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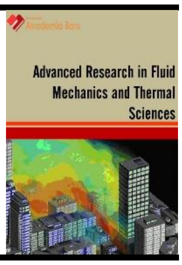

Smart Materials Technologies and Applications in Mechanical Engineering and Renewable Energies

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ABSTRACT

Smart materials have a unique characteristic, these characteristics are very important which made interesting to study their properties and applications in the fields of engineering. In this study, an extensive review of the literature and research published has been carried out because the smart materials included qualitative developments in applied research as well as theoretical research. Smart materials technology has been applied in many fields such as; construction engineering, textile industry, electronics industry and biomedical engineering. However, it has been noted that some disciplines have not invested that unique characteristics and functions offered by smart materials in promotion of their industries or have been used sparingly. Renewable energy is energy comes from wind, sun, geothermal and other sources that would never run out. This study carries out comparative conventional and smart materials for improving the solar energy and photovoltaic cells efficiency by changing the optical properties manner for smart material technologies, to identify the key opportunities and to recommend a strategy for future used in wind turbine technology and actuators. As well as determined the potential role of smart materials by investigating and determined the potential role of smart materials by investigating their properties by compression with the conventional types are essential for employing it to enhance the saving energy in different climates..

Keywords:
Smart materials; renewable energy; wind turbine; piezoelectric

1. Introduction

Smart materials or intelligent materials have characteristics to be able to return to their original shape after deformations. There are many types from these materials, one of the most commonly is shape memory alloy (SMA), and it's used with a wide variety of applications such as Aerospace, Mass transit, Marine, Automotive, Computers and other electronic devices, Consumer goods applications, Civil engineering, Medical equipment applications [1]. The meaning of smart materials is smart and materials. Smart is Significant(S), Measurable (M), Appropriate (A), (Result Oriented) (R), and (Time oriented) (T) [2].

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Smart Materials is Significant, Measurable, Appropriate, (Result Oriented), (Time oriented) plus Materials. The renewable energy sector is very wide, there are five main types of sustainable energy as follows wind turbine, solar cell, Biomass, Geothermal Energy, Hydroelectric Power. This paper focuses on the main two types wind turbine technology and actuator fields.

Actuators can be classified into two types: Conventional and Unconventional actuators. The first type (conventional actuators) commonly used as a main components for mechatronic system, and the other type (Unconventional actuators) more sophisticated than one type (See Figure 1)[3].

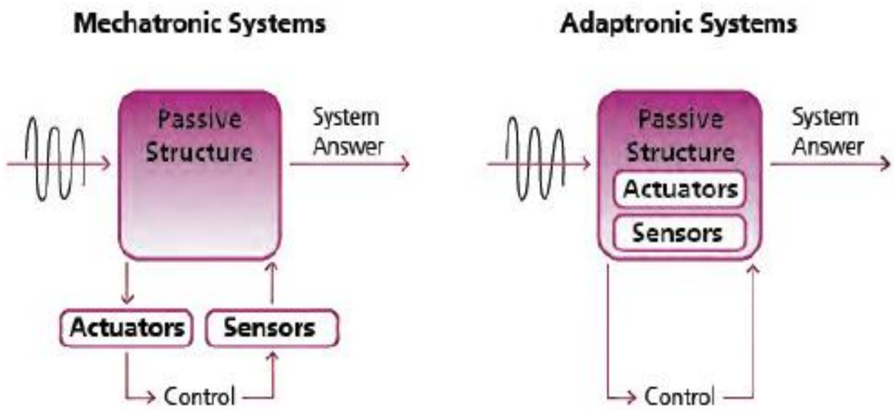

Fig. 1. Characteristics of mechatronic and adaptronic systems

2. Smart Materials Types

They are also called functional materials, which have the self-capability to respond to external stimuli which change their functional status and return to their normal state when that external stimulus is eliminated. Materials can be considered as smart materials when the output is different in one or more from the stimulus input to it. Or give one specific response as a result of a set of external stimuli. Examples of smart materials Zinc oxide varistors (ZNO) [4].There are many types of smart materials, the most important them popular will be illustrated in the subsections.

2.1 Piezoelectric Materials

One of the most important uses of piezoelectric is in actuators. Where his work depends on the electrical input and turning it into a mechanical work. The entry of the electrical charge to the piezoelectric will make its shape quickly change a result of the magnetic field, one of the most important uses of this material is in the means of safety in the automotive industry (air bags).

