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### RESEARCH ARTICLE

#### EVALUATION OF MATERIAL SELECTION FOR POLYMERIC COMPOSITE AUTOMOTIVE BUMPER BEAM USING THE WEIGHTED SUM METHOD (WSM)

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#### Abstract

A bumper beam is the curved bar across the front of an automobile that protects it from getting dented or scratched during minor accidents. Polymeric composite automobile bumper beam material choices. The composites used in vehicle bumper beams need to be selected with care since they have a major job in the distribution and absorption of impact forces during collisions. In recent years, bumper beam applications have seen a rise in the usage of polymeric composites because of their rare connection of mechanical properties, low weight & design flexibility. This introduction's goal is to provide a broad overview of the selection process for elements for polymeric composite automobile bumper beams. Research on bumper of an automobile is very important because a vehicle's bumper is designed to absorb as much impact as possible, protecting the more important parts of the vehicle. In this study, the weighted sum method (WSM) is used to find suitable composite polymer materials for automotive bumper beams. Six different materials are tested in order to choose the absolute material for polymer composite bumper beams in transport. The final rank of this paper is the Glass fibre reinforced epoxy (M-1) in 1st rank, the Carbon fibre reinforced epoxy (M-2) is in 2nd rank, the Carbon fibre reinforced polypropylene (10%) (M-3) is in 6th rank, the Glass fibre reinforced polypropylene (40%) (M-4) is in 3rd rank, the Glass fibre reinforced polyester (30%) (M-5) in 5th rank, the Glass fibre vinyl ester SMC (60%) (M-6) in 4th rank. The final result is done by using the WSM method. For the material selection of automotive bumper beam, the final rank of this paper is the Glass fibre reinforced epoxy (M-1) in 1st rank, the Carbon fibre reinforced epoxy (M-2) is in 2nd rank, the Carbon fibre reinforced polypropylene (10%) (M-3) is in 6th rank, the Glass fibre reinforced polypropylene (40%) (M-4) is in 3rd rank, the Glass fibre reinforced polyester (30%) (M-5) in 5th rank, the Glass fibre vinyl ester SMC (60%) (M-6) in 4th rank. The final result is done by using the WSM method.

