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Strictly as per the compliance and regulations of :

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Abstract - Machinery management tries to control maintenance and operation costs by reducing agricultural machinery damages as well. Today, nanotechnology has an important role in reducing engine wear costs by using nano particles in engine oils. To study the effect of nano oil on agricultural engines, performance of eight Massey Ferguson model 399, tractors manufactured in Iran were studied. Each oil sample was analyzed by atomic absorption spectrometry. In addition, Particle Quantifier (PQ), total base number (TBN), viscosity, fuel and water pollution tests were also applied. The results showed that usage of nano diamond oil additive in agricultural tractor engines would reduce wear in cylinders, gaskets, drive shafts, gears, camshaft and valve mechanisms by 68 percent. Also reduced wear was shown in piston ring, bearing, gaskets and exhaust valves by 64 percent. Furthermore, fuel consumption proved a reduction of 21 percent compared to conventional oil use.

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I. Introduction

Regarding the remarkable role of nanoparticles on oil efficiency, especially at high loads and pressure, nanotechnology would be an important technology by reducing damages served to engine and saving costs of fuel consumption. As machinery progressed, from steam engines to jet fighters, lubrication became an interdisciplinary science involves physics, chemistry, materials, fluid mechanics, and contact mechanics. In particular, one of the first proposed applications for new materials was lubrication as friction reducing nano-bearings in Microsystems (Stephen 2004). Decreasing the lubrication effects on the engine parts, would reduce engine power and increase the fuel consumption in agricultural machinery.

Condition monitoring and maintenance are two essential components of the modern industry (Thirouard et al. 1998). The purpose of condition monitoring is to detect faults occurring in machinery maintenance; on the other hand, is defined to maintain and extend, the lifetime of machinery. With regard to monitoring methods, oil analysis has been considered as an and effective approach because of its capability to reveal the wearing condition of the machinery through the analysis of oil properties and wearing particles (Yuan et al. 2002). Generally, recently replaced components will experience a period of higher wear known as running-in until reaching wearing pattern, under higher load conditions. Wearing will keep increasing, especially if the component is in contact with another part. Many factors control the quantification of these reactions, such as operating conditions (e.g., temperature and humidity distance shipping) and composition of the lubricating oil (Macia et al. 2003). The lubrication layer changes during the engine cycle from the piston ring motions, oil film evaporation and the like; therefore, it affects the piston ring lubricant condition. In fact, major portion of oil consumption arises from bore distortion and poor piston ring sealing resulting from ring and bore wear. Clearly, aluminum exhibits a transition from mild to high wear when the nominal contact stress exceeds a threshold value (Venkataraman and Sundararajan 1996). Application of newer technology and/or materials is being explored to achieve this goal. By employing nanomaterial, much of this objective could be achieved. Nanoscale materials have received much concern in recent years due to their outstanding properties compared to those of micron-size counterparts. Due to the remarkable tribological properties of nanoparticles, together with their good self-repair function against the worn surface and also their environ mental-friendly property, they have been known as excellent candidates for traditional lubricant additives, especially at severe frictional conditions, such as high temperature, high load and sliding speed (Sun-qing et al. 1999). Nano-lubrication therefore can be defined as the art and science necessary to control adhesion, friction, and wear of surfaces coming into contacts at the micro/nano-scale (Stephen 2004). A lot of research has been conducted on the tribological performance of diamond nanoparticles (He- long et al. 2007; Chou and lee 2008). For example, by adding Cu nanoparticles into oil, the average wear scar diameter of the stationary balls at room temperature, 50 ^{o}c, 80 ^{o}c, 110 ^{o}c and 140 ^{o}c was reduced by 13%, 16%, 21%, 23% and 25%, respectively. Therefore friction coefficient was reduced by 5%, 8%, 10%, 15% and 20%, respectively. Accordingly, this indicates that the higher the

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temperature, the better the tribological properties of Cu nanoparticles will be (Gubarevich et al., 2004). It was expected that nano-diamond additive could be increase the oil productivity in the engine, specially at high pressure and loads for agricultural operations. Also, this Y additive was shown to be able to reduce the wear in tractor engines. Basically, the reduction of damages by the use of nanotechnology are not only able to reduce the repair and maintenance costs, but they are also able to control the timelines costs.

