualities, and thermal insulation capabilities. Even with these benefits, limitations including hydrophilic qualities, poor impact strength, non-uniformity, and low processing temperature are undesirable mechanical qualities and restrict their use to semi- and non-structural automotive components [6]. The mechanical characteristics of composites made of natural fibres can be enhanced by hybridization with glass fibre [7]. In this study, the mechanical characteristics for the application of natural fibres to automobile structural components, such as a passenger bumper beam, were enhanced using a hybrid of it and glass for reinforcement, epoxy as the matrix, and modified SMC as the production process. Typically, a polymeric hybrid bumper beam comprises the following steps: Define the constraints and requirements: Establish the precise specifications and limitations for the bumpers beam, including weight restrictions, cost factors, manufacturing restrictions, and mechanical attributes (such as stiffness, strength, and impact resistance). Material filtration Perform a preliminary assessment of potential materials' applicability to bumper beam applications. Think about things like the required material qualities, the kind of polymer matrix (such as thermoset or thermoplastic), the alternatives for reinforcing (such as fiberglass, carbon fibre, or natural fibres). From the result it is seen that rank 4 got the first rank where as is the rank 1 having the lowest rank. Mechanical testing is done as part of the process of choosing materials to assess the performance traits of the potential materials. Additionally, to obtain the requisite stiffness and strength while minimizing weight, weight optimization approaches employing computer-assisted engineering tools can assist in determining the best composite stacking sequence and fibre orientation.

***Key Word**: Polymeric, Endpoint of Life Vehicle (ELV), Fiber and Resin transfer moulding (RTM).*

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I. Introduction

Over the years, there has been a lot of interest in the design research field of design conceptions selection (DCS) (Salonen & Perttula, 2005). One of the crucial steps in the creation of a product is choosing a design idea or set of design concepts. DCS is the concept design decision-making phase, when designers assess concepts in light of the demands of the consumer and their own intentions (Xiao et al., 2007). At the conceptual design stage, choosing the best design concepts is an important choice. The best design concepts should be chosen since a poor design idea cannot be made up for by a good intricate layout and will result in significant redesign costs. A weak product idea may result in expensive redesign expenses, a delay in technology realization, and a risk to successful commercialization (Fung et al., the year 2007). As a result, the first idea at the early stage of the product development process has a substantial impact on the level of success of the product design. Due of the numerous variables that must be taken into account during the selection process, DCS is also regarded as an MCDM challenge. As a result, choosing the most effective layout concepts is a difficult undertaking and the most important step in the creation of a product's design since so many different elements must be taken into account. Making the appropriate choice early in the product development process is crucial. Conceptual design is a preliminary step of the product the process of development that entails coming up with thoughts for solutions to meet the functional or aesthetic demands of a design challenge. The conceptual design phase is crucial to the final product's success because once the After the conceptual design phase was over, the majority of the product's cost and quality were determined by choosing particular ideas (Rehman & Yan, 2003). Therefore, the phase of conceptual design is more crucial and important than the other design stages in the process of developing a product because at this point, it establishes the background work and involves numerous complex evaluation and decision-making tasks, including the process of selecting materials, the selection of design concepts, and the selection of the manufacturing process (Sapuan, 2005; But according to Lin et al. (2004), 85% of lifespan costs are established during the stage of conceptual design of a product's development. Prior to the conclusion of the design phase, the majority of the product's cost is allocated (Ullman, 1992). As a result, one of the crucial steps in the creation of a new product is the conceptual design stage. The significance of making the right choices at the phase of conceptual design is also mentioned. An adequate assessment and decision tool must be taken into account to help the effectiveness in choosing the best design concepts at the conceptual design stage. To help designers choose the best design, a variety of approaches for selecting design concepts have been created. . However, there is no indication of how significant each criterion is, therefore linked judgements are not permitted. As a result, it's possible that the final notion will be vague (Ayag, 2005). For choosing the best design among a variety of design possibilities, Hsiao (1998) suggested a fuzzy decision-making approach. Ozer (2005) created a cohesive structure for comprehending how numerous factors influence decision-making in the evaluation of new products and offered recommendations for minimizing their detrimental effects. In a recent work, Ayag and then Ozdemir (2009) suggested using a fuzzy ANP-based technique to assess a number of design alternatives created in the newly developed pro Hambali et al. 199 duct environment for growth in order to find the one that best meets both the requirements for the design and the feasibility. Figure 1 shows the suggested structure for the selection procedure at the conceptual design stage. idea generation, idea selection, and concept development are the three key design processes that make up the conceptual design stage. The decision-making tasks at the idea selection stage may be split into two primary categories. The first step is known as the selection of the design idea, and the second step is known as the selection of the materials. Analytical hierarchical process (AHP) implementation allows for the simultaneous completion of both of these tasks. Concurrent Design Concept Selection & Material Selection Model, or CDCSMS, is the name of this concurrent system. During the idea selection process during the conceptual design stage, the CDCSMS model helps designers assess and decide the most effective design concepts and materials at the same time.

