Smart Materials: Applications and Future scope

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Abstract—Smart materials changes their shape, color or size on the application of external stimulus like force, light etc. Smart materials already impacted us by their applications in day to day life. Smart materials have the functions of actuator, sensor, self-healing and so. In recent years, smart materials is one of the most progressive fields. It addresses many challenges in defense, bionics, vibrations, medical and aerospace industries. The best way to understand the smart material concept is to look at its uses. The theme of this paper gives Applications and Future scope of Smart Materials. It covers most recent researches in smart materials. Also properties of smart materials are also introduced.

Keywords— Smart materials, MR, ER, SMA, SHM.

I. INTRODUCTION

The terms “smart” and “intelligent” was came from USA and in 1980’s despite of it the materials were there since so many years. Many of them were introduced by government agencies and defense personals. There are various groups of smart materials which are having high tech applications. These consist of Magneto-rheological (MR) fluid, Electro-rheological(ER) fluid, Shape memory Alloys (SMA), Self- Healing Materials (SHM). Mandru et al (2013) studied the actuators based on shape memory effect. These applications are systematic and representative examples in the field of Biomedical engineering. [1] A. Hubert et al (2012) focused on Magnetic Shape Memory Alloys for the design of Micro-mechatronic devices. Self-sensing potentials could also be pursued but technological improvements must be reached to replace efficiently integrated position sensor.[2] Bajaj et al (2012) studied the applications of MR fluid dampers and it’s social impact. This paper concluded that by using the MR damper in suspensions, it will provide both ride comfort and vehicle stability.[3] Kshirsagar Prashant et al (2016) gave the model and analysis of MR fluid brake and concluded that design was safe for the working experiment.[4]

Gawade and jadhav (2012) focused on properties and working of ER fluids and their applications in various sectors.[5] Halsey et al (2000) studied structure and dynamics of ER fluids. Also provided an electro-rheological fluid in the quiescent state, steady shear, and oscillatory shear and concluded that ER fluids in oscillatory shear demonstrate that the chain dynamics, and thus the electro- rheology, is nonlinear.[6] Peng Li et al (2015) gave that Self-healing technology has profound significance to improve safety and reliability of product and great prospects for development and applications in a number of important engineering.[7] Gurumurthy B.M et al (2016) introduced us to New era of materials which is nothing but the self- healing materials. Also reviewed state-of-art self healing techniques that are developed by the researchers in and around the world.[8]

So in short smart materials are playing and going to play vital role in future applications in various areas like automobile, Medical, aerospace etc.

II. WORKING OF SMART MATERIALS

This chapter gives the basic idea about the working of Smart materials which mainly includes MR, ER, SMA, SHM.

1. MR Fluid: MR fluid is nothing but a type of oil which consists of magnetic particles with appropriate proportion in it. When it is subjected to an external magnetic field, there is great increase it viscosity. To understand and predict the behavior of the MR fluid it is necessary to model the fluid mathematically, a task slightly complicated by the varying material properties such as yield stress. As mentioned above, smart fluids are such that they have a low viscosity in the absence of an applied magnetic field, but become quasi-solid with the application of such a field. In the case of MR fluids, the fluid actually assumes properties comparable to a solid when in the activated state, up until a point of yield the shear stress above which shearing occurs. This yield stress commonly referred to as apparent yield stress is dependent on the magnetic field applied to the fluid, but will reach a maximum point after which increases in magnetic flux density have no further effect, as the fluid is then magnetically saturated. The behavior of a MR fluid can thus be considered similar to a Bingham plastic, a material model which has been well-investigated. It basically works in three modes which are Flow mode, Shear Mode and Squeeze flow mode.

