Nanotechnology Applications in Power and Farm Machinery Sector: A Review

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ABSTRACT: Agriculture sector is one of the social, economic elements and indicators of sustainable development in any country, investigating the impact of the introduction of new technologies such as nanotechnology into this sector is of particular importance. In recent years, some research has appeared studying the effect of using nanomaterials as an alternative solution in the field of power and farm machinery on improving the performance of agricultural equipment. This review covers the current applications and challenges that are exploring by the researchers in the area of nanotechnology in improving the production of construction materials and agricultural equipment coatings, such as coatings that are resistant to sunlight and wear in machinery, sensors for increased precision and performance, machinery tires, microprocessors, lubricants, Coolants, and soil conditioners , ultimately, the impact of this technology on improving the performance of agricultural equipment. Finally, it can be concluded that nanotechnology is an essential axis in the development of the power and farm machinery sector. Therefore, we recommend more research to study and suggest a solution for challenges facing the use of this technology and to work on transforming research results into productive projects to link research with investors

Keywords: Nanotechnology, Power and Farm Machinery.

INTRODUCTION: The nanotechnology revolution experienced in the last few years had a huge impact on various science fields (agriculture, chemistry, engineering, biology), also affecting the construction industry. In the engineering field, tractors and agricultural machinery are classified as "mechanical equipment". So, the application of nanotechnology extended to other types of mechanical equipment (earth moving equipment, road construction, cranes, lathes and cutting machines, drilling machines, concrete mixers, civilian and military vehicles, etc.) to satisfy the same purposes of improving performance and durability. It can also be seen nowadays, that the majority of all kinds of equipment including those related to marine, air, and land transportation; depend on internal combustion engines as a main source of power supply.

Conceptually, nanotechnology may be defined as the ability to create new structures at the smallest scale, using tools and techniques that allow the understanding and manipulation of matter at nanoscale, generally from 0.1 to 100 nm (Zhu, Bartos, and Porro 2004). Although this is the most often used definition, a size limitation of nanotechnology to a range below 100 nm seems to exclude numerous materials and devices.

Agriculture is always the most substantial and stable sector because it meets dietary and nutritional requirements in an adequate manner, produces and provides raw materials for food and feed industries. The limit of natural resources such as production land, water, soil, and etc. In addition to the growth of population in the world claim the agricultural development to be economically further, viable, environmentally and efficiently. This alteration will be the vital for achieving many factors in the recent years (Mukhopadhyay 2014). Nanotechnology is emerging as the technological platform for development and transformation of agriculture systems (Scrinis and Lyons 2007).

Since nanotechnology, as one of these new technologies, has a growing trend in the production and manufacture of all the equipment used in everyday life. In the meantime, nanotechnology has special features related to hard-working conditions, design and durability characteristics of agricultural equipment and one of its areas of application can be in the field of producing and manufacturing agricultural equipment with special features in different fields (Dehkordi and Keivani 2017).

1. The application of nanotechnology in the chassis and body of agricultural machinery and equipment:

The hard-working conditions for agricultural machinery and equipment, especially tractors, combines and other machines used in fields or gardens, further specify the need for utilizing more durable parts. Nanocomposites with improved mechanical properties compared to conventional composites can be a new approach to lightening and even replacing metal parts in agricultural machinery. Theoretically, these materials can be easily extruded or molded in the final shape, while they have the same strength of the metal and are lighter (Dehkordi and Keivani 2017). This not only affects increasing the life time of this equipment, but also lightening them, reducing fuel consumption and, consequently, reducing environmental pollution. These composites also have two other advantages. First, nanoparticles significantly provide a more beauty by creating a smooth and uniform network structure, and thus nanocomposites have a more acceptable appearance surface and more transparent colors. Furthermore, nanocomposites are lighter than common composites up to around 22% due to the need for lesser reinforcing materials, and therefore the use of nanocomposites in the production and construction of agricultural equipment and machinery is very important (Vatan-Dolat-Xah 2006).