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**Introduction:-**

A bumper beam is the curved bar across the front of an automobile that protects it from getting dented or scratched during minor accidents. There is a list of benefit requirements, including: Flexural toughness (ITH), also known as impact strength, is one the property that assesses a whether the materials have ability to bear the impulsively loads without breaking or cracking. Flexural strength (FS) evaluates the greatest amount of stress that a substance can endure prior cracking or breaking under bending or flexural loading conditions. Flexural modulus (FM), a mechanical characteristic, gauges a material's stiffness or resistance capacity. It is determined how much bending the material can withstand before experiencing severe elastic deformation. These non-benefit criteria are listed below: Raw material cost refers to the cost paid to get the fundamental inputs or materials required for the manufacture or production of a product, the density of a material (DS) is a physical characteristic that quantifies a substance's mass in relation to its volume. The significance of subject selection in essay production has long been understood. It is challenging to create a systematic strategy to choose the best material since there are so many variables that might affect the decision-making process. The choice of materials is critical for achieving miniaturisation, lowering costs, increasing dependability, and optimising performance of already-existing products. The following are the materials: Glass fibre reinforced epoxy (M1), often known as GRP or fibreglass, is a composite material comprised of glass fibres contained inside an epoxy resin matrix, Carbon fiber reinforced epoxy (M-2) is a composite material made of carbon fibers coated by an epoxy resin matrix, known as carbon fiber reinforced epoxy (CFRP) , Carbon fiber reinforced polypropylene (10%) is a composite of carbon fibres installed in a polypropylene matrix with a carbon fiber content of 10%, called carbon fiber reinforced polypropylene (10%). Comparison along pure polypropylene, this particular mix of components offers improved mechanical qualities, Glass fibre reinforced polypropylene (40%) (M-4) is a composite material with a 40% glass fibre content that mixes glass fibres and polypropylene in a particular ratio. Compared to pure polypropylene, it is a composite that has improved mechanical qualities, Glass fibre reinforced polyester (30%) (M-5) is a composite material made of glass fibres inserted in a polyester resin matrix with a glass fibre content of 30% is referred to as glass fibre reinforced polyester (30%). Compared to pure polyester, this particular mixture of components gives better mechanical qualities, Glass fibre vinyl ester SMC (60%) (M-6) is a specific kind of Sheet Moulding Compound (SMC) known as glass fibre vinyl ester SMC (60%) mixes glass fibres with vinyl esters resin into a composite substance, with the glass fibre component being 60%. Six assessment parameters are taken into account while selecting the optimal material for a car bumper beam. Each material requires a specific material choice. The topic of choosing materials for automobile composite bumper beams is rarely covered in literature [1]. Conception and innovation go hand in hand because thinking is about exploring possible alternatives and finding viable solutions. You can also develop other solutions by imagination. The light composition of polymer composites is the main reason why they are used in automotive engineering, as the use of fuel and exhaust gases should be as economized as possible. A key component made of polymer composites is the bumper system. A weighted objective evaluation technique was used to determine the bumper cover design with the highest utility value. It looks great, is lightweight, and has many other benefits [2]. While polybutylene terephthalate (PBT) polymer has been added to the bio composite, earlier testing did not entirely satisfy bumper PDS impact resistance standards. In order to improve the impact resistance of structures, this new study has chosen the finest options. This study focused on the safety requirements for bumper beam PDS, examined and compared eight various bumper beam designs, and chose the optimal one. This work also demonstrates how to utilise the analysis of finite elements to choose the best structural ideas in order to get around the complicated inherent features of natural fibres and enhance mechanical performance for structural applications in automobiles [3]. Density is a major factor in how effectively a composite material absorbs energy. Natural fibers have not been widely used so far due to some mechanical problems. A realistic design optimization problem often reveals improper method behavior. To provide more Pareto-optimal solutions for these potential areas. The implementation of natural fibres in car structural components is less desirable as a result of these issues. Natural fibres' mechanical characteristics have undergone several improvements. The top three methods for fixing flaws involve changing the resins, reinforcements, and production procedures. By hybridising glass fibres for usage as parts of structure in automobiles, one of the major characteristics of organic fibre composites may be enhanced. However, in order to satisfy the mechanical and financial criteria, only bio-based products need be produced [4]. Optimizing structural components and choosing appropriate materials are two ways to reduce the overall weight of modern car models. An additional 50% or more weight loss has been demonstrated using fiber reinforced polymers. High corrosion resistance and noise reduction are also obtained [5]. Bumper beams are an important element for distributing impact forces. The bumper was also reproduced to make it as close to the real thing as possible. As a result, an accurate model was created by directly linking his CAD (Computer Aided Design) data for the ANSYS bumper [6]. A vehicle bumper is a collection of components at the rear and front of the vehicle that serve to dissipate the dynamic portion of the total energy in high speed collisions and absorb it in low speed collisions without damaging the vehicle [7]. It also serves aesthetic and aerodynamic purposes. When studying

impact, he must distinguish between two main categories: elastic impact and plastic impact. A small amount of energy is lost when two objects come into contact with dynamic interaction, such as when two billiard balls collide. A considerable amount of energy is lost when plastic is impacted. A typical case of elastoplastic collision is when two cars collide or when a car collides with a rigid body [8]. The structure's frequency response function shows the relationship between velocity and wave number amplitude. The former determines when the object's wave velocity reaches supersonic speed and transmits noise, while the latter gives a relative grasp of the amount of noise transmitted [9]. In this work, the sound quality of laminated composite frameworks is examined using wavenumber analysis. Here, the primary goal is to investigate the energy content and absorption's degradation rate (upper limit) and destruction limit (lower limit). To model layered materials in a mosaic structure that resembles the basket form for numerical analysis, a finite element mesh is utilised. This image's [12] cell is the one with the least amount of overlap. The efficacy of composite constructions with copolymer foam cores is fully investigated in this paper using experimental methods. The quality of the material, the characteristics of the collision, and the jet shape all have an influence on the dynamics of the jet. To completely comprehend these factors' impacts, further research is required. The use of theoretical models is necessary to enable this type of analysis to be performed more quickly and cost-effectively [15]. Modern polymer bumper beams have less mass and absorb impact energy much better than earlier steel bumper beams. In order to provide a more Pareto-optimal solution for these feasible regions, Use is made of an outdated weighted sum technique. If a different set of optimum Pareto solutions is discovered, the most effective Pareto patch size test is carried out once more to find any regions that need further adjusting [10]. The density of the reinforcing fibres is what essentially determines how well the material itself absorbs energy. As the fibre density dropped from high to acceptable values, the specific energy generated by the fiber-reinforced pipe climbed from low to high levels. When supporting the pipe, using strong fibres that break boosts the pipe's capacity to take in more energy. Changes in fibre stiffness have a less noticeable impact. Because the material breaks evenly, changing the fibre stiffness has less of an impact on the absorption capacity than does the variation in fibre failure stresses over time[11].