There are many uses of this material, such as detection of vibrations in buildings, microscopy field, fiber optics and photonics, and can be used in sensors that generate electric field due to mechanical stimuli [5]. Previous studies focused on the applications of smart materials in many branches such as fracture assessment, raising the efficiency, fashion, new biomimic, but we noticed that the used of smart materials in renewable energy was scarce.

2.2 Shape Memory Alloy (SMA)

This material has many applications in various fields, which is used in the manufacture of surgical instruments in the medical field as well as in orthodontic because of their direct interaction and change its shape due to effect of the body temperature as well as uses in the other medical applications. SMA applications in domestic field, it has many characteristics such as detected the smoking leakage, alarms, security doors and more other. SMA applications in manufacturing field, It is used in the manufacture of very fine wire, where it can be used in textile industries in the knitting of clothing, where these clothes gain the ability to shrink and the benefits depending on the change in body temperature and its humidity. Thus its help to warm or cool the human body based on the sensitivity to moisture and temperature and hence help to change his condition. SMA applications in Aerospace field.

2.3 Chromic Materials

Under this subtitle falls a group of materials, where the response of these materials lies in changing their color relative to the influence of the outer medium. Include the following materials: Thermochromic, Photochromic, Piezochromic, electrochromic, solvatechromic and carsolchromic [6].

2.4 Magnetostrictive Materials

Magnetostriction can describe the change in the dimensions of the material starting from magnetization, magnetostriction can show a rapid response to magnetic fields, and this response is due to the change in electric current, which can change at the same speed of the electric field, the example of these materials is (Terfenol-D). This material can be used with extremely low resistance and under steady conditions and low frequency. It should be noted that due to the autonomous nature of these materials can provide high resistance in high frequencies (kHz range) [7].

3. Smart Materials Classification

Smart materials have many types and classifications so that can be arranged in Table 1 to illustrate more details for input and output for each one [2].

4. Related Study

In this section will be focus on the relations between renewable energy and smart materials as following.

4.1 Wind Turbine Technology Field

The manufacture of large wind turbines and the increasing sizes and lengths of their blades generate high vibration, which negatively affects the efficiency of the air turbine. As a result, the smart material technology was used in the manufacture of air turbine blades by using a wire of piezoelectric material embedded in the wind turbine blade and smart sandwich structure of wind turbine blades [8].On the other hand, the aerodynamic control methods used in the wind turbine smart structures were purely a study prepared for this purpose as well as the feasibility of future implementation to demonstrate the challenges facing wind turbines and associated standards. Feasibility study prepared based on the approach of calculations and experiences including DUWIND's recent achievement of applying feedback aerodynamic control on a wind tunnel model of a scaled blade for load reduction [9]. By using model OKID/ERA (Observer/Kalman Filter Identification (OKID) method together with Eigen system Realization Algorithm (ERA). to input the vibration data

Table1
Smart Materials Classifications

Smart Material Definition	Types	Name	Input	Output	Energy in Building	
The term smart materials mean any material characterized by its ability to resist and the interaction of the environment without damaging it foe more comfort and efficient.	Change Properties	Thermochromics	Thermal energy	Color	HVAC (thermal comfort) Electronic, Light refrigeration	67%
		Mechanic chromic	Stresses and /or deformations			
		Chemo Chromic	Chemical environments			
		Electro Chromic	Voltage			
		Thermo tropic	Thermal energy	Conductivity, transmissivity, volumetric expansion, and solubility.	HVAC (thermal comfort) Electronic, Light refrigeration	67%
		Photo tropic	Radiation(light)			
		Electro tropic	electricity			
		Adhesion changing materials	light	Attraction forces of adsorption or absorption of atoms or molecules	HVAC (thermal comfort) Electronic, Light refrigeration	67%
			Electrical field			
		Magnetorheological	Magnetic field	Stiffness/ Viscosity change	HVAC (thermal comfort) Electronic, refrigeration	55%
		Electrorheological	Electrical field	Stiffness/ Viscosity change		
		Liquid crystal	Electrical field	Color	HVAC (thermal comfort) Electronic, Light refrigeration	67%
		Shape memory	Thermal energy	Microstructure through a crystalline phase change	HVAC (adaptive ventilation) Electronic, Light refrigeration	
			Electrical field			67%
			Magnetic field			
	Transforms energy	Photo luminescent	Radiation	Light	Light Electronic HVAC refrigeration	67%
		Electro luminescent	Electrical field			
		Chemo luminescent	Chemical environments			
		Thermoluminescent	Thermal energy			
		Light-emitting diodes	Electrical field			
		Photovoltaic	Radiation	electricity	Water heating, electric refrigeration, cooking, HVAC Light	100%
		Electro astrictive	Electrical field	deformation	HVAC (adaptive ventilation) light electronic refrigeration	67%
		Magneto astrictive	Magnetic field			
		Piezoelectric	deformation	electricity	Water heating, electric refrigeration, cooking, light HVAC Light	100%
		Pyroelectric	Thermal energy			
		Thermoelectrics	Thermal energy			

obtained from the beam, satisfactory results were achieved to mitigate the vibration generated in the beam by Using a simple one-dimensional structure of sensors and piezoelectric actuators [10]. The wind turbine blades are one of the most important parts of it. It is exposed to direct damage due to the changing environmental conditions of high and low temperature and high wind speed, and may be caused by the collision of some large species of migratory birds.

