Applications and types of smart materials engineering essay

Smart material are those that change in response to changing conditions in their surrounding or in the application of other directed influences such as passing an electric charge through them. Modern products increasingly use them, shirts that change color with changes in temperature. Smart materials are the materials that have one or more properties that can be significantly changed in a controlled style such as stress, temperature, moisture, pH, electric or magnetic fields.

There are many types of smart material some of which are already common. Some examples are as following:

Types of smart material

Some types of smart materials include:

Piezoelectric – On applying a mechanical stress to these materials it generates an electric current. Piezoelectric microphones transform changes in pressure caused by sound waves into an electrical signal.

Shape memory – After deformation of these materials they remember their original shape and return back to its original shape when heated . Applications include shape memory stents – tubes threaded into arteries that expand on heating to body temperature to allow increased blood flow.

Thermo chromic – These are the materials which change their color in response to changes in temperature. They have been used in bathplugs that change color when the water is too hot.

Photo chromic – These materials change color in response to changes in light conditions. Uses include security ink sand dolls that ‘ tan’ in the sun.

Magneto rheological: it is a fluid that fluids become solid when placed in a magnetic field. They can be used to construct dampers that suppress vibrations. These can be used for buildings and bridges to suppress the damaging effects of,

For example, high winds or earthquakes.

1. 1 pH-sensitive polymers

These are materials which swell/collapse when the pH of the surrounding media changes.

PH sensitive or pH responsive polymers are materials which will respond to the changes in the pH of the surrounding medium by varying their dimensions. Such materials swell or collapse depending on the pH of their environment. This behavior is exhibited due to the presence of certain functional groups in the polymer chain.

1. 2 Magnetostrictive materials exhibit change in shape under the influence of magnetic field and also exhibit change in their magnetization under the influence of mechanical stress

Fig 1. 1

Magnetostrictive material (inside) then magnetizing coil over it and magnetic enclosure completing the magnetic circuit (outside)

It can convert magnetic energy into kinetic energy that is used to build sensors.

1. 3 Temperature-responsive polymers

These are materials which changes upon temperature.

A temperature-responsive polymer is a polymer which undergoes a physical change when external thermal is applied. The ability to undergo such changes makes this class of polymers the category of smart materials.

1. 4 Self-healing materials

These materials have the intrinsic ability to repair damage due to normal usage, thus expanding the material's lifetime . These are the class of smart materials that have the structurally incorporated ability to repair damage caused by mechanical usage over time. The inspiration comes from biological systems, which have the ability to heal after being wounded. Initiation of cracks and other types of damage on a microscopic level has been shown to change thermal, electrical, and acoustical properties, and eventually lead to whole scale failure of the material. Usually, cracks are mended by hand, which is difficult because cracks are often hard to detect. A material (polymers, ceramics, etc) that can intrinsically correct damage caused by normal usage could lower production costs of a number of different industrial processes through longer part lifetime, reduction of inefficiency over time caused by degradation, as well as prevent costs incurred by material failure

Chapter 2

Applications of Smart Materials

There are many possibilities for such materials and structures in the manmade world. Engineering structures could operate at the very limit of their performance envelopes and to their structural limits without fear of exceeding either. These structures could also give maintenance engineers a full report on performance history, as well as the location of defects, whilst having the ability to counteract unwanted or potentially dangerous conditions such as excessive vibration, and affect self repair. The Office of Science and Technology Foresight Programme has stated that `Smart materials … will have an increasing range of applications (and) the underlying sciences in this area … must be maintained at a standard which helps achieve technological objectives', which means that smart materials and structures must solve engineering problems with hitherto unachievable efficiency, and provide an opportunity for new wealth creating products.

2. 1 Smart Materials in Aerospace

Some materials and structures can be termed ' sensual' devices. These are structures that can sense their environment and generate data for use in health and usage monitoring systems (HUMS). To date the most well established application of HUMS are in the field of aerospace, in areas such as aircraft checking.

An airline such as British Airways requires over 1000 employees to service their 747s with extensive routine, ramp, intermediate and major checks to monitor the health and usage of the fleet. Routine checks involve literally dozens of tasks carried out under approximately 12 pages of densely typed check headings. Ramp checks increase in thoroughness every 10 days to 1 month, hanger checks occur every 3 months, ' interchecks' every 15 months, and major checks every 24000 flying hours. In addition to the manpower resources, hanger checks require the aircraft to be out of service for 24 hours, interchecks require 10 days and major checks 5 weeks. The overheads of such safety monitoring are enormous.

An aircraft constructed from a ‘ sensual structure’ could self-monitor its performance to a level beyond that of current data recording, and provide ground crews with enhanced health and usage monitoring. This would minimize the overheads associated with HUMS and allow such aircraft to fly for more hours before human intervention is required.

2. 2 Smart Materials in Civil Engineering Applications

However, ‘ sensual structures’ need not be restricted to hi-tech applications such as aircraft. They could be used in the monitoring of civil engineering structures to assess durability. Monitoring of the current and long term behavior of a bridge would lead to enhanced safety during its life since it would provide early warning of structural problems at a stage where minor repairs would enhance durability, and when used in conjunction with structural rehabilitation could be used to safety monitor the structure beyond its original design life. This would influence the life costs of such structures by reducing upfront construction costs (since smart structures would allow reduced safety factors in initial design), and by extending the safe life of the structure. ‘ Sensual’ materials and structures also have a wide range of potential domestic applications, as in food

2. 3 Its properties which enable them for civil engineering application are

Repeated absorption of large amounts of strain energy under loading without permanent deformation. Possibility to obtain a wide range of cyclic behavior

-from supplemental and fully reentering to highly dissipating-by simply varying the number and/or the characteristics of SMA components.