II. Material and Methods

The experiments were performed at Agro-industry Amir Kabir company which is located in south of Ahwaz, Khouzestan province, Iran. The Agricultural land available in this company which was used for the purpose of this study was about 12000 hectares. In this company there were about 300 Massey Ferguson model 399 tractors being used for sugar cane transportation . Each tractor carried a file , in which all maintenance and repairing were recorded.

a) Research Methodology

Eight Massey Ferguson model 399 tractors were used for this research . These tractors were equal regarding operating conditions . The analysis of data in this study was performed by using a completely randomized block design . Each block of experiment was based on hours and years of operation and maintenance conditions. Engine model was four-stroke and also water-cooled Perkins diesel 1006. Tractors were working about six months in a year (at an average of 10 to 16 hours a day). They were being used for soil preparation and sugarcane transportation in high dust haze conditions. If tractors stopped due to a failure: repair and timeliness costs were measured. The first oil sampling after 120 hours of operation was taken from each tractor while Behran azarakhsh oil (base oil) was used in tractor engines. The samplings were performed immediately after the engine was turned off. Nano oil was used in the four engines and Behran turbo diesel oil in the other engines with equal characteristics . Samplings were taken at 65, 90, 115, 150 hours of the operation. Finally, each sample was analyzed by atomic absorption, while viscosity, pollution of water, and fuel were also measured. The spectrometric test was conducted to measure chemical elements in the particles and also to recognize amount and types of chemical compounds. Spectroscopy is a technique for detecting and quantifying the presence of elements in the oil and is based on the ASTM D -6595 standard. Spectroscopy benefits from the fact that each element has a unique atomic structure. Therefore, when no two elements have the same pattern of spectral lines , the elements can be differentiated. Indeed, the intensity of the emitted light is proportional to the quantity of the element present in the sample allowing the concentration of that element to be determined. The Particle Quantifier (PQ) is a ferrography screening tool. The PQ gives an index value that is not size dependant. This trendable value can assist in identifying large ferrous worn particles, whose size is greater than 10µm. This index helps to confirm growing normal wear, the onset of aggressive wear or the prospect of eminent catastrophic failure. Other indicators were viscosity and viscosity index (VI). The kinematic viscosity of the lubrication oil was measured at 40°C, in mm2/s and were based on the ASTM D445 standard . Analysis of oil samples were calculated and oil type effect was studied on the engine's worn parts . Also, fuel consumption was measured using the full tank method in all the experimental stages.

III. Results

The characteristics of engine wear, TBN and fuel consumption were investigated after using nano and turbo oils in Massey Ferguson model 399 tractors.

a) Iron (Fe)

Effect of oil type on Fe wear ratio was significant ($P \leq 0.05$). Results showed that the use of nano diamond in agricultural tractor engines as an oil additive reduced Iron wear. The average ratio of Fe wear ni turbo oil and nano-oil as shown in Figure 1. The effect of time on the Fe worn particles was significant≤ (0P.01) and they were increased when engine operation was longer. According to Table 1, the use of turbo oil after 150h reduced the Fe wear 1.21 ppm compared to base oil with 120 h operation while this amount was 19 ppm where nano oil was applied.

b) Chromium (Cr)

The analysis of variance showed a significant effect ($P \leq 0.05$) of oil type on Cr wear in tractor engines. According to Figure 1 the meaning of Cr wear effect in tractor engines for turbo-oil was more than that of nanooil. According to Table 1, the use of turbo oil after 150h reduced the Cr wear by 0.24 ppm in comparison with base oil after 120 h operation while this reduction was 1.12 ppm with the use of nano oil.

c) Particle Quantifier (PQ)

