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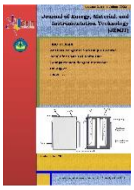

Potential of Carbon Fiber as An Insulation Layer In Anti-Sensor Thermal Pdl: A Review

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Abstract

The advancement of technology, along with the development of the times, makes mastery of technology an absolute thing for the progress of national defense; one of its applications in defense materials is the manufacture of PDL anti-thermal sensor suits. In the PDL anti-thermal sensor suit, carbon fiber is used as insulation. Carbon fiber is a strong, lightweight, and thermal insulator material. This research method uses a qualitative descriptive research method with sources from Google Scholar. In this study, Publish & Perish 8 software was used to help obtain 200 journals on the topics of carbon fiber characteristics, composites, sensors, thermal, carbon fiber resistance generators, carbon fiber thermal conductivity testing, determination of layers of PDL anti-thermal sensor clothes, and the use of carbon fiber as an insulation layer on PDL anti-thermal sensor clothes which were then reviewed as many as 20 journals to be reviewed and summarized for reviewed and summarized to see the potential of carbon fiber as an insulation layer of composite materials in PDL Anti-Thermal Sensor clothing. The conclusion obtained in this study is that carbon fiber has a carbon content of 92% with a solid tensile strength of 452.94 MPa and a low thermal conductivity of 1,13 W/mk and has the potential to be applied as an insulation layer on PDL clothes anti-thermal sensors.

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Abstrak

Kemajuan teknologi seiring dengan perkembangan zaman membuat penguasaan teknologi menjadi hal yang mutlak bagi kemajuan pertahanan nasional, salah satu aplikasinya dalam bidang bahan pertahanan dalam pembuatan baju PDL anti-sensor termal. Dalam baju PDL anti-sensor termal, material serat karbon digunakan sebagai material insulasi. Serat karbon adalah material yang kuat, ringan, dan insulator termal. Metode penelitian ini menggunakan metode penelitian deskriptif kualitatif dengan sumber dari Google Scholar. Dalam penelitian ini, digunakan perangkat lunak Publish & Perish 8 untuk membantu mendapatkan 200 jurnal tentang topik karakteristik serat karbon, komposit, sensor, termal, generator resistansi serat karbon, pengujian konduktivitas termal serat karbon, penentuan lapisan baju PDL anti-sensor termal, dan penggunaan serat karbon sebagai lapisan insulasi pada baju PDL anti-sensor termal yang kemudian ditinjau sebanyak 20 jurnal untuk ditinjau dan diringkas untuk ditinjau dan diringkas untuk melihat potensi serat karbon sebagai lapisan insulasi material komposit dalam baju PDL Anti-Sensor Termal. Kesimpulan yang diperoleh dalam penelitian ini adalah bahwa serat karbon memiliki kandungan karbon sebesar 92% dengan kekuatan tarik yang sangat kuat sebesar 452,94 MPa dan konduktivitas termal rendah sebesar 1,13 W/mk memiliki potensi untuk diterapkan sebagai lapisan insulasi pada baju PDL anti-sensor termal.

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1. Introduction

The advancement of technology is significantly influenced by the progression of the era. Mastery of technology is essential for a country's progress, necessitating that every field of study adapt to technological advancements. This is particularly evident in the field of defense, where technology is utilized in weapons systems and personnel equipment. A notable innovation in this domain is the enhancement of TNI PDL uniforms with anti-thermal sensor properties by incorporating carbon fiber as an additional layer in the composite material.

Composite material combines two or more materials (Matthews & Rawlings, 2003). It is defined as a material whose formation is not homogeneous from two or more materials. With the existence of composites, it will be easy to determine the desired material strength with its composition (Firmansyah et al., 2018)]. For example, its application in the military field is needed in this modern era, where a uniform with anti-thermal sensor material for military personnel is needed. One innovation can be designing PDL clothes made from basic composite anti-thermal sensors.

The innovation of making a design for PDL clothes made from the primary composite anti-thermal sensor is expected to make personnel undetectable by enemies with anti-thermal sensors. The selection of carbon fiber among cotton layers serves as an anti-thermal sensor material. Carbon fiber is expected to be a layer that can help isolate heat on PDL clothes. The lower the conductivity of a material, the better its insulation against heat, so both materials are expected to be able to isolate thermal from personnel so that thermal cameras cannot detect it.

