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Study of Effects of Nano-diamond as an oil additive on engine oil properties and wear rate of the internal parts of agricultural tractors engines

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ABSTRACT
One of the most important factors for agricultural mechanization is management of repair and maintenance costs. Today, tractor is one of the main sources of power in agriculture. The engine overhaul cost is the most rates of repair and maintenance costs. Suitable and high quality engine oil consumption is a more effective factor on engine life increasing. The Nano-science is a new effective method to improving the quality of engine oil and controlling of costs. This study was carried to evaluate the impact of Nano-diamond as an engine oil additive on increasing the oil quality and wearing reduction in the engine oil components. For this purpose, 10 Massey Ferguson 399 tractors were selected from the common tractors in Iran and were classified in two groups. The Nano-diamond as an oil additive material was added to engine oil in one group and was used pure engine oil (without adding any additive) in other one. Then the oil sampling were carried on all tractors engine oil at 50, 100 and 120 hours service time durations and elemental analysis were completely performed on samples. The data were analyzed by SPSS software. Results showed a significant difference at 5% level, between the two groups based on the life oil additives as well as the quantity of erosion particles. The results showed that it is effective to increasing of engine lubricant oil quality as well as reducing of erosion particles quantity, when this additive is used whit 1% concentration based on weight in MF 399 engine lubricant oil tractor. Additionally, resulting from hard Nano-diamond structure, some of the large ferrous particles observed that their quantities have been decreased gradually.

Introduction

A great section of the farm machinery costs are farm tractors costs as main resources of farm power. Farm machinery costs can be divided into two categories: annual ownership costs, which occur regardless of machinery use, and operating costs, which vary directly with the amount of machine use. Operating costs include repairs and maintenance, fuel, lubrication and operator labor. The most portions of operational costs are repairs and maintenance expenses. Increasing of engine parts service life and reduction of wearing of them can be result the decreasing of the costs. One of the factors that directly affect on the service life of engine parts is quality of used engine lubricants. Today, available lubricants have suitable quality to repairs and maintenance costs reduction, because of their improved additives qualities.

The liquid lubricants that most of them produced from oil cannot be have all the needed properties, such as friction reducing, high compressibility, antiwear improving, cooling and anti erosion in engine or machine parts. This has forced producers to using some additives as the oil properties modifier. The rate of this has become more accelerated by presence and progression of nanotechnology. In this regard, some Nano-additives have been reviewed and tested such as titanium borates, titanium oxide, zinc borate, Ferro oxide, calcium carbonate, magnesium Borate, aluminum / tin nanoparticles, polymer materials, inorganic silicates and so on (Zhang et al., 2008; Hu et al., 1998).

However, the teribological mechanisms that act on these particles are very complex, but they can be stated generally in three mechanisms: transfer layer formation, bearing performance and conversion bearing friction to Rolling friction and repair mechanism with nano-particle entering to the pores on the contacted surfaces and making them smoother and polisher (Sunqing et al., 1999; Bakunin et al., 2005).

The result of wear and friction in mechanical working methods and procedures is Energy and material shortages that leading to output or productivity reduction. These deficiencies are frictional characteristics which occur on wearing surfaces zone due to abrasive material ability, therefore a minimum pressure is necessary to this material shows its anti wearing role (Zhang and Tung, 2007).

This study was focused on carbon based Nano-diamonds. Many studies have been carried on performance of carbon based Nano-diamonds (Gubarevich et al., 2004; Chou & Lee, 2008). Chu et al. (2010) were used from carbon based Nano-diamonds, whit 1, 2 and %3 concentration based on weight at 60°c temperature on disc implement. The sample with %3 concentration had the best effect on improving of anti abrasion characteristics of disc (Chu et al., 2010).

Wu et al. (2007) were reported that coefficient of friction reached to almost 0.09 and depths of abrasion were 25 and 34 µm at 25 and 100N loads, respectively, when they used Nano-particles and high temperature (Wu et al., 2007).

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In other study, Peng et al. (2009) were used adjusted carbon based Nano-diamond with 110 nm particles diameters. They resulted that the best and the most optimized of percentage of these Nano-particles based on weigh which will provide the least width of wear, is 0.2-%0.5. Then it will provide a protection layer on the given surface (Peng et al., 2009).

Chou and Lee (2010), were studied the distribution behavior of carbon based Nano-diamond on the carbon steel and aluminum alloy. They reported that these Nano-particles have the better distribution ability with higher viscosity of base oil, and also this Nano- particles as solid additive into oil lubricant, have improved the behavior related to carbon steel surface as well as steel alloy (Chou and Lee, 2010).

In this study, was studied the carbon based Nano-diamonds effects on Massey Ferguson tractors (type 399) engine lubricant oil and compared to the tractors measurements when this Nano-diamond did not used.

