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REVIEW ARTICLE

Application of nanotechnology in farm power, machinery and operations: a review

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ABSTRACT: Farm Machinery and Power Engineering is one of the major discipline of agricultural engineering which deals with the mechanization of agricultural operations. Farm machinery includes simple farm tools like sickle, spade etc. to complex machines like laser land leveller, combine harvesters etc., whereas farm power deals with the prime mover required to operate different tools/implements/machinery like electric motor, diesel engine, tractor, power tiller etc. In this review paper, an attempt has been made to explore the possibility of using the nanotechnology in the development of agriculture machinery and various prime movers to enhance the performance parameters in terms of increased strength of various components, enhanced wear and corrosion resistance etc. The nanomaterials which can be harnessed to reduce the wear of various components have been outlined. Potential aspects of nanomaterials and nanocoating in the engine components and tractors for improving their efficiency in terms of weight, cost and lifetime; nano-emulsions and nano-particles in diesel fuel for manipulating the combustion and emission characteristics; nano-lubricants for reduced friction; nano-filled friction materials for more coefficient of friction in clutch and brakes; nanoparticle embedment in the tyres for reduced rolling resistance and better traction. Nanocoatings are used in agricultural machinery for improved appearance, rust and corrosion prevention, weather resistance, thermal protection, extended service life, fewer breakdowns. Nanobatteries are also used for more powerful, smaller and lighter batteries and carbon nanotube membranes are used for better desalination of irrigation water. Nanofertilizers for ensuring higher nutrient use efficiency; smart sensors to detect and treat disease efficiently and effectively; nanotechnology to reduce weight, extend flight time and increase the durability of drones; classic nanostructures like carbon nanotubes (CNT) to make solar cells lighter, cheaper and more efficient etc. have been reviewed systematically for thorough understanding and adoption.

1. INTRODUCTION

Nanotechnology deals with materials which function at a scale of 100 nanometres or less. In practical terms, a nanometre is eighty thousand times smaller than the diameter of a human hair. Nanotechnology may be defined as the manipulation or self-assembly of individual atoms, molecules or molecular clusters into structures to create materials devices with new or vastly different properties. It is a multidisciplinary approach which includes engineering sciences, chemistry, physics and material sciences.

A variety of nano-materials with attractive properties have been developed. The prominent members of this list include carbon nanotubes (CNT), inorganic non-metallic nanomaterials, metal alloys, nano-clays, nano-polymers and nono-composites (Anonymous, 2012b). These materials exhibit properties different at nanoscale than at macroscale. This is due to high superficial area and the quantum effects at the nanoscale. The improved properties which can be advantageously applied in the field of agricultural engineering include- improved mechanical properties (tensile strength, stiffness, toughness, friction coefficient), dimensional

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stability, thermal stability, thermal conductivity and reinforcement.

In agriculture, the nanotechnology have found useful place in plant germination and growth, nutrient and drug delivery system, disease diagnosis and screening, vector and pest detection/control and chemical residue detection and food quality enhancement (Khot *et al*., 2012). This paper specifically sheds light on potential aspects of nanotechnology in different areas of agricultural engineering particularly in farm machinery and power engineering discipline.

2. NANOTECHNOLOGY IN FARM POWER

2.1. Engine and Other Mechanical Components

Engine power is versatile form of power available at Indian farms. Any nano-technological improvement in engine functional components will directly improve its efficiency in terms of weight, cost and lifetime. Nano technology can improve the resistance of engine moving components against wear and tear due to normal usage. In conventional mode, the material is made wear resistant by coating it with another hard material, which is easily delaminated and fractured. Aluminium oxide dispersed with metals in its nanopores has showed promising results in reducing wear. Aluminium reinforced nanocomposites (Premnath *et al*., 2018) were 63.7-81.1% stronger in terms of Brinell hardness number (Anonymous, 2012a, 2014) and 16% stronger in terms of tensile strength than base alloys. Ceramic nanoparticles like Al_2O_3, SiO_2 and TiO_2 have been found as appropriate surface hardening materials to improve scratch resistance of metals (Bautista *et al*., 2011; Bose, 2013; Gerberich and Yang, 2003; Sangermano and Messori, 2010; Zhao, 2014). Alumina and carbon nano-tubes (CNT) based ceramic nanocomposite has shown increase in toughness (Ahmad *et al*., 2010; Chen *et al*., 2000; H. J. Kim *et al*., 2014; Nam *et al*., 2014; Puchy *et al*., 2013) of the metals. These materials can be harnessed to reduce the wear of the engine components like piston, cylinder liner, crankshaft, camshaft, valves, rocker arm assembly, power transmission shafts, gears etc.