1.1. The Effect of Nano-Structured Coating material on Reducing Abrasive Wear of Tillage Tools:

Wear is the most important limiting factor of life and performance of cutting tools and other tillage tools. The tillage blades are exposed to severe wear because adverse friction of cutting the soil and separating it from the ground in an intact way compared with other agricultural tools. Wear of tillage tools is a kind of roaring wear. Roaring wear mechanism is created in contact with each other in the presence of hard particles on one or both tool surfaces. The hard roughness of the surface can also be the cause of this type of wear (Rabinowicz and Tanner 1966). The wear depends on many parameters such as geometry, strength and surface properties. Moisture content can be an important factor in this regard. Changes in moisture can affect the wear resistance of the nanostructured materials in different orders (Czichos and Misra 1978).

Since the use of sunlight-resistant and wear-resistant paint in the machinery is essential, nanometric coatings for various purposes such as increased strength, improved bending and sheeting properties, protective coatings resistant to corrosion, scratches, wear and nanocomposites have been used due to high strength and durability against environmental factors. One of the most important applications of this technology in the machinery industry is the production of materials such as Mica and Talc which in addition to the apparent beauty, has increased the strength and, in part, the weight loss of agricultural equipment, and finally, has caused to reduce the compaction of agricultural soils and be lacking the formation of hard layers. Furthermore, the application of nanotechnology in the production of agricultural machinery and equipment will cause reducing in fuel consumption in agricultural machinery and increase the life of parts and, ultimately, increase economic efficiency. Ceramic coatings of nanoparticles contribute to thermal stability and erosion resistance in engine parts (Asadi-Fard 2017).

Hardness and wear resistance are two important properties of objects that are used in a wear environment. By definition, hardness of a material and its resistance to plastic deformation is localized and has a direct relationship with wear resistance. Nickel electroplating is based on using a nickel anode and applying a direct current to the anode and cathode in an aqueous environment containing nickel ions. Passing a direct current causes anode electrode dissolution in the electrolyte and nickel is coated on the cathode. It has been proved that stiffness can be increased by fine grain size materials, without reducing the flexibility of the material. In nickel nanostructured coatings which have an average grain size of about 100 nm and produced by electroplating method, wear resistance is about 100 to 170 times than nickel coatings with the average grain size of about 100 micrometers. The coefficient of friction of these coatings is about 40 to 50 percent less than conventional nickel coatings (Ebrahimi et al. 1999).

Size and shape of grains in a coating have large effects on the mechanical properties such as hardness. The smaller the grain size of a coating, the less the friction coefficient will be. These differences are due to the changing in wear mechanism by changes in the grains size. Wear resistance of a conventional nickel coating is low. However, nickel nanostructured coatings have high resistance against wear. There is a relationship between the shape, grain size of coating and mechanical and physical properties of coating with the conditions of plating that awareness of this relationship makes nano-nickel coating replacement with chromium coating affordable (Ebrahimi et al. 1999)

(Abed, Bahrololoom, and Kasraei 2019) studied the influence of three methods of coating, including DC electroplating, pulse electroplating and the electro plasma methods for coating of nickel compounds on pieces carved from high carbon steel material (Ck60). Resistance of the coatings to abrasion was assessed with the criterion of proportion of weight reduction due to abrasion in the farm of operations. They found that coating made by DC electroplating, improved abrasion resistance in the samples by 30.41%. The coatings made by pulse electroplating on the pieces could improve abrasion resistance relative to raw samples by 55.83%. In the electro plasma method, by formation of coatings that had complex compositions, resistance to abrasion increased up to 90% relative to raw samples. It is noteworthy that such resistance to abrasion was in samples with the 480 HV and average grain size of 38 nanometers. The less the average sizes of grains of nickel Nano-coatings of the structure, the more the hardness and, consequently, the more wear resistance.

(Zain El-Din et al. 2019) studied the reducing wear behavior of soil working tools by coating and treating processes of the tool surfaces. Three different carbon steel materials: API 52, M238 and K110 was used. Some of the previous specimens were treated with two different coating materials: Hard chrome, HCR, and carbon nanotubes- hard chrome composite, CNTs + HCR. The other specimens were treated by: conventional heat treatment, HT, and nirtocarborizing treatment, NC. Both the coated and treated tool specimens were mounted on a circular soil bin containing sandy clay loam soil at 14% moisture content. The working speed was adjusted at 5 km/h (1.39 m/s). The coating thickness and the mass of tools were measured before and after each test. The test duration of tillage operation was conducted for 200 h for both coated and treated tools. Results obtained from all tests showed that, the wearing rate of coated specimens by carbon nanotubes-hard chrome composite CNTs + HCR were the minimum compared with other treatments. Results also showed that the surface roughness was the minimum.