### Methodology:-

It is simple to utilise the Weighted Sum approach, which is best suited for issues with a single dimension. The option that meets the following equation is the best one if there are m choices and n criteria:

$$A^*_{wsm} = M \text{ ax } \sum_i^j a_{ij} w_j$$

The total value of an election is the sum of its parts. Solving multidimensional decision-making problems using this strategy is challenging. The assumption of additional benefits is refuted by a mixture of several dimensions and thus a large number of units [18]. As shown in Figure 1, applying the traditional weighted sum method concentrates a large number of solutions near fixed locations and branch points. No solution. Occurs in recesses. The figure displays two common problems with the WSM approach: - Often, the answers are not conveyed equitably. – Some of the portions of the Pareto front are not amenable to solution discovery using the weighted-sum method. To solve this issue, the weighting factor's number of steps cannot be raised. Although the weighted-sum approach is straightforward to apply and has the ability to emphasise the relative relevance of a variety of objective functions, these are the key limitations that prevent its widespread use. Realistic design optimisation issues [17] frequently show the method's bad behaviour. On order to offer more Pareto optimum solutions on these feasible domains, the conventional weighted sum approach is then utilised as inefficiency. The Pareto ideal patch size review is once more carried out to identify the regions that need extra fine-tuning when another set of Pareto optimum solutions is found. Up to the point of no return is reached; these steps are repeated [21]. Only addition, addition, and sorting are required for the actual extraction procedure. It uses the weighted sum approach, as the name says. Earlier, we discussed potential keyword development and images. To get this weighted collection of 4-dimensional feature vectors, we still need a weight vector. Weighting is necessary because the four traits have different levels of differentiation. Of course, if the feature can distinguish between sentences and non-keywords more clearly, we should pay more attention. This study was driven by the fact that people can manually calculate their weight. However, manually computing weight matrices for different domains is too time consuming. For perceptual learning, we use several concepts [27]. The weighted sum approach was regularly used both in advance and actively before EMO algorithms were widely used, which implies that a weight vectors was both set before the search or gradually altered within the search. In this study, experimental techniques are used to thoroughly investigate the performance of composite structures with polymer foam cores. Jet dynamics are influenced by various factors such as material grade, impact properties, and jet geometry. Some research is required to fully understand the effects of these components. The use of theoretical models is necessary to enable this type of analysis to be performed more quickly and cost-effectively [20]. The subsequent stage responses in these genuine areas subsequently make use of

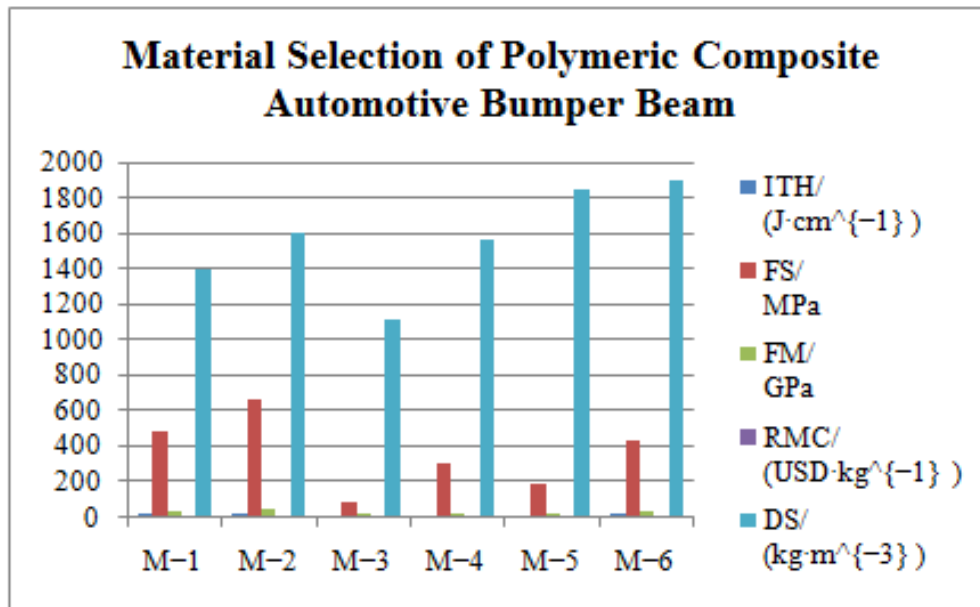
the weighted sum technique. When fresh Pareto optimum solutions are obtained, the assessment is once more carried out to identify which regions need further amplification. The repetition of each of these steps continues until the termination condition is satisfied [23]. The main problem with the weighted sum strategy, as with most scoring techniques, is the application of weights to account for changes in the objective function domain and the use of weights to indicate different importance of objectives. is sometimes difficult to distinguish between Modern polymer bumper beams have less mass and absorb impact energy much better than earlier steel bumper beams. To provide a more Pareto-optimal solution for these possible domains, a traditional weighted sum approach is used, which is inefficient [16].