2.2. Clutches and Brakes

A clutch is a mechanical component that makes smooth, gradual connection of two coaxial shafts rotating at different speeds whereas a brake slows down, stops or control the speed of an automotive system by controlled dissipation of energy. Both uses friction material as their functional component. Conventional styrene butadiene rubber and nitrile-butadiene rubber which is used to make clutch facings, disc brake pads and brake linings can be replaced with nano-filled friction materials. These friction materials have low wearing rate and improved friction coefficient (Du *et al*., 2011; Liu *et al*., 2006). Adding silicon carbide (SiC), alumina and silica into metal hybrid composites enhance the frictional as well wear resistance property of material (Navin and Deivasigamani, 2015). Material coated with nano particles of silica carbide (SiC) exhibits best frictional properties followed by alumina and silica; and also silica results best wear resistance followed by Sic and alumina (Bijwe *et al*., 2012). The performance of brake friction material can be enhanced by adding nano-clay and multi-walled carbon-nanotubes (Singh *et al*., 2015).

2.3. Tyres and Batteries

2.3.1. Tyre

Tyre performance is dependent on its rubber composition which is in direct contact with soil or road. In conventional methods, material like carbon black, calcium silicate and silica are added as filler to enhance the physical properties- like- tear resistance, reduced rolling resistance, abrasion resistance and grip(Edwards, 1990) of the rubber. The incorporation of these material at nanometric scale can significantly improve tyre properties. Nano particle reinforcement leads to increase the strength and fatigue characterizations of rubber materials(Al-Wazir, 2018; Fritzsche *et al.*, 2009; Y. A. Kim *et al.*, 2006; Nah *et al.*, 2010; Sui *et al.*, 2008)reported enhanced mechanical stiffness and tensile strength by the dispersion of Carbon nanotubes (CNT) in silica-filled natural rubber. Carbon nanotubes composite with styrene-butadiene rubber depicted increase in tensile strength, tear strength and hardness almost by 600%, 250% and 70%, respectively (Zhou *et al.*, 2010) Nanoparticles embedment in tyre rubber can significantly reduce rolling resistance and result into better traction in comparison to traditional carbon black based tyres. Different composition of other nano-family members like graphene, alumina, carbon nano-fibres and reinforced polymer nanocomposites can be used to improve mechanical properties of tyre rubber as desired.

2.3.2. Batteries

Traditional lithium-ion technology uses active materials, such as cobalt-oxide or manganese oxide, with particles that range in size between 5 and 20 micrometers (5000 and 20000 nanometers - over 100 times nanoscale). As per demand of modern agricultural machinery, there is need to increase the available power from a battery and decrease time required to recharge it. This can be achieved by coating the surface of an electrode with nanoparticles. This increases the surface area of the electrode thereby allowing more current to flow between the electrode and the chemicals inside the battery (Bruce *et al*., 2008).

Carbon nanotubes (CNT) are now being used to replace conventional graphite electrodes in batteries. These nanomaterials have extraordinary high surface area, good electrical conductivity and linear geometry which make their surface areas highly accessible to battery electrolyte resulting in increased electricity output. The conductivity of electrolytes is also increased by introducing nanoparticle into it and this equally leads to increased energy output. The increase in output from a given amount of material results in more powerful, smaller and lighter batteries which can be used for a wide range of applications. Also nano batteries which can recharge at about 60 times faster than conventional batteries have been developed. Some of these can operate over a broader range of temperature than is currently achievable. Again batteries which prevent electrodes contact prior to activation have also been developed using nanotechnology and this gives limitless shelf life and longer active life to such batteries. In the case of capacitors, millions of nanotubes are used to increase the electrode surface area and thus the amount of energy that can be held since the storage capacity of capacitors are proportional to the surface area of the electrode (Echiegu, 2016).

