DESIGN AND DEVELOPMENT OF COMPOSITES BASED ON BASALT/CERAMIC FIBERS FOR HIGH TEMPERATURE APPLICATIONS

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ABSTRACT

Composite materials for high-temperature applications are advanced materials composed of two or more distinct constituents, typically a matrix and reinforcing fibers, designed to withstand elevated temperatures while maintaining structural integrity. These materials offer superior strength, thermal stability, and corrosion resistance, making them crucial in industries like aerospace, automotive, and energy for components exposed to extreme heat and stress. This innovative approach focuses on creating composite materials using nano-filled epoxy resins, specifically tailored for aeronautical structural components. These materials not only provide effective lightning strike protection but also enhance their thermal stability. The epoxy matrix is formulated by blending a tetrafunctional epoxy precursor with a reactive diluent, reducing moisture content and facilitating the dispersion of nano-fillers. This diluent not only aids in better distribution but also accelerates the curing process of the epoxy mixtures, ultimately increasing their structural integrity and thermal resistance compared to epoxy alone. The primary objective of this research is to investigate and analyze the mechanical characteristics such as tensile strength, impact strength, strain, hardness, wear resistance, and fatigue properties of two types of composites: 100% Basalt fabric epoxy composite and 100% Ceramic fabric epoxy composite. The study involves varying different parameters to assess the mechanical attributes. Additionally, the research aims to assess the mechanical properties of Basalt and Ceramic fabric epoxy hybrid composites with varying blend ratios. Following the development and testing of these mechanical properties, the research evaluates the performance of these composites in high-temperature applications. This assessment is carried out through finite element analysis, and the results are compared with an existing composite product designed for high-temperature use.

Keywords: Composite Materials, Mechanical Properties, Basalt Fabric, Ceramic Fabric, Epoxy Composite, High-Temperature Applications

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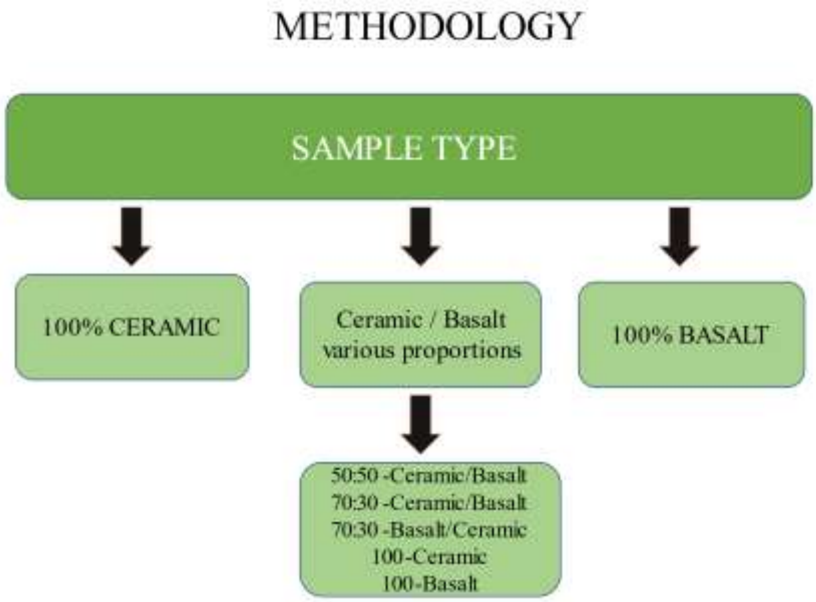
INTRODUCTION

Advanced composite materials have revolutionized high-temperature applications, offering strength and thermal stability crucial for industries like aerospace and automotive. This research delves into nano filled epoxy resins tailored for aeronautical components, providing lightning strike protection and thermal stability. The epoxy matrix, formed by combining a tetrafunctional epoxy precursor with a reactive diluent, enhances material integrity. The study scrutinizes mechanical properties, such as tensile and impact strength, strain, hardness, wear, and fatigue, in two main composite types: 100% Basalt fabric epoxy and 100% Ceramic fabric epoxy. Various parameters are adjusted to understand their effects hybrid composites, blending Basalt and Ceramic fabric with epoxy, are also evaluated with varying ratios for optimal configurations. After development and testing, the performance of these materials in high-temperature applications is assessed using finite element analysis. Results are compared with an existing high-temperature composite, providing invaluable insights for industries demanding materials capable of withstanding extreme thermal conditions.