1.2. The Effect of Nano Coating material on engine performance:

In a traditional internal combustion engine (ICE), roughly 33% of the fuel supplied is converted into useful operation, for exhaust gases a large part of the energy is wasted and the remaining part of the energy is discharged in the form of heat through the cooling system (Taymaz 2006). Through reducing heat losses, the diesel engine efficiency can be increased. Reducing the flow of heat through the internal combustion engine walls is the main objective of adiabatic engines which are also known as low heat rejection engines. Also, this kind of engines named as coated engines with thermal barriers (Murthy et al. 2010).

The thermal barrier coated engines are otherwise known as LHR engines. Due to the insulation of the cylinder wall the heat transfer through the cylinder walls to the cooling system is reduced which changes the combustion characteristics of the diesel engine. Thermal barrier coatings control the inside of cylinder heat rejection, protect the thermal fatigue of underlying metallic surfaces and also decrease CO, smoke, HC emissions (Yilmaz and Gumus 2017) .The diesel engine with its combustion chamber walls, cylinder head, liner, and piston crown insulated by ceramics is referred to as LHR engine (Garud et al. 2017).

There are a wide range of ceramic coatings that can be applied to metal components in order to increase their functional properties. Ceramic materials, like magnesium zirconated and zirconia, exhibiting a high rank of hardness, thermal resistance, and elevated melting points are being used as heat barrier coatings for engine parts. The piston surface and valves of a single cylinder diesel engine were coated with ZrO_2 ceramic coating material in order to reduce the heat rejected from the mentioned part (Işcan 2016).

(Ramalingam, Rajendran, and Ganesan 2016) investigated that when copper and nickel nano catalyst coatings were used on the piston top hydrocarbons emissions were reduced by 64%, smoke level reduced up to 21%, NOX emissions also reduced up to 45%, brake thermal efficiency and specific fuel consumption were improved in copper nano catalyst coated pistons.

2. The application of nanotechnology in the production of lubricants required in agricultural machinery and equipment:

Wear and tear on engine components is common because of friction and it happens in all machinery with moving parts. The functions of automotive engine oil are providing stable oil film between sliding surfaces, provides reliable engine operation in a wide temperature range, rust/corrosion protection of the engine parts, cleaning the sludge from engine parts, prevention of foaming, absorption heat from engine parts, reduction the losses power and engine vibrations.

Engine oil lubricants make up nearly one-half of the lubricant market and therefore attract a lot of interest. Currently lubricant formulators are looking to achieve improved fuel economy through lower viscosity engine oils and by using new and more effective friction modifiers (Jao, Devlin, and Aradi 2014).

Nano particulate additives may function in different ways. The mechanisms by which oils having nano-additives reduce friction and wear under boundary lubrication are the colloidal effect, rolling effect, small-size effect, protective film effect and third body effect (Li et al. 2006) . Soft nanomaterials act as a cohesive third body that can exist between two surfaces to reduce wear and reduce friction, which radically deforms under load and accommodates surface velocity differences mostly by adhering to surfaces and shearing in the bulk medium. Granular nanomaterials are cohesion less hard particles that adequately maintain their spherical geometry under load and accommodate surface velocity differences through sliding and rolling at low shear rates (Deepika 2020).

(Ali et al. 2016) showed that the friction coefficient during boundary lubrication decreased by 35-51% near ends of the stroke (TDC and BDC) for the Al_2O_3 and TiO_2 nano-lubricants, respectively. The significant decline in the friction coefficient might be because of the leading role of nanomaterials to act through different mechanisms such as micro rolling bearing, film deposition, and mending effect mechanisms. Additionally, the spherical morphology of the nanoparticles used as nanoparticles lube additives is also considered an important factor that supplies a rolling effect between rubbing surfaces. Because of this reason, nano lubricants are most effective under boundary lubrication conditions.

(Li et al. 2010) reported that the absorbency of nano lubricant with ZrO_2/SiO_2 nanoparticles was still stable after 56 h. but, at 76 h the nanoparticles stability was decreased by 3.5%. (Ali et al. 2018) explained that development of nano-lubricants with a high concentration of nanoparticles is difficult because of agglomeration problem. Hence, the dispersion stability of the nanoparticles in lubricant oils remains a key challenge in the formulation of nano-lubricants owing to the short time of the stability. Therefore, it is substantial to study the related influencing factors to improve the nanoparticles stability in lube oils.