2.4. Fuel and Lubricants

2.4.1. Diesel fuel

A study on performance, combustion and emission characteristics of a single cylinder direct injection (DI) diesel engine with three fuel series: biodiesel–diesel (B20), biodiesel–diesel–nanoparticles (B20A30C30) and biodiesel–nanoparticles (B100A30C30) was conducted. The nanoparticles such as Alumina (Al_2O_3) and Cerium oxide (CeO_2) of each 30 ppm were mixed with the fuel blends by means of an ultrasonicator, to attain uniform suspension. Owing to the higher surface area/volume ratio characteristics of nanoparticles, the degree of mixing and chemical reactivity were enhanced during the combustion, attaining better performance, combustion and emission attributes of the diesel engine. The brake thermal efficiency of the engine for the nanoparticles dispersed test fuel (B20A30C30) significantly improved by 12%, followed by 30% reduction in NO emission, 60% reduction in carbon monoxide emission, 44% reduction in hydrocarbon emission and 38% reduction in smoke emission, compared to that of B100 (Prabu, 2018).

2.4.2. Lubricant

Lubricant is a material that reduces the friction between surfaces in mutual contact. In combustion engines, the piston and rings assembly is responsible for 40 to 50% of the frictional losses (Ali and Xianjun, 2015). Conventional lubricants decreases the friction coefficient between surfaces but this is also accompanied by reduced viscosity of the oil. The low viscosity leads to reduced load-carrying capacity of the lubricant. Under high load and low speed conditions, where the two surfaces are so close to each other that contact between them might be possible (boundary lubrication), the traditional lubricating oils becomes lesser effective. In such cases, the nano-lubricants plays an important role. These lubricants are stable at high temperature, have high surface area and higher thermal conductivity than their conventional counterparts (Martin and Ohmae, 2008). This results into improved engine performance and fuel economy. Aluminium oxide and titanium oxide based nano lubricants decreases the friction coefficient by 35-51% near the ends of the engine strokes (Ali, Xianjun, Elagouz, *et al.*, 2016). Carbon and graphite nano tubes can enhance the lubricity of regular engine oil(Esfe *et al.*, 2016; Ettefaghi *et al.*, 2013).

2.4.3. Fuel injection

Conventional fuel injection methods suffers from major drawbacks like poor atomization, incomplete combustion, carbon build-up, exhaust emissions toxic to environment. Evenly distributed and uniformly sized molecules of fuel mixed well with air results into efficient burning. Impregnating petrol or diesel molecules with nano-particles can stop clustering of hydrocarbons and thus lead to complete combustion.Water particles in the range of 0.1~0.5µm are uniformly dispersed into liquid fuels(Selim and Ghannam, 2010) along with an additive to stabilize the emulsion. This emulsion have high effective surface area of fuel particles to react with air and results into drastic improvements in fuel efficiency and reduction in harmful emissions (Khalife *et al.*, 2017) Diesel-water emulsion significantly reduce the formation of carbon monoxide, nitrogen oxides and particulate matter in the combustion chamber (Ali, Xianjun, Turkson, *et al.*, 2016; Annamalai *et al.*, 2016; Bidita *et al.*, 2016; Khalife *et al.*, 2017). Biofuels prepared through contemporary biological processes like anaerobic digestioncan also be emulsified with water in the same way. Production of biofuels from vegetable oils using nano-catalyst also have high conversion rate of the oil (Boz *et al.*, 2009).

2.4.4. Emission control

The exhaust gases from combustion engines contain components which are harmful to the environment. Major members in this list are hydrocarbons, carbon monoxide (CO), NO_x, particulate matter, sulphur oxide (SO_x) and volatile organic compounds (VOCs). These components have variety of negative effects on public health and the natural environment. Due to growing environment concern and regulatory limits, these pollutants must be broken down into non-harmful components. Conventionally, this is done by using different catalysts (Johnson, 2008). These active catalyst are mounted at exhaust pipes in steel housing. When the emission passes over them, it is broken down in simpler compounds like nitrogen, carbon, sulphur etc. Due to small catalyst surface, these catalyst have short life span. Nano technology can play important role in increasing the active area of the catalysts to react with pollutants. Nano-fuel additives are effective in reducing pollutants in emissions. Addition of Alumina and Cerium oxide nano particles in Jatropha biodiesel at mixed proportions of 10, 30 and 60 parts per million, has reduced nitric oxide, carbon monoxide, unburned hydrocarbon and smoke emission by 13%, 60%, 33% and 32% respectively (Prabu and Anand, 2016) Magnalium (Al-Mg) and cobalt oxide (Co_3O_4) (Ganesh and Gowrishankar, 2011), MgO-CeO_2-supported platinum (Olympiou and Efstathiou, 2011), zinc oxide (Karthikeyan *et al*., 2014), Mn_2O_3 (Jeon *et al*., 2014) and other metal nano catalyst can effectively make the emission cleaner besides increasing the brake thermal efficiency. Gold, otherwise considered as an inert material, in its nano form has shown ability to oxidize carbon monoxide (CO) effectively (Corti *et al*., 2002; Hvolbæk *et al*., 2007).