Materials And Methods

Nano-particles properties

The carbon based Nano-diamond that used in this research, had this properties: spherical shaped with average particles diameters 4-6 nm and whit 1% concentration based on weight.

Farm tests

In this research, 10 tractors from available farmer's tractors were selected in Karaj township in Iran. These tractors were grouped in two categories. Usual engine lubricant oils without any nano-particles were used for first group tractors (method 1). The Nano-particles were added in engine lubricant oils of second group tractors for three stages (method 2). First the engine oils of tractors replaced with new oils, then were added Nano-particles in them (stage 1). They were replaced with new oils together with nano-particles (stage 2), and this stage were repeated for third time (stage 3). All tractors were used normally in farmer's lands. Samplings from engine oils of all above-mentioned tractors were carried out, after 50, 100 and 120 hours work time at each stages. These samples were sent to condition monitoring laboratory of Alborz Tadbirkaran, for testing.

Laboratory tests

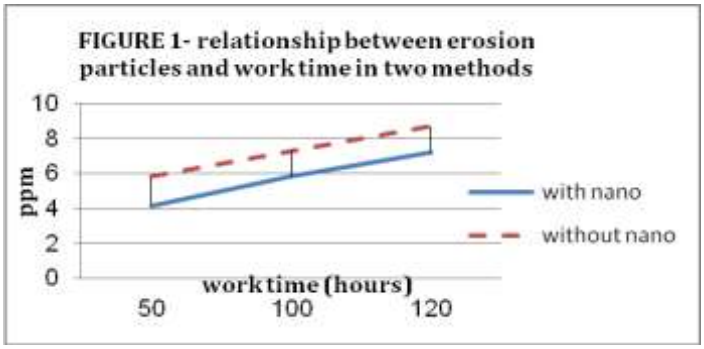
The laboratory tests were carried on the oil samples that prepared in previous stage of test (the farm tests). The laboratory tests consist of erosion particles, additives quantity, PQ number, viscosity and pollutants. The descriptive statistical analyses separately were carried on means of three above mentioned stages and two methods data. The means of data between the above two methods (with and without Nano-diamond methods) were compared by F test method in SPSS software. The statistical inference was carried on means of two methods data.

Results And Discussion

Descriptive statistics

a erosion particles

The results showed that using of nano-diamond can reduced the considerable quantity of erosion particles, and can has effective role to improving of internal parts of engine. It readily is visible that the amounts of these particles were less than without nano- particles methode, on all work time duration (FIGURE 1).



Ferrous particles

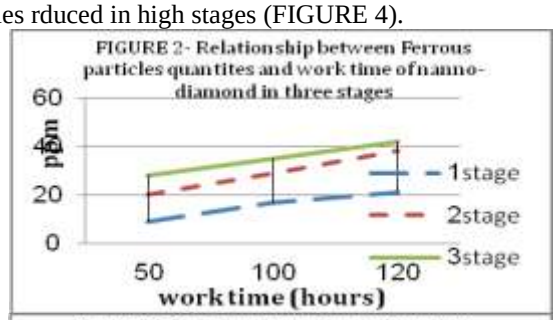
The analytical results showed that the quantities of ferrous particles in without nano-particles method were more than other method. The rate of increasing amount of Fe in this method is greater than other method. When Nano-particles are used, the quantity of Fe particles will increase due to their structural hardness, but it is much less than without Nano-particles method. It was resulted the fewer rates in the next samples too. This indicates that the effects of the Nano-particles, over time, are more clearly visible (FIGURE 2).

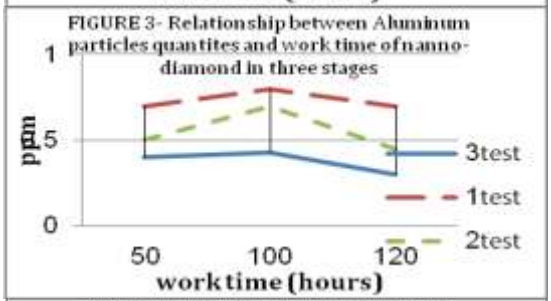
Aluminum particles

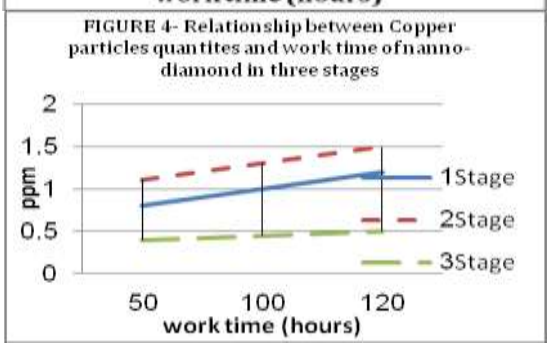
In stages 2 and 3, the quantity of aluminum particles decreased, and the slope of their increasing rates were much less than stage 1. Because of the Nano-additive structure, the curve is increasing but the slope of this curve reduced, over time (FIGURE 3).

