Study of Material Selection for Impellers in Centrifugal Blowers: A Review

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***Abstract*— The selection of materials has a significant impact on the endurance, reliability, and performance of mechanical systems, making it an essential component of engineering design. This study looks into how important material choice is for optimizing mechanical performance in various kinds of engineering applications. This study clarifies the many parameters influencing material selection, including mechanical qualities, environmental variables, manufacturing processes, and economic considerations, through a thorough examination of the literature and research. Key methodology for material selection, includes screening and gathering of material properties, scaling down properties, calculating positive decisions, and weighing factors. To further demonstrate the benefits and practical effects of making well-informed material choices, case studies showcasing effective material selection procedures across a range of engineering areas are provided, to reduce weight and increase the strength of the product.**

***Index Terms*— Centrifugal Blower, Ashby Chart, Impeller Design, Material Seletion.**

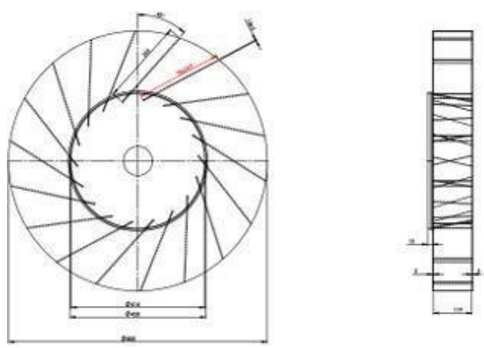
I. INTRODUCTION

As engineering students, we're well aware of the complexity involved in selecting the right material for our projects.

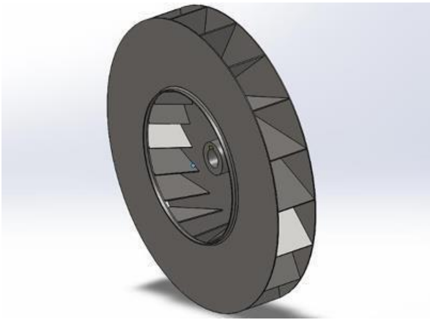
From initial screening to alternative comparison and finally selecting the optimal option, the process entails meticulous steps,[1]. Numerical methods such as analytical and computer-aided procedures provide systematic frameworks for decision-making, drawing upon a wealth of supporting data on microstructure, environmental performance, and other relevant aspects. This review aims to categorize and elucidate the primary types of material selection techniques, shedding light on the evolving landscape of material selection in the mechanical industry. Material selection is one of the main functions of effective design and it determines the reliability of the design in terms of industrial and economical aspects. If the product does not meet appropriate material combination a great design may fail to be profitable product,[2].

In this research article, we delve into the crucial role that material selection plays in enhancing mechanical performance across various engineering applications. Our goal is to equip fellow engineers with practical recommendations and insights to navigate the intricate process of material selection. By synthesizing current knowledge and approaches, we aim to provide actionable strategies for optimizing material selection. Furthermore, through case examples drawn from practical engineering settings, we highlight the tangible benefits of making accurate material selections, demonstrating the real-world impact of informed decision-making.

The importance of material selection cannot be overstated, as it permeates every aspect of engineering, from consumer electronics to aerospace components. Each engineering profession presents its own unique set of challenges and concerns when it comes to material selection, underscoring the difficulty of these crucial decisions. Through this research, we aim to contribute to the collective understanding of material selection methodologies, empowering engineers to make informed choices that optimize performance and reliability in their respective fields. In this case study, our focus revolves around the appealing process of material selection specifically modified for the impeller of a centrifugal blower.



(a)

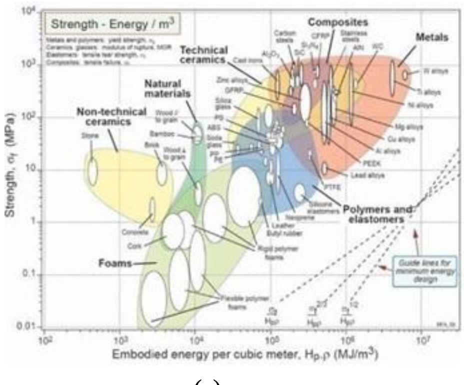


The impeller design of a centrifugal blower is shown above.

(b) Impeller design

The centrifugal blowers or centrifugal fans are used in HVAC systems, wastewater treatments, vacuum cleaners, air pollution control, advanced Materials used in "High-Tec" applications, usually designed for maximum performance, and normally expensive. Examples are titanium alloys for supersonic air planes,[2], etc. The process of material selection is suited for the impeller and the material selection is carried out with the help of the Ashby chart.

