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APPLICATIONS OF NANOTECHNOLOGY IN MILITARY AIRCRAFT

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ABSTRACT

Aviation has been considered as a real initiator of research and development for a huge number of technological advances. The objective of this paper is to highlight the novel technological advances in the field of nanotechnology with relates to aviation. Nanotechnology is considered as one of the most sophisticated technologies in the world as it deals with manipulating matter on atomic and molecular scale ranging from 1 nm to 100 nm. Nanotechnology and its applications to aviation can be categorized as reducing weight of aircraft by using lighter materials which lead to improve the fuel efficiencies and improvement of aerodynamic performance in order to enhance efficiency of the aircraft. Due to the higher strength and flexibility of nano materials there are potentials of making canopies with transparent material and also the hydrophobic properties of nanomaterials will enhance better performance in windshields which leads to give better visibility during rainy and misty weather conditions even without wipers. A part from all above facts, there are several nano modified composites which have the potential of reducing vibrations in aircraft which leads to reduce the noise of aircraft. Further, there are a lot of modifications can be done for the airframe structures using these advanced materials. There are unique set of characteristics for some nanomaterials which included ballistic electron transport and high current carrying capacity, which has a tendency to do a revolution in future electronic systems. In summary, the novel technologies provide a platform to modify the existing systems in aircraft. Keywords— Asymmetric, Aircraft, Military, Nanotechnology.



1. INTRODUCTION

Humans have developed novel technologies for military purposes and these novel technologies have usually created new military opportunities which, in turn, required new procedures and concepts. When we consider winning of a war, technological superiority itself does not win wars. One of the major factors are skillful exploitation of the opportunities that technology creates and also technology is important by depending on the task and mission it serves, especially for the asymmetric threats. Technology can play a significant role towards war objectives, but we should tackle it in a skillful manner and we should have a good understanding of what exactly it is that one wants to accomplish. Basically, technology needs to be understood in its dynamics. Hence, we need to look at the overall context in which technology is being applied [1].

Air power is a technological instrument and the development of it cannot separate from technological advancement. There is a tendency from innovative aviators to find out innovative solutions to address asymmetrical threats. As per the literature [2], many air power experts believe that innovative technology can deliver fruitful solutions to address current security crisis [2]. Asymmetric threats have risen to the forefront of national security concerns in recent years. Technological advancements in airpower provides unique capabilities in the areas of dominant maneuver and precision engagement such as tactical aircraft including stealth and standoff precision weapons [3].

Advancements in technology are intended to revolutionize modern warfare and

nanotechnology is one of those emerging technologies. As per the literature [4], The United States of America is currently the leader of the development of nano based applications for military and national defence [4]. The objective of this paper is to highlight the potential applications in emerging technologies to address asymmetric warfare.

2. INTEGRITY OF TECHNOLOGY IN AIRPOWER TO ADDRESS ASYMMETRIC THREATS

Air power is a versatile and multi-faceted instrument that can find in many applications in defence. It assists to avoid aggression, promoting security and also it supports for people [4]. Asymmetric threats differ from creating asymmetry in conventional warfare through imbalances in force levels, technologies of weapons and sensors, etc. in a theatre of operations, specific locality or even between two or more adversaries in regular warfare, to the means of fighting a state through irregular/unconventional warfare in the form of guerrilla warfare or in the form of terrorism [5]. In order to address asymmetric threats air power can be used but we must learn to use it with skill and also it is essential to look beyond its technology in such a way that technology can best be applied to address the causes of conflict. This means we should accommodate both technological and human dimensions in airpower [4].

2.1 Nano technology in Aviation

The success of airpower depends on various factors such as reduction of weight



in aircraft, usage of materials with multifunctional properties, usage of renewable fuels with low level consumption of fuel, lowering the number of repairs and many more. Out of all the emerging technologies Nanotechnology is one of the key technologies which has a very strong innovation driver and also it can be seen as a strategic technology for future economy in the world. Nanomaterials which have extraordinary properties may dramatically effect for the functions of aviation industry. Some of the design improvement possibilities encounter with nanotechnology are such as faster, miniature, highly maneuverable, self-healing and light weight materials with unique mechanical and multifunctional properties [6].