On the other hand, a turbine blades must be hardened enough to survive for a long period because of difficulty to maintain. For these reasons, composite materials have been used to overcome some of them, especially in horizontal wind turbines (HAWTs). But other unresolved problems, such as the long-term deterioration of material property, distort the localized shape of the wind turbine blades and other problems. For this reason, the shape memory alloy (SMA), which is Nitinol (NiTi) has been embedded in the blade to alleviate the load [11].

Power harvesting technology provides a solution for the operation of remote sensing devices where there is an urgent need to develop remote sensing systems on the blades of wind turbines, especially when increasing the size and numbers of wind turbines as is the case in wind farms. Due to the difficulty of installing power supplies or embedded them with sensors on wind turbine blades this technique has been used, it is tested experimentally on Whisper 500 residential-scale wind turbine has been performed in which both solar panels and piezoelectric devices have been installed on the turbine blades to provide power to two different wireless sensing systems. Solar panels and piezoelectric devices are installed on the wind turbine blades. In this case, piezoelectric harvesting can be used to supplement the solar harvesting output via a multi-source solution [12].

4.2 Actuator Field

Piezoelectric actuators have a wide range of configuration that is depend on the force requirement as well as on the displacement as shown in Figure 2. There are many types of actuators, in this study the author focus on two types of actuators multi-layer stack actuators and second one bending mode actuators. The zero-load displacement and force for multi-layer stake at frequencies substantially may be expressed by the relations [13]. In the following Figure 2 shows the force and displacement ranges for piezoelectric actuators.

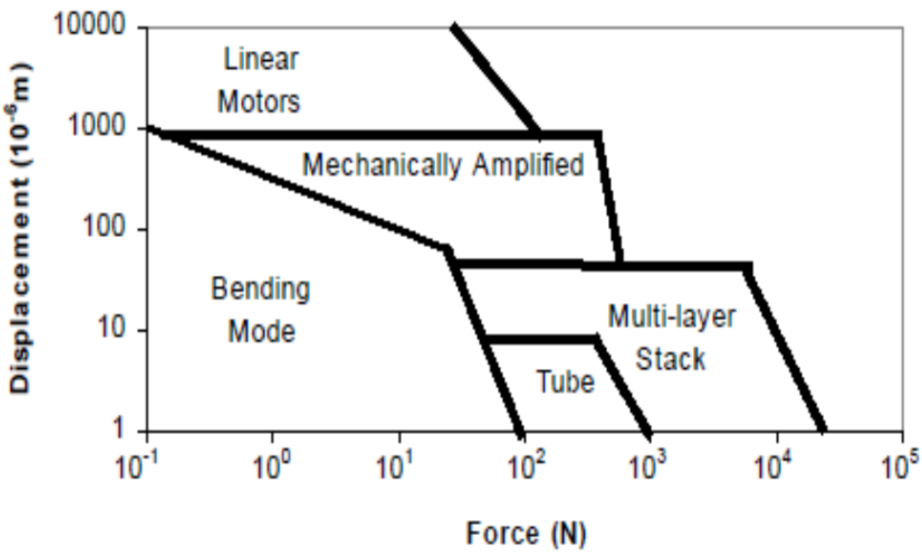

Fig. 2. Ranges of force and displacement for the piezoelectric actuators [13]

$$\Delta L = Nd_{33}V \tag{1}$$

$$F = Nd_{33}VY\left(\frac{A}{h}\right) \tag{2}$$

In which
N : Number of layers in a stack
d33 : Constant of the piezoelectric charge
V : Voltage
Y : Average Young's Modulus of a stack
A : Area of the stack
H : Height of the stack

The second type is bending actuators it's usually consist of two plates are bonded together, one plate biased to expand while the other biased to contract. For a cantilever configuration, if the one end of the plate is fixed whereas other is free to deflect, in this case can be find the zero-load displacement from the following equation.