Engineering designers use graphical tools called Ashby charts, which were first proposed by Michael Ashby, to help in material selection. Based on performance requirements and limits, engineers can make well-informed judgments by using the systematic comparison of material qualities presented in these charts,[4].



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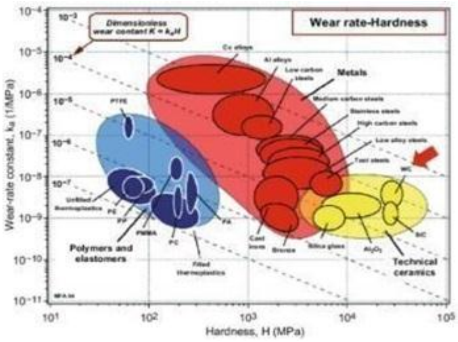

(d)

The above images show an example of Ashby charts.

Ashby charts: Ashby charts, there is increasing emphasis on materials efficiency-design that uses materials effectively and with as little damage to the environment as possible,[4]. The Ashby charts, which are used to select materials, are made up of two logarithmic exponentials, designated as the X and Y axes, respectively. the lines on both axes represent the requirements for the material selections, and they are extended till the end of the logarithmic exponential. The bubbles distinguish the material families. The intersection areas give the materials best suited for the requirements. Materials selection for composites is a tedious task because, unlike homogeneous materials like polymer, ceramics, steel, and metal, it involves consideration of different matrix and reinforcement systems,[5].

The material selection is according to the American Society for Testing and Materials [ASTM] standards. There are many standards like ANSI, API, DIN, ISA, & etc. But an international standard organization entitled ASTM International publishes voluntary consensus for a wide range of systems, materials, services, and goods,[6].

1	ANSI	American National Standard Institute
2	AISC	American Institute of Steel Construction
3	ASM	American Society of Metals
4	ASTM	American Society of Testing and Materials
5	DIN	Deutsches Institute of Normung
6	FCC	Federal Communication Commission
7	ISA	Instrument Society of America
8	IS	Indian Standard Institution

II. METHODOLOGY

1. Screening
2. Gathering mechanical properties
3. Scaled values
4. Positive Decisions
5. Calculating performance index

For the goal of material selection, we need to understand the functions, objectives, variables, and restrictions during the screening process. After the screening process, we need to gather the mechanical properties of the materials gained by using the Ashby chart. The Ashby chart is selected based on the objectives given in the screening process,[1]. The objectives are given based on cost and chemical compositions.

Following our goals, the materials we obtained from theAshby chart are as follows:

1. Gray cast iron
2. Carbin steel
3. Titanium alloy
4. Nickel alloy
5. Aluminium alloy
6. Aluminium matrix composite – 1
7. Aluminium matrix composite – 2
8. Titanium matrix composite.

The importance of property selection is to get the coefficient of friction, wear rate, thermal capacity, thermal conductivity, specific gravity, yield strength, tensile strength, density, corrosion, machinability, specific modulus, toughness, thermal expansion, specific heat, and hardness.

The mechanical properties are considered for Carbon steel. The carbon content typically ranges from 0.05% to 2.0%, depending on the grade and intended application. Carbon steel is known for its strength, hardness, and relatively low cost compared to other alloy steels.

	MECHANICAL PROPERTIES				
	1	2	3	4	5
Materials	Young's modulus (GPa)	Poisson's ratio	Yield strength (elastic limit) (MPa)	Tensile strength (MPa)	Density (kg/m^3)
Carbon steel, AISI 1010, C 0.40%	205	0.285	172	310	7800
Carbon steel, AISI 1015, C 0.41%	205	0.285	255	345	7800
Carbon steel, AISI 1020 C 0.41%	205	0.285	265	355	7800
Carbon steel, AISI 1025, C 0.42%	200	0.32	248	379	7820

1. Mechanical properties of Carbon Steel

For engineering and materials science research, development, and testing procedures to be efficient and successful, it is imperative to scale down the values of a material's mechanical properties. It makes cost-effective, fast, and perceptive analysis easier, which results in better designs, goods, and procedures. To get scale-down values we need to calculate Young's modulus, Poisson's ratio, Yield strength, Tensile strength, and Density.