II. Materials and Methodology

Considerations for choosing materials for a thermoplastic composite bumper beam include their mechanical characteristics, weight, cost, production method, and environmental effect. The standard materials and process for material selection are described in the following broad outline Specify the bumper beam's functional requirements, such as durability against impacts, energy absorption, weight restrictions, and dimensional restrictions. Take into account any legal or industry standards that must be followed. Identify possible materials to the synthetic bumper beam under option number two, "Materials." Fiber-reinforced composites, which blend fibres like carbon fibre, fiberglass, or aramid (Kevlar) fibres with a polymer matrix like epoxy, polyurethane that or thermoplastic resins, are a popular choice. Compare and contrast the strengths, stiffness, resistance to impact, density, and cost of various fibres and resins. Material Properties Evaluation: Test the potential materials mechanically to ascertain their performance traits. This might include fatigue qualities, impact resistance, flexural strength, and tensile strength. Think about other aspects including durability, chemical resistance, and temperature resistance. Weight optimization Consider the strength of the components and the intended performance standards when analyzing the overall weight of a composite bumper beam. To attain the requisite strength and stiffness while reducing weight, optimize the laminate layering sequence and fibre orientation using CAE (computer-aided engineering) tools or simulation software. production Considerations: - Assess the affordability and viability of the production procedures for the materials chosen, including manually lay-up, resin transfer moulding (RTM), compression moulding, and filament winding. Take into account elements like the amount of production, the cycle time, the need for tools, and overall cost-effectiveness.

III. Result and Discussion

TABLE 1. Material Selection of Polymeric Composite Bumper Beam

Material selection of polymeric composite automotive bumper beam					
Material	ITH/ (J·cm^{−1})	FS/ MPa	FM/ GPa	RMC/ (USD·kg^{−1})	DS/ (kg·m^{−3})
Glass fibre reinforced epoxy	21.2	483	20.7	4	1 400
Carbon fibre reinforced epoxy	10.6	656	34.5	6	1 600
Carbon fibre reinforced polypropylene (10%)	3.2	75.8	13.8	5	1 110
Glass fiber reinforced polypropylene (40%)	7.52	294	11.4	1	1 560
Glass fibre reinforced polyester (30%)	8.54	179	11	2	1 850

Table 1 shows Material selection of polymeric composite automotive bumper beam get the values of Glass fibre reinforced epoxy, Carbon fibre reinforced epoxy Carbon fibre reinforced polypropylene (10%), Glass fiber reinforced polypropylene (40%), Glass fibre reinforced polyester (30%).

Table 2 Material Selection of Polymeric Composite Bumper Beam

Material	ITH/ (J·cm^{−1})	FS/MPa	FM/GPa	RMC/ (USD·kg^{−1})
Glass fibre reinforced epoxy	1.00000	0.73628	0.53140	0.25000
Carbon fibre reinforced epoxy	0.50000	1.00000	0.31884	0.16667
Carbon fibre reinforced polypropylene (10%)	0.15094	0.11555	0.79710	0.20000
Glass fiber reinforced polypropylene (40%)	0.35472	0.44817	0.96491	1.00000
Glass fibre reinforced polyester (30%)	0.40283	0.27287	1.00000	0.50000

Table 2 shows Material selection of polymeric composite automotive bumper beam get the values of Glass fibre reinforced epoxy, Carbon fibre reinforced epoxy Carbon fibre reinforced polypropylene (10%), Glass fiber reinforced polypropylene (40%) Glass fibre reinforced polyester (30%)