Inspection of the analysis of variance showed that the effects of oil type and time on PQ in tractor engines were significant ($P \leq 0.05$) and ($P \leq 0.01$), respectively. Figure 1 shows higher PQ index for turbo-oil compared to nano-oil. The use of turbo oil after 150h increased the PQ index to 0.88 ppm compared to base oil while this reduction was 17 ppm when nano oil was used (Table-1). 3

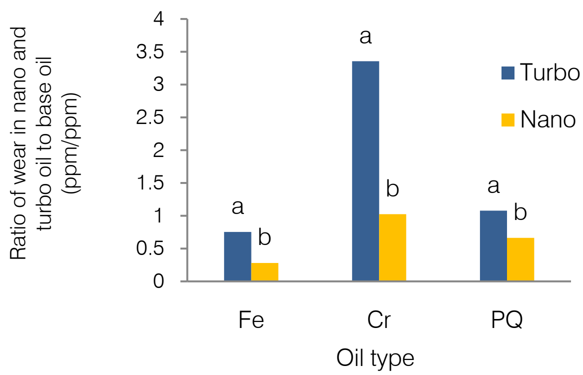

Fig.1 : Mean of different effect of oil type measuring friction on Engine parts

d) Viscosity

The effect of oil type on viscosity rate was significant ($P \leq 0.05$). Results showed that the use of nano diamond in agricultural tractor engines as an oil additive reduced the viscosity loss. Effect of time on the viscosity ratio was significant ($P \leq 0.01$). According to Table 1, the loss of Viscosity was 21.25 cSt with the use of nano oil after 150h, compared to base oil with 120h of operation also the loss increased by 13.5 cSt with the use of turbo oil in comparison with base oil.

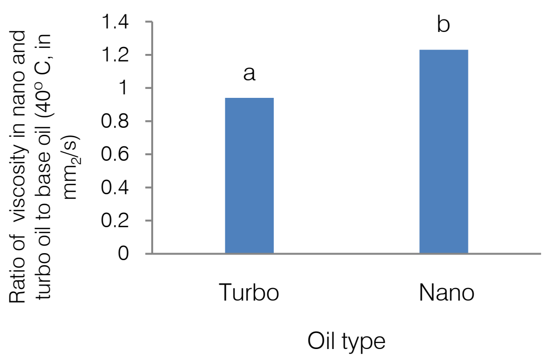

Fig. 2 : Mean of different effect of oil type measuring viscosity

Table 1 : The effect of oil type on wear and viscosity in Massey Ferguson 399 model tractors

Oil type	Base (120h)	Turbo (150h)	Base (120h)	Nano (150h)
Fe	17.5	16.29	38	19
Cr	0.68	0.44	1.75	0.63
PQ	11	11.88	27	10
Vis. @ 40 °C-cSt	164.2	150.7	157	178.3

e) Fuel Consumption

Results showed that the effect of oil type on fuel consumption was significant ($P \leq 0.05$). According toFigure 3 the reduction of fuel consumption was 1.1 litr/h were nano oil was used after 150h of noitarepo compared to base oil with 120h.

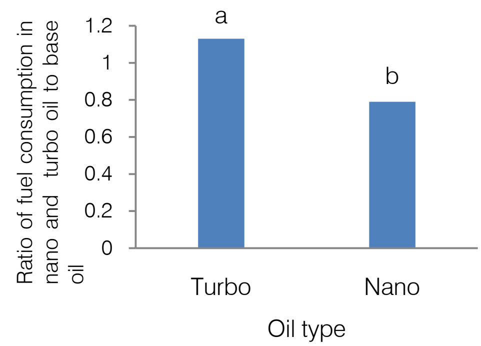

Fig. 3 : Mean of different effect of oil type on fuel consumption in Massey Ferguson 399 model tractors