3. Application of Nano Coolants for agricultural machinery and equipment:

The cooling system serves three important functions. First, it removes excess heat from the engine; second, it maintains the engine operating temperature where it works most efficiently; and finally, it brings the engine up to the right operating temperature as quickly as possible. In recent days nano coolant has come to overcome requirement of better heat transfer because of low thermal conductivity of conventional fluid such as water and ethylene glycol (Saxena and Soni 2018).

(Chavan and Pise 2014) studied forced convective heat transfer in an Al_2O_3/water nanofluid. Five different concentrations of nanofluids in the range of 0–1.0 vol. % were prepared by the addition of Al_2O_3 nanoparticles into the water. Obtained results elucidate that increasing the fluid circulating rate can improve the heat transfer performance. The application of the nanofluid with low concentration can enhance heat transfer efficiency up to 40–45% in comparison with pure water.

(Chougule and Sahu 2014) studied the forced convective heat transfer performance of two different nano fluids, Al_2O_3-water and CNT-water in an automobile radiator. Four different concentrations of nano fluid in the range of 0.15–1 vol. % were prepared by the additions of nano particles into the water as base fluid. The result illustrated that nano fluids exhibit enormous change in the heat transfer compared with the pure water. The heat transfer performance of CNT-water nano fluid was found to be better than Al_2O_3-water nano coolant.

(Salamon, Senthil kumar, and Thirumalini 2017) analyzed experimentally and compared the heat transfer characteristics of water/propylene glycol based TiO2 nano fluid with pure water and water/propylene glycol mixture. Two different concentrations of nano fluids were prepared by adding 0.1 vol. % and 0.3 vol. % of TiO2 nano particles into water/propylene glycol mixture (70:30). The results showed that the Nusselt number of the nano fluid coolant increases which increases the convection heat transfer coefficient and consequently increase in flow rate. At low inlet coolant temperature, the water/propylene glycol mixture showed higher heat transfer rate when compared with nano fluid coolant. At higher operating temperature and higher coolant flow rate, 0.3 vol. % of TiO2 nano fluid enhances the heat transfer rate by 8.5% when compared to base fluids.

A huge amount of research has been conducted on nano coolant within last decades. applications of the research works were focused mainly on water and ethylene glycol based nano coolant, very few researches of the synthesis of oil-based nanofluids have been found. (Xuan and Li 2000)explained that oil-based nano fluids exhibited better enhancement of heat transfer characteristics compared to water based nano fluids, and that the viscosity of the oil could be crucial for the dispersion and stability of nano fluids.

4. The application of nanotechnology in agricultural equipment and machinery tires:

Agriculture has faced a gradual transition towards higher working speeds for all machines involved and greater use of transport-oriented farm tractors, due to a constantly-increasing demand for higher productivities and lower costs. This change raises lots of issues for many technical systems of agricultural vehicles. **t**he mechanical behavior of agricultural tire is a matter of extreme interest as it is related to the comfort of operators, to the adherence of agricultural machines, and to the compaction of agricultural soil. Moreover, the deformability of the tires plays a fundamental role in vehicle stability in terms of side rollover. The behavior of a loaded tire during its deformation is complex, due to the combined contributions of the structure components, the tread rubber and the air contained within it (Anifantis, Cutini, and Bietresato 2020).

The presence of nanoparticles in the structure of tire increases wear resistance, strength (improving the mechanical properties of the fracture) and the smoothness and elegance of the apparent beauty of the tire. All of these factors produce a high-quality product that can last longer in a variety of conditions for tractors and combines. By adding these nanoparticles to the tire, the amount of rubber required for the tire is reduced, and the tire becomes lighter and cheaper and remains cooler while moving. Today, nanotechnology has created a profound transformation in the industry (Dehkordi and Keivani 2017).

(El-Zomor 2019) evaluated the tire performance characteristics under different operating conditions. The tire load deflection characteristic has been examined by loading and unloading the tested tire while resting on a hard surface at three inflation pressures. Three different percentages of CuO (copper oxide) nanoparticles have been used to evaluate their effect on the tire hysteresis losses. The results showed that the higher hysteresis losses were at tire inflation pressure 20 psi. Adding CuO nanoparticle in very small amounts with the enclosed air of the tested tire can be useful for improving its performance significantly and decreasing the hysteresis losses.