Nano based science and engineering is a broad and interdisciplinary platform of research and development activities that have been growing explosively during the past few years in the world. It has the potential of revolutionizing the methods in which materials and products are manufactured and nature of properties that can be accessed.

Nano defines as to the size scale of 1 nanometer (nm) = 10^{-9} m. It refers to the matter whose length scale, in any dimension, is approximately 1 to 100 nanometers [7]. The current trend is to use nanomaterials almost in the entire aircraft because nanomaterials can be metals, ceramics, polymeric materials, or even composite materials. Therefore, it can be used anywhere in the aircraft depending on the requirement. Thus, nanotechnology is a very critical enabling technology for modern aviation [8].

3. DESIRABLE PROPERTIES OF NANOTECHNOLOGY TOWARDS AVIATION

3.1 Light weight

There is a potential of replace the existing metals using the reinforced nano-composite plastics which lead to reduce both weight of the structure and also the Radar Cross Signature (RCS) of military weapon platforms. Smart components having built-in conditions and also load monitoring sensors can improve detection or monitoring of important parameters.

3.2 Adaptive Structure

Some of the nanomaterials have the ability to adapt to changing conditions such as adaptive camouflage and also vary from flexible in to rigid and vice versa. Shape memory alloys is one of the examples for adaptive materials, which memories the original shape. As per the literature [9], Shape memory alloys can be used in sleeves of some fighter aircraft. Apart from all of above properties, if we use self - healing materials this material itself can repair its own defects.

3.3 Reduction of Vibrations

Aircraft are also on vibration and it is a way of wasting energy. There are nano modified composites which have the potential of reducing vibrations. Particularly in aircraft the rotator wing suppression of vibration is a great design challenge. Nanocomposite materials are in a position to reduces vibrations.

3.4 Absorption of Radar



The detection to radar decline with the presence of Radar absorption coatings and camouflage as composites reduces Radar cross section. Nanotechnology can be used to develop antiballistic structures and shock absorbing nanotubes. Nanoparticles can be used as surface coverings or coatings to make it harder, smoother, and/or stealthier. Detection from Infar Red (IR) image is also not possible with composites.

3.5 Enhance in Aerodynamic properties

Composite materials which are made out of nanomaterials give light weight and more strength to the structure while lowering RCS for military aircraft. Aircraft which are made out of nano based materials give more thrust to weight ratio and also less maintenance problems. All these aspects can be considered as advantages in aviation.

4. POTENTIAL NANO TECHNOLOGICAL APPLICATIONS IN AVIATION

4.1. Airframe structures

When we consider desired properties of materials which are required for airframe structures consists with light in weight, high in strength, high in toughness, high in corrosion resistance, easily repairable and less maintenance with high durability. There are several nano materials which can



align with these required properties in airframe systems (Fig. 1).

Fig. 1: Airframe structures

There are modern aviation design requirements such as faster, miniature, highly maneuverable, self-healing, eco-friendly, lightweight and stealth systems can be fulfilled by the materials having extraordinary multifunctional properties.

Carbon Nanotube (CNT) is one of the nanomaterials which compliant with the above requirements. CNT (Fig. 2) based polymer composites have wide range of Young's modulus, high strength, Impact resistance and high thermal performance. Some of the examples for these kind of polymers are CNT/Epoxy, CNT/Polyimide, and CNT/Polypropylene which can be used for Airframe structures.

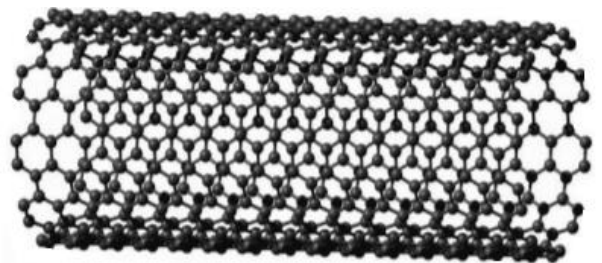


Fig. 2: Carbon nanotube

The extra ordinary electrostatic discharge and electro-magnetic interference (EMI) shielding properties can be obtained by metal nano particles incorporated with composites. These materials can be used to construct structures which are resistant to lightning strikes. So this will be an added advantage for the airframe structures.

