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Smart Materials Research for Satellite Applications

J.P.Angelena *, A.Stanley Raj** , S. Jerome Das***

*Assistant Professor, Department of Physics, Loyola College, Nungambakkam, Chennai 600 034, India

Email id: *angelenaj_81@yahoo.com

** Assistant Professor, Department of Physics, Loyola College, Nungambakkam, Chennai 600 034, India

**stanleyraj_84@yahoo.co.in

*** Associate Professor, Department of Physics, Loyola College, Nungambakkam, Chennai 600 034, India

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Abstract:

Conventional materials used in past are outdated because of the nature of materials which are not adaptive and lack of technological advancements. Advanced smart engineering and technology have highly integrated components with exemplary nature of adaptive and customizable characteristics. Smart materials and structures can imitate the behavior of natural systems and the adaptive nature and properties will be helpful in building structures and eco friendly materials. Especially in the arena of conserving the nature, our generation should rely on smart materials which are capable of bringing the non hazardous materials to prevail on earth. The major groups of smart materials are classified as shape memory alloys, magnetostrictive materials, piezoelectric and electro magneto rheological fluids. It can couple with other materials to make remarkable properties to apply in bioengineering, piezoceramics, dielectric elastomers, sensors, robotics, aerospace engineering, medical field and several industrial applications. This review work brings out the advancements in smart materials research and its applications in several fields of science and engineering. Since smart materials are light weight, compatible, non corrosion and having long life span, it will turn out to be the active materials in shaping the future world more enthralling and eco friendly.

Keywords — Smart Materials, Satellite applications, Shape memory alloys, Space engineering

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I. INTRODUCTION

According to the recent research, smart materials replaced most of the conventional materials because of the nature of functional properties. Giant electrorheological fluids producing 50-60% higher yield than conventional ER [1, 2]. Materials like carbon nano fibers, graphite nano tubes, grapheme rods, fumed oxide and silica are widely employed [3]. Magneto rheological elastomers exhibit viscoelastic properties [4, 5] and are capable of sensing resistance based on deformation strain. Studies revealed that the controllable electric resistance can be achieved by adjusting normal force and magnetic field. Researchers examined cellulose, a renewable polymer that can be applied in sensors and actuators. It has the advantages of biocompatibility, biodegradability, environmental friendly and low cost. Ionic polymer metal composite (IPMMC) shows large strain with low drive voltage. This article deals with the smart materials applications in space science and technology. Especially in satellite technology, smart materials ensures improved efficiency and successful performance based on their properties are explained.

II. II. CLASSIFICATION OF SMART MATERIALS:

PIEZOCERAMICS:

Piezoceramics works on the principle of piezoelectric effect. According to inverse piezoelectric effect, electric field parallel to the direction of polarization stimulates on expansion of ceramics [6]. Multilayer ceramics consists of layers thinner than 100μm can generate high electric fields and has potential application in actuators [7]. It can act as a powerful cutting tool.

Shape Memory Alloys:

Shape Memory Alloys is an alloy that can be deformed while cooling and it retains its original shape when heated. They are light weight and are better alternatives to conventional actuators such as hydraulic and pneumatic system. It eliminates extraneous systems. It can respond to temperature/rate of change of temperature which are simple and frictionless. It can be used in passive, active or superelastic design. The most recoverable starin for these materials without permanent damage is upto 8%. The yield stress for NiTi can reach upto 500MPa [8].

III. Actuators for space applications:

Actuators are mechanical or electromechanical devices that gives control over systems which operate electrically, mechanically or by various fluid such as air, hydraulics etc., Actuators use stored energy of compressed sir to move the piston which are useful in robotics, solenoid valves etc.,In space, actuators are applied in operating platform and payload devices. Many spacecrafts have solar arrays or payload needs to be continuously rotated or orient at a particular direction during mission. Spacecraft embark certain mechanism like optical adjustments, thrusters, shuttlers that can be manifested using such smart materials to enhance its performance [12].

Piezoelectric actuators:

Piezoelectric actuators have major advantage in space applications because of its magnetic property, easy operating, precision and accuracy. The major disadvantage is that this piezoelectric actuators powered to maintain certain position which are contradictory to apply in space technology.

Next generation actuators:

These kinds of materials are well suitable for applying it in cryogenic environment and have no hysteresis loss.

IV. Composite structure with adaptable nature:

Self healing technology is one of the advanced technologies in space applications dedicated by European Space Agency (ESA) [9]. Self healing technology can repair or do maintenance while micro cracking or damages from thermo mechanical cycle. Currently this technology is at initial stage.

Electroactive Polymers:

European Space Agency (ESA) framed a new technology in large aperture reconfigurable antennas and solar sails [10, 11]. The outcome of this electroactive polymers are unfeasible development in terms of cost and risk maintenance.

Undoubtedly piezoelectric actuators and Shape memory alloys plays major role in space applications. Adaptive nature and acceptance level of feasibility mode, this substantial technological innovations become the prime part of interest in space technology.

V. Potential applications of actuators:

- Switching actuators
- Controlled actuators
- Self-sufficient actuators

Switching actuators:

Switching actuators working based on shape memory alloys which can be applied in unlocking petrol cap. The conventional petrol cap is highly complex and it requires element of quantity of 10 with a weight of 104 g. This new type of actuator uses shape memory alloys achieves 10 mm stroke and applies a force about 10 N. It enables a significant weight reduction of 71% and is completely noise free operation. As it is light weight and it can be applied in space technology for easy unlocking of oxygen masks in case of any pressure drop in space.

Self-sufficient actuators:

The principle of self sufficient actuator is to set the axial preload during operation without stopping the regular process. The device is implemented in standard drives with some minor changes in design.

Controlled actuators:

It is a new technology using shape memory alloys in mechatronics. It acts as anti-vibration device for low frequencies that can be applied in robotics to stabilize the lens for improved picture quality. Due vibrations, temperature changes and leakage in conductors may cause damage to satellite components. It can be avoided using controlled actuators with conductor stiffness. Smart materials lead to new integrated and distributed concept for simple actuation system. As smart materials are light weight, robust and having low maintenance cost, it can be applied in space science and technology for futuristic missions.

The state of art in applying smart materials for use in space drags severe attention in futuristic space applications. The short comings and disadvantages in structural mechanics can be resolved by applying smart materials so that the performance and cost efficiency of small or minimum budgeted satellite can be achieved.

VI. Conclusion:

The described actuators and other components for space applications are well established. The simple application of actuators is in control engineering and it is one of the essential part in designing spacecraft. Today more conventional technologies have been replaced and the mission to space is widely preferred to be stalled with advanced smart materials. Undoubtedly shape memory alloys, electroactive polymers, piezoelectric actuators covers wide range of applications in making precision space instruments especially in control engineering, antennas and solar panels. Several on robit experiments are deployed with the mechanism based on smart materials. Smart materials have been considered as one of the prominent technologies for specific space applications. As satellites and space crafts are required to reduce the weight so that the mission to have successful life span and low maintenance, it is appropriate to rely on smart materials which can help to enable the future and long term missions to space more successful.

Smart materials are designed to have significantly large change in the properties such as stress, temperature, elasticity, electric and magnetic fields. Smart materials are applied in light weight construction, control engineering, satellite communications, avionics, etc., The design of smart materials is a highly integrated component for technically design and develop the high dynamic system which are far beyond the conventional manufacturing technology. The overall three group of smart materials are Piezoceramics, shape memory alloys and dielectric elastomers. Smart materials have various applications because of its adaptability and reliability. It can detect and prevent corrosion and other disaster in atmosphere. It has long life and reduced maintenance.

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