The Applications of Nanotechnology in Mechanical Engineering

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***Abstract*— Nanotechnology has become an all-embracing term, which means different things to different people. Nanotechnology is interface technologies that are include many different science and applications area. Nanotechnology falls into this category and offers fundamentally new capabilities to architect a board array of the novel materials, composites and structure on a molecular scale. Here discusses on some of the applications for nanotechnology and shows a few cases of them. That is believed to have the highest probability of success in competitive industry. The nanotechnology that are economically promising for the future include those that have applications in information technology, electronics, building materials, household appliances, textiles, cosmetics, food, environmental technologies, energy technologies and medicine etc.,**

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I.INTRODUCTION

Nanotechnology deals with studies of phenomena and manipulation with elements of matter at the atomic, molecular and macromolecular level (rangefrom1to100nm), where the properties of matter are significantly different from their properties at larger scales of dimensions. Nanotechnology is science, engineering and technology conducted at the nanoscale, which is about 1 to 100 nm where nano denotes the scale range of 10-9 and nanotechnology refers the properties of atoms and molecules measuring thoroughly 0.1 to 1000 nm. Nanotechnology is highly interdisciplinary as a field, and it requires knowledge drawn from a variety of scientific and engineering arenas. There are two main types of approaches to nanotechnology: the first approach is Top-down and another one is Bottom-up approach. The Top-down approach involves taking layer structures that are either reduced down size until they reach the nano-scale or deacon structured into their composite parts. The other hand the Bottom-up approach is where materials are constructed from the atomic or molecular components. Designing at the nanoscale is working in a world where physics, chemistry, electrical engineering, mechanical engineering, and even biology become unified into an integrated field. “Building blocks” for nanomaterials include carbon-based components and organics, semiconductors, metals, and metal oxides; nanomaterials are the infrastructure, or building blocks, for nanotechnology. The last decade has seen advancement in every side of nanotechnology such as: nanoparticles and powders; nanolayers and coats; electrical, optic and mechanical nanodevices; and nanostructure biological materials. Presently, nanotechnology is estimated to be influential in the next 20-30 years, in all fields of science and technology.

USES OF NANOTECNOLOGY IN MECHANICAL ENGINEERING:

The nanotechnology in mechanical engineering and manufacturing is immensely useful to the field. Nanotechnology can be used to increasing the life of the components and automobile parts. A many number of materials can be enhanced by the use of nanotechnology. Nanomaterials exhibit unique physical and chemical properties and impart enhancements to engineered materials. There including better magnetic properties, improved mechanical activity and increased optical properties. Developments are being made to improve the properties of the materials and to find alternative precursors that can give desirable properties on the materials.

FUNDAMENTALS CONCEPTS IN NANOTECHNOLOGY:

Nanotechnology involve the ability to see and to control individual atoms and molecules, everything on earth is made up of atoms the food we eat the cloths we wear the building and houses we live in, and our own bodies. Here are a few illustrative examples.

- There are 25,400,000 nanometer an inch.
- A sheet of news paper is about 100,000 nanometer thick.

The microscopes needed to see things at the nanoscale were invented relatively recently. Although modern nanoscience and nanotechnology are quite new, nanoscale materials were used for centuries. Today's scientists and engineers are finding a wide variety of ways to deliberately make materials at the nanoscience to take advantage of their enhanced properties. such as higher strength, lighter weight, increased control of light spectrum and greater chemical reactivity than their large-scale counter parts.

WHAT ARE NANOMATERIALS?

Nanoscale materials are defined as a set of substances where at least one dimension is less than approximately 100 nanometers. A nanometer is one millionth of a millimeter approximately 100,000 times smaller than the diameter of a human hair. Nanomaterials are of interest because at this scale unique optical, magnetic, electrical, and other properties emerge. These emergent properties have the potential for great impacts in electronics, medicine, and other fields.

Fig-1 NanoMaterial

Nanomaterials are resources designed at the molecular (nanometre) level to take advantage of their small size and novel properties which are generally not seen in their conventional, bulk counterparts. The two main reasons why materials at the nano scale can have different properties are increased relative surface area and new quantum effects.

IMPORTANT OF NANOMATERIALS:

These materials have created a high interest in recent years by virtue of their unusual mechanical, electrical, optical and magnetic properties. Some examples are given below:

- Nanophase ceramics are of particular interest because they are more ductile at elevated temperatures as compared to the coarse-grained ceramics.
- Nanostructured semiconductors are known to show various non-linear optical properties. Semiconductor Q-particles also show quantum confinement effects which may lead to special properties, like the luminescence in silicon powders and silicon germanium quantum dots as infrared optoelectronic devices. Nanostructured semiconductors are used as window layers in solar cells.
- Nanosized metallic powders have been used for the production of gas tight materials, dense parts and porous coatings. Cold welding properties combined with the ductility make them suitable for metal-metal bonding especially in the electronic industry.