The addition of appropriate nanoparticles in rubber composites shows a positive impact on the safety and durability of tires. (Alkhazraji 2018) revealed that the addition of nano-Al_2O_3 in rubber composite enhances wear resistance over time. In addition, it also showed that nano-Al_2O_3 (2.5%) with carbon black (60 phr) tremendously improved the wear rate by up to 800%, hence enhancing the safety and durability of the tires in a real application. However, in the near future, there is a need to find effective nanomaterials which could enhance the performance of tires over longer periods.

Carbon Black, conventional highly dispersible (HD) silica and two emerging nanomaterials: nano clays and new generation HD, high surface area (HD-HS) silica. These four are the most promising nanomaterials because there are a lot of data concerning them, they have been studied by many different manufacturers. Nanomaterials can be released to the environment from rubber particles wearing off or from blowouts. These mechanisms release vulcanized rubber that contains nanomaterials. The release of nanomaterials from the rubber depends on the properties of the nanomaterial and the degradation potential of the rubber in the environment.

5. Application of nanomaterials as a soil conditioner:

One of the advantages of nanoscale delivery vehicles in agronomic applications is its improved stability of the payloads against degradation in the environment, thereby increasing its effectiveness while reducing the amount applied. This reduction helps address agricultural chemicals run-off and alleviate the environmental consequence. The nanoscale delivery vehicles may be designed to “anchor” to plant roots or the surrounding soil structures and organic matter if molecular or conformational affinity between the delivery nanoscale structure and targeted structures and matters in soil could be utilized (Johnston 2010). Controlled release mechanisms allow the active ingredients to be slowly taken up, hence, avoiding temporal overdose, reducing the amount of agricultural chemicals used, and minimizing the input and waste. Environmental consideration including precision farming can reduce pollution to a minimum.

In soils, nano-size materials are hydrated and have large surface areas, and so appear to control moisture retention, permeability, solute transport, pesticide retention and availability on plant nutrients in soils. Nanomaterials also control exchange reactions of dissolved inorganic and organic species between the soil solution and colloidal surfaces. Their surface physiochemical properties provide much reactivity to soil biotic processes (Schwarz, Contescu, and Putyera 2004).

(Zheng 2011) concluded that combining the commercial positive allosteric modulator (PAM) with magnetite nanoparticles will achieve some synergistic effects that are beneficial for soil erosion control and in situ immobilization of leachable metals. First, given the anionic functional groups of PAM, strong interactions between PAM and the magnetite particles are expected. As a result, the nanoparticles may serve as "joints" or "bridges" between multiple PAM molecules, forming a polymeric network that is supposedly more effective for binding fine soil particles, and thus, soil erosion control; and second, the PAM molecules serve as a bridging agent that prevent the nanoparticles from agglomeration, and thus, maintaining high specific surface area and sorption capacity for binding leachable toxic metals such as arsenic.

(Zein El-Din et al. 2016) concluded that the use of sulfonated polyaniline (SPANI) as a nano material soil conditioner for controlling soil surface crust is appropriate from the use of polyaniline (PANI). The optimum rate of (SPANI) was 0.678%, which gave the lowest values of the soil resistance to penetration.

6. Application of Nano sensors in agricultural machinery and equipment

The relationships among field conditions, crops, and strategies for planting, irrigating, and harvesting are complex, yet vital for the success of the enterprise. Agricultural machines such as tractors, combines, mowers, and balers are key to smooth operations. Intelligent, addressable sensors on the machines and in the fields, enable farm managers to keep track of operations that are not only widely dispersed but also in motion.

Precision agriculture (PA), which has always been a long-standing wish, helps to obtain the highest output (yield) and the lowest input (fertilizers, pesticides, herbicides). The purpose of PA is to collect and process data related to the diversification of soil characteristics and the changing conditions of product production in order to increase the productivity of inputs in small units of agricultural land. One of the major roles of nanotech-based agricultural machinery and equipment is an increase in the use of automated sensors that are connected to GPS devices for real-time control. Nano sensors can be spread across the field and control and regulate the soil conditions and growth of the product. By using nano-tubes or nano-carriers, nano sensors can be constructed that are so small and can measure the size of a protein or even smaller molecules. In addition, it can be made nanoparticles or nano-surface that are able to produce electrical and chemical signals against contaminants like bacteria. It can be significantly increased the amount of product with the use of intelligent nano-sensors in precision agriculture machinery and equipment (Dehkordi and Keivani 2017).