MATERIALS AND METHODOLOGY



MATERIALS

The materials required for the designing and development of composites are

as follows

- BASALT FABRIC
- CERAMIC FABRIC
- EPOXY RESIN
- EPOXY HARDENER
- FOIL SHEET

Basalt Fabric is a type of reinforcement material made from natural basalt fibers, often used to provide strength and durability to composite structures. Ceramic Fabric is another reinforcement material made from ceramic fibers, known for its high-temperature resistance and lightweight properties, suitable for high-performance applications. Epoxy Resin is a common matrix material used to bind and encase the reinforcement fibers, providing structural integrity and resistance to environmental factors. Epoxy Hardener is Used in conjunction with epoxy resin to initiate the curing process, ensuring that the composite material hardens and becomes rigid. Foil Sheet can be used as a barrier or decorative layer in composite structures, providing additional strength and protection.

Epoxy resins are commonly used in composites for high-temperature applications due to their excellent heat resistance, chemical resistance, and mechanical properties. These resins can withstand temperatures of up to 300°C (572°F) or even higher, depending on the specific epoxy formulation. They are often reinforced with high-temperature-resistant fibers like carbon fiber or glass fiber to create composite materials that can perform well under extreme heat conditions. Epoxy composites are used in various industries, including aerospace, automotive, and the manufacturing of parts for high-temperature machinery. The specific choice of epoxy resin and reinforcement materials will depend on the application's requirements and the desired performance characteristics.

BASALT FABRIC

CERAMIC FABRIC

FIBER PARTICULARS

BASALT FIBER

Properties	**Values**
Temperature withstand	-260° to 700°c

Thermal conductivity	0.031Wm^{-1}
Tensile strength	2.8–3.1 GPa
Elastic modulus	85–87 GPa
Elongation at break	3.15%
Density	2.67 g/cm^3

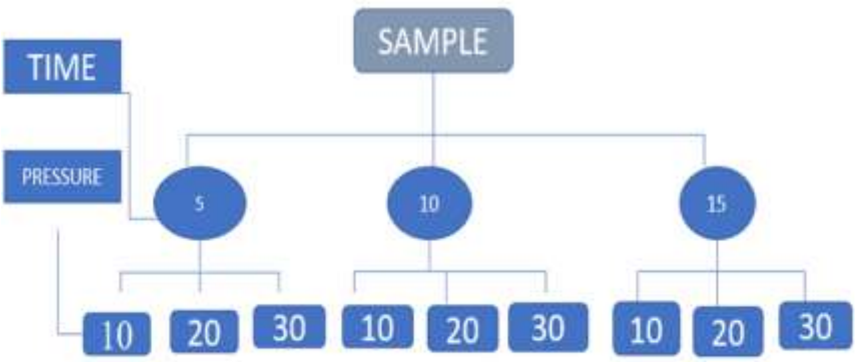
CERAMIC FIBER

Properties	**Values**
Temperature withstand	1800° to 1600°c
Thermal conductivity	0.031Wm^{-1}
Tensile strength	1-3 GPa
Elastic modulus	200-400 GPa
Elongation at break	1%
Density	1.5-3.0 g/cm^3

SAMPLE PREPARATION

Parameters required:

- Temperature - Room temp
- Time-5,10 and 15 min
- Pressure-10,20,30 kg/cm^2



- It involves getting a sample ready for further analysis, testing, or experimentation. Proper sample preparation is essential to ensure accurate and reliable results
- .Here, the standard room temperature, typically ranging from 20 to 25 degrees Celsius, is specified. Maintaining a consistent temperature is important as it can influence the properties of the sample and the reactions involved in preparation.
- Three different time intervals are considered: 5 minutes, 10 minutes, and 15 minutes.
- Three pressure levels are defined: 10 kg/cm^2, 20 kg/cm^2, and 30 kg/cm^2.

