Nanoparticles Exceptional Properties: Applications in Internal Combustion Engines

Saddam Khan [a)], Yogesh Dewang [b)], Jitendra Raghuwanshi [c)] and Vipin Sharma [d)]

Department of Mechanical Engineering, Lakshmi Narain College of Technology, Bhopal-462002
[d)]Corresponding author: vipinsati@gmail.com
[a)]dewang.yogesh3@gmail.com
[b)]dewang.yogesh3@gmail.com
[c)]jitendralnct@rediffmail.com

Abstract. Nanomaterials consist of larger fraction of surface atoms and the fraction of surface atoms increases with the decrease in size. Increase in surface atoms and high surface area provides exceptional properties to nanomaterials. In internal combustion engine the nanoparticles are used as fuel or lubricant additives and in catalytic convertors. The nanoparticles added in fuel offer distinct advantages of improved combustion characteristics, shortened ignition delay and fast energy release. In lubricants addition of nanoparticles significantly reduces friction between contact surfaces. High reactivity of nanoparticles enhanced the performance of catalytic convertor.

INTRODUCTION

Nanotechnology advancement successfully addressed various issues and challenges in engineering applications. Properties of nanomaterials are significantly different from their bulk materials owing to synergistic effect of various phenomena [1, 2]. The nanomaterial characteristics mainly depend on their size and can vary significantly at different length scales in the nanometer regime [2, 3]. Exceptional properties of nanomaterials are due to increase in fraction of surface atom as compared to interior atom and quantum size effect (Fig. 1). Surface atoms are more active as compared to the bulk atoms owing to fewer adjacent coordinate atoms or more dangling bonds [4]. The surface atoms are not fully bonded on all sides, and therefore have one or more dangling bonds. So there is less energy input required to break the bonds for participation in a chemical reaction [5]. The nanoparticles can burn and release energy much more easily owing to their large surface area to volume ratio and short oxidizer diffusion length. For example, metallic aluminum nanoparticles of nearly 100 nanometers can be ignited at 250 °C as compared to nearly 2000 °C for the bulk aluminum [6].

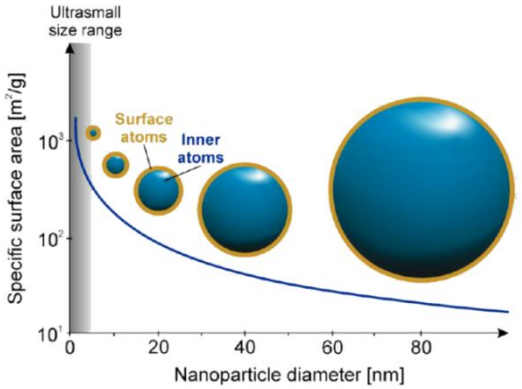

FIGURE 1. Increase in fraction of surface atoms as size of particle decreases. Reprinted with permission [7]

Nanoparticles are extensively used as the fuel additives, lubricant additives and catalyst for reduction in harmful emissions [8, 9]. Nanoparticles due to the high surface area can offer distinct advantages of improved combustion characteristics, high reactivity, shortened ignition delay and fast energy release. The metal oxide nanoparticles in the combustion chamber librates oxygen and provide extra oxygen for better combustion characteristics. The objective of the present study is to review the contributions made by previous researchers in the domain of enhancing the properties of fuels in internal combustion engines through addition of nanoparticles being as fuel additives.

NANOLUBRICANTS

Nanolubricants are oil-based lubricants added with nano particles to reduce friction and wear in the tribopair. In the nanolubricants, nano particles of metals (e.g. Zn, Al, Cu, Fe and Ti) and their oxides, molybdenum disulfide (MoS_2), metal borates, graphite, fullerenes and nano diamond particles are commonly used. It was reported that use of nano lubricants showed the significant reduction of 10-20% in friction and also affected wear mechanisms [9]. The nanoparticles serve different functions in combustion chamber as an additive is shown in Fig. 2. Mainly the nanoparticles can provide rolling action between contact surfaces and thus reduces friction. Wear scars and pit formed due to material removal can also be filled by nanoparticles which further restrict the damage caused by scars or pits. Formation of tribofilm is also promoted due to the presence of nanoparticles which helps in protection of contact surfaces . In a study, it was reported that copper nanoparticles stick to the tribopair and forms a lubricating copper thin film, known as tribofilm or mechanically mixed layer [9]. The mechanically mixed layer is easily formed in the tribopair under different conditions and its stability affects the wear mechanism [10].

