MATERIAL SELECTION AND MECHANICAL PROPERTIES IN LEAF SPRING APPLICATION: A REVIEW

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ABSTRACT

In the industrial world, leaf springs are an important component of vehicles. Therefore, material selection is very influential in producing good mechanical properties that can affect leaf spring performance. In this review article, the author aims to review and compile articles on relevant previous studies to compare the best alternative materials other than steel that meet the criteria for the application of leaf springs. The review method used in this article is to search for articles that are relevant to the keyword material, leaf springs, and mechanical properties. After that, the author will collect articles and choose articles that have the criteria to be reviewed. Then the articles that meet the criteria will be reviewed by extracting the data to the review table. As a result, 24 articles will be reviewed. Then the author will extract data on each article, namely material, tensile strength, and flexure. Flexural and tensile strength are used as quality criteria for each material. The conclusion of the review article obtained is that carbon/epoxy has the potential as an alternative steel material because carbon/epoxy has the highest tensile strength with a value of 1841MPa, and flexural strength with a value of 1646.7MPa is close to steel as shown in the review table. However, further research is needed, such as proper design and more efficient manufacturing methods to produce innovative leaf spring components with high quality and acceptable quality in the industry.

Keywords: leaf springs, steel, carbon/epoxy, flexural, tensile

1 INTRODUCTION

Developments in the field of transportation and vehicle exhaust in recent years have experienced a significant increase which has a negative impact on human survival. This problem occurs because 95% of vehicle fuel is currently dominated by fossils (Ashori A et al., 2008). Therefore, the government has been aggressively innovating and enforcing strict regulations, especially in the transportation sector.

In the world of the automotive industry, especially in cars and trains, the market competition is quite tight. Industries are competing to create automatic components that have innovations in terms of being environmentally friendly, energy-efficient, and free of pollution emissions. Minimizing the weight of a component is one way of innovation to improve performance in the automotive sector. Some of the positive impacts are reduced fuel consumption and can provide optimal performance when operating. This optimization can be achieved by selecting the right material and good mechanical properties according to the application of customized objects that are useful for the development of the automotive world in the future.

A leaf spring is one of the components in the vehicle that has a very important role. Leaf springs have a function to distribute the load from the vehicle frame to the drive and wheels so that in the process, there is no shock load which is feared to damage the components. The development of manufacturing processes in the industrial world has indicated replacing materials with better ones without compromising their mechanical properties. Spring suspension is a potential component because it has a contribution of 10-20% of the total weight. The main criteria for leaf spring material must have good fatigue resistance and durability. One of these criteria can be achieved by the use of materials and design optimization (Gebremeskel SA et al., 2012. Patnaik M et al., 2012). Therefore, the selection of the right material can improve the performance and resistance of leaf springs (Shankar GSS et al., 2006).

The fabrication of leaf springs is currently dominated by steel. This is quite reasonable because steel is a leaf spring material with good mechanical properties. Steel has advantages, namely good mechanical properties, resistance, and fabrication is quite simple and inexpensive. However, it is possible that alternative materials will be used in the future. Because nowadays, researchers have done a lot of research, namely replacing leaf spring materials using composites. Composites have the potential to have good strength and resistance to fatigue. Composites also have good vibration absorption capabilities, thereby reducing noise. Another advantage is that composite materials are five times lighter in weight than metal (Shokrieh et al 2003). However, composites have drawbacks. Namely, the fabrication is quite difficult, and the method must be adjusted so that it can produce the desired material characteristics.

So many studies have been done on applying materials intended for leaf springs. In fact, in the automotive industry, several components have used alternative materials. However, the industry is not yet optimal and is still reviewing from all aspects, namely, quality, manufacturing methods, design, and safety (Jancirani J et al., 2015). Therefore, a systematic and in-depth review is needed to answer these challenges. In this paper, the author will review previous research articles so that later the author can conclude the right material and mechanical properties, which later is expected to be able to conclude the use of alternative materials other than steel which can later be used for the application of leaf springs.

2. MATERIALS AND METHODS

The quality of leaf springs can generally be judged from 2 criteria: the right material and good mechanical properties. These two things are very important because they affect the performance of the leaf spring when it receives a load while operating (V. Khatkar et al., 2019). Leaf springs are designed to withstand distributed loads and release them back. Therefore, the performance in driving is very dependent on the performance of the leaf springs. The formula used to determine the relationship between strains is, (Gebremeskel SA et al., 2012).

$$U = \sigma^2/\rho E \qquad (1)$$

Where σ^2 is the allowable stress and is Young's modulus and density of the material used. This shows that a high value of material strength, low modulus and density will result in a large strain.

