EVALUATION OF MECHANICAL PROPERTIES OF PHENOLIC COMPOSITE WITH NANO ADDITION REVIEW

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Abstract:
As an emerging material, nanomaterials have attracted extensive attention due to their small size, surface effect and quantum tunneling effect, as well as potential applications in traditional materials, medical devices, electronic devices, coatings and other industries. Herein, the influence of nanoparticle selection, production process, grain size, and grain boundary structures on the mechanical properties of nanomaterials is introduced he low mechanical properties of phenolic resin can be improved by the uses of nanofillers. The interaction between nanofillers and the phenolic matrix dominates the performance of the composite structures. Therefore, the modification of nanofiller plays a crucial role in improving the mechanical performance of the phenolic nanocomposites. In their study the properties of various nanofiller reinforced phenolic composites. Composites were processed with the modified polymer and carbon fibers were used as continuous reinforcement. The ablative properties of the materials obtained were studied by the oxyacetylene torch test and the ablated samples were observed by scanning electron microscopy.

Keywords*: phenolic nanocomposites, Mechanical properties*

1.0 INTRODUCTION

During recent years, many studies have been done on nano-scale-reinforced composites. Researchers found that nano-scale-reinforced composites, especially polymer-based nano-composite have considerable properties compared to polymer matrices with a low-volume fraction **[1].** The main advantages of this type of materials are strength-to-weight ratio, reduced permeability to gas, and composition resistance to solvent and thermal stability. In recent years, nanoparticles reinforced resin coatings have drawn a considerable attention, caused by the improvements on various properties, such as rheological properties, curing performance, heat stability and other mechanical properties **[2].** The use of inorganic particles in the nano scale range is particularly attractive, since it improves the properties of the polymers by controlling the degree of interaction between the polymer and the nanoparticles via a top–down approach Due to the unique surface and volume effects of nanoparticles, the performance of modified phenolic resin will be greatly improved Moreover, the surface of the nanoparticles has unpaired atoms, which can be physically or chemically bonded to the phenolic resin to enhance the interface with the matrix, thereby the performance of phenolic resin has been improved By the introduction of nanoparticles, the mechanical properties of phenolic resin can be significantly improved **[3].** To the best of our knowledge, few works have been conducted on the manufacture and properties of phenolic resin film modified by nanoparticles. It is necessary to study

nanoparticles modified phenolic resin film on the microscale and nanoscale **[4].** In this paper, the effects of introducing nano-silica particles on the rheological properties and curing properties of phenolic resin film are investigated. By comparison in the rheological properties and curing properties of phenolic resin film, the optimum mass fraction of introduced nano-silica particles could be found **[5].** Finally, the distribution of nano-silica particles on the surface of composites and the mechanical properties of nano-silica modified phenolic composites are characterized by scanning electron microscope and universal material testing machine in order to understand each mechanism operating during the resin film infusion (RFI) process.

Phenolic resins Applications:

Phenolic resins are good for high-temperature applications where parts must meet fire safety standards. Phenolic resins are used in a wide range of applications, including electronics, ballistics, mine ventilation, offshore water pipe systems, aerospace, rail and mass transit.

Uses of Phenolic resins

- It is used as an antiseptic.
- It is used as a disinfectant in household cleaners.
- It is used in the preparation of resins, dyes, explosives, lubricants, pesticides, plastics, drugs, etc.