$$\delta = \left(\frac{3}{2}\right) d_{31} \frac{L^2}{t} E \tag{3}$$

and blocked force from the following equation.

$$F = \left(\frac{3}{8}\right) d_{31} Y \frac{wt^2}{L} E \tag{4}$$

In which
δ : Cantilever deflection
d31 : The constant of piezoelectric
L : Length of cantilever
w : Width of Cantilever
t : Totally ceramic thickness
Y: Structure's effective Young's modulus
E: Electrical Field
E for series-connected plates is (V/t) and for parallel is (2V/t)

Active vibration control (AVC) is the technique has been developed by using piezoelectric stack and implemented on areal time structure closed-loop control system and hardware carried out to evaluate the AVC system performance. The amplitude control in four modes have been controlled by more than 60% [14].

Terfenol-D is the scientific name of one of the magnetostrictive materials in the field of the smart materials, which is alloy of iron, terbium and dysprosiumTb0.3Dy0.7Fe1. It is very important to find a description of the type of fracture that occurs in it, because it is used in the field of mechanical loads, magnetostrictive and industrial applications. A study of three types of mechanical changes (single-edge pre-cracked Terfenol-D specimens) was carried out. The failure of different loads under the influence of the magnetic field was measured. As the giant magnetostrictive materials are very fragile, the energy density approach, finite element methods to detect themselves, magnetic field correction and the effect of the load rate on the fracture resistance, and to propose the relationship between the radius of the control unit and the loading rate[15].The integration of smart materials with each other gives the specification very high and more advanced. Three categories of smart materials (piezo-ceramics, shape memory alloy and dielectric elastomers) have been combined to give smart tools for smart designs (more complex control systems than others) such as manufacturing of hand prosthesis [3]. Actuators should be developed from smart materials, like that Shape Memory Alloy (SMA) and Electro Active Polymers, are very much suitable for smart flexible lifesaving robots due to the development of large. Strain and actuation force. Nitinol is an excellent material for medical applications [1]. Developed a new-bio mimic pump used to achieve miniaturization in its size and volume. This actuation technique is proposed to pumps the fluid based on the flow principles and pressure difference that is coming from varying of the cross-sectional of flexible tube. SMA have been used as actuators to keeping the size and weight of the device. The main advantages of this technique, no need external pressure device and the flow can made bidirectional [16].

5. Analysis and Results

From the sought the literature review, that can see clearly the SMAT materials technologies are very useful and important to improve the product specifications and maintain the product working under various environmental and hard conditions. From this context, the author also sees there are a very scarce new technique in the SMART materials in renewable energy field for example in storage field and wind turbine, on the other hand the authors find the application of smart materials in mechanical field also scars but it used very broadly in other fields such textile industry, medical, dentist industry etc. The percentage of the goal fields are represented in the Table 2.

Table 2
The percentage of SMART materials technologies used through the chose period

Year	SMART Materials Technologies	Percentage
2017	Fracture assessment	0.076
2016	Design, Raising the Efficiency	0.153
2015	Fashion, smart designs	0.153
2014	Magnetomechanical Modeling	0.076
2013	Wind turbine monitoring	0.076
2012	New biomimic, flexible structure, wind turbine blade, vehicle structure	0.307
2011	-	0
2010	Wind turbine blades	0.076
2009	-	0
2008	-	0
2007	Rotor control	0.076

To capture the functional advantages regarding to solar energy applications; should be comparing among conventional materials, advanced materials and smart materials. Conventional glazing only offers fixed transmittance and control of energy passing through it. Given the wide range of illumination conditions and glare, a dynamic glazing with adjustable transmittance offers the best solution. Photovoltaics can be integrated as power sources for smart windows. In this way a switchable window could be a completely stand-alone smart system. A new range of large-area flat panel display including light-weight and flexible displays are being developed.

Polymer gels are unique smart materials in the sense that they can respond to many different stimuli. Poly (N-is opropylacrylamide) (abbreviated as PNIPA) and another hydrogels of polymer can be used to create an intelligent glass halogen that can reduce the amount of heat and light transmitted. This halogen is used by placing it between two transparent glasses, it works as a filter for the Fallen light. Where the degree of transparency changes directly with the temperature falling on it, this adjustment can be made from the protection glasses for the eye from harmful rays.

When sunlight reaches the glazing window in the ideal windows, it will be moved or reflected or may be absorbed by the glass depending on the optical properties of the glass. It must be noted that the sun's rays are composed of two radiations, one visible and the other invisible, as well as consists of several spectra where solar energy is distributed between these spectra and unevenly.

