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## Effect of Multi-Walled Carbon Nanotubes on Automotive and Aerospace Applications- Case Study

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### ABSTRACT

Generally, MWCNTs are allotropes of carbon with a cylindrical nanostructure. Nano tubes have been constructed with length-to-diameter ratio of up to 132,000,000:1, significantly larger than for any other material. These cylindrical carbon molecules have unusual properties, which are valuable for nanotechnology, automotive, aerospace applications and other fields of materials science and technology. The diesel engines have advantages like durability, reliability and fuel economy compared to their counterpart gasoline engines. The main problems associated with diesel engines are their higher emission of particulate matter (PM) and Nitric oxides associated with various global hazards. Reduction of hazardous tail pipe emission from the engine using different methods such as engine modification, fuel alteration with nano particle additives, and exhaust gas treatment are the feasible methods for reducing the same. Through prior journal studies and from experimental studies conducted on MWCNT nano particle biodiesel blends, it was found that they have the capability of reducing  $\text{NO}_x$ , HC, and CO emissions, and increasing brake thermal efficiency closer to the value of conventional diesel. The properties of these nanostructures are so unique and enhanced that it is finding applications in various spheres of life – right from automotive to optical and to space applications. Owing to their exceptional morphological characteristics, electric, thermal and mechanical, carbon nano tubes yield a material particularly promising as reinforcement in the composite materials with metallic matrixes, ceramics and polymers for various aerospace applications.

**Keywords:** Nanotubes, Carbon Nanotubes, Multi walled Carbon Nanotubes, Biofuel, Nanoparticles.

### I. INTRODUCTION

Carbon nanotubes (CNTs) are seamless cylinders of one or more layers of grapheme (denoted single-wall, SWNT, or multiwall, MWNT), with open or closed ends <sup>[1,2]</sup>. Perfect CNTs have all carbons bonded in a hexagonal lattice except at their ends, whereas defects in mass produced CNTs introduce pentagons, heptagons, and other imperfections in the sidewalls that generally degrade desired properties. Diameters of SWNTs and MWNTs are typically 0.8 to 2 nm and 5 to 20 nm, respectively, although MWNT diameters can exceed 100 nm. CNT lengths range from less than 100 nm to several centimeters, thereby bridging molecular

and macroscopic scales. When considering the cross-sectional area of the CNT walls only, an elastic modulus approaching 1 Tpa and a tensile strength of 100 Gpa has been measured for individual MWNTs <sup>[3]</sup>. This strength is over 10-fold higher than any industrial fiber. MWNTs are typically metallic and can carry currents of up to  $10^9 \text{ A cm}^{-2}$ <sup>[4]</sup>. Individual CNT walls can be metallic or semiconducting depending on the orientation of the graphene lattice with respect to the tube axis, which is called the chirality. Individual SWNTs can have a thermal conductivity of  $3500 \text{ W m}^{-1} \text{ K}^{-1}$  at room temperature, based on the wall area<sup>[5]</sup>; this exceeds the thermal

conductivity of diamond. The beginning of widespread CNT research in the early 1990s was preceded in the 1980s by the first industrial synthesis of what are now known as MWNTs and documented observations of hollow carbon Nanofibres as early as the 1950s. However, CNT-related commercial activity has grown most substantially during the past decade. Most CNT production today is used in bulk composite materials and thin films, which rely on unorganized CNT architectures having limited properties. Organized CNT architectures such as vertically aligned forests, yarns, and sheets show promise to scale up the properties of individual CNTs and realize new functionalities, including shape recovery, dry adhesion, high damping, terahertz polarization, large-stroke actuation, near-ideal black-body absorption, and thermo-acoustic sound emission. However, presently realized mechanical, thermal, and electrical properties of CNT macrostructures such as yarns and sheets remain significantly lower than those of individual CNTs. Meanwhile, buoyed by large-volume bulk production, CNT powders have already been incorporated in many commercial applications and are now entering the growth phase of their product life cycle. In view of these trends, this review focuses on the most promising present and future commercial applications of CNTs, along with related challenges that will drive continued research and development.