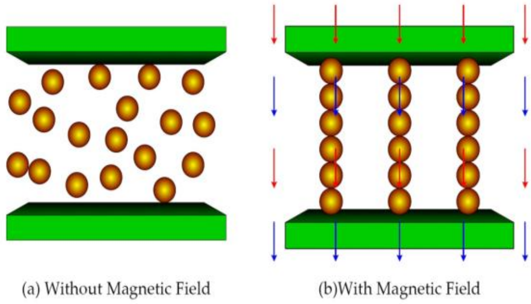

Fig. 2.1 Working of MR fluid

Limitations

1. High density, due to presence of iron.

2. Expensive.

3. Fluids are subject to thickening after prolonged use and need replacing.

2. ER FLUID: It is a suspension of extremely fine non-conducting but electrically active particles up to 50 micrometers diameter in an electrically insulating fluid. The apparent viscosity of these fluids changes reversibly by an order of up to 100,000 in response to an electric field**.** The change in apparent viscosity is dependent on the applied electric field, i.e. the potential divided by the distance between the plates. The change is not a simple change in viscosity, hence these fluids are now known as ER fluids, rather than by the older term Electro Viscous fluids. The effect is better described as an electric field dependent shear yield stress. When activated an ER fluid behaves as Bingham plastic a type of viscoelastic material, with a yield point which is determined by the electric field strength. After the yield point is reached, the fluid shears as a fluid, i.e. the incremental shear stress is proportional to the rate of shear in a Newtonian fluid there is no yield point and stress is directly proportional to shear. Hence the resistance to motion of the fluid can be controlled by adjusting the applied electric field.

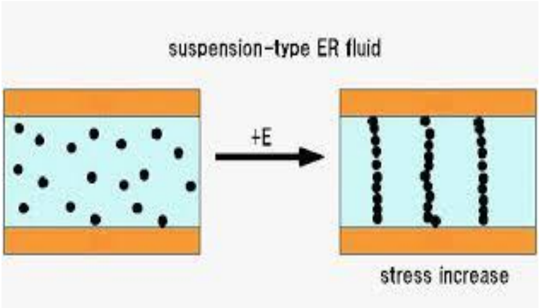

Fig. 2.2 Working of ER fluid

Limitations:

1. Increase in apparent viscosity experienced by most Electro-rheological fluids used in shear or flow modes are relatively limited.

2. High density, due to presence of iron.

3. Shape Memory Alloys (SMA): Certain metallic materials will, after an apparent plastic deformation. Return to their original shape when heated. The same materials, in a certain temperature range, can be strained up to approx."Shape Memory" describes the effect of restoring the original shape of a plastically deformed sample by heating it. This phenomenon results from a crystalline phase change known as "thermoelastic martensitic transformation". At temperatures below the transformation temperature shape memory alloys are martensitic, In this condition, Their microstructure is characterized by "self-accommodating twins", The manensite is soft and can be deformed quite easily by de-twinning. Heating above the transformation temperature recovers the original shape and converts the material to its high strength Austenitic Condition.

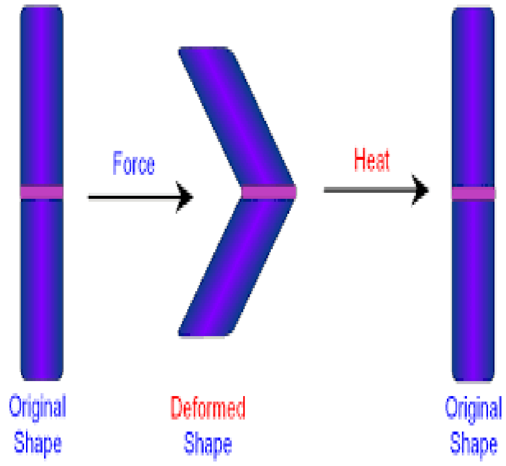

Fig. 2.3 Shape Memory Alloy Principle

Limitations:

1. Non-linear behavior

2. low response speed

3. low energy efficiency

4. Self Healing Material (SHM): Nothing lasts forever, although some natural materials certainly do their best. Materials that we use everyday generally stop working for three different reasons, which are ageing, wear, and defects. The best-known self-healing materials have built-in microcapsules 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. It works in a similar way to a type of adhesive (glue) called epoxy, which is supplied in the form of two liquid polymers in separate containers. When you mix the liquids together, a chemical reaction occurs and a strong adhesive forms. Self-healing materials can use embedded capsules in a variety of different ways. 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. When the material fails and the capsules break, the monomer mixes with the polymer, more polymerization occurs, and the damage is healed effectively by creating more of the original material to replace the damaged area. Typically, a powdered chemical catalyst has to be embedded as well so the polymerization will happen at a relatively low, everyday temperature and pressure.

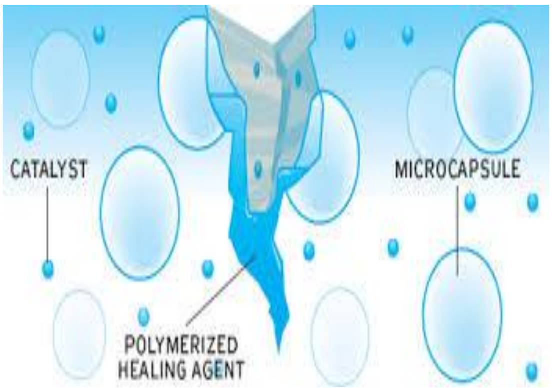

Fig 2.4 Self Healing material

Limitation:

1. The encapsulation method.

III. APPLICATIONS OF SMART MATERIALS

This chapter gives the applications of smart materials in engineering and technology.