Thermal conductivity, according to (D.C. Giancoli, 1998)] is a significant incentive for a material's ability to conduct heat. Heat transfer can be through convection, conduction, or convection. The calorific value becomes a significant variable for the conductivity properties of a material. Knowledge of the thermal conductivity of a material is essential. It is related to the working principle of thermal sensors. Thermal sensors are commonly used to detect the temperature of objects in an environment. The material's ability to conduct heat can also be known by knowing the thermal conductivity. The lower the material's conductivity, the better it isolates an object's thermal. This research aims to see the potential of carbon as an anti-thermal insulation material so that it can be applied to PDL.

2. Methods

2.1 Research Type

This journal uses a qualitative descriptive method. This method uses analysis from various sources, which are then reviewed in the journal (Lestari & Mita, 2016). The qualitative descriptive method utilizes primary or secondary data so that researchers can find knowledge and research at a specific time (Mukhtar, 2013). It makes research on the potential of carbon fiber as an insulation layer in anti-thermal sensor pdf clothes have in-depth results by describing the findings from the source of the literature study being examined.

2.2 Data Source

The data source used is Google Scholar, which was used in the last ten years of research from 2013 until 2023. In this study, Publish & Perish 8 software will be used to help get 200 journals on the topics of carbon fiber characteristics, composites, sensors, thermal, testing of carbon fiber resistance, testing of carbon fiber thermal conductivity, determination of layers of anti-thermal sensor pdl clothes, and the use of carbon fiber as an insulation layer in anti- thermal sensor PDL clothes which are then reviewed as many as 17 articles to be reviewed and summarized to see the potential of carbon fiber as an insulation layer of composite material in anti-thermal sensor PDL clothes. The 17 articles have been selected from 200 journals that can be collected by Publish and Perish 8 software consisting of national and international journals that Google Scholar has recorded.

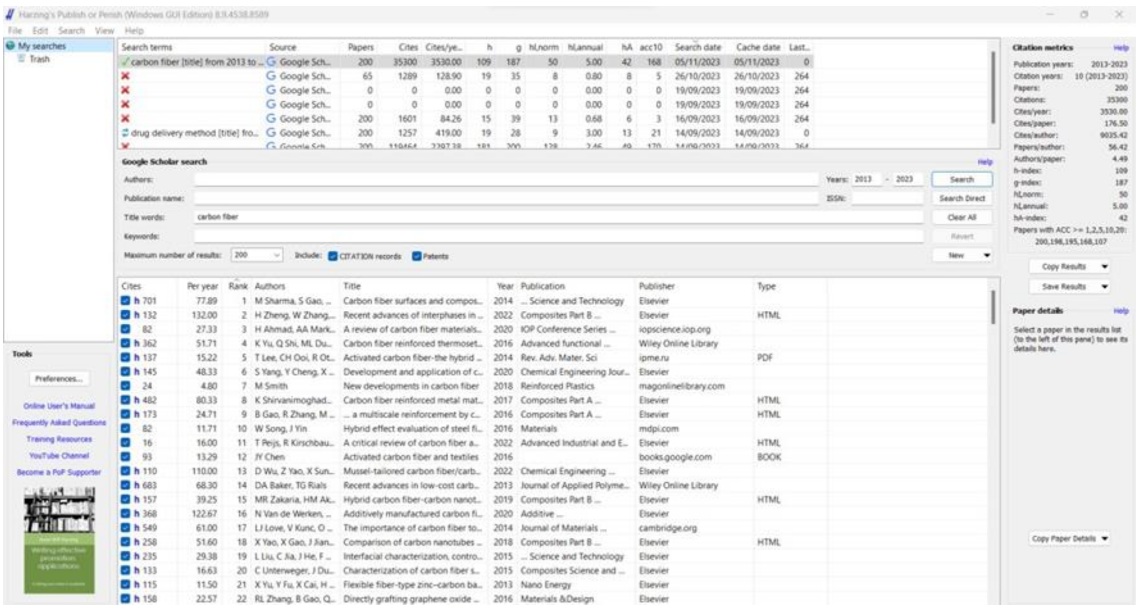

Figure 1. Display of the GUI for Publish & Perish 8 software, searching for journals with the topic of Carbon Fiber that were published in the range of years 2013-2023

3. Results and Discussions

3.1. Characteristics of Carbon Fiber

Carbon fiber contains 92% carbon (Huang, 2009). It has good tensile strength and low thermal conductivity. Carbon fiber is often used in woven textiles, prepreg, continuous fibers, and chopped strands with filament winding, compression molding, vacuum bagging, and injection molding processes (Huang, 2009). Its atomic fiber structure is similar to graphite, with a hexagonal shape (Huang, 2009).