2.5. Energy

Even in the area of non-renewable energy generation, nanotechnology is equally useful. By making the production of fuel from low grade raw material economical, the technology can address the shortage of fossil fuels, such as diesel and gasoline. It can also be used to make the production of fuels from normal raw materials more efficiently. And by reducing friction using lubricants fortified with nanoparticles, energy consumption from conventional engines can be significantly reduced leading to increased service life of engines.

Reducing cost and improving conversion efficiency are the main tasks in order to make photovoltaic energy competitive and able to substitute traditional fossil energies. Nanotechnology seems to be the way by which photovoltaics can be developed, whether in inorganic or organic solar cells. Wide-bandgap nanostructured materials (nanomaterials) prepared from II–VI and III–V elements are attracting an increased attention for their potential applications in emerging energy. They can be prepared in different geometric shapes, including nanowires (NWs), nano belts, nano springs, nanoc ombs, and nano pagodas. Variations in the atom arrangements in order to minimize the electrostatic energy originated from the ionic charge on the polar surface are responsible for a wide range of nanostructures (Tala-ighil, 2015).

Classic nanostructures such as carbon nanotubes (CNT), fullerenes and quantum dots are being used to make solar cells lighter, cheaper and more efficient. The increased surface area to volume ratio of nanoparticles enhances solar radiation collection by exposing more conducting surfaces to solar radiation. Also the use of nanomaterials such as lead selenide results in more electrons (and therefore more electricity) to be released when hit by a photon of light. Structural properties of PV cells are additionally being modified using nanotechnology.

3. NANOTECHNOLOGY IN FARM MACHINERY

3.1. Tillage Machinery

Proper tools and equipment are essential for performing effective tillage operations. For every tillage practices there is need of tools and implement of proper quality and strength. The work condition of agricultural tools and implements is quite different and the tool undergoes wear due to availability of hard mineral particles in soil. The alloy steel with highly abrasive and corrosion resistant is beyond affordability of farmers so the material mostly used for soil engaging tools are medium carbon steel with small addition of manganese and silicon (Stabryla, 2007). The major constraint in use of medium carbon steel is its low wear and abrasion resistant property. Some manufacturer apply heat treatment like full quenching and tempering or surface hardening to soil engaging tool for improving their hardness but tool with low hardness undergo abrasive wear while products with high hardness wear out slowly, but they often crack. To overcome this problem in last few years micro-alloyed steels are being used which have high wear resistance and are only 10% more expensive than medium carbon steel(Stabryla, 2004). For increasing life of agricultural tools there is need of steels which has resistant to abrasion, mechanical loads, and hydrogen penetration. Some researchers have reported that steel with a micro-addition of boron in a quantity of 0.002–0.005% in low carbon steels improves hardening ability and strengthens grain boundaries(Lunarska *et al.*, 2005).

Corrosion is also a major factor for influencing the life of agricultural tool. It is chemical or electrochemical reaction between a material and its environment. It produces deterioration of the material or of its properties(Trethewey and Chamberlain, 1995). The corrosion of soil engaging tool depends on its working environment and its behaviour in wet as well as dry condition. Application of nanotechnology in the field of corrosion protection requires good understanding of the corrosion behavior of the materials at microstructure level. Nanostructured materials of 1–100 nm are known for their outstanding mechanical and physical properties due to their extremely fine grain size and high grain boundary volume fraction(Nalwa, 2000).Nanoporous metals (NPMs) made by dealloying represent a class of functional materials with the unique structural properties of mechanical rigidity, electrical conductivity, and high corrosion resistance (Ding and Chen, 2009).

Heavy weight agricultural machinery create soil compaction and causes excess load on prime mover. By reducing the weight of machinery we can increase the fuel efficiency, reduce CO_2 emissions as well as production cost. It is estimated that by reducing the weight of an automobile by 10% there will be fuel economy of 7% (Coelho *et al.*, 2012). The materials of engine parts of machinery should have higher thermal resistance and other parts of body should have high mechanical strength. Carbon nanotubes (CNT) have very less weight and around 150 times stronger than that of steel. Therefore CNTs are good substitute for steel in machinery which gives us more strength and weight reduction(Steevan, 2015).