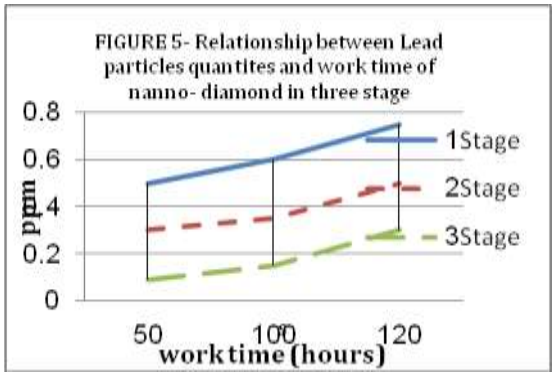
Copper particles

The quantities of copper particles, same to the two previous particles, were greater in alimentary stages than next stages of the Nano-diamond usage. The slope of the increasing rat of the particles rduced in high stages (FIGURE 4).







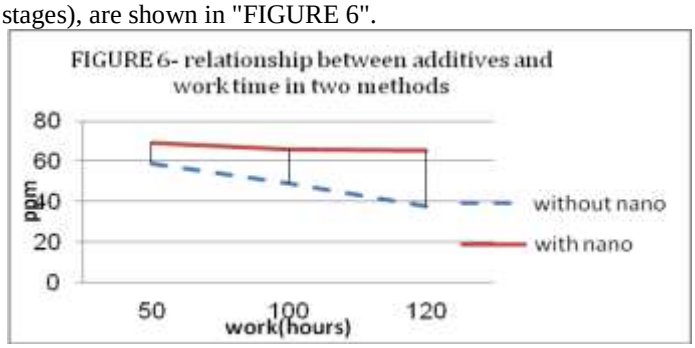


Lead particles

The lead (Pb) particles quantities also increased in first stage then decreased by repetition of the stages. Quantity of this element when used the Nano-diamond was less than without nano-particles method (FIGURE 5).

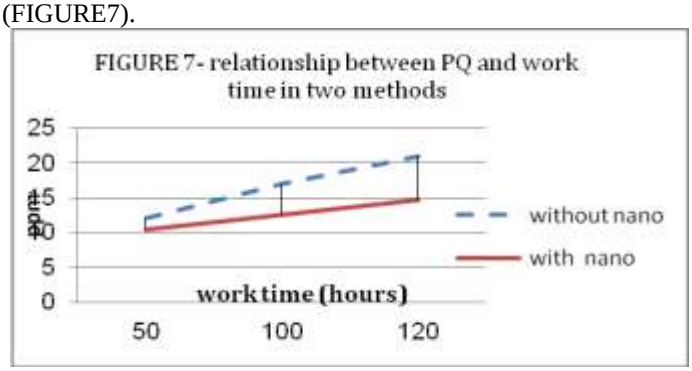
b. Additives

The quantities of additives normally decrease as the work time increase, due to internal condition of engine. In this process, the rat of decreasing at life time will be controlled, and be constant, when nano-diamond are used. This means that, the concentrations of these materials are almost constant, and oil properties are protected, then the oil service life is increased. On the other hand, protection of oil properties causing to more effective performance and finally the service of the engine will be durable. The variations rat in two stages (with and without stages), are shown in "FIGURE 6".



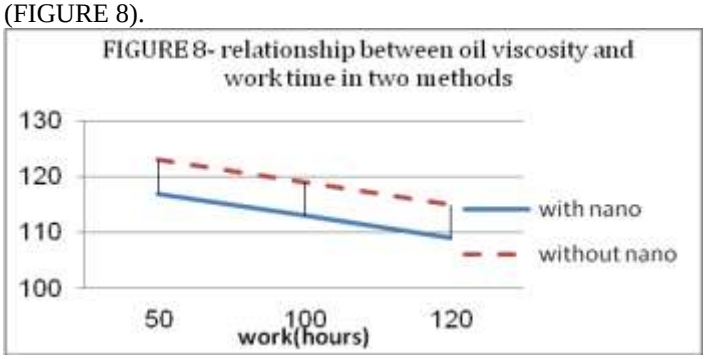
c. PQ

Because of the hardness structure of the Nano-diamond, the first samples had greater the pq number than without Nano-diamond samples, but the slope of the PQ curve reduced in last samples. Instead, in pq curve of samples without Nano-diamond, the slope increased as the service time was increased (FIGURE7).