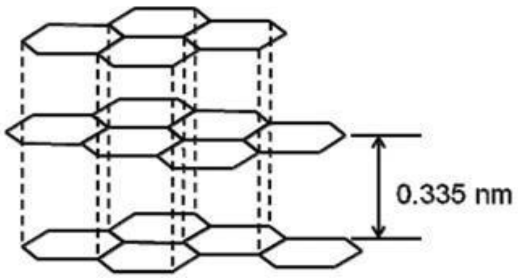

Figure 2. Hexagonal Structure of Carbon Fiber (Setiawan & Ardianto, 2018; Huang, 2009)

The hexagonal shape of the carbon fiber structure provides mechanical solid properties. Because of this property, carbon fiber is widely used in industries requiring strength. It is also used to manufacture carbon composites, which have high strength and are lightweight.

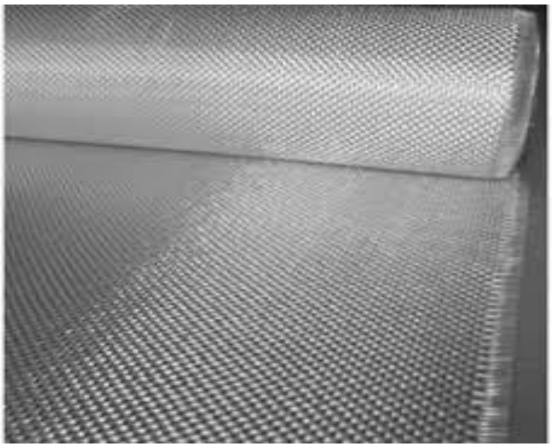

Figure 3. Carbon Fiber (M. I. Putra & G. Nugroho, 2021)

3.2. Composite

A composite is a combination of two or more materials that have different properties without dissolving them, so they can still be distinguished because there is still a clear structure. According to Setiawan and Ardianto (2018), a composite is a material consisting of a combination of two or more materials that are mechanically and characteristically very different from the original form. The advantage of composites compared to metals is that they have better mechanical properties and are not corrosive (Efri Mahmuda et al., 2013). Each property of the constituent material in the composite will affect the properties of the composite (Putra & Nugroho, 2021). Composites are very popular because of the flexibility of the combination between composites, which allows users to adjust the constituent material of the composite according to the desired function with a budget that suits the pocket. Composites have also developed as a substitute for metals in engineering, such as property, transportation, and architecture. The industry greatly feels its advantages because it is corrosion-resistant, lightweight, and cheap to manufacture (Lies Banowati et al., 2022).

Figure 4. Composite (Wiratama, 2017)

Composites are divided into two elements: filler matrices in the form of fibers and binder matrices (Huda, 2018). The selection of the type of fiber is crucial to determine the properties and strength of the composite. In the manufacture of anti-thermal sensor clothing, several layers are used in the PDL, including a carbon fiber layer. The resin transfer molding method is used on the carbon fiber layer, which aims to glue the fine fibers on the carbon fiber so they can be fully covered. Examples of composites are carbon fiber, fiberglass, and PVC. This study will also compare carbon fiber and glass fiber in terms of the strength of their attractiveness. In the presence of composites, the strength of the primary material can be more potent than that of the raw material.

3.3. Thermal Sensor

The development of automatic vision systems has grown rapidly in the last few decades (Gade & Moeslund, 2014). However, there is a reasonably complicated problem in capturing images or objects with minimal light conditions (Huda, 2018). Then, to overcome this, sensors such as 3D sensors (SwissRanger, 2012) and infrared sensors (Sony Electronics Inc., 2012) were developed to overcome. A thermal sensor is a component that can detect an object's thermal by looking at the temperature difference in the material. The infrared spectrum has a wavelength (3-14 μm). This infrared sensor can detect the thermal properties of a material. Infrared sensors can detect infrared radiation based on the temperature difference of the object. In its application, for example, in humans, the thermal camera will capture the difference in human body temperature compared to its environment so that humans can be detected well. This ability makes thermal cameras often used in surveillance and detection.

