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The Effect of Mixing Carbon Black N330 and N660 in Fiber Reinforcement Plastic Matrix System for Fire Retardance in Marine Application

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Abstract

The composite materials are increasingly being used in applications where their fire response is a critical consideration. Composite in the marine application was growing rapidly especially in the ship and boat building was prevalent in recent decades. As the synthetic materials nowadays are more flammable, they required modification to decrease their flammability through the addition of flame-retardant compounds. This journal presents an investigation of a combination of two series of carbon black namely N330 and N660 in order to improve the fire resistance. The method was, by mixed two different series of carbon black (N330 and N660) into the resin and deployed using vacuum infusion process to get 5 mm thickness of polymer composite. The flame test will be conducted and the properties of fire retardant being studied. A factor to be recorded and identify was flame spread and burn rate including smoke density.

Keywords

Carbon black; N330; N660; Flame retardance; FRP; Marine application

Introduction

Composite materials are being used for boats and ships of ever-increasing size. Yachts over 50 meters and the 70 meter Swedish Visby class corvette are examples of how design and fabrication methods have improved [1]. Nevertheless, the rapidly growing polymer market increases the risk of fire. The competition for reducing the costs and the activities for increasing the recyclability are advantageous from many aspects but promote the use of cheap and flammable polymers [2]. Fire Safety is just one part of that overall safety concern, an inherent problem with composite materials are that they are combustible [3]. The composite had to go through modification either by the physical or chemical reaction. Additional of filler in composite such carbon black was the alternative method to be practical practice. Additional of mixed carbon black with different series (N330 + N660) and quantity be proposed whereby the expected result from modification process will enhance the composite structure by the act on the chemical change and prove it as one of the alternative flame retardant agents. Vacuum Infusion process will be used in this research to get the equal thickness. The flame test will be conducted on composite to study the burning rate, burning distance of fire and it fire-retardant characteristics including the effect of filler towards mechanical properties of the composite.

Background of Study

The intention to reduce fire risk has been stated clearly in regulation even become important issues in every aspect of product manufacturing based on the composite. In manufacturing of composite by using vacuum infusion process with mixed of

Carbon black (N330 + N660) into resin is expected can reduce the fire risk and also act as fire retardant agent whereas the time scale can be achieved within 15 seconds faster than resin without filler.

Objective of research

First is to determine the effect of weight percentage (wt%), particle size (N series) and different amount of carbon black in one mixture towards fire retardant properties. Second is to identify the burning rate, fire distance travel and physical condition of the composite after the fire has been removed. Third is to analyze the effect of different particle size (N series) and weight percentage (wt%) on dispersion, interlayer and free nanohole volume for its fire retardant properties. Fourth is to investigate and prove the optimum design suitable for fire retardant as the best practice.

Scope and significance

Develop a new type of composite as a fire retardant material by using vacuum infusion process and two types of carbon black N330 and N660 as the filler for fire retard agent The addition of carbon black into resin was the alternative filler that requires low cost but can offer good strength and high stiffness of composite. The application of carbon black can retard the fire within less than 30 seconds with suitable of weight percentage (wt %), the amount of mixture and the selection of size particles (N series).

The expected reaction was based on the good dispersion, interlayer and less of free nanohole volume (porosity) in the composite which one of a factor that supports the combustion. The burning rate and fire travel distance also can be reduced spontaneously due to the influence of carbon black particle size.

Literature Review

The composite materials are being used extensively in marine and shipbuilding all around the world. The properties of composite that consist of higher stiffness and strength by weight than most other materials, including metals such steel and aluminum were the main factor why composite has higher demand. Composite has significantly reduced and minimized all the cost involved. The application of composites to maritime crafts was initially driven by a need for lightweight, strong, corrosion resistant and durable naval boats [1,4]. However, the composite structures are still bombarded with costly certifications, safety considerations, process, and design standardization barriers. The production of composite comes with a variety of techniques, gently from the hand lay up to high precision mechanization. The changes of processing techniques aim at a high modulus of polymer and advanced reactive processing techniques

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[5]. Reinforcements for marine composite structures are primarily E-glass due to its cost for strength and workability characteristics [6]. For ease of fabrication and to achieve specific properties, such as improved through-thickness strength, continuous fibers are converted into a wide variety of reinforcement forms [7].

Mechanical properties of fibre-reinforced composites are dependent on the properties of the constituent materials (Figure 1) (type, quantity, fiber distribution and orientation and void content).