As decreasing the size of the nano particle increases the surface to volume ratio, the higher surface area is more relevant for catalytic reactivity and improved magnetic properties as compared to their bulk form. Therefore adding some metal oxide nano particle to biofuel will improve its properties and in turn the engine performance improves and reduces the harmful gases from engine exhaust as well.

## II. CARBON NANOTUBES

The study of nanotubes has advance tremendously in a relatively short span since its first discovery in 1991 by Iijima <sup>[1]</sup>. The properties of these nanostructures are so unique and enhanced that it is finding applications in various spheres of life – right from bio-medical to optical and to space applications <sup>[2-11]</sup>. Essentially two

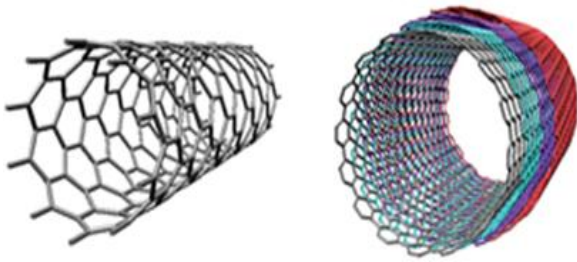
families of carbon nano tubes exist: SWNT or (single wall nano tubes), that are constituted by only one rectilinear tubular unity and the other MWNT (multi wall nanotubes}, that are constituted by a series of coaxial SWNT. Though generally both the types have high aspect ratio, high tensile strength, low mass density, etc. the actual values could vary depending on whether it is SWNT or MWNT. Of the two types SWNT is better suited for mechanical applications. Owing to their exceptional morphological characteristics, electric, thermal and mechanical, carbon nano tubes yield a material particularly promising as reinforcement in the composite materials with metallic matrixes, ceramics and polymers. The key factor in preparing a good composite rests on good dispersion of the nano tubes, the control of the bonding between nano tubes and matrix, the density of the composite material <sup>[2]</sup>. Besides, the type of nano tubes (SWNT, MWNT) the synthesis mode (arc discharge, laser, CVD) etc. are important variables since they determine the perfection of the structure and the reactivity of the surface.

### Carbon nanotubes properties are remarkable at several levels:

- 1) SWCNT possess exceptional mechanical characteristics, their tensile strength being a hundred times greater than steel's
- 2) All nanotubes are expected to be very good thermal conductors along the tube, exhibiting a property known as "ballistic conduction" <sup>[6]</sup> (the transport of electrons in a medium with negligible electrical resistivity due to scattering-ballistic transport is determined by electronic structure of semiconductor <sup>[7]</sup>, but good insulators laterally to the tube axis.
- 3) Thermal conductivity along its axis of about  $3500 \text{ W m}^{-1} \cdot \text{K}^{-1}$ , comparing this value to copper, a metal well known for its good thermal conductivity, which transmits  $385 \text{ W} \cdot \text{m}^{-1} \cdot \text{K}^{-1}$  <sup>[8]</sup>

- 4) Carbon nanotubes can be either metallic or semiconducting depending on their orientation (geometry).

Carbon nanotubes (CNTs) describe a family of non materials made up entirely of carbon. In this family, multi-walled carbon nanotubes (MWCNTs) are of special interest for the industry and will be the subject of this paper. Structurally MWCNTs consist of multiple layers of graphite superimposed and rolled in on them to form tubular shapes shown in fig.1.



**Fig.1:** SWCNT and MWCNT

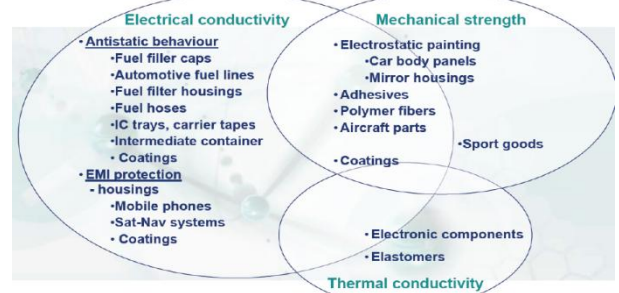
#### *i. Improved properties*

Such cylindrical graphitic polymeric structures have novel or improved properties that make them potentially useful in a wide variety of applications in electronics, optics and other fields of materials science. Carbon nanotubes are endowed with exceptionally high material properties, very close to their theoretical limits, such as electrical and thermal conductivity, strength, stiffness, and toughness.