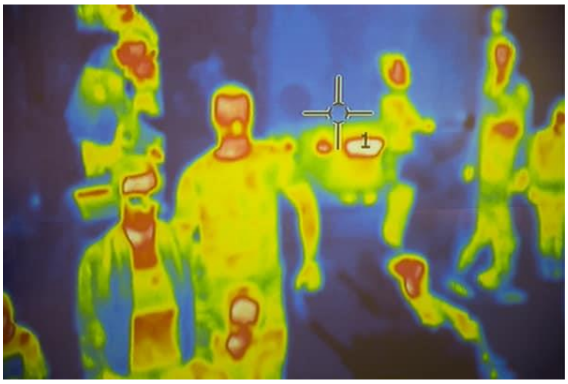

Figure 5. Application of Thermal Sensors on Humans (Gabay,2021)

3.4. Testing of Carbon Fiber Resistance

A series of tests must be conducted to understand a material's characteristics. It serves to identify the potential strength before being combined into a composite. The development of composite materials aims to improve the quality of mechanical, physical, and wear resistance properties (Ketut Suarsana et al., 2017). Knowing these potentials will impact the selection of materials. This selection is related to the product design stage. One of the tests conducted is resistance testing. Tensile testing tests the material's strength by applying a load in the opposite direction (Negoro et al., 2023). Tensile testing is formed with a modified size, where one of the ends has been connected to a load-measuring device (D.C. Giancoli, 1998).

Banowati conducted resistance testing, also known as tensile testing, in her experiment by preparing four layers of carbon fiber using ASTM D792 with dimensions according to the tool's standard. She then vacuum-bagged three test specimens. It is also done on fiberglass to compare the tensile strength of the two materials (Lies Banowati et al., 2022).

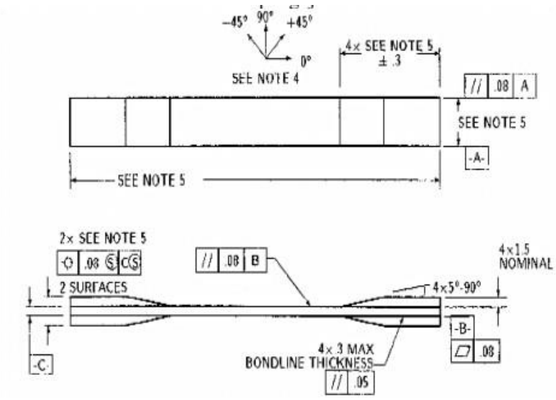

Figure 6. Standard Dimensions of Tensile Testing Layer with ASTM D792 Tool (Bonowati, 2022) The following table shows the results of Banorwati's experiment.

Table1. Maximum Load and Tensile Strength of Glass Fiber (Lies Banowati et al., 2022)

Test Specimen	Maximum Load(N)	Cross-Sectional Area (mm)	Elongation (mm^2)	Tensile Strength (MPa)
1	3.73	25.81	3.74	144.77
2	4.35	28.00	4.79	155.58
3	4.06	28.60	7.18	142.13

Table2. Maksimum Load dan Tensile Strenght Carbon Fiber (Lies Banowati et al., 2022)

Test Specimen	Maximum Load(N)	Cross-Sectional Area (mm)	Elongation (mm^2)	Tensile Strength (MPa)
1	4.78	25.01	4.78	453.65
2	4.95	24.62	4.95	479.20
3	5.43	26.18	5.43	425.98

From the data above, it can be known that the maximum tensile strength of glass fiber reaches 155.58 with an average of 147.49 MPa, and the maximum tensile strength of carbon fiber reaches 479.40 MPa with an average of 452.94 MPa. It already illustrates how strong carbon fiber is compared to E-glass material, with a carbon fiber percentage of 150% more potent than that of E-glass. Compared with the research conducted by (Fadhil et al., 2014), the results obtained got twice better value. In contrast, in the experiment, Sugeng only got a value of 200 Mpa for carbon fiber material.

3.5. Thermal Conductivity Testing

A heat transfer is an event of energy transfer that causes temperature differences. Heat transfer affects life on Earth (Alim et al., 2017). One of the heat transfers is conduction, where in conduction, there is a process of energy transfer from one place to another due to the rapid movement of electrons in the medium. Temperature differences between mediums cause heat transfer (J P Holman, 2010)

Thermal conductivity is the coefficient of a material that describes its heat resistance properties. Objects with higher thermal conductivity values also have higher heat conduction, so with thermal conductivity, materials can be classified as conductors or insulators (Prihartono & Irhamsyah,2022). The higher the thermal conductivity, the greater the ability to conduct heat. According to Fourier's law, the following is the equation of thermal conductivity of a material:

$$k = -\frac{qk}{A} \cdot \frac{dx}{dT} \quad \textbf{(1)}$$

with qk as conduction heat transfer rate (Watt), k as the thermal conductivity of materials (w/m^0c), A as cross-sectional area (m^2), and dT/dx as Gradient temperature x (c/m).