2.0 LITERATURE REVIEW

Ali Mostofizadeh et al **[6]** In recent years, many theoretical and experimental studies have been carried out to develop one of the most interesting aspects of the science and nanotechnology which is called carbon-related Nano materials. The goal of in their study is to provide a review of some of the most exciting and important developments in the synthesis, properties, and applications of low-dimensional carbon nanomaterial's. Maurizio Natali et al **[7]** In this work, we investigated the ablative properties of two carbon Nano filler-based composites. In particular, carbon black (CB) and multi-walled carbon nanotubes (MWNTs) were used to produce highly loaded (50 wt. %) Phenolic composites. J. S. Tate et al **[8]** a combination of sonication and high shear mixing to insure uniform dispersion of MWCNT. The composite test specimens were tested by using an oxyacetylene test bed (OTB) applying a heat flux of 1000 W/cm2 for duration of 45 seconds. Composite specimens with 2 wt. % MWCNT showed reduction in mass loss, recession in length, and in situ temperatures compared to control composites P. Sanoj **[9]** Composite materials have been steadily substituting metals and alloys due to their better thermo mechanical properties. The successful application of composite materials for high temperature zones in aerospace applications has resulted in extensive exploration of cost-effective ablative materials. LEN de Almeida et al **[10]** The main objective of this research work was to obtain two formulations of ablative composites. These composites are also known as ablative structural composites, for applications in atmospherically severe conditions according to the high temperature, hot gaseous products flow generated from the burning of solid propellants. Mohan Kumar. L **[11]** The external surface of a re-entry space vehicle experiences high heat flux and temperatures of the order of 2500°C during re-entry into the atmosphere and the internal contour of a rocket motor nozzle has to encounter temperatures above 2000°C during its operation. M Satyanarayana Gupta **[12]**

Carbon-Phenolic composites are meant for heat protection of the aerospace structures like aircraft skins, nozzles and heat shields during the aerodynamics loading conditions. Phenolic resin matrix composites are used as ablative liners to resist thermal and erosive environment. The manufacturing process of Carbon Phenolic composite structure requires curing. L Asaro et al **[13]** Mesoporous silica particles and carbon black were selected as fillers for a resold-type Phenolic resin, to be used as a matrix for ablative materials. Composites were processed with the modified polymer and carbon fibers were used as continuous reinforcement. Huu Nguyen et al **[14]** The effect of CNTs on the microstructure and thermal property of these composites was investigated. FESEM analysis indicated that the surface structure of Phenolic/graphite composites became denser and more homogeneous with the presence of CNTs. Colonel Vijay Kumar **[15]** Ablative composites are highly endothermic sacrificial thermal protection materials that are indispensable to the aerospace industry. Polymeric ablatives are the most versatile and the largest class of thermal protection materials due to their capability to be to varied hyper thermal environments. Feng Xu et al **[16]** In this study, the surface-decorated ZrB_2/SIC and its modified carbon fabric reinforced phenolic composites have been successfully prepared. The self-modification mechanism of the surface-decorated ZrB_2/SIC particles was characterized.

3.0 Methodology

Phenolic resins are found in myriad industrial products. Phenolic laminates are made by impregnating one or more layers of a base material such as paper, fiberglass, or cotton with phenolic resin and laminating the resin-saturated base material under heat and pressure. The resin fully polymerizes (cures) during this process forming the thermoset polymer matrix [17]. The base material choice depends on the intended application of the finished product. Paper phenolics are used in manufacturing electrical components such as punch-through boards, in household laminates, and in paper composite panels. Glass phenolics are particularly well suited for use in the high speed bearing market [18]. Phenolic resins are also used for making exterior plywood commonly known as *weather and boil proof* (WBP) plywood because phenolic resins have no melting point but only a decomposing point in the temperature zone of 220 °C (428 °F) and above

Phenolic resin:

It is notable for being a type of thermoset polymer, meaning that it cures into an altered form than when it is uncured; however, unlike other varieties of plastic polymers, it cannot be re-melted and re-molded. This comes with the cost of recyclability, as the resin cannot be re-molded after it is cured and taken shape. Other polymer resins include polyester, urethane, epoxy, and melamine, but let's look at the properties and uses of phenolic resin to convince you why phenolic resin is the right thermoset for your business [19,20]]. Phenols are organic aromatic compounds containing -OH functional group directly attached with the aromatic ring with general formula C_6H_5OH. Phenol is widely used as antiseptic, disinfectant, anesthetic and household cleaning products. Phenol is also used as starting material or produce as an intermediate in industry.