Moreover, MWCNTs are polymers of pure carbon and can be reacted and manipulated using the rich chemistry of carbon. This provides opportunity to modify the structure and to optimize solubility and dispersion, allowing innovative applications in materials, electronics, chemical processing and energy management, to name just a few. In summary, three properties of MWCNTs are specifically interesting for the industry: the electrical conductivity (as conductive as copper), their mechanical strength (Up to 15 to 20 times stronger than steel and 5 times lighter) and their thermal conductivity (same as that of diamond and more than five times that of copper). A combination of these impressive properties enables a whole new variety of useful and beneficial applications.

#### *ii. Potential applications*

Because of their special physio-chemical properties, MWCNTs are expected to play a major role in numerous applications. Development time is an essential criterion that determines when an application will reach the market. When plotted against time, several broad categories of applications can be recognized: those in place currently or available in the short term, those to be expected mid-term, and those still in the realm of early R&D, classified as long-term shown in fig.2.



**Fig.2:** Potential Applications of MWCNT

#### *iii. Current / short-term applications*

Current or short-term applications are often based on the use of MWCNTs as a superior replacement of electrically conductive carbon blacks. Much of the history of plastics over the last half century has been a replacement for metal. For structural applications, plastics have made tremendous headway. However where electrical conductivity is required, metals are still preferred to plastics. This deficiency can be overcome by upgrading plastics with conductive fillers such as carbon black and graphite fibers. However the loading required providing the necessary conductivity is typically high, and the structural properties of the resulting plastic parts are highly degraded. Due to their high conductivity, high aspect ratio, and natural tendency to form ropes, MWCNTs are ideal in providing inherently long conductive pathways even at ultra-low loadings. The lower loading of additive can offer several advantages such as better process ability or higher retention of the mechanical properties of the original polymer. This is why the use of carbon nanotubes for antistatic and conductive applications in polymers is already

a commercial reality, growing in sectors such as electronics and the automotive industry. For these applications, carbon nanotubes can compete with additives such as highly conductive carbon black on a price performance basis. Applications that exploit this behavior of CNTs include EMI/RFI (electromagnetic and radio frequency interference) shielding composites, electrostatic dissipation (ESD), antistatic materials and (even transparent!) coatings. Concrete examples in the automotive industry are fuel systems components and fuel lines, exterior body parts for electrostatic painting as well as, in the electronic industry, conveyor belts, manufacturing tools and equipments, wafer carriers, clean room equipments, etc. Structural composites made of carbon fiber (or glass fiber) and a thermo set have been improved quite substantially by the introduction of carbon Nanotubes. The benefit is not achieved by replacing the reinforcing carbon fiber but by enhancing the properties of the matrix material (epoxide). Almost every sports item on the market can be improved by using CNT. These high-end models are usually used by professional athletes as they are often lighter weighted and more durable. These new structural composite materials based on CNT reinforced thermoplastics or thermo sets combine low density and strong mechanical properties and will open the way to new developments in particular by replacing metals in various mechanical applications where a weight reduction could save energy, like in automotive industry. Moreover thanks to the good thermal conductivity of CNT, it is possible to develop composite materials able to quickly dissipate the heat and consequently to act as protective equipment in various fields.

#### *iv. Medium to long-term applications*

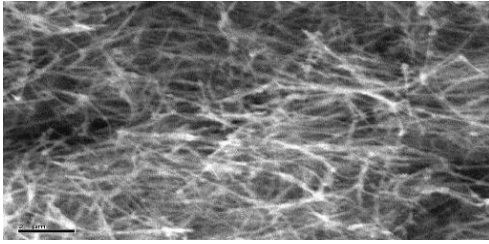
Several running applications will be expanded to other industries. For example, the improvement of mechanical properties in epoxy-glass fiber or epoxy-carbon fiber composites already known from the sport industry can also be used in the construction of light weighted composites for wind power generators and in the aircraft industry. Due to the nature of these industries, more technical testing and longer