**Result & Discussion:-**

**TABLE 1. Material selection of polymeric composite automotive bumper beam**

Material	ITH/ ( $J \cdot cm^{-1}$ )	FS/ MPa	FM/ GPa	RMC/ ( $USD \cdot kg^{-1}$ )	DS/ ( $kg \cdot m^{-3}$ )
M-1	21.2	483	20.7	4	1400
M-2	10.6	656	34.5	6	1600
M-3	3.2	75.8	13.8	5	1110
M-4	7.52	294	11.4	1	1560
M-5	8.54	179	11	2	1850
M-6	12.8	427	17.9	3	1900

Table 1 shows the Material selection of polymeric composite automotive bumper beam using the Analysis method in WSM Alternative: Glass fibre reinforced epoxy (M-1), Carbon fibre reinforced epoxy (M-2), and Carbon fibre reinforced polypropylene (10%) (M-3), Glass fibre reinforced polypropylene (40%) (M-4), Glass fibre reinforced polyester (30%) (M-5), Glass fibre vinyl ester SMC (60%) (M-6).Evaluation preference: impact toughness (ITH), flexural strength (FS), flexural modulus (FM) , Raw material cost, the density of a material (DS).

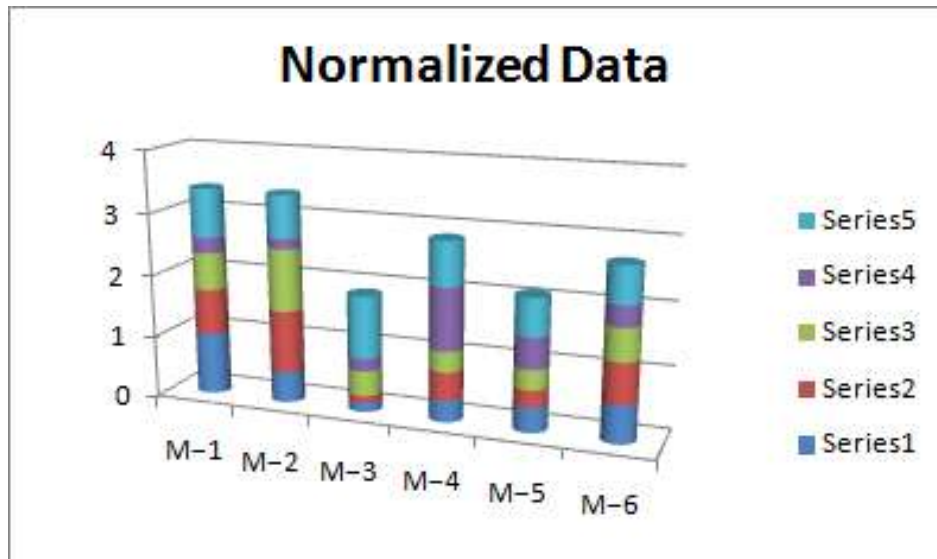


**Table 2:-** Normalized data.

Normalized data				
1	0.736280488	0.6	0.25	0.792857143
0.5	1	1	0.166666667	0.69375
0.150943396	0.11554878	0.4	0.2	1
0.354716981	0.448170732	0.330434783	1	0.711538462
0.402830189	0.272865854	0.31884058	0.5	0.6

0.603773585	0.650914634	0.51884058	0.333333333	0.584210526
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Table 2 shows the Normalized data for Alternative: (M-1), (M-2), (M-3), (M-4), (M-5), (M-6).Evaluation preference:ITH, FS, FM, Raw material cost, DS.