Table 1: Mechanical properties of Phenolic resin

Tensile Strength	90 MPa
Flexural Strength	152 MPa
Water Absorption 24 hrs	1.8%
Density	1.34 g/cm3

Sample preparation

A certain amount of phenolic resin is treated as 100 parts, and 0, 2, 4 and 6 parts of nano-silica are introduced respectively. The preparation of resin film is as follows. First, B80 phenolic resin and nano-silica particles are placed in an oven at 80°C for about 1 hour. By high-speed mechanical dispersion, 2, 4 and 6 parts of nano-silica particles are added to 100 parts of phenolic resin. Then the phenolic resin containing nano-silica is taken out and put into a mold with a doctor blade. After cooling to room temperature, the resin film has been prepared.

Table 2: Review on Fenolic composite with nano Addition

Author	Year	Description
Dr. N. Kishore Nath	2021	A Composite Material is a macroscopic combination of two or more distinct materials, having a recognizable interface between them. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications.
Filip Kateusz et al	2021	The mechanical properties, thermal conductivity and thermal capacity of the composites were determined. Raman spectroscopy and Fourier transform infrared spectroscopy were used to investigate the carbon matrix composition and structure.
L. Paglia, et al	2021	In this work, two different kinds of carbon-Phenolic ablators with a density of 0.3 g/cm^3 were manufactured and their mechanical and thermal properties were experimentally evaluated.
Umar Farooq et al	2021	The influence of Nano diamonds (NDs) on the thermal and ablative performance of carbon fiber-reinforced–epoxy matrix composites was explored. The ablative response of the composites with 0.2 wt. % and 0.4 wt. % NDs was studied through pre-and post-burning morphologies of the composite surfaces by evaluation of temperature profiles, weight loss,

		and erosion rate.
Wenjie Yuan et al	2021	The effect of SiB CN powder on properties of Phenolic resins and composites was analyzed. Compared with Phenolic resins, the thermal stability of SiB CN powder modified Phenolic resins (the SiB CN Phenolic resins) by characterization of thermo gravimetric analysis (TGA) improved clearly.
Tingli Yang et al	2022	Carbon fiber fabric-reinforced Phenolic resin composites are widely used as thermal protection materials for thermal protection systems in hypersonic vehicles and capsules. The high-temperature performance of the composites as well as the oxidation behavior of the carbon fibers was studied.
Maurizio Natali	2022	During last decades a plethora of high temperature materials have been developed to work as a Thermal Protection System (TPS). However, graphite has relatively poor mechanical properties, but exhibits low resistance to the thermal shocks.
Megha Choudhary et al	2022	In this review, we provide a rundown of these structures and discuss in detail the numerous methods used to process CNT-reinforced materials, such as chemical vapor deposition (CVD), ball milling, hot pressing, and selective laser melting.
Raghu Raja P et al	2022	The effect of Nano zirconia, Nano titanic and fumed silica on the mechanical, thermal, and ablation behavior of carbon-Phenolic (C-PH) composites is investigated the manufacturing of C-PH laminates, the mechanical properties such as tensile strength and hardness are evaluated and the effect of these fillers is investigated.

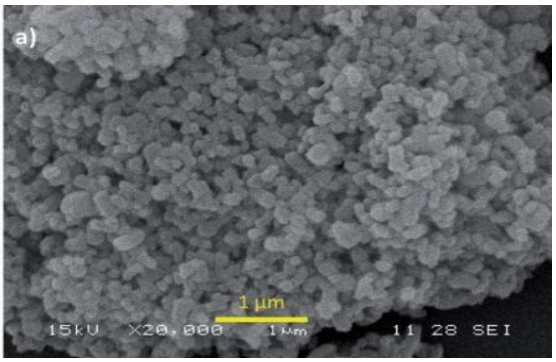
4.0 Ablative properties of phenolic/carbon composites

In the materials with silica particles, mesoporosity is clearly seen, and darker areas are associated to overlapping of two

or more particles. In the materials with CB the spherical aggregates can be observed.

Mechanical test:

To study the mechanical properties of the composites, 3-points bending test was conducted on the composite specimens by a hydraulic testing machine (Instron 6025) according to ASTM D7264 standard. The ultimate bending results of composites were average data of diffrent tests.