1. The MR Dampers can be used as Seismic dampers which will operate under the resonance frequency of the building by absorbing shock waves and oscillations that can cause harm, within the structure. This makes the dampers able to make any building earthquake proof.

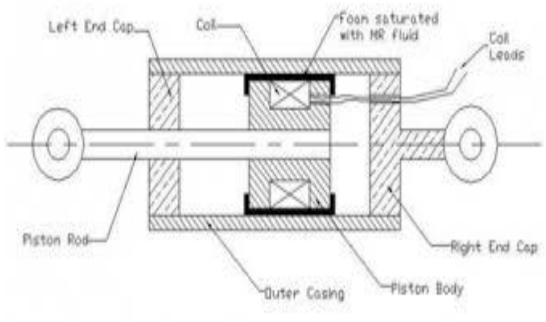

Fig 3.1 MR Damper

2. MR fluid dampers are used to control the vibrations induced by the string winds. They are also used to avoid the seismic action. The Dongting Bridge is a cable stayed bridge which crosses Dongting Lake where it meets the Yangtze River in south central China. The Dongting Bridge is the first cable-stayed bridge to use MR dampers for absorbing rain and wind induced vibrations. The results are a very significant reduction in vibrations of the bridge structure.

Fig 3.2 Dongting Bridge

3. An **electro-rheological clutch** (ER clutch) comprises drive and driven members, generally parallel to each other, that can be selectively engaged by the application of a voltage to an ER fluid. The ER fluid is used as the coupling between the input and the output The clutch acts as a power amplifier and the effect is fast (of the order of milliseconds) and reversible.

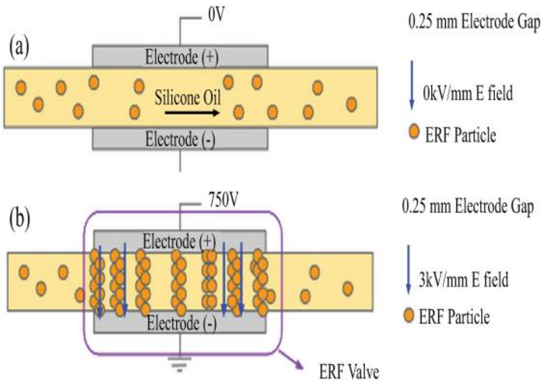

Fig 3.3 ER fluid clutch

4. Broken bones can be mended with shape memory alloys. The alloy plate has a memory transfer temperature that is close to body temperature, and is attached to both ends of the broken bone. From body heat, the plate wants to contract and retain its original shape, therefore exerting a compression force on the broken bone at the place of fracture. After the bone has healed, the plate continues exerting the compressive force, and aids in strengthening during rehabilitation. Memory metals also apply to hip replacements, considering the high level of super -elasticity.

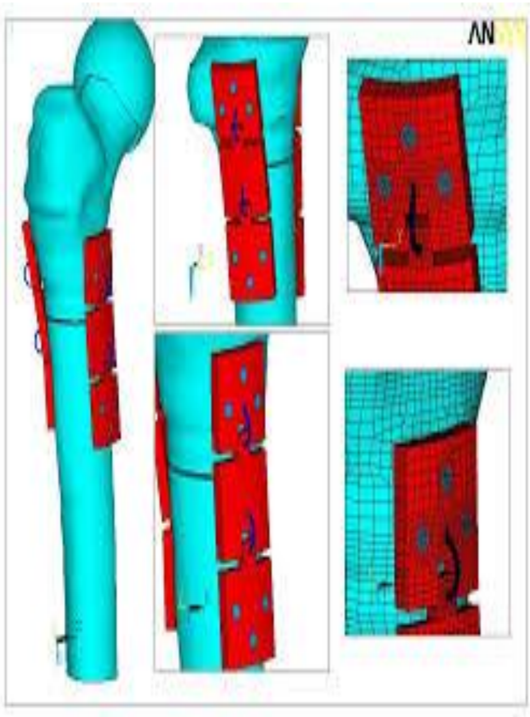

Fig 3.4 SMA Bones

5. Electrical shape memory actuators have been suggested to replace solenoids, electric motors etc. By controlUng the power during electrical actuation, specific levels of force andlor specific positions can be maintained. A variety of valves, triggering devices, animated objects, toys etc. are presently being marketed.