IV. Discussion

Oil type affects engine components wear and fuel consumption. The nano-oils had less opportunity to contact the metal surface because of the presence of nanoparticles, whereas conventional oil is in direct contact with the metal surfaces. Lee et al. (2009) found that the friction coefficient of the nano-oil was less than that pure oil over the entire orbiting speed ranges between 300 and 3000 rpm. Consequently, reduction of the Fe particles wear had an important effect on reducing engine parts damages, for example cylinders, gaskets, drive shaft, wheel gear, the desire cam, and valve mechanism. This can therefore reduce the cost of repairing engine parts. Ginzburg et al. (2002) and Rapoport et al. (2002) reported that the fullerene particles suspended in the nano-oil had spherical structure and played a role as ball-bearings on the friction surfaces, this phenomena was identified by the lower friction coefficient of nano-oil compared to regular oil. The presence of nano-particles in oil reduced the metal-metal contact in tractor engines. Due to the applied high Cr in engine component; reduction in friction effect by nano-oil was significant. It is assumed that carbon nanoparticles were coated on the frictional surfaces so that the presence of nanoparticles between the frictional surfaces seemed to prevent metal contact. As more nanoparticles were added to the coated area, the microstructure of the coating became finer and more compact (Erb 1995). Chromium was highly used in engine components as rings, tapered roller bearings, gaskets and exhaust valves. Piston ring dynamics is very important for the lubricant characteristic of reciprocating engines which leads to the consequences of engine wear and amount of lubricating oil consumption (Wannatong et al. 2007). As a result, the nanoparticles reduced friction in these engine parts through better lubrication. It appears less metal contacts occur with the presence of nanoparticles in the oil suspension. This is because nanoparticles, which were inserted between the friction surfaces, improved the lubrication performance by increasing viscosity and preventing contact between the metal surfaces. Effect of nano-oil in reducing PQ showed nanodiamond additive could play an important role in better lubrication and reduced damages and parts wear in tractor engines. Very high friction coefficients can occur in practical mechanical contact when there is a breakdown or absence of lubrication. It can be seen that the wear scar diameter and friction coefficient of oil containing nanoparticles are lower than those of pure oil. Hsiao et al (2009) previously reported a large reduction in the friction appeared after adding 2% or/and 3% of the nano-diamond a tnacirbuldditive to a base oil. The nano-additive reduced the risk of direct metal–metal contact hence achieving a very positive tribological role against surface adhesion, wear, and eventually global friction. In other zones of the same lubricated contact; it could be found that a nano-film did completely separate the contacting surfaces (Hsiao et al. 2009; Van Alsten and Granick 1988). This reveals that the addition of nano-diamond additive is beneficial to postpone or even avoid scuffings during the test. The viscosity of oil changes with temperature. The frictional heat raises the temperature of the interface and the oil. Frictional heat makes the temperature at contact spots to rise continuously. It appears that the temperature of oil containing nanoparticles is lower. Viscosity affects heat generation in bearings, gears, pistons, etc., due to internal fluid friction. Furthermore, formation of lubricating films, rate of oil consumption, starting of machines at various temperatures, is all affected by viscosity (Saurabh 2005). The dispersion nano-diamond particles in oil collected the oil cells with dimensions about 6 microns, increased the viscosity of the lubrication, and created a thin layer on the surface. Also better heat transfer with use of nano-diamond particles in engine oil reduced the viscosity loss, increased the stability of lubricating, and reduced the oil drip. Nano-diamond as additives in oil can effectively improve the lubricating properties of oil. The nano diamond by increasing of the lubrication and insulation improved the engine efficiency and reduced the fuel consumption in tractor engines.

V. Conclusion

In summary, nano-diamond particle resulted in an improvement of anti-scuffing performance in the engine oil. Using of nano diamond in agricultural tractor engines as an oil additive was able to reduce the wear in cylinders, gaskets, drive shaft, gears, camshaft, and valve mechanism by 68 percent . Also this additive reduced the wear in rings, the bearings, gaskets and exhaust valve by 64 percent. This could indirectly indicate that the nano-oil enhanced the characteristics of the antiwear and friction resistance on the engine parts. As a result of various tests, the nano-particles in lubrication oil improved the lubricating performance on the friction surfaces by reducing wear on metal surface. Durability of the nano-oil utilized in agricultural tractor engines was 22 percent more than turbo-oil. Also fuel consumption was reduced 21 percent compared to conventional oil.

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