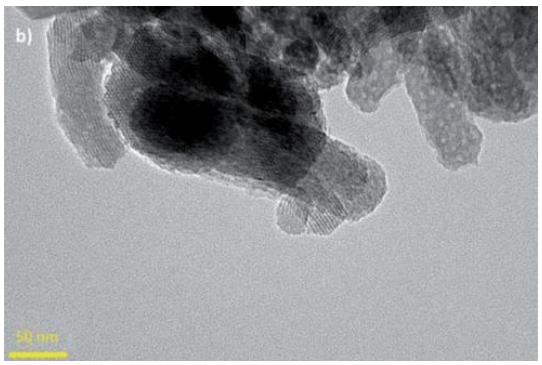


Figure 1: (a) SEM and (b) TEM of the mesoporous silica particles used as filler in the phenolic resin.

The fractured surface of cross-linked phenolic matrix in the composite without MWCNTs is very smooth (Fig.), whilst the MWCNTs result in crack pinning effects and formation of rough surface structures

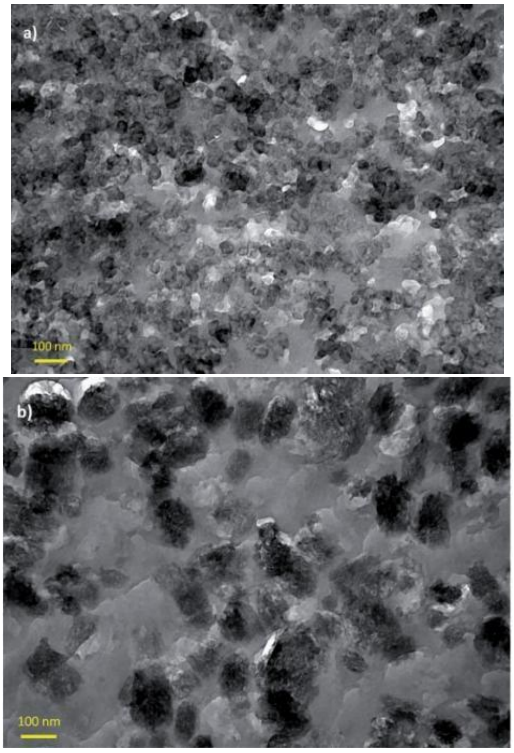


Figure 2: TEM images of (a) phenolic resin with 20 wt.% of CB (b) phenolic resin with 20 wt.% of mesoporous silica particles

The difference in the surface roughness indicates different fracture pathways. The fractured surface of the pure composite is in a brittle nature but that of nanocomposites in a ductile nature. It is possible to clearly identify the MWCNTs are distinguishable as bright single When composites are used as ablatives for thermal protection, density must be taken into account. A decrease in the total weight of space rockets by using materials with better properties will result in a reduction in the amount of fuel used or an increase in the payload each aggregate is made up of elementary particles of about 50 nm. A good dispersion in the phenolic resin was confirmed.

Conclusions:

In recent years, carbon fibre/phenolic composites modified with nanomaterial have attracted great interest in the field of

advanced, high-performance materials and structures Considering that such composite has 44% by volume of carbon fibers, it could be inferred that its properties could be improved by increasing the fiber content and maintaining the amount of CB. The composite with 20 wt. % of mesoporous silica particles exhibited the lowest mass erosion rate (0.129 g/s), indicating that the damage was more localized and that the melt silica (observed as white areas in the burnt plates) remained above the carbon fibers, protecting the surface of the material during fire exposure. The morphology of the burnt surfaces was investigated by SEM analysis. The formation of a strong carbon network char achieved by addition of MWCNTs was responsible for noticeable improvements of ablation properties. Furthermore, the presence of MWCNTs on the surface ensured higher re-radiation efficiency and improves the ablation property of carbon fibre/phenolic nanocomposites. Accordingly, the addition of MWCNTs could represent an effective way to enhance the thermal and mechanical properties of carbon fibre/ phenolic composites at low filler concentrations.

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