Firstly, Conventional Type: When conventional glass absorbs solar energy, it will increase its temperature and this leads to heat exchange with the environment. One of the characteristics of glass is that it allows the penetration of heat into the buildings and this affects negatively or positively on the internal temperature of the building, where it is possible to avoid this heat exchange using low emission coating (low-E). An important characteristic of this type is that it has a high reflection in the infrared (wave-length 3–50 µm) area and very high light transmittance where it has very low emission. Heat loss can be minimized by low coatings, which in turn reflect solar heat, which is in the form of long-directed infrared radiation, which returns to inside the building and is kept inside. This is often suitable for cold climates where there is an urgent need to raise the temperature of the building. Secondly Advanced Type: The properties of glass materials can be controlled for the purpose of obtaining the desired requirements, in addition there are materials with a unique interesting properties including smart glasses. Thirdly Smart Type: It should be noted that there are two types of smart glazing, passive and active. External stimulation has the greatest effect in influencing such a type, there are several types of stimulation such as heat, light, electric current or voltage and thus will effect on the optical properties of these materials [17].

6. Future Research and Conclusions

SMART materials are very important for many sectors and fields in the world of technology, by analysis the last studies noticed that the methodologies of SMART materials are an active and effective role in improving product specifications and features by resist the hard and fluctuate conditions of the weather and environment too, also it can be resist the suddenly changes in the working places because their properties and specifications. Along the period which has been selected (2007-2017).

This research showed the vital role of smart materials applications in many fields such as textile industry, renewable engineering, biomedical engineering and medical engineering but in fact there is very scarce application in wind turbine field and mechanical branch a shown in Figure 3. So this study strongly recommends to conduct more and more research in two fields mentioned above. On the other hand, the author recommends should be finding new ways to integrate SMART materials technology with other engineering branches especially wind turbine and mechanical engineering to get maximum advantages from it and utilization from its features.

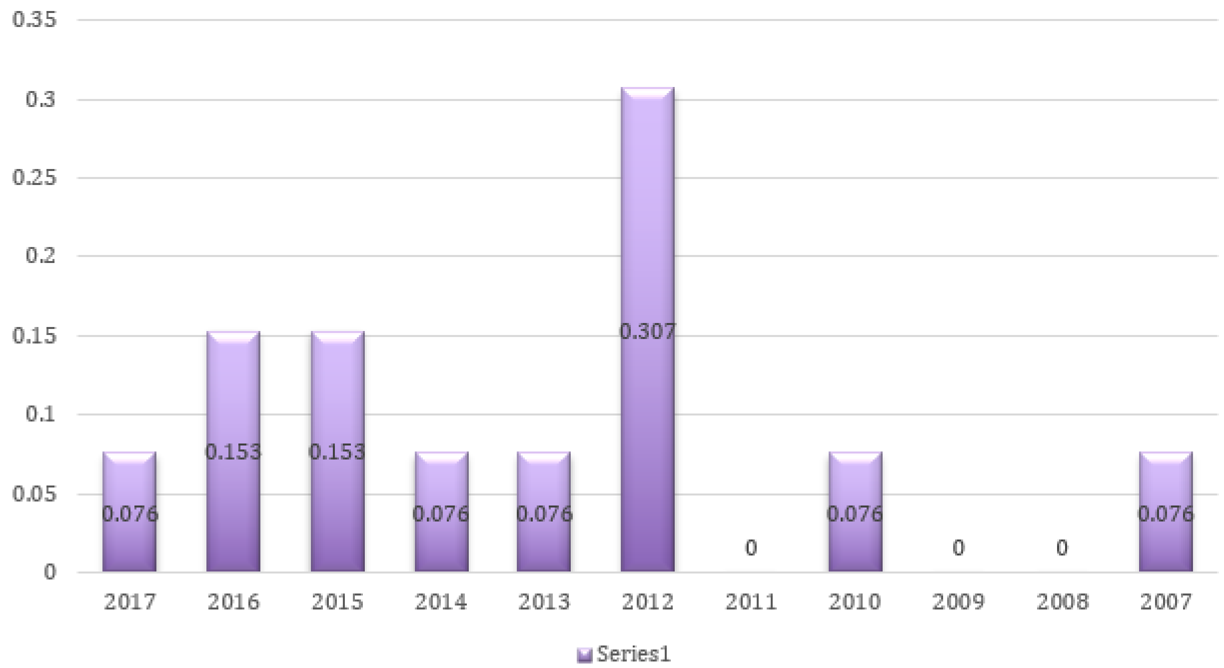

Fig. 3. The percentage of SMART materials technologies used through the chose period

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