certification time will be required. Other medium term applications may include electrical conductive inks for printable circuits, low cost RFID tags or antennas in cars. In the longer term, Carbon Nanotubes may also play a role in the modification of existing textile materials using electrostatic self-assembly and atomic layer deposition techniques to create novel and customizable surfaces on conventional textile materials with emphasis on natural fibers. This opens the way to the development of smart and intelligent textiles that combine new innovative functions. Carbon nanotubes are endowed with exceptionally high material properties, very close to their theoretical limits. A combination of these impressive properties enables a whole new variety of useful and beneficial applications. Depending of the amount of R&D efforts necessary to bring a particular product to the market, it can be differentiated between short, mid and long-term applications. Current or short-term applications are often based on the use of MWCNTs as a superior replacement of electrically conductive carbon blacks. This is especially advantageous in the automotive and electronic industries. New structural composite materials based on CNT reinforced thermoplastics combine low density and strong mechanical properties. Currently almost every sports item on the market can be improved by using CNT.

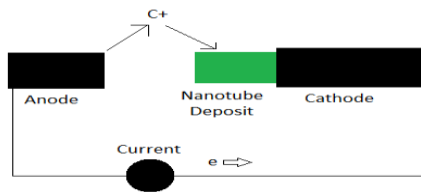
#### *v. Carbon Nanotubes formation*

Carbon nanotubes were synthesized by thermal arc plasma process after optimization of the synthesis parameters. Carbon nanotubes were synthesized in a DC arc plasma system in helium atmosphere at a pressure of 600 torr. Arc was struck between two electrodes consisting of a high purity graphite rod and a block of graphite. The discharge is typically carried out at a voltage of 20V and a current in the range of 80 – 100 A. Some amount of the evaporated carbon condenses on the tip of the cathode, forming a slag-like hard deposit. The deposit in the cathode consists of bundles of carbon nanotubes mixed with small quantity of

amorphous carbon. The as-synthesized samples were characterized by means of SEM as shown in fig.4.

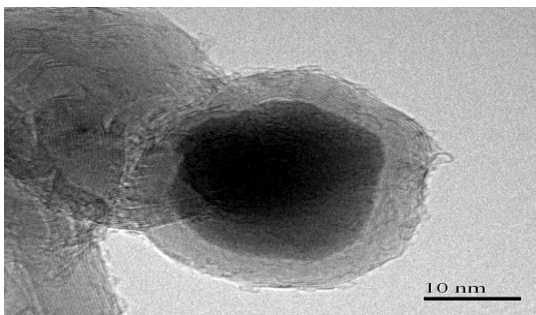
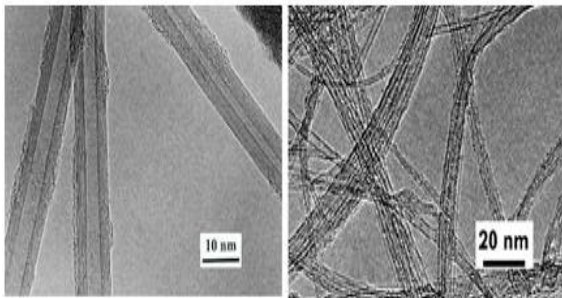