Figure 1 Material Selection of Polymeric Composite Bumper Beam

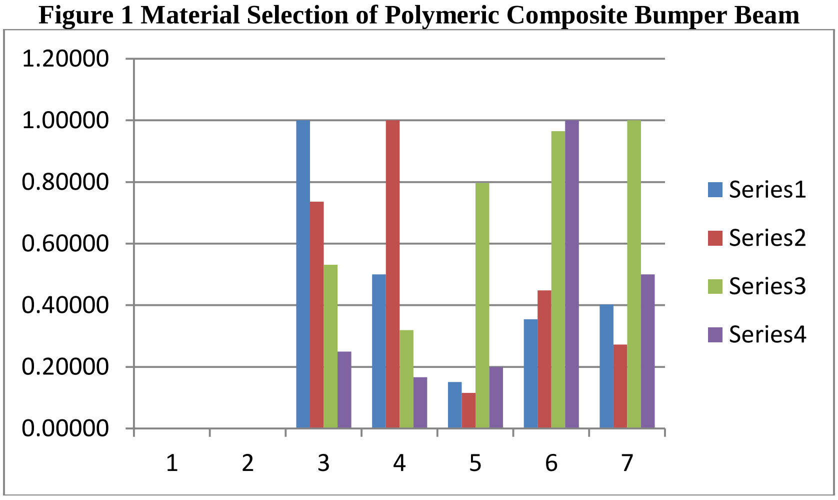

Figure 1 shows Material selection of polymeric composite automotive bumper beam get the values of Glass fibre reinforced epoxy, Carbon fibre reinforced epoxy Carbon fibre reinforced polypropylene (10%), Glass fiber reinforced polypropylene (40%), Glass fibre reinforced polyester (30%).

Table 3. Weight of the Material Selection of Polymeric Composite Bumper Beam

Weight			
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25

0.25	0.25	0.25	0.25

In the table3 shows the weight of the Material Selection of Polymeric Composite Bumper Beam

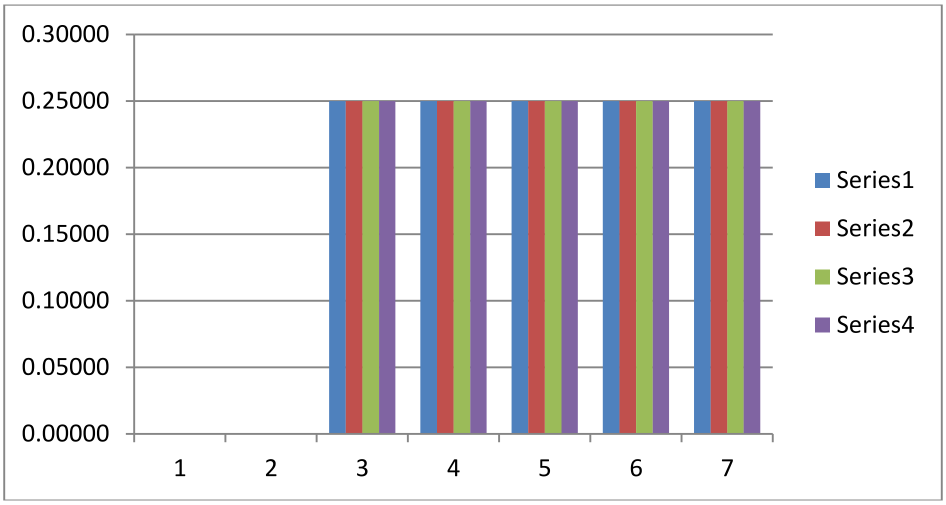

Figure 2. Weight of the Material Selection of Polymeric Composite Bumper Beam

In the figure 2shows the weight of the Material Selection of Polymeric Composite Bumper Beam

Table 4. Weighted normalized decision matrix

Weighted normalized decision matrix			
0.25000	0.18407	0.13285	0.06250
0.12500	0.25000	0.07971	0.04167
0.03774	0.02889	0.19928	0.05000
0.08868	0.11204	0.24123	0.25000
0.10071	0.06822	0.25000	0.12500