Carbon fiber material has low thermal conductivity. It was proven in an experiment conducted (Thermtest Instrument, 2023) using a round carbon fiber sample which was then tested with the MPV instrument to obtain its thermal conductivity value. The MPV is equipped with an MPTS sensor based on the anisotropic module that can read the thermal conductivity value of the provided sample. By using the sensor, the measurement value will directly enter the iTPS application to be input and corrected. The results can be seen as follows:

Table 3. Nilai Konduktivitas Thermal Air, Serat Karbon, Titanium, Cobalt, dan Aluminium.

Number	Material	Temperature (Celcius)	Thermal Conductivity Coefficient (W/mk)
1	Air	20	0.134
2	Carbon Fiber	23.3	1.13
3	Titanium	25	25.91
4	Cobalt	-	84.395
5	Aluminium	-	225.94

The data above show that carbon fiber's thermal conductivity is very low compared to metal materials. The thermal conductivity of carbon fiber is only 1.13 W/mk, while the thermal conductivity of aluminum reaches 255.94 W/mk.

3.6. Design of Anti-Thermal Sensor PDL Clothing Layers

The components used to manufacture anti-thermal sensor PDL clothing will be described at this stage. The components used are cloth made of 60% Polyester + 40% wool, Aluminum foil, carbon composite, and furing cloth. These materials are then arranged one by one like a stack consisting of layers with the following explanation:

3.6.1. Basic Material Layer

The basic material will be PDL clothes consisting of 60% polyester and 40% wool. These materials are used in the base material so that it is not too stiff after adding the next layer. This layer can absorb sweat and provide comfort for clothing users. An all-size size is used for the basic size of the material so that it can adjust for the user's body.

3.6.2. Reflective Layer

The first layer added is a valuable reflective layer for reflecting infrared sensors. Aluminum foil is chosen for this reflective layer, which has been proven to reflect infrared sensors. Aluminum foil can also be easily found in electrical equipment stores. Aluminum foil is the primary material to disguise body heat to be detected by thermal cameras. A thicker layer of aluminum foil is added to body hot spots, such as the neck, armpits, and navel.

3.6.3 Insulation Layer

This layer will use carbon fiber that has become a composite. The addition of materials such as resin to the carbon composite serves to unite the fibers in the carbon and make it stronger and lighter. This layer aims to maintain body temperature so that it is not too conspicuous. Carbon-based yarn is also used to connect the carbon layer to reduce heat further so that the clothes can be covered with heat perfectly.

3.6.4. Layer Cover

Layer Cover Furing is the final layer because it gives the product a sensation of softness and comfort. The layer cover also prevents the worn layers from coming out of the clothes. Using furring as a final layer makes the shirt's shape more solid and can still be worn comfortably. It is because furing has rigid properties and can form clothes according to the user's body.

3.7. Utilization of Carbon Fiber as an Insulation Layer in Anti-Thermal

Sensor PDL Clothing In anti-thermal sensor PDL clothing is composed of several layers. Carbon fiber that has become a composite with the addition of resin becomes an insulation layer. The insulation layer in the material serves as a structure used to reduce the flow of heat, sound, or electricity in the environment. Insulation in anti-thermal sensor PDL clothing makes more use of its function in preventing heat. The addition of an insulation layer to reduce heat has been successfully applied to lower the room temperature of a building by considering the method of installing insulation, the thickness of the insulation, and the orientation of the object that affects the room temperature(Marina, 2020) As in a computer that is given thermal paste to ensure efficient heat transfer on the device, the addition of a thermal insulation layer based on carbon fiber composite in anti-thermal pdl clothing makes it more efficient in isolating the heat temperature of the wearer so that it is increasingly difficult to be detected by a thermal camera.

4. Conclusions

From this research, it can be concluded that carbon fiber is a fiber that contains 92% carbon within it, with a hexagonal structure. In its application, carbon fiber can be used as one of the materials in composites by mixing it with resin. From a series of carbon fiber tests, it can be known that carbon fiber has tensile solid strength with 452.94 MPa and has low thermal conductivity with 1.13 W/mk. With these tests, carbon fiber can be used in one of the layers in the manufacture of anti-thermal sensor PDL clothing by adding resin, which aims to close the fibers tightly, thus producing a solid structure for producing perfect carbon composite quality with its low thermal conductivity, lightness, and strong strength as an insulation layer in anti-thermal sensor pdl clothing. This research is expected to be the initial research in determining the components to be further applied in the design of anti-thermal sensor pdl clothing.

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