**Table 3:-** Weightages.

Weight				
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20

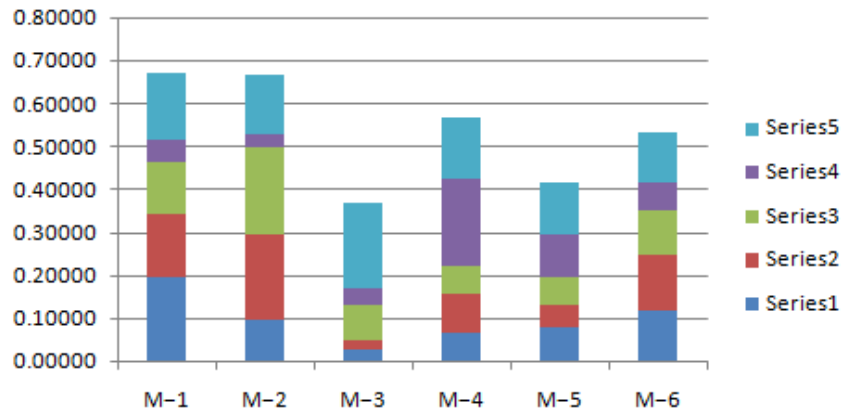
Table 3 lists the weights that were employed in the study. For the analysis, we use identical weights for each of the parameters.

**TABLE 4. Weighted normalized decision matrix**

Weighted normalized decision matrix				
0.20000	0.14726	0.12000	0.05000	0.15857
0.10000	0.20000	0.20000	0.03333	0.13875
0.03019	0.02311	0.08000	0.04000	0.20000
0.07094	0.08963	0.06609	0.20000	0.14231
0.08057	0.05457	0.06377	0.10000	0.12000
0.12075	0.13018	0.10377	0.06667	0.11684

Table 4 shows the weighted normalized decision matrix for Alternative: (M-2), Carbon fibre reinforced polypropylene (10%) (M-3), (M-5), (M-6).Evaluation preference includes benefit criteria: impact toughness, flexural strength, flexural modulus, Non-benefit criteria: Raw material cost, the density of a material (DS).