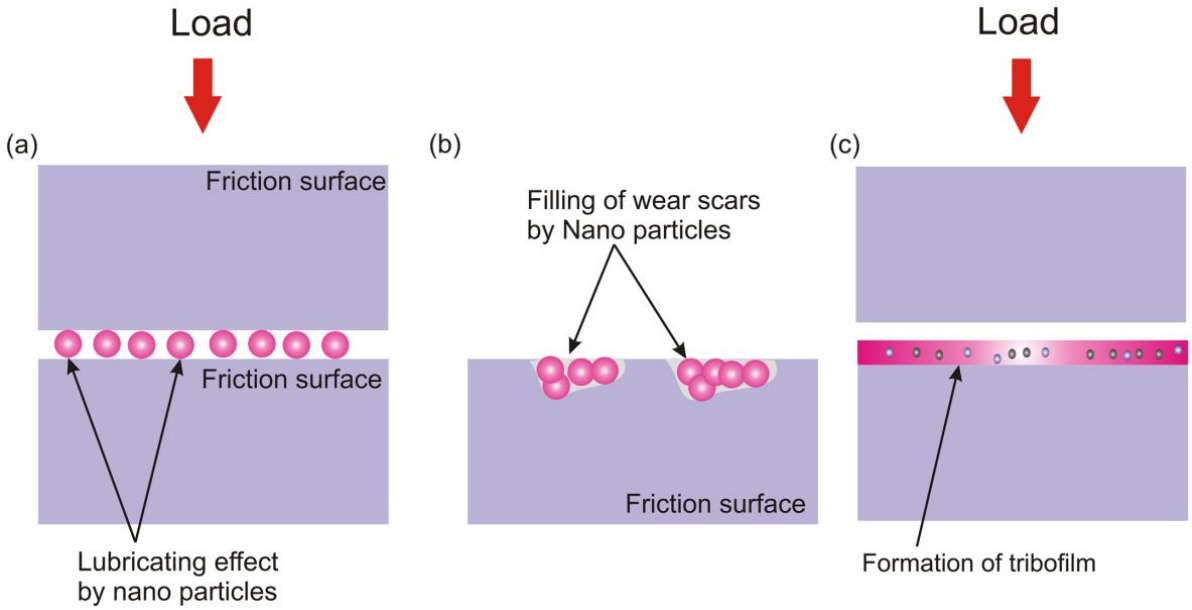

FIGURE 2. Schematic presentation of nanoparticles different roles as an additive (a) lubricating effect (b) filling of wear scars (c) formation of tribofilm.

METAL OXIDES

Nanosize metal oxides such as Al_2O_3, CeO_2, MgO, TiO_2, CuO, ZrO_2, ZnO etc. are used as fuel additives to promote complete combustion. Superior catalytic activity of nanoparticles shortened ignition delay which further improves combustion characteristics. The metal oxide nanoparticles laden fuel during combustion process provides extra oxygen and reduce harmful exhaust emissions to greater extent [8]. Better combustion characteristics due to addition of nanoparticles resulted in the increase of brake thermal efficiency (BTE) and decrease in the brake specific fuel consumption (BSFC).

CONCLUSION

This study has focused on the role of nanoparticles being as fuel additives for the fuels used in internal combustion engines for achievement of proper combustion. The following are the major conclusions drawn on the basis of present study:

- It is found that usage of nanoparticles as nanolubricants (fuel additives) has reduced coefficient of friction in a range of 10-20 %.
- It is also recognized that nanoparticles helps in formation of tribofilm is also which actually protect contact surfaces and also wear.
- It is also realized that usage of nanoparticles being as metal oxides help in shortening of ignition delay period, which in turn improves better combustion and brake thermal efficiency and reduces brake specific fuel consumption.

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