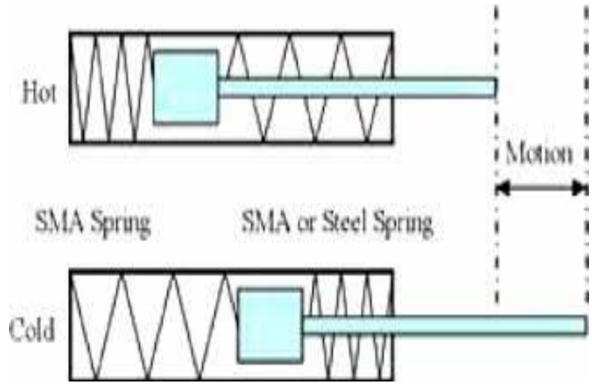

Fig 3.5 SMA Actuator

6. Cracks in concrete are a common phenomenon due to the relatively low tensile strength. Durability of concrete is impaired by these cracks since they provide an easy path for the transportation of liquids and gasses that potentially contain harmful subs. liquids and gasses that potentially contain harmful substances. If micro-cracks grow and reach the reinforcement, not only the concrete itself may be attacked, but also the reinforcement will be corroded. Therefore, it is important to control the crack width and to heal the cracks as soon as possible. Concrete has an autogenously healing capacity as unhydrated cement is present in the matrix. When water contacts the unhydrated cement, further hydration occurs. Furthermore, dissolved CO_2 reacts with Ca^{2+} to form $CaCO_3$ crystals. These two mechanisms, however, may only heal small cracks. To enhance the healing mechanism, microfibres are added to the mixture. By mixing microfibres in the concrete, multiple cracking occurs. So, not one wide crack, but several small cracks are formed, which close more easily due to autogenously healing.

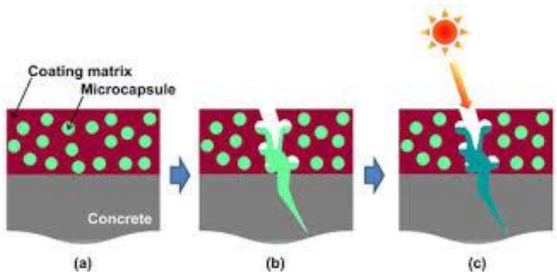

Fig 3.5 SHM (concrete)

7. Scientists believe new self-healing material for use in airplane construction could repair cracks in aircraft in a manner similar to the way human skin heals itself. carbon fibre reinforced materials that are currently used widely in sports equipment. They have developed tiny micro-spheres – or hollow capsules – that are filled with a healing agent. The micro-spheres are implanted into the carbon fibre composite material, along with a catalyst. Upon impact, the micro-spheres spheres break open. When the liquid comes into contact with the catalyst, there

is a hardening of the two materials, effectively gluing the crack caused by impact back together.

IV. FUTURE SCOPE

The development of true smart materials at the atomic scale is still some way off, although the enabling technologies are under development. These require novel aspects of nanotechnology and the newly developing science of shape chemistry. 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. In many of these applications, the cost benefit analyses of such systems have yet to be fully demonstrated. The Office of Science and Technology‘s Foresight Programme has recognized these systems as a strategic technology for the future, having considerable potential for wealth creation through the development of hitherto unknown products, and performance enhancement of existing products in a broad range of industrial sectors. The core of Yanagida‘s philosophy of ken materials is such a concept. This is technodemocracy where the general public understands and own the technology. **Technodemocracy** can come about only through education and exposure of the general public to these technologies. However, such general acceptance of smart materials. and structures may in fact be more difficult than some of the technological hurdles associated with their development. The potential future benefits of smart materials, structures and systems are amazing in their scope. This technology gives promise of optimum responses to highly complex problem areas by, for example, providing early warning of the problems or adapting the response to cope with unforeseen conditions, thus enhancing the survivability of the system and improving its life cycle.

V. CONCLUSION

By reviewing the literature, need of Smart Materials in engineering and technology against the traditional materials is studied. In depth knowledge of Smart Materials is achieved. Current and Future applications of Smart Materials are reviewed with its future scope.

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