**Fig.3:** SEM images of CNT with arc discharge



**Fig.4:** Mechanism of Carbon Nanotubes formation

### III. SEM IMAGES OF MWCNT

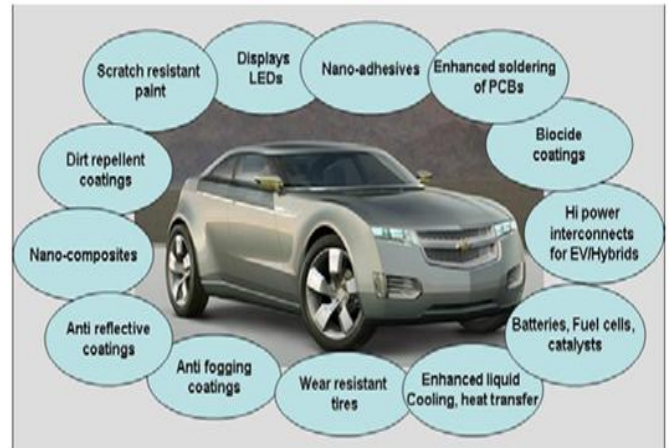


**Fig.5:** SEM Image of MWCNTs Nanoparticles

#### *i. MWCNT's for automotive applications*

Metal nanoparticle are being considered for potential use in catalytic converters since the catalytic reactivity is significantly enhanced due to the increased surface area and altered electronic structure of the metal nanoparticle. Coolants utilize nanoparticle and nano-powders to increase the efficiency of heat transfer and

potentially reduce the size of the automotive cooling equipment. Some manufacturers are currently using nano magnetic fluids in shock absorbers to increase vibration control efficiency. Wear-resistant, hard surface nano-coatings are being investigated for applications in bearings, cylinders, valves, and other highly stressed areas.



**Fig.6:** Automotive applications of nanotechnology

#### *ii. Benefits of CNT's as filler in plastic materials*

Multi-walled carbon nanotubes are characterized by very high mechanical strength, very good electrical conductivity and very good thermal conductivity. They can be easily dispersed in plastic materials and improve their mechanical properties in such a way that significant weight reduction can be achieved at equal and Mechanical performances. These performances allow energy and resource saving. When used in automotive or aircraft applications, this will lead to fuel saving and consequently to a reduced ecological burden and lowering of CO<sub>2</sub> emissions.

- Application in anti-fouling coating.
- Nanocyl recently developed a new, solvent less, eco-friendly anti fouling coating for marine applications: BioCyl TM
- Application in fire protective coating
- Protective thermal coatings containing on MWCNTs have been developed which can reduce insulation weight in automotive and aerospace applications. CNT can be used as non-halogenated flame retardant to improve the thermal stability of polymers. Example: about 100°C gain of thermal

stability for polyethylene in a classical test, with a lower filler content, a weight reduction and an easy processing.

- CNT can improve thermal protective coatings

Example: Protection of metal and other substrate by a thin layer of plastic material containing less than 1wt% of MWCNTs, instead of commercial solutions containing 40 % of additive. This leads to weight reduction in insulation.

#### iii. MWCNT Nano Additives

The effect of Multi-walled Carbon Nanotubes (MWCNT's) on the engine performance is tested by measuring the performance characteristics and emission characteristics, and comparison it with the conventional fuel. Emphasis is given on comparison with other nano particle biodiesel blends.

#### iv. MWCNT's for Aerospace applications

Shielding avionics from electro-magnetic interference (EMI) have become trickier with composites. Embedding wire meshes into the non-conductive composite material is a well-known solution, but it is not optimal. Metal and composites expand and corrode differently, and the metal adds weight. Carbon nanotubes (CNT) present the possibility of the perfect solution. For nearly 20 years, the super-strength, lightweight material has found commercial application in golf clubs and bicycles, but has made few in-roads into the aerospace industry. That curious exclusion seems to be changing, and the EMI application is most responsible. NASA have already launched its Juno spacecraft into space using the CNT-based EMShield. CNT is a conductive and load-bearing material, so it can channel away undesired electromagnetic energy without adding the support structure required for metal-based EMI materials. It may not be long before CNT becomes attractive in other niche applications. Embedding strips of conductive CNT material into the wing's leading edge or engine nacelle is a potential solution. The next step is to move CNT material from niche applications to aircraft structures.

## IV. RESULTS AND DISCUSSION

### 4.1 Variation of Brake Thermal Efficiency

The variation of brake thermal efficiency with brake power for nanoparticle blends of MWCN, HOME, Diesel and other Nanoparticle Biodiesel Blends is as shown in Fig. 6.1. The HOME resulted in inferior performance due to its higher viscosity (nearly twice diesel) and lower volatility and lower calorific value compared to diesel. However the brake thermal efficiency of the HOME- nano-particle blended fuels improved compared to neat HOME operation. This could probably be attributed to the better combustion characteristics of HOME- nanoparticle blends. In general, the nano-sized particles possess high surface area and reactive surfaces that contribute to higher chemical reactivity and act as potential catalyst. Brake thermal efficiency of MWCNT blended biodiesel is found to be higher compared to Carbon fibre and Titanium (IV) oxide blended biodiesel. This could probably be attributed to the better combustion characteristics of MWCNT blended biodiesel. In general, the MWCNT Nanoparticles possess high thermal conductivity, surface area and reactive surfaces that contribute to higher chemical reactivity to act as a potential catalyst. In this perspective, the catalytic activity of HOME+50 MWCNT could have improved due to the existence of high surface area and active surfaces provided by Carbon Nanotubes as shown in fig.7.