	1	2	3	4	5
Materials	Young's modulus	Poisson's ratio	Yield strength (elastic limit)	Tensile strength	Density
Carbon steel, AISI 1010, C 0.40%	100	0.285	65	82	100
Carbon steel, AISI 1015, C 0.41%	100	0.285	96	91	100
Carbon steel, AISI 1020, C 0.41%	100	0.285	100	94	100
Carbon steel, AISI 1025, C 0.42%	97	0.32	94	100	99

2. Scaled down values of Carbon Steel The formulas used for the scale-down process are,

1. Young's Modulus = numerical *100 / max. value in list
2. Yield strength = numerical *100 / max. value in list
3. Tensile strength = numerical *100 / max. value in list
4. Density = min. value in list *100 / numerical value of property

The next step in the material selection process is to get the positive decisions and weighing factor of the scaled-down values.

Positive decisions in the context of material selection or decision-making processes could include choices that result in desirable results, including choosing a material that satisfies requirements for performance, cost, and other factors specific to a given application. A project, product, or process's success, efficacy, or efficiency are all influenced by wise decisions.

In a decision-making process, a weighing factor is usually a numerical value that is allocated to each criterion or parameter to represent its relative relevance or priority.

Engineers frequently have to weigh a variety of considerations when making decisions, particularly when it comes to material selection or design optimization. These factors could include cost, performance, durability, and environmental impact. By allocating weighing factors, engineers can compare and objectively assess various solutions according to how well they meet these requirements. By considering each criterion's relative importance in reaching the project's or process's overall goals, weighing factors helps guarantee that decisions are made methodically and objectively.

	Positive decisions	Weighting factor (X)
Young's modulus (GPa)	2	0.09
Poisson's ratio	3	0.142
Yield strength (elastic limit) (MPa)	6	0.285
Tensile strength (MPa)	4	0.19
Density (kg/m^3)	6	0.285
Total =	21	1.00

3. Positive Decisions of properties of Carbon Steel

Formula used:

Weighting Factor = positive decisions / Total

The final step in the material selection process in calculating the performance index. A performance index can be created based on mechanical qualities, cost, weight, environmental impact, or any other pertinent criterion in the context of material selection or engineering design. Performance indices are a useful

Material	Performance index
Carbon steel, AISI 1010, C 0.40%	**71.6**
Carbon steel, AISI 1015, C 0.41%	55.8
Carbon steel, AISI 1020, C 0.41%	56.5
Carbon steel, AISI 1025, C 0.42%	57.1

tool for engineers to assess various materials or design possibilities and to help them make well-informed decisions that balance competing goals and improve overall performance. The performance index helps engineers choose the best material by giving a numerical assessment of how well each material performs to certain parameters. The material having the highest performance index is finalized for manufacturing.

4. Performance index of Carbon Steel

As we can see the performance index of Carbon steel, AISI 1010, C 0.40% is high, and then this material is finalized for the impeller of the centrifugal blower for manufacturing.

The performance index of Carbon steel, AISI 1010, C 0.40% is 71.6

Carbon steel: Carbon is the principal alloying ingredient of carbon steel, which is a type of steel alloy mostly made of iron and carbon. Since it is inexpensive, versatile, and has good mechanical qualities, it is one of the most commonly utilized materials in many different industries. Some points of carbon steel given economic considerations are:

1. Cost-Effectiveness: When compared to many other steel alloys and substitute materials, carbon steel is typically less expensive. It is an economically appealing choice for many different applications due to its abundance and very inexpensive cost of production. Manufacturers nationwide are battling to maximize cost savings from missed output due to equipment downtime, while customers are concerned about safety,[3].
2. Availability of Raw Materials: Iron ore and coal are the two main raw materials needed to produce carbon steel, and their frequent availability and accessibility add to the material's affordability. Because of its accessibility, carbon steel is a cost- effective option for a variety of sectors.

Maintenance and Durability: Throughout a structure's or component's lifetime, carbon steel's durability and corrosion resistance can lead to decreased maintenance expenditures,[3]. Industries that use carbon steel may see large long-term cost reductions as a result of lower maintenance requirements.

III. CONCLUSION

This research article offers a thorough examination of the impeller material selection process in centrifugal fans, with a particular emphasis on important factors that should be known to student researchers. The study investigates several variables that affect material choices, such as cost-effectiveness, environmental impact, and mechanical characteristics. The goal of the paper is to provide students with the information and resources they need to make wise decisions when working on engineering design projects by combining the body of current research with useful insights. The study also addresses the financial aspects of material selection, stressing the significance of striking a balance between budgetary limits and performance objectives. It also discusses sustainability and recyclable materials, emphasizing the importance of making ethical material selections in engineering design. In general, this study paper offers direction, understanding, and useful suggestions for maximizing design results, making it an invaluable tool for student researchers starting material selection projects for centrifugal fan impellers.

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