In the table 4 shows the Weighted normalized decision matrix values of weight of the Material Selection of Polymeric Composite Bumper Beam

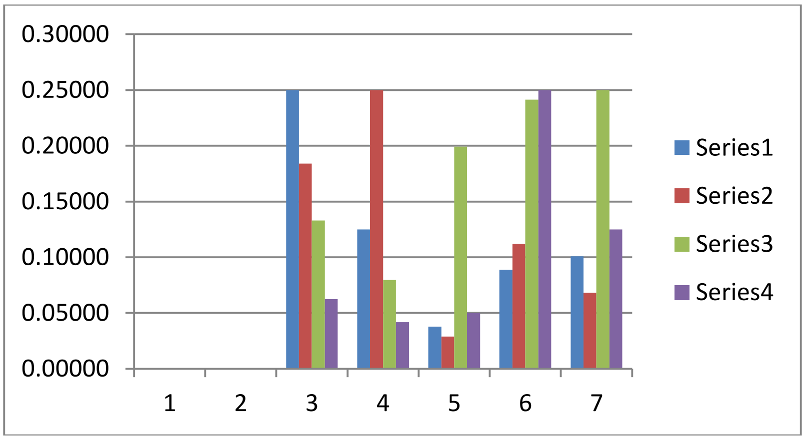

Figure 3. ***Weighted normalized decision matrix***

In the figure 3 shows the Weighted normalized decision matrix values of weight of the Material Selection Of Polymeric Composite Bumper Beam.

Table 5. RANK

Material	Rank
Glass fibre reinforced epoxy	2
Carbon fibre reinforced epoxy	4
Carbon fibre reinforced polypropylene (10%)	5
Glass fiber reinforced polypropylene (40%)	1
Glass fibre reinforced polyester (30%)	3

In this table 5 shows the rank of the materials Glass fiber reinforced polypropylene (40%) got first rank and Carbon fibre reinforced polypropylene (10%) got last rank.

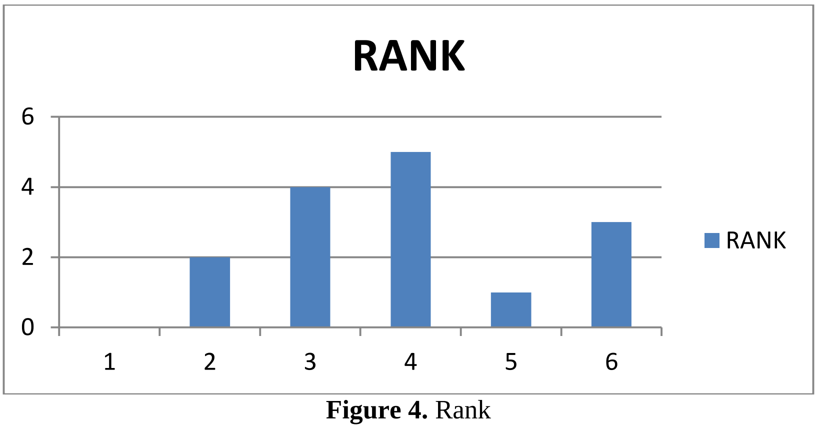

Figure 4. Rank

In this figure 4 shows the rank of the materials Glass fiber reinforced polypropylene (40%) got first rank and Carbon fibre reinforced polypropylene (10%) got last rank.

Table 6. Performance value

Performance value			
1.00000	0.73628	0.53140	0.25000
0.50000	1.00000	0.31884	0.16667
0.15094	0.11555	0.79710	0.20000
0.35472	0.44817	0.96491	1.00000
0.40283	0.27287	1.00000	0.50000

In this table 6 shows the performance value of the Material Selection Of Polymeric Composite Bumper Beam