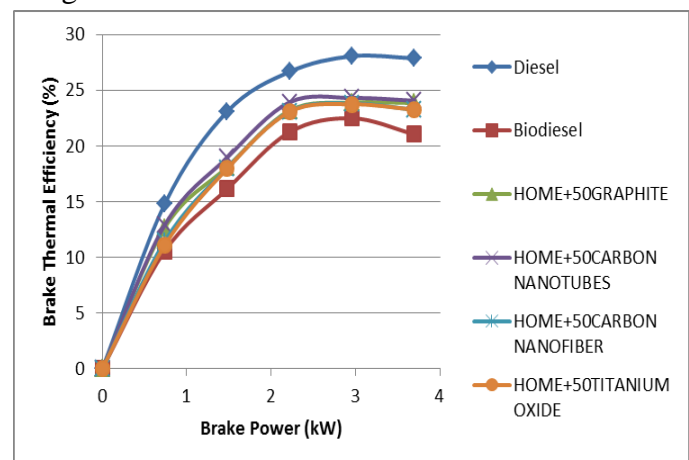


Fig. 7: Variation of Brake thermal efficiency with brake power

### 4.2 Variation of HC Emissions

The variation of Hydrocarbon emissions from the engine fuelled with HOME and different Nanoparticles blended fuels are shown in Fig.8. MWCNT Nanoparticles acts as oxidation catalyst and lowers the carbon combustion activation temperature and thereby enhances hydrocarbon oxidation, promoting complete combustion. Thus HC emission for HOME operation was higher compared to that of HOME+ Nanoparticles blended fuels. Lower thermal efficiency of the HOME operation with incomplete combustion resulted in the observed trend. However HC emissions were marginally lower for the HOME+50MWCNT blended fuel than HOME+50GRAPHITE, HOME+50CARBON and HOME+50TITANIUM (IV) OXIDE blended fuels. This could be due to higher catalytic activity and improved combustion characteristics of HOME+50 MWCNT blended fuel, which leads to improved combustion.

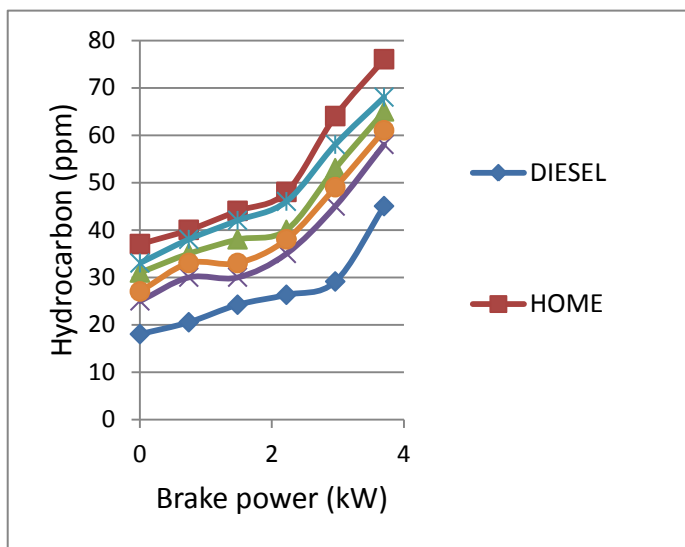


Fig.8: Variation of Hydrocarbon with brake power.