Usable strain range of 70%

Extraordinary fatigue resistance under large strain cycles

Their great durability and reliability in the long run.

2. 4 STRUCTURAL APPLICATION OF SMART MATERIALS

The development of durable and cost effective high performance construction materials and systems is important for the economic well being of a country mainly because the cost of civil infrastructure constitutes a major portion of the national wealth. To address the problems of deteriorating civil infrastructure, research is very essential on smart materials. This paper highlights the use of smart materials for the optimal performance and safe design of buildings and other infrastructures particularly those under the threat of earthquake and other natural hazards. The peculiar properties of the shape memory alloys for smart structures render a promising area of research in this field.

Fig 2. 1

to achieve speed improvements on existing bridges and to maintain the track in a straight and non-deformed configuration as the train passes With the help of optimal control methodology the train will pass the bridge with reduced track deflections and vibrations and thus velocity could be safely increased. Fig2. 1 shows various positions of the train with and without active railway track support.

Chapter3

3. 1 Reducing waste

Producers are forced to consider the entire life of a product at the design stage and customers are increasingly demanding more environmentally sensitive products. Innovative use of smart materials has the potential to reduce waste and to simplify recycling.

Electronic waste – Electronic waste is the fastest growing component of domestic waste in the UK. Electrical equipment requires that it should be processed before disposal to remove hazardous and recyclable materials. Disassembly of product is expensive and time consuming but the use of smart materials could help to automate the process. Research in this active disassembly has been carried out by UK companies. Active Disassembly Research Ltd. One example uses fasteners constructed from shape memory materials 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.

3. 2 Research in the UK

Smart materials and systems are interdisciplinary subject areas so funding does not come from a single research council. However, the majority of research council funding is allocated by the Engineering and Physical

Sciences Research Council (EPSRC). Materials research is one of its six core programmers and it currently has a commitment of £21m to smart materials research in 28 UK universities. This includes the EPSRC's contribution to smart materials projects run in collaboration with 35different organizations including the Ministry of Defense British Aerospace In addition to research councils, the government also allocates funding through the Technology Strategy Board. This is an executive non-departmental public body established by the Government to stimulate innovation in those areas which offer the greatest scope for boosting UK growth and productivity. Advanced materials are one of the Technology Strategy Board's key technology areas, which provide the framework for deciding where it should invest funding and support activities. In 2007, as part of its support for collaborative research and development, the Technology Strategy Board allocated funding of £7m to a competition for research proposals in Smart Bioactive and Nano structured Materials for Health

The Ministry of Defense identifies " smart materials and active structures" as a priority technology. However, its investment in these areas has decreased markedly in recent years as developments are increasingly driven by global civil markets and commodity products that are often adequate for itsneeds. 2 It currently emphasizes monitoring external research rather than producing it in-house.

3. 3 Research worldwide

The US is the world leader in smart materials research mainly because of the large defence research and development budget. The US Defense Advanced Research Projects Agency has had an in-house programme of smart materials and structures research since the early 1990s, in contrast to the UK. However the UK is strong in many areas and is at the forefront of research into structures that can repair themselves. Other observations so that materials can be sorted automatically. The companies have collaborated with Nokia and believe that this technology could be in use in the next two years.

3. 4 Reducing food waste

Food makes up approximately one fifth of the UK's waste. One third of food grown for consumption in the UK is thrown away, much of which is food that has reached its best before date without being eaten . These dates are conservative estimates and actual product life may be longer. Manufacturers are now looking for ways to extend product life with packaging, often using smart materials.

CHAPTER 4

FUTURE

4. 1 In Nanotechnology to Revolutionize Smart Materials Technology

The nanotechnology is set to accelerate development of improved and complicated smart material technologies. Researchers are now considering the possibilities of designing, altering, and controlling material structure at nanoscale levels in order to enhance material performance and process efficiency. The advancements in nanomaterials are expected to increase product quality and performance, and they are finding acceptance in diverse applications such as sensors and electronic devices. Nanosensor particles assist in creating tools for analyzing living cells and serve as reporters in industrial process monitoring. In the future, smart materials are likely to derive their success from nanotechnology that is likely to be instrumental in creating more varied, complex, and intelligent systems.

4. 2 Smart Materials Expected to Cater to Diverse Applications

The advances and improvements in smart materials allow them to cater to a diverse set of applications, especially in the defense, aerospace, healthcare, electronics, and semiconductor industries. Although very few of these applications are at present commercially viable, their potential for future acceptance is irrefutable. " Smart materials are particularly useful for cellular production," observes the analyst. " With the addition of cellular fluid and by regulating the cell's shape and mechanical conditions, smart materials – especially polymers – can mimic these cells' interactions and exhibit effective results."

The computer industry is also adopting smart materials for read/write head micropositioners and next-generation data storage devices. Researchers are developing piezo-accelerometers that anticipate and correct head-motion-related read/write errors. In the healthcare markets, smart material technologies are making their way into several analytical devices for detecting and diagnosing complex medical conditions. With future advances, smart materials are also likely to be useful for fabricating insulin pumps and drug delivery devices.