TESTING

After preparation of different composition of sample the following test are conducted:

1. Tensile strength
2. Flexural stress
3. Impact strength

TENSILE STRENGTH

Tensile strength tests for composites in high-temperature applications are crucial for assessing the material's ability to withstand mechanical forces at elevated temperatures. This helps engineers determine the composite's structural integrity and suitability for applications like aerospace, automotive, and industrial processes, where exposure to high temperatures is common. By measuring tensile strength under these conditions, it ensures the material can maintain its structural performance and safety in demanding environments. A tensile tester, which can be called a pull tester or a universal testing machine (UTM), is an electromechanical testing device used to exert a pulling force on a material, allowing us to measure its tensile strength and observe how it deforms until it eventually breaks.

FLEXURAL STRESS

Flexural strength tests for high-temperature composite applications assess the material's ability to withstand bending stress at elevated temperatures. This data helps engineers determine if the composite can maintain structural integrity under such conditions, crucial for applications like aerospace or automotive components exposed to extreme heat. It guides material selection and design to ensure safety and performance in demanding environments. The flexural strength of a material refers to the highest stress that material can withstand when subjected to bending before it starts to deform. To determine this strength, a widely used method involves conducting a transverse bending test using a three-point flexural testing technique.

IMPACT STRENGTH

Impact strength measures a material's ability to resist sudden impacts, preventing cracks or deformation. It's vital for evaluating how well a material withstands sudden forces. Common materials for impact testing are metals, plastics, wood, composites, ceramics, and polymers. These materials often take the form of sheets or rods, with results depending on test type, loading speed, and temperature. Materials can undergo ductile or brittle failure; brittle failure requires less energy to initiate and propagate cracks, leading to failure, while ductile failure demands a higher load to propagate cracks until failure.

CONCLUSION

The utilization of basalt and ceramic fibers combined with epoxy resin in composite materials is a promising avenue for high-temperature applications. The flexural strength tests have revealed their ability to withstand bending loads, which is critical in structural applications. The tensile strength tests have demonstrated their resistance to stretching forces, further underscoring their potential for applications under thermal stress. Additionally, the impact strength tests indicate that these composites can withstand sudden mechanical loads, making them suitable for various industrial and aerospace applications. This research highlights the importance of material innovation and the development of advanced composites tailored for high-temperature environments. However, ongoing research and refinement are required to fine-tune the manufacturing processes, optimize material ratios, and enhance the overall performance of these composites. As such, these findings pave the way for the continued advancement of composite materials, which hold great promise for applications in industries where extreme temperatures and mechanical stresses are common challenges

REFERENCES

1.Dr. M. Belmont Institute of Ceramics and Glass CSIC. Campus de Cantoblanco

Kelsen 5. 28049 Madrid, SPAIN The author acknowledges the financial support of the "Ramón

y Cajal" program (MEC, Spain).June 2006

2.Tim Overkamp, Boris Mahltig and Yordan Kyosev2018, Vol. 47(5) 815–833,

The Author(s) 2016.

3.Shuai Xu a, Lingzhi Chen a, b, Mengqiang Gong a, Xueli Hu b, Xiaoge Zhang b

Zhangjian Zhou a, */ Composites Part B 111 (2017) 143e147.

4.Peter Baldus,Martin Jansen,Dieter Sporn, www.sciencemag.org SCIENCE VOL 285 30 JULY 1999.

5.T.M.N. Afiq S.M. Sapuan, R.A. Ilyas,Muhammad Nur Afiq Tunan on 26 January 2021.

6.D. Koch et al. / Composites Science and Technology 68 (2008) 1165–1172

7.Tibor CZIGÁNY∗, János VAD∗∗ and Kornél PÖLÖSKEI∗ July 13, 2004.

8.Senol Yılmaz ,*, Gunhan Bayrak , Saduman Sen , Ugur Sen .21 April 2005.

9.Bulent Ozturka,, Fazlı Arslana, Sultan Ozturkb aDepartment of Mechanical Engineering, Karadeniz Technical University, Trabzon, Turkey bBes-ikdu¨zu¨ Technical College, Karadeniz Technical University, Trabzon, Turkey Received 22 April 2005.