In the first stage, the author will search for articles according to keywords related to the topic. The criteria in the search process are the research topic is the application of leaf spring components, the articles taken must have a span of the last 10 years to maintain relevance, and are in English. The English article was chosen because the author wanted to reach a fairly broad scope so that the articles obtained were quite a lot.

In the process of selecting the article, it must match the criteria desired by the author. In the article, the topic of leaf springs must be used, explaining the material used, there is an explanation of the mechanical properties, namely the bending strength, tensile strength and deformation of the material. Mechanical properties are used as the main criteria to assess the material's quality, which will be used as a comparison for each material during the review process.

After searching, you will find quite a variety of articles. However, in meeting the criteria for articles to be reviewed, the author will only include articles that meet the criteria, namely, the application of material on leaf springs, the materials used, testing methods, and data on mechanical properties for example, tensile strength, bending, deformation and so on.

3. RESULTS AND DISCUSSION

3.1 Systematic literature search

The search for relevant literature articles used several criteria which should be the purpose of this review article. The article search focuses on articles from 2001 to 2022 years. Then the article is re-screened using keywords, namely material, leaf springs, and mechanical properties. The article is focused on English-language articles.

3.2 Article Selection

In the process of selecting articles that meet the criteria, exclusion and inclusion criteria are used. Exclusion and inclusion criteria were used to review further articles to be extracted to the review table. The results of the final screening showed that there were 18 articles that met the criteria, namely the presence of material, mechanical properties, and application to leaf springs.

3.3 Data Extraction

The authors individually assessed all publications based on the inclusion criteria, and the reference lists of all relevant articles were also checked to discover other prospective data sources. The data will then be placed into a table for examination, as seen in table.1.

Table 1. Review of material data for the application of leaf springs

Study and Year	Countries	Methods	Materials	Tensile Strength (MPa)	Flexural Strength (MPa)	Max. Deflection (mm)
(Vikas Khatkar et al., 2020)	India	Experimental	Textile Fibber	358.20 + 1.3	522.42 + 1.3	/
(Shiva Shankar et al., 2006)	India	FEA	Steel	/	511	90
			Composite (E-Glass/Epoxy)	/	466	94
		Experimental	Steel	/	503.3	107.5
			Composite (E-Glass/Epoxy)	/	473	105
(Jadhav Mahesh V et al., 2012)	India	Analytical	Composite	/	210.37	/
			EN-47	/	210.37	/
		FEA	Composite	/	219.36	/
			EN-47	/	224.6	/
(S. Jebarose Juliyana et al., 2017)	India	Experimental	Steel	503.3	/	107.5
			Composite (E-Glass/Epoxy)	473	/	105
		FEA	Steel	490.082	/	88.291
			Composite(E-Glass/Epoxy)	484.864	/	93.407
(Ekhlas Edan Kader et al. ., 2021)	Iraq	Experimental	Epoxy	25	105	/
			Carbon Fibbers	145	278	/
			Glass Fibbers	170	953	/
			Glass/Carbon Fibbers	184	333	/
(Senthil Kumar et al., 2007)	India	Experimental	Steel	/	680.05	155
		Analytical		/	982.05	133.03
		FEA		/	744.32	134.67
(Vikas Khatkar et al., 2019)	India	Experimental	Composite (Fibber E-glass)	455.90 ± 1.6	/	/
(Ekhlas Edan Kader et al., 2021)	Iraq	Experimental	Glass fibre	788.07	/	103.07
			Sisal fibre	107.039	/	88.43
			Hybrid fibre	365.119	/	101.73
(Ramesh Kumar et al., 2021)	India	FEA	Composite	58.1	121.1	/
(Harmeet Singh et al., 2018)	India	Experimental	EN45	1158	/	/
			Carbon Epoxy	1841	/	/
			Aluminium	575	/	/
			Boron Carbide	750	/	/
	India	FEA	Steel EN45	/	252.08	/

(Jenarthanan M.P et al., 2017)			Carbon/Glass Composite	/	312.23	/
(T. Keerthi vasan et al., 2019)	India	Experimental	Composite (Carbon and Glass Fibber)	570	92.96	/
(Anwer J. Al-Obaidi et al., 2019)	Iraq	Experimental	Steel	1967	/	/
			E glass/epoxy	906	/	/
			E glass/polyester	679	/	/
(Rama Krishna et al., 2020)	India	Experimental	Carbon Fibre Epoxy	/	1646.7	/
			Glass Fibre Epoxy	/	814.8	/
(M. Senthil Khumar et al., 2006)	India	Experimental	Composite (E-glass/Epoxy)	/	222	94
		Analytical		/	310.82	59.2
		FEA		/	215.46	60.65
(Kueh et al., 2012)	Malaysia	FEA	Steel	946.8	941.79	168.63
			E-glass/epoxy	210.28	223.58	42.67
			E-glass/vinyl ester	210.3	223.52	44.54
(Sorathiya Mehul et al., 2014)	India	FEA	Steel	/	224.26	/
		Analytical		/	197.683	/
(Howida Mohamed et al., 2020)	Egypt	Experimental	Glass Fibre	/	482.17	/
			Polyester	/	431.427	/
		FEA	Glass Fibre	/	485.65	/
			Polyester	/	436.31	/