3.2. Protection of Farm Machinery

Theadvantages to paint machines are improved appearance, rust and corrosion prevention, weather resistance, thermal protection, extended equipment service life, fewer breakdowns, enhanced productivity, ease of maintenance, increased savings and higher resale value(Hughes, 2015).Nano-coatings are materials that are produced by shrinking the material at the molecular level to form a denser product. Many of the nanoparticles like nano- ZnO are non-toxic in nature and thus add another advantage to coating industry. Nano-coating can be applied in many ways including chemical Vapor Phase Deposition (VPD), physical Vapor Phase Deposition, electrochemical deposition, Sol-gel methods, electro-spark deposition and laser beam surface treatment (Khanna, 2008).

Nanoparticles such as Zirconium dioxide (ZrO2), Aluminium oxyhydroxide (AlO(OH)), and Silicon dioxide (SiO2) are embedded in ultra violet curable lacquers which results in improved abrasion resistance. Using nanoparticles of titania or zinc oxide will help to improve UV resistance property(Seubert *et al.*, 2012). For achieving better scratch and abrasion resistant film, siloxane encapsulated SiO2 nanoparticles can be used (Gläsel *et al.*, 2000). Different nano-materials useful for painting and their functions are given in Table 1.

A multifunctional amorphous alloy possesses three corrosion protection abilities when deployed as a coating over structural alloys. The coating (i) functions as a local corrosion barrier, (ii) serves as a sacrificial anode, and (iii) supplies soluble ions used as corrosion inhibitors by engineering metallurgical and electrochemical properties (Presuel-Moreno *et al*., 2008)**.**

Tungsten Carbide nano-particles dispersed in a metal Tungsten matrix results in enhanced hardness and abrasion resistance. The coating can be produced up to 100 microns thick, which is unique for hard Chemical Vapour Deposition (CVD) coatings. As a nano-structured material, it demonstrates outstanding toughness, crack and impact resistance. The gas-phase CVD process enables the coating of internal surfaces and complex designs such as valves, hydraulic components and pump cylinders. The pore-free coating is resistant to acids and aggressive media. This combination of wear resistance and chemical resistance makes CVD Tungsten Carbide coating an attractive solution to coat critical components in high wear and/or aggressive media environments (Zhuk, 2010).

Table 1.
Nanomaterials useful for painting and their function.

Nanomaterials	Function
SiO_2, Al_2O_3, ZrO_2	Scratch resistance
Nanoclay, graphene	Gas barrier
CuO, TiO_2, ZnO	Antimicrobial
Nanoclay	Corrosion and fire retardant
TiO_2, ZnO, $BaSO_4$, CeO_2, graphene	Ultraviolet stability
SiO_2, $CaSiO_3$, CNTs, TiO_2	Impact resistance
CNTs, ZrO_2, nanoclay	Heat resistance
SnO_2, CNTs, graphene	Electrical conductivity

(Source: Mathew et al., 2019)

3.3. Drones

Nanotechnology is being used far more widely in the drone industry to reduce weight, to extend flight times, to enhance the performance of small components and to increase the durability of the materials. Time spent in landing, swapping batteries and regaining a position wastes lot of time. Increased battery life will ensure a steady, controlled flight without interruptions. Nano-nouvelle in Australia created graphene batteries which lightens the weight and helps to increase the flight time. Their new batteries increase the storage capacity of lithium-ion batteries by up to 50%. Nanocoatings could help by strengthening components, without adding too much weight. It also takes care of risk of damage in bad weather and adverse temperatures (Anonymous, 2016).

Nanotechnology is also being used to develop new agrochemical formulations, improving the performance of active ingredients to strengthen potency of the spray, which subsequently will allow a greater area to be treated with the same volume of liquid. The UAVs, equipped with a tank and nozzles, link to an iPad or tablet and use GPS navigation. Aerial mapping data of disease hotspots or weed infestations is integrated with the UAV control software, enabling the programming of a pre-planned course to target specific areas of a field (Anonymous, 2016).