PROPERTIES OF NANOMATERIALS:

- Nanomaterials have the structural features in between of those of atoms and the bulk
- While most microstructured materials have similar properties to the corresponding bulk materials, the properties of materials with nanometer dimensions are significantly different from those of atoms and bulks materials. This is mainly due to the nanometer size of the materials which render them: (i) large fraction of surface atoms; (ii) high surface energy; (iii) spatial confinement; (iv) reduced imperfections, which do not exist in the corresponding bulk materials.
- Due to their small dimensions, nanomaterials have extremely large surface area to volume ratio, which makes a large to be the surface or interfacial atoms, resulting in more "surface" dependent material properties.

NANOCOMPOSITE:

Nanocomposites can be made with a variety of enhanced physical, thermal and other unique properties. They have properties that are superior to conventional microscale composites and can be synthesized using simple and inexpensive techniques. Materials are needed to meet a wide range of energy efficient applications with light weight, high mechanical strength, unique color, electrical properties and high reliability in extreme environments. The term nanocomposite encompasses a wide range of materials right from three dimensional metal matrix composites, two dimensional lamellar composites and nano-wires of single dimension to zero-dimensional core-shells all representing many variations of nano-mixed & layered materials. Though various composite materials like fiberglass and reinforced plastics are now in wide use for numerous applications, there has been continued demand for novel composites with desirable properties for many other applications.

NANO-COMPOSITES – BASIC INGREDIENTS:

There has been a great deal of interest in polymer nanocomposites over the last few years. There are different types of commercially available nano-particles that can be incorporated into the polymer matrix to form polymer nanocomposites. Polymer nanocomposites consist of a polymeric material (e.g., thermoplastics, thermosets, or elastomers) with reinforcement of nano-particles. Polymeric nanocomposites can be broadly classified as

- Nanoclay-reinforced composites
- Carbon nanotube-reinforced composites
- Nanofibre-reinforced composites, and
- Inorganic particle-reinforced composites.

NANOCLAY-REINFORCED COMPOSITES:

The term clay has been understood to be made of small inorganic particles (part of soil fraction <2 mm), without any definite composition or crystallinity. The clay mineral (also called a phyllosilicate) is usually of a layered type and a fraction of hydrous, magnesium, or aluminum silicates. Every clay mineral contains two types of sheets, tetrahedral (T) and octahedral (O). For a better understanding the major clay mineral groups along with their ideal structural chemical compositions are listed in table 1.

Table 1 Major Group's of Clay Minerals

Sl No	Group Name	Member Minerals	General Formula	Remarks
1	kaolinite	kaolinite, dickite, nacrite	$Al_2Si_2O_5(OH)_4$	members are polymorphs (composed of the same formula and different structure)
2	montmoril-lonite or smectite	montmorillonite, pyrophyllite, talc, vermiculite, sauconite, saponite, nontronite	$(Ca,Na,H)(Al,Mg,Fe,Zn)_2(Si,Al)_4O_{10}(OH)_2$-$XH_2O$	X indicates varying level of water in mineral type
3	illite	illite	$(K,H)Al_2(Si,Al)_4O_{10}(OH)_2$-$XH_2O$	X indicates varying level of water in mineral type
4	chlorite	(i) amesite, (ii) chamosite, (iii) cookeite, (iv) nimite etc.	(i) $(Mg,Fe)_4Al_4Si_2O_{10}(OH)_8$ (ii) $(Fe,Mg)_3Fe_3AlSi_3O_{10}(OH)_8$ (iii) $LiAl_5Si_3O_{10}(OH)_8$ (iv) $Ni,Mg,Fe,Al)_6AlSi_3O_{10}(OH)_8$	each member mineral has separate formula; this group has relatively larger member minerals and is sometimes considered as a separate group, not as part of clays

CARBON NANOTUBE-REINFORCED COMPOSITES:

Another important type of carbon filler is carbon nanotubes and nanofibres. Much publicity has surrounded the development of single wall carbon nanotubes, that called Buckytubes, but while these are still some way off large-scale commercial production, the corresponding multi-layer carbon nanotubes have been known for some time and, furthermore, are available in practical commercial quantities. The layers consist of graphitic carbon and the tubes typically have an internal diameter of 5 nm and external diameter of. 10 nm (Figure1)