3.4 Discussion

Tensile strength of a material is one of the mechanical properties considered in assessing the quality of leaf springs. Below is the data that has been included from the articles that have been reviewed.

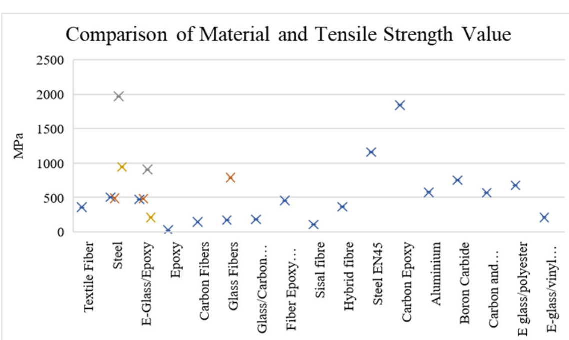

Figure 1. Comparison of Materials and Tensile Strength Value

Based on the results of the article review that the author has done, 17 materials are applied to the tensile strength of the leaf spring. From Figure 1, steel is still the material with the best tensile test value with a tensile strength value of 1967 MPa. This is very reasonable because steel is the dominant material in applying leaf springs. However, in the graph, it is interesting to see that the composite with a mixture of carbon/epoxy has a tensile strength value almost close to steel, which is 1841 MPa. Carbon epoxy is a resin mixture material obtained by polymerization method and epoxide reinforced with carbon fiber. Composites with an epoxy mixture have good potential as an alternative to steel compared to other composite materials. However, from a fabrication point of view, this material is still a challenge in the industrial world.

This is one of the weaknesses and problems in composite materials. And the second is the cost is quite expensive because the materials are difficult to obtain. Therefore, until now, steel is still superior in all respects compared to other materials, especially non-metals. Therefore, researchers continue to develop new methods and materials, hoping that alternative materials other than steel will be obtained in the future. There are challenges for future research and innovation, namely the right design and method to produce quality leaf spring materials.

In addition to tensile strength, the second criterion in assessing the quality of a material is bending strength. Bending strength is used to assess the suitability of the material when receiving load distribution, and this is directly related to the performance of one of the vehicle components. Below are the results of the assessment of the material and the value of its bending strength.

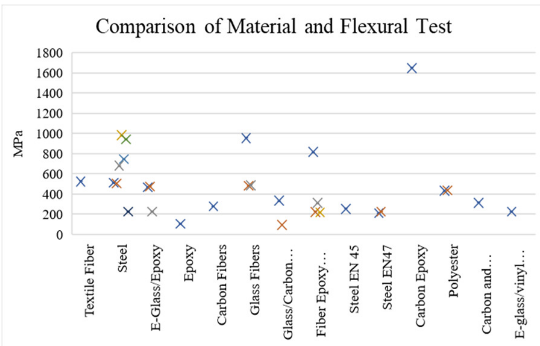

Figure 2. Comparison of Materials and Bending Strength

The picture above is the result of data inclusion in the article that has been reviewed which produces 14 leaf spring materials that have varying tensile strength values. Interestingly, carbon epoxy is the material with the highest value, which is 1646.7 MPa. Even steel only ranks second with a value of 941 MPa. These results confirm that carbon/epoxy is a potential alternative material to replace steel in leaf spring applications.

4. CONCLUSION

After reviewing article reviews and data inclusion analysis, the authors conclude that there are 18 different materials that have been studied by researchers to date. As seen in the data shown in the review table, the tensile and flexural strength of each material varies greatly. This is due to the different characteristics and methods used in the articles reviewed which allow different test results. But in general, in the review conducted by researchers, it was found that the biggest contribution was the material used. The review results obtained are that steel still has the highest value compared to other materials and for composite materials the highest is carbon/epoxy. As for the flexural strength, carbon/epoxy has the highest value, followed by steel. Thus, carbon/epoxy is the most potential material to be developed in leaf spring applications as an alternative to leaf spring steel. Therefore, carbon/epoxy materials need to be further researched and developed with appropriate designs, more efficient manufacturing methods.

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