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Smart materials: a review of capabilities and applications

Prince Kumar Sharma[1], Tejendra Singh[2],

[1]Student, Mechanical Department, JECRC Foundation, Jaipur
Prince.sh29@gmail.com
[2]Assistant Professor, Mechanical Department, JECRC Foundation, Jaipur
Tejendrasingh.me@jecrc.ac.in

Abstract: The demands from aerospace, defense, automotive and industrial branches on more advanced and innovative materials has led to the development of new smart materials. Smart materials have some special physical properties that changes with the response and with of input such as stress, temperature electric and magnetic field.Their smartness can be characterized by its self-adaptability, self-sensing and self-healing in response to any external stimuli. Certain properties are far beyond to the conventional actuation system. The advantages of these material possess to use in special areas such as vibration control, high dynamic system for instance. These material includes the piezoelectric materials, dielectric elastomers, magnetorheological fluids, electroactive polymers and some other materials. This paper shows the capabilities and application of the smart materials.

Keywords:piezoelectric, self-healing, shape changing, electrostrictive, photomechanical, smart gel.

INTRODUCTION: -

Technology is becoming increasingly protruding in our daily lives, in many ways affecting the demands of modern living. Smart materials have been promoted widely as a feature of technology that will support all manner of novel products with unique capabilities. Smart materials are difficult to define in clear terms but are often thought of as materials which respond to some outer physical or chemical stimulus in a controlled manner to conduct a predetermined task. smart material technology is self-healing (SH) materials, smart sensing materials and sensing skins and shape-changing materials. The terms "smart" and "intelligent" are used interchangeably for these materials. These materials have the qualitiesto fit in the surrounding and in order to response the physical changes, they can modify their form, themdimensions or even their mechanical properties. smart systems can offer a simplified approach to the control of various material and system characteristics such as noise, shape and vibration, etc., depending on the smart materials used. Sensor and actuator configurations will play an important role in smart structures. The smart materials didn’t forget to add the textile industry. The textile also using the smart materials for the purpose of better tomorrow. In fact, protection and military clothing has been the main growth sector for smart textiles between 2010 and 2014. It also featured in an astronaut space suit that could inflate/deflate, light up, and heat/cool itself. Traditional textile coatings are commonly passive protections or decorations for the substrate for which they are designed and are applied by providing a barrier on the surface. Furthermore, an active coating is to be considered smart. It is able to sense a change in conditions and respond to it in a predictable and conspicuous manner. Generally speaking, an active coating gives textiles intelligent properties more than just functional performance. The application of the smart materials includes the aerospace sector, construction sector, textile sector, in temperature sensitive devices, civil engineering and many more.

SMART MATERIALS: -

Smart materials are designed materials that have more than one properties that can be significantly changed in a controlled fashion by external stimuli, such as stress, temperature, moisture, pH, electric or magnetic fields.
Different types of smart materials are being used now a day those hold all the physical and chemical abilities and changes their properties according to the environment and need at that situation.

Self-healing materials: -
The self-healing materials can be thought as the materials which respond to the damage by automatically applying some repairing mechanism. Several SH mechanismshave been proposed or demonstrated. The first self-healing materials are polymers (plastics made from long, repeating molecules) with a kind of embedded internal adhesive.

Embedded healing agents: - The most best-known self-healing materials have built-in microcapsules (tiny embedded pockets) filled with a glue-like chemical that can repair damage. If the material cracks inside, the capsules break open, the repair material "wicks" out, and the crack seals up. The simplest approach is for the capsules to release an adhesive that simply fills the crack and binds the material together. In a slightly different approach, the main body of the material is a solid polymer, while the capsules contain a liquid monomer. A powered material is needed as the catalyst so that a reaction can take place. The main drawback with the encapsulation method is that the capsules have to be very small indeed or they weaken the material in which they're embedded

Microvascular materials

Microvascular materials contain a vascular network for the storage and transport of functional fluids within a host material. When a failure occurs, the pressure is released at one end of the tube causing the healing agent to pump in to the place where it's needed.

Shape-memory materials

Shape memory materials (SMMs) are able to recover the form of original shape at the presence of the right stimulus. Shape memory materials (SMMs) are featured by the ability to recover their original shape from a significant and seemingly plastic deformation when a particular stimulus is applied.

Reversible polymers

Self-healing polymers are based on stimuli responsive, dynamically bonding functional groups that allow the material to undergo reversible deboning in response to a pre-selected trigger such as heat, light or ph. Self-healing polymers are based on stimuli responsive, dynamically bonding functional groups that allow the material to undergo reversible deboning in response to a pre-selected trigger such as heat, light or ph. The first self-healing materials we're likely to see in mass production will be paints andcoatings that can better survive the weather and other kinds of surface wear-and-tear.