4.2. Modifications in Aero engine

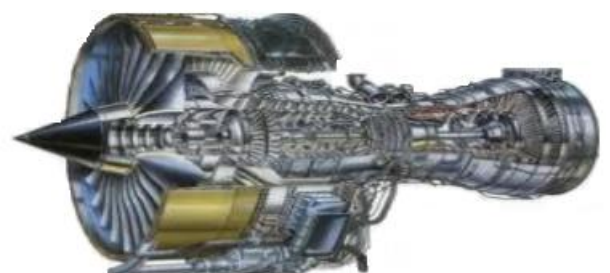




Fig. 3: Parts of the Aero engine

The purpose of applying a coating for structures and surfaces of the aircraft are to protect it from harsh environments. These environmental conditions are such as ability to withstand for extreme temperatures, extreme climates, corrosion, abrasion and wear of engine parts (Fig. 3). Nano materials based coatings can allow to function in engines at higher temperatures. As an example even though magnesium alloys are light in weight than steel or aluminium it is vulnerable to corrode due to the high chemical reactivity. These issues can be rectified with the addition of nano materials.

4.3. Modifications to electro communication system in aircraft



Fig. 4: Aircraft electro communication system

In addition to the properties discussed for CNT in section 4.1, there are unique set of properties for CNT which included ballistic electron transport and high current carrying capacity, which make CNTs great in future avionics. This leads to improve the performances in Aircraft electro communication system (Fig. 4).

In the usage of MEMS (Micro Electro Mechanical Sensors) it reduces the size of

equipment as a whole [4] but with nanotechnology it introduces NEMS (Nano Electro Mechanical Sensors) and OLED (Organic Light Emitting Diode) systems where the electricity passes over a thin nano polymer film layer. This produces colour and light. In the presence of high number of dots of lights, it gives a better picture while consuming less power. Hence, the displays or the screens will be small with less power consumption and also it produces clear image. Nanotechnology will assist to reduce the weight of electronic systems while increasing the processing speed. This may lead for a revolution in avionics [10].

4.4 Applicability in stealth applications

Stealth Technology deals with aircraft in order to restrict their visibility. Therefore, their enemies are not in a position to detect by Radar.



Radar antenna

Fig. 5: Radar Detection Technique

As shown in Fig. 5, Radar signals are constantly bombarding in airspace to identify airplanes. Other than that by measuring the acoustic (sound) disturbances, visual contact and also infrared (heat) signatures are assist to detect airplanes. By lowering or eliminating these telltale signals the visibility can be limited and this is the technique behind stealth technology.

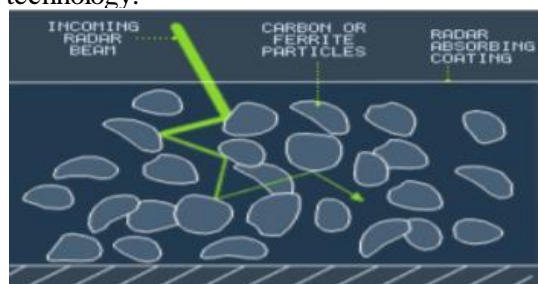




Fig. 6: Stealth Technique

When the panels on aircraft are angled, the radar is scattered and no signal returns back. As shown in Fig. 6, when the surface of aircraft covers with a layer of absorbent materials it reduces any other signature the aircraft might leave. A part from all above the “shape” is also plays a major role for invisibility of stealth aircraft. Extreme aerodynamics can maintain air turbulence to a minimum which lead to cut down noise on flying. There are specially designed low-noise engines at the inside of aircraft. The hot fumes are then having the capability of being mixed with cool air before leaving the aircraft. This can mislead the heat sensors on the ground. This mechanism eliminates the detection by heat seeking missiles. As given in Fig. 6, nano based materials can use to obtain these discussed properties which are desirable to promote stealth techniques.