### 4.3 Variation of CO Emissions

The variation of Carbon monoxide for different nanoparticle-biodiesel blended fuels and home is shown in Fig.9. The CO emissions for HOME were higher as compared to the HOME-nano particle blended fuels. This could be due to its lower thermal efficiency resulting in incomplete combustion. However CO emissions were marginally lower for the HOME+50 MWCNT Nanoparticles blended fuel than HOME+50GRAPHITE, HOME+50 CARBON and

HOME+50TITANIUM (IV) OXIDE blended fuel. This is due to the higher catalytic activity and improved combustion characteristics of HOME+50 MWCNT blend, leading to improved combustion resulting in better performance. MWCNT Nanoparticles have their own special characteristics like higher thermal conductivity; higher surface area for catalytic activity and showed better results compared to the HOME+50 GRAPHITE HOME+50 TITANIUM (IV) OXIDE and HOME+50CARBON blended fuels.

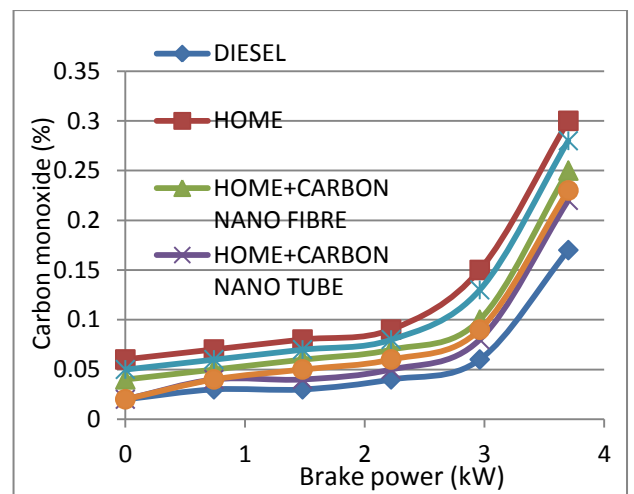


Fig.9: Variation of carbon monoxide with brake power.

### 4.4 Variation of NO<sub>x</sub> Emissions

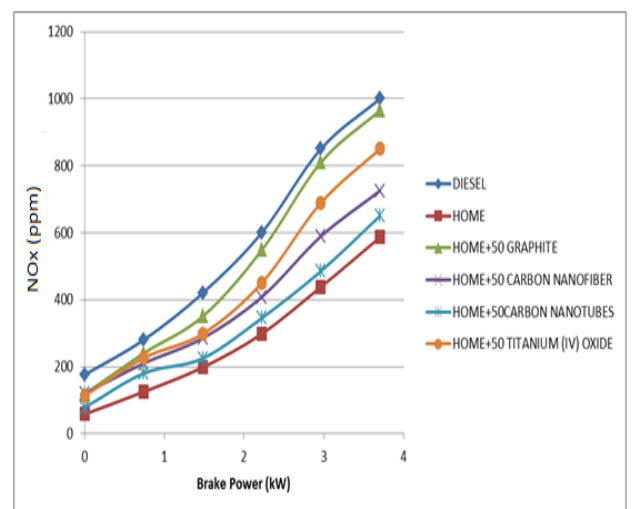


Fig.10: Variation of nitric oxide with brake power

The variation of Nitric oxide emission for HOME-Nanoparticles blended fuels is shown in Fig.10.

HOME + 50 MWCNT showed lower NO<sub>x</sub> emissions compared to other HOME-Nanoparticles blended fuels. This could be due to lower heat release rates of HOME during premixed combustion phase, which lead to lower peak temperatures. The complete combustion may lead to increased temperatures inside the combustion chamber, with higher NO<sub>x</sub> formation. This is because of higher premixed combustion heat release rates and complete combustion being observed with HOME+50 GRAPHITE blends.