Carbon black

Carbon black was produced and obtained by charring organic material such wood, bone or collecting soot from burning oil and these were not very pure in their chemical composition because soot has a small surface area of available carbon due to their large particle size and low carbon content. They typically contain large quantities of solvent-extractable materials and their ash content can be 50% or more [8-10]. X-Ray investigations show that the carbon is mainly in the form of very small crystallites with a graphite-like structure [11]. The primary particles of carbon black are nearly spherical in shape with diameter 10 to 100 nanometres (nm). Carbon black does not exist in form of primary particles, but primary particles fuse to form aggregates (50 to 500 nm) which contain a large number of primary particles. Carbon black is one of the most stable chemical products with extremely fluffy fine powder with large surface area. One reason that tends to use carbon black as filler in most product nowadays is to begin when carbon black uses as filler or additive in tire manufacturing (Figure 2).

Carbon black is manufactured by controlled vapour-phase pyrolysis and partial combustion of hydrocarbons. Carbon black being recognizes or referred to the process or the source from which it made. Each various processes have the certain unique characteristic that makes them different in grades.

Process of carbon black

Carbon black was produced many centuries ago, whereby the application was use as pigment in ink and lacquers via simple lampblack process. At the nineteenth century, the channel black process was developed. At the beginning of the twentieth century, the production was increased rapidly and gas furnace process was introduced. Carbon black was produced by incomplete combustion or thermal decomposition or liquid hydrocarbons under controlled vapour-phase pyrolysis of hydrocarbon conditions and the final product will be in form of powdered of the element carbon.

Properties of carbon black (CB)

The bond between two molecules of carbon black or aggregates that bind together is known as Van Der Wall's forces and this force is weak and can easily break up. The structure of carbon black is mainly in the form of very small crystallites with graphite. Carbon is the sixth most abundant element in the universe and commonly obtains from coal deposits. Three naturally occurring allotropes of carbon are known to exist is amorphous, graphite and diamond. There are three main properties of carbon black that are, particle size, structure and surface chemistry.

- Particle size is the size of spherical particles in carbon black. This spherical particle is the fundamental property which largely affects the blackness and dispersibility of the material. Smaller the particle size, higher the blackness of carbon black and easily dispersed, meanwhile, it will become difficult due to an increase in coagulation force.
- The size of the particle chain is called structure. Increasing the structure sizes will improve dispersibility and lowers the blackness. Carbon black with a larger structure, in particular, shows an excellent conductive property. Increasing the structure typically increases the modulus, hardness, electrical conductivity, and compound viscosity [12].
- Surface chemistry is the various functional groups such as hydroxyl or carboxyl group found on the surface of carbon black together with their amount or composition. Surface area measurements give an indirect characterization of carbon black particle size. Based on surface area, thermal black can be classified as an N900 series black while furnace black fall within the N100 to N700 series [13].

The properties and grades of carbon black that largely determine its use are related to structure, surface area, and condition. The system of the designation of types was developed in the production and consumer industries which used the initial letters of words that describe a particular carbon black. This system, originally adopted in 1966, is primarily for rubber-grade carbon blacks and consists of a letter followed by a three-digit number [14]. The letter N stands for the normal cure of a rubber compound. The first number following the letter designates the group number, which is determined by the average primary particle size.

Fire retardant on composite

Synthetic polymers are generally more flammable than their natural counterparts. The flammability of a material is not an intrinsic property, like its density or heat capacity, but is dependent

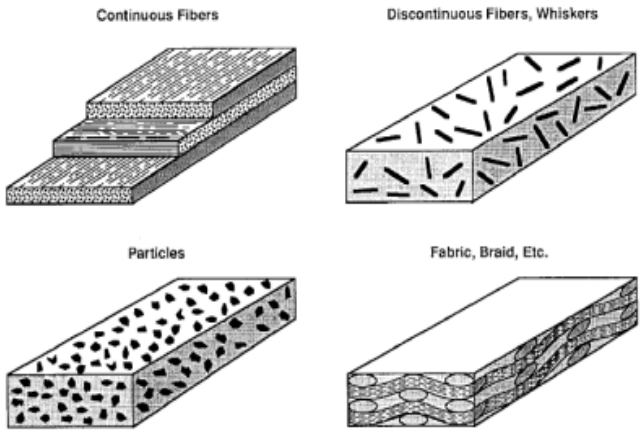

Figure 1: Reinforcement forms.

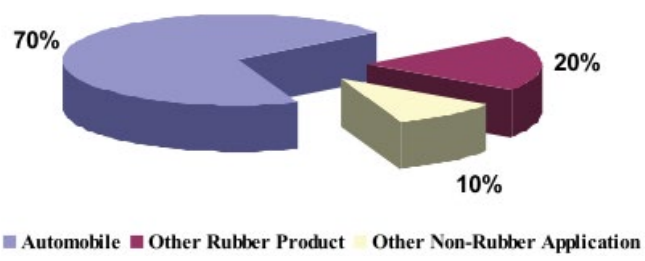

Figure 2: Consumability of Carbon black [Auchter J.F (2005)].

on the fire conditions. However, excessive ventilation may remove heat from the flame, while additional heat may also result in melting or char formation, each of which could reduce fire growth [15]. Environmental regulation has restricted the use of some halogenated flame-retardant additives [16,17], therefore, a search for alternative additive tend to say that the nanoparticle fillers are highly attractive for this purpose.