5. FUTURE APPLICATIONS IN NANOTECHNOLOGY IN AVIATION

5.1 Nano sensor

Nano Air Vehicle (NAV) (Fig. 7) design with an extremely small wing span (less than 7.5 cm) and also with an ultra-lightweight (less than 10 grams). These air vehicles designed for military missions. Modified nano sensors are been used in these designs.



Fig. 7: Nano Air Vehicle

5.2 Nanotechnology enable survival kit

When we consider survival kit of fighter aircraft which can be used for the survival of pilot, it contains essential items like knife, water purifier tablets, high calories chocolates etc.

It is also proposed to modernize the contents of survival kit as follows,

- Nanomaterial based weapons and power sources which reduce weight by 20 - 30 % for soldier to carry.
- Nanotechnology enable war tag with Radio Frequency Identification, so that it can be used for rescue and searching operations.

5.3 Nano materials coated aircraft canopy

Aircraft canopy can be coated with nanomaterials typically with Carbon nanotubes which will reduces Electromagnetic Interference (EMI) from space while enhancing the strength. This application has a tendency to reduce the threat for the pilot as well as for avionics electronic systems.

5.4 Nano technology in Rocket Propellants

As per the literature, nanotechnology will also make vehicles faster. Rocket fuel additive based on Aluminum nanoparticles increase efficiency of burning hydrocarbon fuels. Such additive can also enhance the efficiency of powder burn in a rifle cartridge [11].



5.5 Nanomaterials as wear and corrosion resistant coatings

The performance of aircraft engines can be enhanced by SiC nanoparticles. SiC particles can be used to reinforce Al_2O_3 , TiN nanocrystallites which are embedded in amorphous Si_3N_4 . This combination will act as a wear resistant coatings. Further, Nano Chromium itself act as a corrosion resistant property which also has the potential of use in aircraft.

5.6 Nano fabrics in aviation

Nano fabrics give additional advantages over conventional fabrics such as super strong and light weight. As per the literature [12], this nano fiber as the capability of make blast-proof doors for aircraft.

6. CONCLUDING REMARKS

Nano technology can be considered as one of the emerging technologies in the world as it is involving in many multidisciplinary fields. Aviation is one of the fields which is blessing with involvement of Nanotechnology. Even though the world scenario is such, yet Sri Lanka is not dealing with nanotechnology especially in Aviation. Mostly in European countries get the benefits of nanotechnology as they develop nanotechnology based systems and materials. They basically focus to improve the existing systems while exploring the novel materials which are having extensive properties. These materials and systems pave the path to improve the aviation industry in those countries. Nano technology based developed materials will revolutionize military technology, from processors to display screens and also from body armor to air filters. Particularly,

Nanotechnology has a great impact on stealth technology in aviation which gives low visibility to the radar signals. This is very important phenomena when it comes to asymmetric threats.

As nanomaterials have their own characteristics namely, light in weight, high in strength, high in toughness, corrosion resistance, self-healing. Hence nanomaterials are vulnerable to use in aviation industry [13]. Nanotechnology enable designing of sub-systems for military in order to enhance operation capabilities in survival kit modernization and display system of aircraft. Apart from these, modifications for airframe structures, electro communication system and also for aero engines are possible with nanotechnology. Nanotechnology based modifications deal with process improvement in aircraft which will directly assist to address asymmetric threats.

7. CHALLENGES

However, even though there are potential applications in nanotechnology for military applications more research work has to be done in order to identify the drawback of this technology. As this is a novel technology still very little is known about this technology and its side effects as this technology deal with the particles which are in the range of 1 nm to 100 nm in scale. It is unknown if producing items this small could be harmful to the manufacturers or to the end users. It is also not known if these nanoscale devices could penetrate through the skin on the human body. As the world is moving continuously with the nanotechnological advancements day by day, hopefully the possibilities for safer and assistance with nanotechnology should be



greater than the damage. Because the world has already entered to new “nano era” at the beginning of the 21st century [14].

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