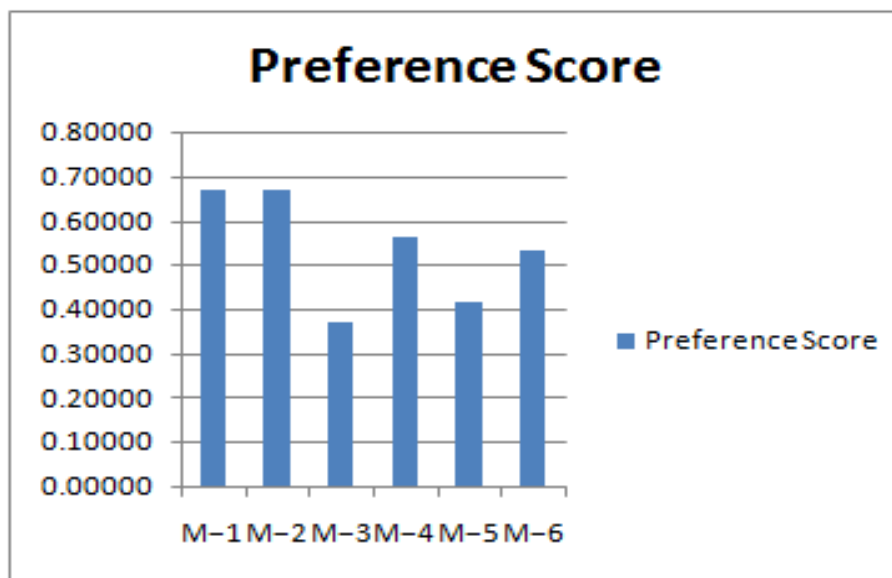
### Weighted normalized decision matrix

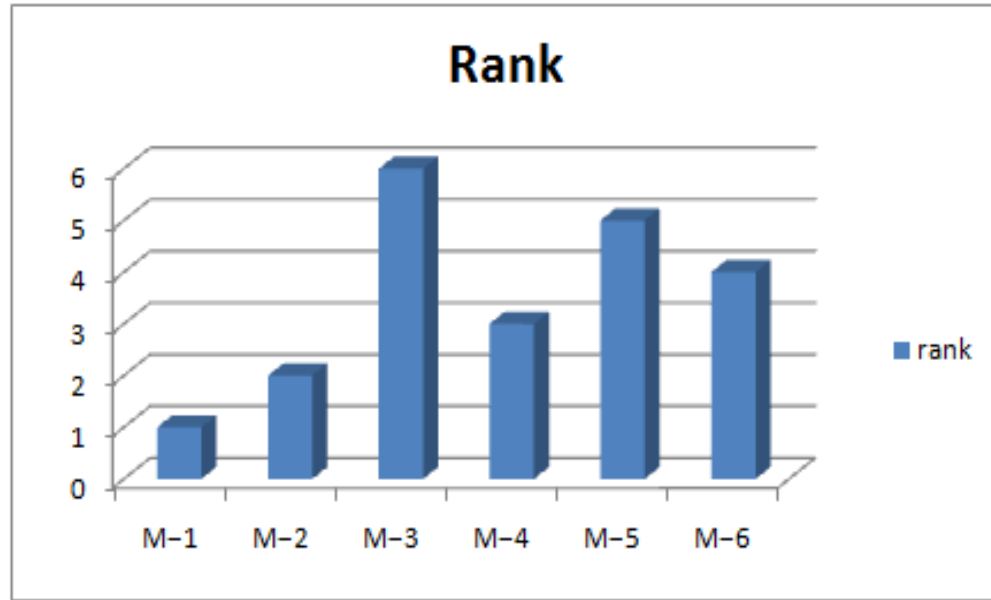


**Table 5:-** Preference Score & Rank.

	Preference Score	rank
M-1	0.67583	1
M-2	0.67208	2
M-3	0.37330	6
M-4	0.56897	3
M-5	0.41891	5
M-6	0.53821	4

Table 5 shows the final rank of this paper the Glass fibre reinforced epoxy (M-1) in 1st rank, the Carbon fibre reinforced epoxy (M-2) is in 2nd rank, the Carbon fibre reinforced polypropylene (10%) (M-3) is in 6th rank, the Glass fibre reinforced polypropylene (40%) (M-4) is in 3rd rank, the Glass fibre reinforced polyester (30%) (M-5) in 5th rank, the Glass fibre vinyl ester SMC (60%) (M-6) in 4th rank. The final result is done by using the WSM method.





### Conclusion:-

Polymeric composite automobile bumper beam material choices. This introduction's goal is to provide a broad overview of the selection process for elements for polymeric composite automobile bumper beams. These works use experimental methods to thoroughly examine the performance of composite structures with polymer-foam cores. Beam dynamics are influenced by a wide range of factors, including material qualities, collision characteristics, and beam shape. Several researches are required to fully understand the impacts of these. However, if we were to calculate weight matrices for various domains manually, it would take too much time. For perceptual learning, we employ a few concepts. The weighted sum approach was regularly used both in advance and actively before EMO algorithms were widely used, which implies that a weight vectors was both set before the search or gradually altered within the search. The subsequent stage responses in these genuine areas subsequently make use of the weighted sum technique components. The use of theoretical models is required for this type of analysis to be quicker and less expensive. A bumper beam is the curved bar across the front of an automobile that protects it from getting dented or scratched during minor accidents. Research on bumper of an automobile is very important because a vehicle's bumper is designed to absorb as much impact as possible, protecting the more important parts of the vehicle.