4. NANOTECHNOLOGY IN IRRIGATION AND FERTILIZER APPLICATION

4.1. Irrigation

Irrigation is the artificial application of water to farmland and the crops in order to boost agricultural production and performance (Michael and Ojha, 2018). The quality of water used for irrigation is essential for better yield, maintenance of soil productivity and protection of the environment. A fluidized bed photo reactor amended with nano-sized TiO_2 coated on silica beads and illuminated by UV light (254 nm, 18 W cm^{-2}) was capable of removing 99.9% of bacteria and viruses from water with less than 60 seconds of contact time (Brame *et al*., 2014).

Salinity of ground water is a major problem for which number of low-energy alternatives have been developed by using nanotechnology, among which the three most promising are: (a) protein–polymer biomimetic membranes, (2) aligned carbon nanotube membranes and (3) thin film nanocomposite membranes. These technologies have shown up to 1000 times better desalination efficiencies than RO, as these have high water permeability due to the presence of carbon nanotube membranes in their structure (Dasgupta *et al*., 2017).

4.2. Plant Protection and Fertilizer Application

Agricultural production is to a great extent influenced by some plant diseases and insect pests, causing great economic losses. In this context, nanotechnology can be applied in agriculture by means of precision and controlled release of pesticides, insecticides, herbicides, and insect repellents. With development of new equipment for detection of disease, disease diagnosis, increasing nutrient absorbing ability of plant, etc. nanotechnology will bring revolution in agriculture and food industries. Smart sensors and smart delivery systems will help the agricultural industry combat viruses and other crop pathogens. In upcoming time, nano structured catalysts will be available which will increase the efficiency of pesticides and herbicides, allowing lower doses to be used (Shaimaa and Mostafa, 2015).

In precision farming practice, Normalized Difference in Vegetative Index (NDVI) sensor or green seeker is a tool to identify the plant disease and deficiency of fertilizer in crop. NDVI uses light emitting diodes (nano-based) to generate red and near infrared light which are used to calculate NDVI values. Green seeker calculates the normalized difference in vegetative index using red and near infra-red light. It is based on the simple principle that plant chlorophyll absorb red light as an energy source during photosynthesis. Therefore, healthy plants absorb more red lights and reflect larger amounts of near infra-red light than those that are unhealthy and thus give higher NDVI value. NDVI is calculated using following equation (Duhan *et al*., 2017):

$$NDVI = NIR_{reflected} - Red_{reflected}/NIR_{reflected} + Red_{reflected} \quad ...(1)$$

Nowadays, Nano-fertilizers are increasingly been used as alternates to bulk fertilizers and reduce pollution of soil and water by different agrochemicals. Nano-fertilizers facilitate the slow and steady release of nutrients and thereby reduce the loss of nutrients and enhance the nutrient use efficiency (Abobatta, 2018). Fertilizers with sulphur nanocoating (≤100 nm layer) are useful as slow release fertilizers because sulphur contents are beneficial especially for sulphur deficient soils. IFFCO environment friendly nano urea (liquid) fertilizer is available for precision and sustainable agriculture which reduces the requirement of conventional Urea by 50% and has efficacy of one bottle liquid (500 mL) is equivalent to one bag of urea (Anonymous, 2020).

In the area of biomass production, nanotechnology can be used to enhance bio-availability of plant nutrient and to detect and treat diseases efficiently and effectively using smart sensors. It can also be used to increase the efficiency of herbicides and pesticides thereby allowing for the use of smaller doses. All these leads to reduced cost of production and increased biomass yield. The biomass can be in form of fuel wood which can be harvested and used for cooking. It can also be in form of algae or crops such as oilseeds which can be used for the production of biofuels. A method of extracting oil from algae without destroying the plants is also being developed. Nanoparticles with many pores are used to soak up the oil like sponge and this oil can be processed into biodiesel (Echiegu, 2016).

5. CONCLUSIONS

Though nanoscience and nanotechnology is being used in diversified branches of engineering, its application in farm machinery and farm power is very less. This may be due to sophisticated technology involved in adopting nano-technology, apprehension in escalation of cost of production and poor awareness amongst the small manufacturers of farm machinery.This review paper will definitely be an eye-opener for all those involved in research and development of agricultural machinery and tractor industry, as systematic review of possible inclusion of nanotechnology in different sub-systems of tractors and various farm machinery. This will definitely enhance the overall performance of the machinery in terms of reduced weight, enhanced wear and tear resistance, weather resistance, thermal protection, extended equipment service life, fewer breakdowns andenhanced productivitybesides ease of maintenance, increased savings and higher resale value.

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