Shape-changing materials

Materials and structures which can experience a huge shape change have highlighted firmly in sci-fi yet are presently the point of genuine examination, with applications foreseen in the aviation, biomedical and different enterprises. Shape-changing brilliant materials incorporate materials and items that can reversibly change their shape or potentially measurements in light of at least one upgrades through outside impacts, the impact of light, temperature, weight, an electric or attractive field, or a compound boost. there are materials and items that can change their shape without changing their measurements, and different materials and items that hold their shape yet change their measurements

Conceivable applications for these shape changers incorporate actuators, tranquilize conveyance frameworks and self-gathering gadgets. The savvy materials could likewise be utilized to unfurl sun oriented boards on a satellite without the requirement for battery-controlled mechanical gadgets. Avoiding the additional progression of mediator gear can bring flexibility and lessen expenses of such procedures.

Piezoelectric materials

These are also the one of the most common type of smart materials. Piezoelectric materials have tendency to produce voltage when stress is applied and same process can happen in a reversible manner. the piezoelectric effect was first reported by Pierre and Jacques Curie in 1880. The piezoelectric effect is caused by an asymmetry in the unit cell and the resulting relationship between mechanical distortion and electric dipole separation.
PZT materials are available in a wide variety of compositions that are optimized for different applications. Lead titanate compositions have been developed to achieve very high anisotropy in piezoelectric properties. PMN-PT is a relaxer perovskite that exhibits low hysteresis and high strain near a diffuse ferroelectric to Para electric transition. Piezoelectric materials have Very high frequency response and are Self-generating, so no need of external source. But It is not suitable for measurement in static condition. Since the device operates with the small electric charge, they need high impedance cable for electrical interface.

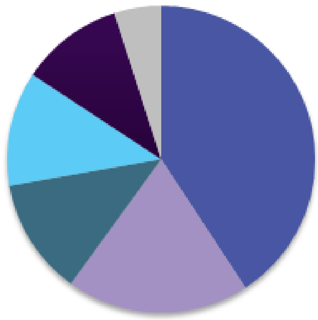

Figure-1 piezoelectric material consumption

Electrostrictive materials

These material as the same properties as piezoelectric material, but the mechanical change is proportional to the square of the electric field. the electrostrictive actuators use a lead-magnesium-niobate (PMN) crystal stack while piezoelectric actuators uselead-zirconate-titanate (PZT) based ceramics.Two types of electrostrictive materials will be described: (1) relaxor ferroelectrics with diffuse phase transitions, and (2) ant ferroelectric ceramics with a field-induced ferroelectric phase. uses for electrostrictive transducers include adaptive optic systems, micro positioners, and smart transducers in which the size of the piezoelectric coefficient can be adjusted with a dc bias field.These materials are mostly used in projectors for submarines and surface vessel.

Smart gels

These are the gels that can shrink or swell by several order of magnitude. Some of these can also be programmed to absorb

release fluids in response to a chemical or physical Stimulus.
SMART GEL reacts with ALL TYPES of contamination of organics (food residues such as proteins, fats, sugars, flavorings, phenolic compounds, oxalates and microorganisms); whereas most quick-tests are limited to the specific detection of glucose, lactose, or ATP proteins of microorganisms. Smart gels contain fluids (usually water) in a matrix of large, complex polymers. These polymers are special in that they respond to stimuli in an advanced way.

Photomechanical materials

The photomechanical materials are basically photostrictive materials which undergo a very small deformation under the effect of light (photons) and used to make a walking device that is powered by modulated light. A reversible shape change can be created by photo isomerization of hematic liquid crystal elastomers (LCEs). Also, a highly doped LCE has been observed to swim on the surface of water in response to light.

Nano textiles: -

The development of smart Nano textiles has the potential to revolutionize the functionality of our clothing and the fabrics in our surroundings. Nanostructured composite fibers are one area where nanotechnology is already having a huge impact within the textile industry. The sports industry has driven much research within the textile industry to help improve athletic performance, personal comfort, and protection from the elements. For the military The Smart Shirt by Sensate was initially developed by the Georgia Tech Research Corporation and for military applications.

Applications: -

Smart materials find a wide range of applications due to their varied response to external stimuli. The different areas of application can be in our day to day life, aerospace, civil engineering applications and mechatronics to name a few. The scope of application of smart material includes solving engineering problems with unfeasible efficiency and provides an opportunity for creation of new products that generate revenue.

In the Field of Defense and Space

Smart materials have developed techniques to control vibrations and change shape in helicopter rotor blades. Shape-memory-alloy devices are also being developed that are capable of achieving accelerated breakup of vortex waves of submarines and similarly different adaptive control surfaces are developed for airplane wings.