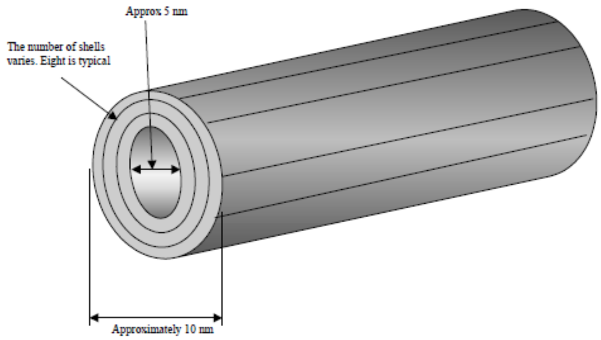

Fig-1Structure of a multi-layer carbon nanotube.

NANOFIBER-REINFORCED COMPOSITES:

Carbon nanofibers (CNF) are a unique form of vapourgrown carbon fibres that fill the gap in physical properties between conventional carbon fibres (5.10 µm) and carbon nanotubes (1.10 nm). The reduced diameter of nanofiber provides a larger surface area with surface functionalities in the fiber. Typically CNF are not concentric cylinders; the length of the fibre can be varied from about 100 µm to several cm, and the diameter is of the order of 100. 200 nm with an average aspect ratio greater than 100. The most common structure of CNF is the truncated cones, but there are wide ranges of morphologies (cone, stacked coins, etc). CNF have the morphology where these are hollow at the centre (much like a MWNT) and have a larger diameter than MWNT but the individual layers are not arranged in concentric tubes.

INORGANIC PARTICLE-REINFORCED COMPOSITES:

Nanoparticles are often defined as particles of < 100 nm in diameter. Nanometer-sized particles have been made from different organic.inorganic particles and these impart improved properties to composite materials. Different particles have been used to prepare polymer/inorganic particle nanocomposites, including:

- ✓ Metals (Al, Fe, Au, Ag, etc.)
- ✓ Metal oxides (ZnO, Al2O3, CaCO3, TiO2, etc.)
- ✓ Nonmetal oxide (SiO2)
- ✓ Other (SiC)

The selection of nanoparticles depends on the desired thermal, mechanical, and electrical properties of the nanocomposites. For example, Al nanoparticles are often selected due to their high conductivity; calcium carbonate (CaCO3) particles are chosen because of their low cost and silicon carbide (SiC) nanoparticles are used because of their high hardness, corrosion resistance, and strength.

SELECTED APPLICATION OF NANOMATERIALS AND NANOTECHNOLOGY:

Nanotechnology and Nanomaterials having wide range of applications in the field of energy sectors, It is evident that nanomaterials split their conventional counterparts because of their superior chemical, physical, and mechanical properties and of their exceptional formability.

ENERGY SECTORS:

The most advanced nanotechnology related to energy storage, conversion, manufacturing improvements by reducing materials and process rates, energy saving [Example: Better thermal Insulation] and enhanced renewable energy sources.

A reduction of energy consumption can be reached by better insulation systems by the use of more efficient lighting or combustion systems and by use of lighter and stronger materials in the transportation sector. Nanotechnological approaches like light-emitting diodes [LED] or quantum caged atoms[QCA's] could lead to a strong reduction of energy consumption for illumination. The solar cells have layers of several different semiconductors stacked together to absorb light at different energies but they still only manage to use 40% of the sun's energy. Nanotechnology could help increases the efficiency of light conversion by using nanostructures with a continuum of band gaps.

HEAVY INDUSTRY'S:

An inevitable use of nanotechnology will be in heavy industries.

AEROSPACE:

Lighter and stronger materials will be of immense use to aircraft manufactures, leading to increased performance, spacecraft will also benefit where weight is a major factor. Nanotechnology would help to reduce the size of equipment and there by decrease of fuel-consumption required to get it airplane.

Fig-2 Nano Aero Space

CATALYSIS:

The application of potential nanoparticles in catalysis ranges from fuel cell to catalytic converters and photo catalytic devices. The synthesis provides novel “nanomaterials” and in the long run, superior processes such as “self-assembly” will enable energy time preserving strategies. Platinum nanoparticles are now being considered in the next generation of automotive catalytic converters because the very high surface area of nanoparticles could reduce the amount of platinum required.

AUTOMOBILE INDUSTRY:

The present-days automobile vehicle has more inner components parts in the system. Those parts are more hard wearing and more heat-resistant. The auto engine wastes loft of fuel and to create a population because of incomplete gas combustion. Now nanotechnology and nanomaterials are likely to play a significant role in sparkplugs. Since nanomaterials are strongest, harder and resist wear and erosion, they are currently being considered for the use in sparkplug.