The increasing demand for greener and biodegradable materials leading to the satisfaction of society requires a compelling towards the advancement of nano-materials science [17]. The use of composite material without any flame retardant is dangerous for human safety.

Fire retardant improvement

Any substance other than water that reduces the fuel flammability or delays their combustion is referred as "Flame Retardant" (FR). This includes typically chemical retardants and also substances that work by physical action which retards the flame by blocking the fire either physically or by initiating a chemical reaction [4]. Flame retardant differs from each other by common chemical or physical properties and mode of action [4,18]. The use of flame retardants is to prevent the flame from entry into the material, as well as prevent the spread of flame and even extinguished completely [19]. In other hand, flame retardants are one of the hidden layers of protection against the potentially devastating impact of fire [20]. The improvement of flame retardant can be achieved by inhibiting or by disrupting the combustion cycle. Three different ways can be interrupted the cycle [21-23].

- By incorporating such chemicals that decompose endothermically when exposed to heat and thus these chemicals prevent the temperature from reaching the pyrolysis temperature of composite materials.
- By incorporating such chemicals that produce more non-flammable by-products and more char during pyrolysis reaction. This char layer acts as a physical barrier which hinders the heat and mass transfer between gasses and condenses phase. This mechanism is known as condensed phase mechanism.
- The gas phase mechanism. In this case, during combustion, the flame retardant chemicals release more non-flammable gasses leading to reduction in effective oxygen concentration in the flame zone and thus act as a flame retardant agent

There are two ways to improve the flame behavior or fire performance of composite, either by improving the fire performance of composite making constituents' i.e. matrix and reinforcing agent; or by providing a protective coating of flame retardant around the core composite. Between the other composites, it was observed that glass-reinforced unsaturated polyester composite contributed to least fire risk but none of these was flame retardant in nature. Flame retardancy of thermo set composite materials can be modified in different ways such in addition to usual char forming catalytic effect, they also have a low melting point and form a glassy film around the burning component when expose to fire.

Nanomaterials have higher surface energy due to their nanoscale dimensions and when these nanoparticles are dispersed properly into the polymeric matrixes are known to improve thermal, mechanical and fire performance properties of the composite materials [24-26]. The combinations of additive or reactive flame retardants will create the synergistic or antagonistic effect. This effect can be produced by the combinations of additive and reactive flame retardants. The synergists show no or only negligible effectiveness when used alone so, they are used together with specific flame retardants to get the synergistic effect [4].

Methodology

Material used for composite fabrication

The material involved such, chopped strand mat, woven roving, wax and non-wax epoxy resin and carbon black with different series that is N330 and N660.

Instrumental approach

The test methods most often used to measure the fire reaction and fire-resistive properties of composites. Therefore, determination of the fire reaction properties is important because it will influence on the early stages in the growth of the fire. The ability of a structure to retain functionality in a fire and prevent the spread of fire is known as Fire resistance. Fire resistance also describes the changes to the load-bearing integrity of a structure during a fire, and here the key resistive properties are the retention of stiffness, strength and creep resistance during a fire and the residual mechanical properties following it.

Types of flame test

The flame test will be conducted to identify flammability, burn rate, flame spread, and smoke generation. The test that will be conducted as follow:

1) Radiant Heat Panel – to investigate the surface spread of the flame on composite
2) Smoke Chamber – to investigate the smoke density produced during the experiment. The measurement of the toxicity of thermal decomposition products.
3) LOI Chamber – to investigate the limiting oxygen and the smoke toxicity
4) Laboratory Burner – to investigate the flammability of the product.

The standard used during the experiment such:

- BS 476: Part 7: 1997
- ASTM D2843
- ASTM D2863
- UL 94

Specimen preparation

The sample was fabricated by using vacuum infusion process. The resin was driven into a dry laminate using a vacuum pressure. This process in which the lay-up is cured under pressure generated by drawing a vacuum in the space between the lay-up and a flexible sheet placed over it (Table 1).

The expected outcomes

To create a new type of composite that can retard the fire within less than 30 s as required by the International maritime Organization (IMO) and classification society. In another hand to propose the combination of two series of carbon black (N330 and N660) mixed with resin as the new alternative for fire retardant additive inside

Table 1: Composition of CB for fabrication new type of composite.

COMPONENT	SAMPLE					
	CB0	CB1	CB2	CB3	CB4	CB5
RESIN						
WAX	100					
NON WAX	100					
MEKP	2%					
CARBON BLACK (CB)						
N330	0	3	6	9	12	15
N6660	15	12	9	6	3	0

polymeric composite as one of the compatible additives within the suitable weight percentage. By right, these will contribute to minimizing the cost, save more life, and property.

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