In Nuclear Industries

Smart material technology offers new opportunities in nuclear industrial sector for safety enhancement, personal exposure reduction, life-cycle cost reduction and performance improvement. However, the radiation environments connected with nuclear operations represent a unique challenge to the testing, qualification and use of smart materials. However, the use of smart materials in nuclear facilities requires a great knowledge about the materials respond to irradiation and how this response is influenced by the radiation dose.

Biomedical Applications

Certain materials like poly-electrolyte gels are being experimented for artificial-muscle applications, where a polymer matrix swollen with a solvent that can expand or contract when exposed to an electric field or other stimulation. In addition, due to biodegradability of these materials, it may make it useful as a drug-delivery system.

Carbon fiber reinforced concrete

Its ability to conduct electricity and most importantly, capacity to change its conductivity with mechanical stress makes a promising material for smart structures. It is evolved as a part of DRC technology (Densified Reinforced Composites).Thehigh density coupled with a choice of fibers ranging from stainless steel to chopped carbon and Kevlar,

Reducing Waste

Electronic waste is fastest growing waste in the world and becoming a great problem for the human world. During disposal and processing of such wastes, hazardous and recyclable materials should be removed first. Recently fasteners constructed from shape memory materials are used that can self release on heating. Once the fasteners have been released, components can be separated simply by shaking the product. By using fasteners that react to different temperatures, products could be disassembled hierarchically so that materials can be sorted automatically.

Health

Biosensors made from smart materials can be used to monitor blood sugar levels in diabetics and communicate with a pump that administers insulin as required. Now-a-days different companies are developing smart orthopedic implants such as fracture plates that can sense whether bones are healing and communicate data to the surgeon. Small scale clinical trials of such implants have been successful and they could be available within the next five years. Other possible devices include replacement joints that communicate when they become loose or if there is an infection.

Military Applications

A number of distinctly military applications for the use of smart materials and smart systems can be delineated, among them: - In battle soldiers could wear a T-shirt made of special tactile material that can detect a variety of signals from the human body, such as detection of hits by bullets. Ground, marine or space smart vehicles will be a feature of future battles. The identification and detection of such targets, as well as the subsequent decision to take action with or without operator intervention, is another potential application of smart systems.

The future for the smart materials

The smart materials are being used now a day for the different purpose and the researched are also going on for further improvement in smart materials. Worldwide, considerable effort is being deployed to develop smart materials and structures. The technological benefits of such systems have begun to be identified and, demonstrators are under construction for a wide range of applications from space and aerospace, to civil engineering and domestic products. he development of true smart materials at the atomic scale is still some way off, although the enabling technologies are under development. Worldwide, considerable effort is being deployed to develop smart materials and structures and the technological benefits of such systems have begun to be identified and, demonstrators are under construction for a wide range of applications from space and aerospace, to civil engineering and domestic products these systems are recognized as a strategic technology for the future,

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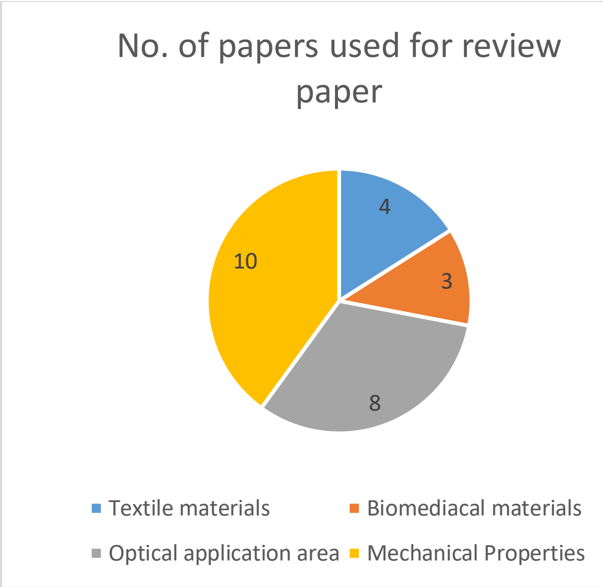

Figure: - 2 chart shows the no of paper included

Conclusion: -

The technology of smart materials interdisciplinary field. Starting with the basic sciences such as physics, chemistry, mechanics, computing and electronics it also covers the applied sciences and engineering such as aeronautics and mechanical engineering. This shows a fast growing technology and better future. Smart materials have all the possible potentials to fulfill maximum requirements of the changing trend which ultimately resulted in use of Smart materials in almost all the sectors of Engineering, Medical field and textile industry. There is numerous type of smart materials but still lots of research and work is going to be done in the field of these materials to make it familiar in all the field.

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