Fuel Tanks:

The ability of nanoclay incorporation to reduce solvent transmission through polymers such as polyamides has been demonstrated. Available data reveals significant reductions in fuel transmission through polyamide–6/66 polymers by incorporation of nanoclay filler. As a result, considerable interest is now being seen in these materials as both fuel tank and fuel line components for cars. Of further interest for this type of application, the reduced fuel transmission characteristics are accompanied by significant material cost reductions.

COATINGS :

Nanocoating refers to the act of covering a material with a layer on the nanometer scale or to cover a nanoscaled entity. Nanocoating forms a nanocomposite that comprises a combination of two or more different substances of nanometer size, thereby producing a material that generally has enhanced or specific targeted properties due to the combined properties and/or structuring effects of the components.

STEEL COATINGS:

The nanotechnology in steel material its help to improve the physical properties of steel, fatigue or the structural failure of steel is due to cyclic loading. Steel cables can be strength the using carbon nanotubes are stronger cables are reduce the costs of the constructions.

FOOD COATINGS:

A nanocomposite coating process could improve food packaging by placing anti-microbial agents directly on the surface of the coated film. They can also improve the mechanical and heat-resistance properties and lower the oxygen transmission rate. Research is being performed to apply nanotechnology to the detection of chemical and biological substances for sensing’s in foods.

GLASS COATINGS AND OTHER AREAS

Glass also makes use of nanotechnology. TiO_2 nanoparticles are used to coat glazing it has sterilizing and anti-fouling properties. $TiO_2$is hydrophilic which can attract rain drops that wash off the dirt particles. Glass is using a clear instrument layer sandwiched between glass panels formed of silica nanoparticles which turns into a rigid and opaque fire shield when heated.

FIRE RETARDATION:

Polymers containing a few weight per cent of nanoparticle clays have greatly improved fire resistance as reported by Gilman. The thermal properties of the PNC are improved, melting and dripping are delayed, and rate of burning is greatly reduced (by more than half). The presence of flake-like clay nanoparticles reduces the diffusion of polymer decomposition volatiles (the fuel) to the burning surface and reduces diffusion of air into the polymer.

CORROSION PROTECTION:

Corrosion protection of metals and alloys is normally achieved by surface coatings which must resist both mechanical damage (scratching, impact, abrasion) and chemical attack (salts, acids and bases, solvents). It should also not be damaged (cracked) by having a coefficient of thermal expansion greatly different from the metal to be protected. PNCs have improved scratch and abrasion resistance, due to their higher hardness combined with improved elastic.

SPORTS:

Nanotechnology may also play a role in sports such as soccer, football, and baseball. Materials for new athletic shoes may be made in order to make the shoe lighter (and the athlete faster).Baseball bats already on the market are made with carbon nanotubes which reinforce the resin, which is said to improve its performance by making it lighter.

CONCLUSION:

Nanotechnology is revolutionizing the world of materials. It has very high impact in developing a new generation of composites with enhanced functionality and a wide range of applications. The data on processing, characterization and applications helps researchers in understanding and utilizing the special chemical and material principles underlying these cutting-edge polymer nanocomposites. Although Nanocomposites are realizing many key applications in numerous industrial fields, a number of key technical and economic barriers exist to widespread commercialization. These include impact performance, the complex formulation relationships and routes to achieving and measuring nanofiller dispersion and exfoliation in the polymer matrix. Investment in state-of-the-art equipment and the enlargement of core research team's is another bottleneck to bring out innovative technologies on nanocomposites.

Future trends include the extension of this nanotechnology to additional types of polymer system, where the development of new compatibility strategies would likely to be a prerequisite. Production of PVC-based systems is still some way off and challenges remain to be solved in PET nanocomposites. Additional reinforcement of clay nanocomposites by glass fiber is currently being investigated. There is also interest in the development of electrically conducting clay nanocomposites. While considerable basic research activities are currently underway at Indian academic institutions & national research labs, immediate exercises on product development-cum-demonstration should be taken up in active collaboration with the industries in the country. The nanotechnology will positively influence the Energy, Heavy Industries and Automobile industry. Due to small size of nanomaterials their physical and chemical properties can be manipulated to improve the overall properties of convectional material. The use of nanotechnology has also helped to created more efficient and sustainable materials. The uses of steel, glass, coatings made from nanotechnology helps to protection the corrosion of the layers.

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