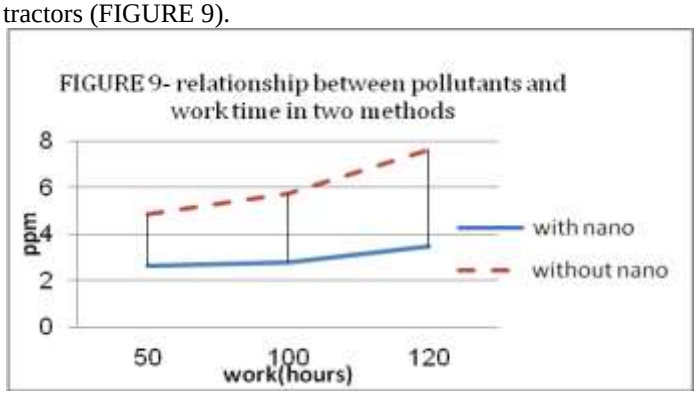
d. Viscosity

The most important lubricant oil property is the viscosity. Since existing the friction between fluid layers, the engine efficiency will decreased and the system temperature will increased, when the viscosity of lubricant oil is high. Instead, when the viscosity is very low, the ability of stable oil film formation will be minimum, then the part wearing strongly will increased by metal to metal contact. The factors that affect on viscosity variation are lubricant oil work time, components and pollution, water mixed and other failures. The Nano- diamond has positive role, since its effects on additives concentrate as a lubricant component. The results show that viscosity decreasing occurs in higher range than normal range and lubricant viscosity approximately protects itself quality in service life duration (FIGURE 8).



e. Pollutants

Very factors affect on pollutions, that the most important of them is silica, such as dust particles entering through the intake ambient air and wearing of internal parts that have silicate compounds such as seals. The pollutants approximately were decreased because of Nano-diamond positive effects on lubricant quality, and of parts wearing reducing, but the rate increases too, this may be due to workplace dusty conditions of tractors (FIGURE 9).



Statistical inference

a. Erosion particles

The erosion particles were measured for all samples and results of F test showed that has significant difference at 5% level between two methods (with and without Nano-diamond). Because of the their amounts in used Nano-diamond stage were low, can be concluded that the use of Nano- diamond have positive and effective role on erosion reduction in engines and farm tractors (TABLE 1).

TABLE 1. ANNOVA test between two methods data for erosion particles of oil

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
erosion	Equal variances assumed	.027	.870	-25.649	28	.000	-9.50667	.37065	-10.26590	-8.74743
	Equal variances not assumed			-25.649	25.632	.000	-9.50667	.37065	-10.26907	-8.74426

b Additives

The results of oil additives analyzing showed that there is significant difference in level of 5% between two methods. As the result of this analysis can reported that the Nano-diamond has effective role on oil properties protection and increasing the oil service life time (TABLE 2).

Table 2. ANNOVA test between two methods data for oil additives

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
additive	Equal variances assumed	6.573	.016	8.698	28	.000	4.33022	.49782	3.31048	5.34996
	Equal variances not assumed			8.698	19.273	.000	4.33022	.49782	3.28927	5.37117

c Metallic particles PQ

The results show that the quantity of these metallic particles is significant difference in level of 5% between two methods. Regarding to the mean of these particles quantities, we can understand that the Nano-diamond can greatly reduce the quantity of metallic particles (TABLE 3).

Table 3. ANNOVA test between two methods data for oil PQ

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PQ	Equal variances assumed	8.003	.009	-10.470	28	.000	-1.67444	.15992	-2.00203	-1.34686
	Equal variances not assumed			-10.470	17.496	.000	-1.67444	.15992	-2.01112	-1.33777

d Viscosity

Between oil viscosities in two methods have No significant difference. Since some factors such as oil work time, oil components, pollution and mixing together other materials, maybe this factors be caused that the Nano-diamond effect is not significant (TABLE 4).

Table 5. ANNOVA test between two methods data for oil pollutants

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
pollution	Equal variances assumed	.168	.685	-49.624	28	.000	-3.13289	.06313	-3.26221	-3.00357
	Equal variances not assumed			-49.624	27.500	.000	-3.13289	.06313	-3.26232	-3.00346

e pollutants

The analytical results of pollutants data showed no significant different between two methods. Since many factors other than the oil properties affect on the pollutants formation, this maybe caused of the factors such as ambient particles e.g. dust, low engine temperature, unsuitable sealing, new oil pollution, unsuitable new oil storing, combustion chamber products, unsuitable oil cooler (TABLE 5).

Conclusion

This study provides information about the Nano-diamond as an oil additive roles on lubricant oil engines properties and wear of internal parts of engine. As a general conclusion, we can state that the nano- diamond using as lubricant oil engine additive have effectives impacts on erosion particles, additives and metallic solids particles of oil. Effects of the Nano-diamond on all oil properties will be more strongly due to structural hardness of Nano- diamond, when duration of its usage is Longley.

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