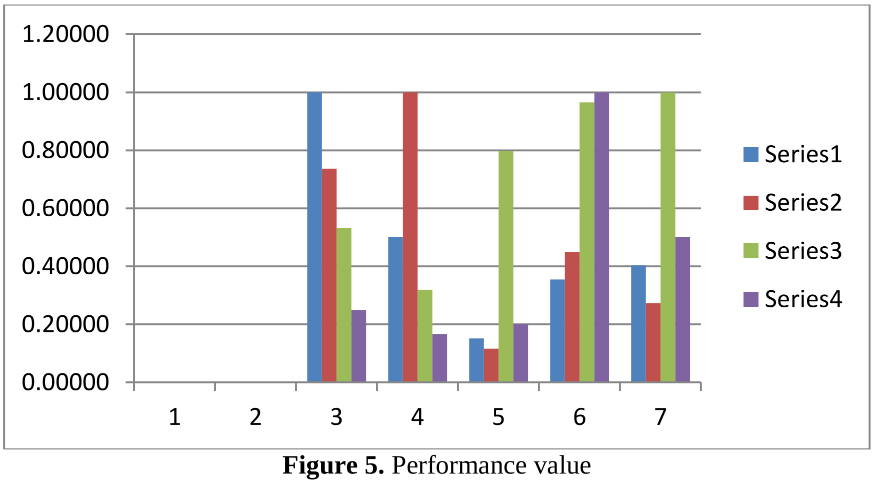

Figure 5. Performance value

In this figure 5 shows the performance value of the Material Selection of Polymeric Composite Bumper Beam

Table 7. Preference Score

Material	**Preference Score**
Glass fibre reinforced epoxy	0.55924
Carbon fibre reinforced epoxy	0.40374
Carbon fibre reinforced polypropylene (10%)	0.22963
Glass fiber reinforced polypropylene (40%)	0.62583
Glass fibre reinforced polyester (30%)	0.48418

In this table 7 shows the preference score of the Material Selection of Polymeric Composite Bumper Beam. Glass fiber reinforced polypropylene (40%) got high value of 0.62583 and Carbon fibre reinforced polypropylene (10%) got low value of 0.22963.

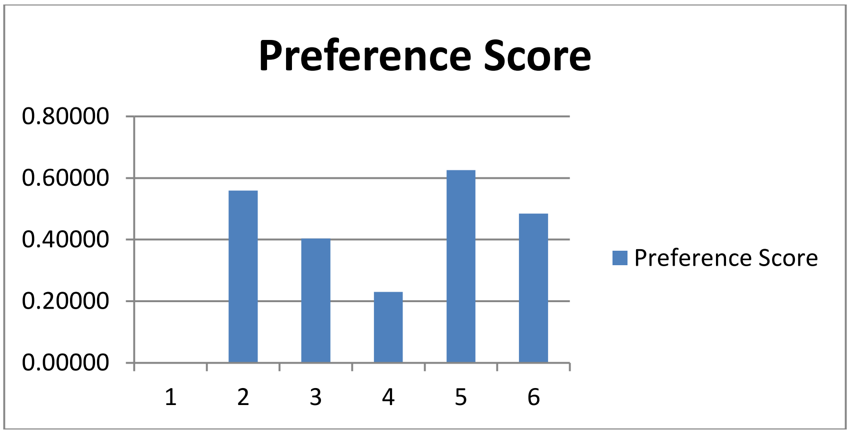

Figure 6. Preference score

In this figure 6 shows the preference score of the Material Selection of Polymeric Composite Bumper Beam. Glass fiber reinforced polypropylene (40%) got high value of 0.62583 and Carbon fibre reinforced polypropylene (10%) got low value of 0.22963.

IV. Conclusion

In conclusion, a polymeric hybrid bumper beam's material selection procedure entails assessing a number of variables, including mechanical characteristics, weight, cost, the viability of production, and environmental effect. These elements may be taken into account in order to select the best material, one that not only fulfils the functional specifications but is also economical and ecologically friendly. For polymeric composites bumper beams, fiber-reinforced composites like carbon fibre, fiberglass, or aramid fibres are frequently used in conjunction with a polymer matrix like epoxy, polyurethane that or thermoplastic resins. When compared to conventional metallic materials, these materials are comparatively lightweight while providing high levels of rigidity, strength, and impact resistance. Mechanical testing is done as part of the process of choosing materials to assess the performance traits of the potential materials. Additionally, to obtain the requisite stiffness and strength while minimizing weight, weight optimization approaches employing computer-assisted engineering tools can assist in determining the best composite stacking sequence and fibre orientation.

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