## V. CONCLUSION

- Addition of MWCNT to HOME enhances the combustion characteristics and catalytic activity of the fuel, and thereby reduces the emissions and ignition delay during combustion.
- HOME+50MWCNT blended fuel shows better results as compared to the HOME+50 GRAPHITE, HOME+50 TITANIUM(IV) OXIDE and HOME+50 CARBON blended fuel in terms of increased brake thermal efficiency and reduced emission of smoke, Hydrocarbons, carbon monoxide.
- Nitric oxide emissions of HOME+50MWCNT were lower compared to HOME+50GRAPHITE, HOME+50CARBON HOME+50TITANIUM (IV) OXIDE blended fuel.
- The performance characteristics of HOME+50 MWCNT blend is almost comparable to that of diesel and is itself a good substitute for diesel
- The HOME+50MWCNT is a fuel blend with very high potential, due to closeness to diesel in performance and lower emission, and should be promoted for further research.
- The effect of Multi-walled Carbon Nanotubes is immense and appreciable in the automotive sector, with ample scope for optimization.

## REFERENCES

1. Iijima S., Nature (London) 354, 56 (1991).
2. Ahn C H et al. 2004 Springer Handbook of Nanotechnology, Bharat Bhushan Editor.

3. S. Bellucci, Phys. Stat. Sol. (c) 2, 34 (2005).
4. S. Bellucci, Nucl. Instr. Meth. B 234, 57 (2005).
5. S. Bellucci, Atti XVII Congresso AIV, Ed. Compositori (2005), p. 61, ISBN 88-7794-495-1.
6. S. Bellucci, C. Balasubramanian, F. Mancina, M. Marchetti, M. Regi, F. Tombolini, 3rd International Conference on Experimental Mechanics, Proc. of SPIE Vol. 5852 (2005), p. 121, ISSN 0277-786X, ISBN 0-8194-5852-X.
7. S. Bellucci, CANEUS 2004-Conference on Micro-Nano-Technologies, Nov. 2004, Monterey, CA, USA, AIAA paper 2004-6752.
8. S. Bellucci, C. Balasubramanian, G. Giannini, F. Mancina, M. Marchetti, M. Regi, F. Tombolini, CANEUS2004-Conference on Micro-Nano-Technologies, Nov. 2004, Monterey, CA, USA, AIAA paper 2004-6709.
9. Bottini M., Bruckner S., Nika K., Bottini N., Bellucci S., Magrini A., Bergamaschi A., Mustelin T., Toxicology Letters, 160, 121 (2006).
10. M. Bottini, L. Tautz, H. Huynh, E. Monosov, N. Bottini, M. I. Dawson, S. Bellucci, T. Mustelin, Chem. Commun. 6,758(2005).
11. M. Bottini, C. Balasubramanian, M. I. Dawson, A. Bergamaschi, S. Bellucci, T. Mustelin, J. Phys. Chem. B (in
12. Himanshu Tyagi, Jose R. Pacheco, Patrick E. Phelan, Paul Arentzen, Ravi Prasher, Robert Peck, Taewoo Lee, Increased Hot-Plate Ignition Probability for Nanoparticle-Laden Diesel Fuel. January 29, 2008.
13. Arul Mozhi Selvan, V.R. B. Anand, M. Udayakumar Effects of cerium oxide nanoparticle addition in diesel and diesel-biodiesel-ethanol blends on the performance and emission characteristics of



- a C.I engine, ARPN Journal of Engineering and Applied Sciences SEPTEMBER 2009, Vol. 4, No. 7.
14. Daniel M. Dabbs, Frederick L. Dryer, Ilhan A. Aksay Justin L. Sabourin, Richard A. Yetter, Functionalized Graphene Sheet Colloids for Enhanced Fuel/Propellant Combustion, 2009 Vol. 3 No. 12: pp 3945–3954.
  15. Grant A. Risha, Richard A. Yetter Steven F. Son. Metal particle combustion and nanotechnology. Proceedings of the Combustion Institute 32 (2009); pp 1819–1838.
  16. Jeffrey R. Potts, Ji Won Suk, Rodney S. Ruoff, ShanthiMurali, WeiweiCai, Xuesong Li, Yanwu Zhu, Graphene and Graphene Oxide: Synthesis, Properties, and Applications, 2010 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.
  17. Ranaware.A.A, Satpute.S.T. Correlation between Effects of Cerium Oxide Nanoparticles and Ferro fluid on the Performance and Emission Characteristics of a C.I. Engine. IOSR Journal of Mechanical and Civil Engineering 2010 (IOSR-JMCE) ISSN: 2278-1684, PP: 55-59.