FUTURE SCOPE AND CONCLUSIONS

Numerous studies suggest that nanotechnology will have major, long-term effects on agriculture sector. Still, the full potential of nanotechnology in the agricultural and food industry is yet to be realized and is gradually moving from theoretical knowledge towards the application regime. In general, component failures of equipment are mainly caused by abrasive wear, corrosion, fatigue wear and cracks. This obviously limits its application in agriculture equipment. Conventional coatings are difficult to avoid defects such as cracks, and the occurrence of cracks deteriorates the wear resistance of the coating. The addition of nanoparticles refines the grains, thereby suppressing cracks. Thereby improving the strength, toughness, corrosion resistance, wear resistance and thermal barrier. Therefore, nanostructured coatings will promote the upgrading of traditional industries with their good performance and durability, and eventually replace traditional technologies and produce good social and economic benefits. With the continuous development and development of surface nanotechnology, nanostructured coatings will surely be used in larger scale applications in industrial production. Due to their outstanding advantage for lubrication and cooling, nano lubricant additives and nano coolants have major potential for future development. Research should be further carried out on lowering costs. The high cost subtracts strong limitations of their application. Research on the compatibility between nanoparticle additives and other additives should be carried out. Their mixture may not have the positive synergy even if their respective properties are very good.

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الملخص العربي

تطبيقات تقنية النانو في قطاع الجرارات والآلات الزراعية: مقال مرجعي

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تقنيات النانو هي العلم الذي يهتم بدراسة ومعالجة المادة على المستوى الذري أو الجزيئي للحصول على مواد ذات حجم نانومتري وشكل محدد ولها خواص جديدة وفريدة. وأظهرت هذه التقنية طفرة نوعية في كافة المجالات وخصوصاً في مجال الطب والصناعة والهندسة والطاقة المتجددة والزراعة والمياه. يعد استخدام وتطبيق تقنية النانو فى القطاع الزراعي من المشروعات الهامة التي سوف تؤثر بشكل بالغ على برنامج التنمية في جمهورية مصر العربية. في الآونة الاخيرة ظهرت بعض الابحاث التي تدرس أثر استخدام تقنية النانو في مجال القدرة والآلات الزراعية على تحسين اداء الآلات والجرارات الزراعية. فعلى سبيل المثال يمكن استخدام المواد النانوية في طلاء الآلات الزراعية مثل أسلحة الحرث التي تتعرض لضرر كبير نتيجة التآكل الحادث لها على المدى القريب وكذلك يمكن استخدامها في طلاء اجزاء المحرك مما يزيد من العمر التشغيلي لهم ويقلل استهلاك الوقود بشكل كبير كما يقلل من القدرة المفقودة لهم. كذلك أمكن استخدام بعض المواد النانومترية كإضافات الى زيت تزيت المحركات او وسيط التبريد مما يحسن اداء المحرك بشكل كبير ويطيل العمر التشغيلي له. يمكن ايضا استخدام المواد النانومترية كمحسنات للتربة لعلاج بعض مشاكل التربة مثل تسرب المياه في الأراضي الرملية أو تكون القشرة السطحية الصلبة في الأراضي الجيرية والتي تؤثر بشكل كبير على إنتاجية الأراضي الزراعية. كما يمكن استخدامها في تحسين اداء الاطارات للجرارات والآلات الزراعية وانتاج اجهزة استشعار دقيقة لمتابعة وتحسين أداء العمليات الزراعية. ومن كل ما سبق نجد ان استخدام تقنية النانو تعد محورا أساسيا في تنمية قطاع القوى والآلات الزراعية لذلك نوصى بمزيد من الابحاث لدراسة واقتراح علاج لبعض المعوقات التي تقابل استخدام هذه التقنية الحديثة والعمل على تحويل نتائج البحوث إلى مشروعات إنتاجية للربط بين البحث العلمي والمستثمرين.