### References:-

- [1] Hambali, A., S. M. Sapuan, N. Ismail, and Y. Nukman. "Material selection of polymeric composite automotive bumper beam using analytical hierarchy process." *Journal of Central South University of Technology* 17 (2010): 244-256.
- [2] Sapuan, S. M., M. A. Maleque, M. Hameedullah, M. N. Suddin, and N. Ismail. "A note on the conceptual design of polymeric composite automotive bumper system." *Journal of materials processing technology* 159, no. 2 (2005): 145-151.
- [3] Davoodi, M. M., S. M. Sapuan, D. Ahmad, A. Aidy, A. Khalina, and Mehdi Jonoobi. "Concept selection of car bumper beam with developed hybrid bio-composite material." *Materials & Design* 32, no. 10 (2011): 4857-4865.
- [4] Davoodi, M. M., S. M. Sapuan, Desa Ahmad, Aidy Ali, A. Khalina, and Mehdi Jonoobi. "Mechanical properties of hybrid kenaf/glass reinforced epoxy composite for passenger car bumper beam." *Materials & Design* 31, no. 10 (2010): 4927-4932.
- [5] Adesina, O. T., T. Jamiru, E. R. Sadiku, O. F. Ogunbiyi, and L. W. Beneke. "Mechanical evaluation of hybrid natural fibre-reinforced polymeric composites for automotive bumper beam: a review." *The International Journal of Advanced Manufacturing Technology* 103 (2019): 1781-1797.
- [6] Hosseinzadeh, Ramin, Mahmood M. Shokrieh, and Larry B. Lessard. "Parametric study of automotive composite bumper beams subjected to low-velocity impacts." *Composite Structures* 68, no. 4 (2005): 419-427.

- [7] Davoodi, M. M., S. M. Sapuan, Ali Aidy, NA Abu Osman, AzimAtaollahiOshkour, and WAB Wan Abas. "Development process of new bumper beam for passenger car: A review." *Materials & Design* 40 (2012): 304-313.
- [8] Marzbanrad, Javad, MasoudAlijanpour, and Mahdi SaeidKiasat. "Design and analysis of an automotive bumper beam in low-speed frontal crashes." *Thin-walled structures* 47, no. 8-9 (2009): 902-911.
- [9] Sargianis, James J., Hyung-Ick Kim, Erik Andres, and JonghwanSuhr. "Sound and vibration damping characteristics in natural material based sandwich composites." *Composite Structures* 96 (2013): 538-544.
- [10] Singh, Nand Kishore, and K. K. Singh. "Review on impact analysis of FRP composites validated by LS-DYNA." *Polymer Composites* 36, no. 10 (2015): 1786-1798.
- [11] Ivañez, Inés, Carlos Santiuste, and Sonia Sanchez-Saez. "FEM analysis of dynamic flexural behaviour of composite sandwich beams with foam core." *Composite Structures* 92, no. 9 (2010): 2285-2291.
- [12] Zeng, Fang, HuiXie, Qiming Liu, Fan Li, and Wei Tan. "Design and optimization of a new composite bumper beam in high-speed frontal crashes." *Structural and Multidisciplinary Optimization* 53 (2016): 115-122.
- [13] Jacob, George C., John F. Fellers, SrdanSimunovic, and J. Michael Starbuck. "Energy absorption in polymer composites for automotive crashworthiness." *Journal of composite materials* 36, no. 7 (2002): 813-850.
- [14] San Cristóbal Mateo, José Ramón, and José Ramón San Cristóbal Mateo. "Weighted sum method and weighted product method." *Multi criteria analysis in the renewable energy industry* (2012): 19-22.
- [15] Kim, Il Yong, and Oliver L. De Weck. "Adaptive weighted-sum method for bi-objective optimization: Pareto front generation." *Structural and multidisciplinary optimization* 29 (2005): 149-158.
- [16] Kim, Il Yong, and O. L. De Weck. "Adaptive weighted sum method for multiobjective optimization: a new method for Pareto front generation." *Structural and multidisciplinary optimization* 31, no. 2 (2006): 105-116.
- [17] Liu, Wenshuo, and Wenxin Li. "To determine the weight in a weighted sum method for domain-Specific keyword extraction." In *2009 International Conference on Computer Engineering and Technology*, vol. 1, pp. 11-15. IEEE, 2009.
- [18] Wang, Rui, Zhongbao Zhou, HisaoIshibuchi, Tianjun Liao, and Tao Zhang. "Localized weighted sum method for many-objective optimization." *IEEE Transactions on Evolutionary Computation* 22, no. 1 (2016): 3-18.
- [19] Zhang, Ke-shi, Zhong-hua Han, Wei-ji Li, and Wen-ping Song. "Bilevel adaptive weighted sum method for multidisciplinary multi-objective optimization." *AIAA journal* 46, no. 10 (2008): 2611-2622.
- [20] Marler, R. Timothy, and Jasbir S. Arora. "The weighted sum method for multi-objective optimization: new insights." *Structural and multidisciplinary optimization* 41 (2010): 853-862.