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Optimal Spent Engine Oil Admixture Ratio for Economic Crucible Furnace Firing

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ABSTRACT: A crucible furnace was designed and constructed from locally sourced materials and fired using spent engine oil (SEO). While combustion of SEO was effective during evaluation which was done with the melting of Aluminium-Silicon alloy scrap metals in the crucible furnace, its continuous availability cannot be guaranteed. Experimental analysis was carried out with SEO mixed in proportions 1 : 5, 1 : 2, 1 : 1, 2 : 1 and 5 : 1 with diesel and kerosene with a aim to reduce cost. The fuel samples were comparable with the conventional fuels in terms of the physico-chemical properties evaluated. The cost of the admixed fuel reduced as the quantity of SEO in the mixture was increased. Similarly, the least amount of time taken to combust 450 ml was achieved with the fuel mixture with the least SEO ratio. Maximum temperature build up of 190 ^{o}C was achieved when the 450 ml fuel sample had kerosene as two third of its content, and maximum of 124 ^{o}C when equal proportion of diesel was added to SEO. Moreover, for melting purposes, admixtures with diesel will be recommended because of its higher calorific content that is burnt slowly. This is suitable for the latent heat required in melting.

Keywords: Spent engine oil; Admixture; Crucible furnace; Diesel; Kerosene

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INTRODUCTION

Globally, there has been increase in fossil fuel usage for industrial machines and engines, energy generation systems and transportation vehicles. This has led to increase in generation of spent engine oil (SEO) which had been used for lubricating the engines. Without appropriate economic demand for the SEO it is disposed of indiscriminately in the environment to constitute pollution due to accumulation of toxic chemicals (benzene, toluene, ethylbenzene, xylene and polycyclic aromatic hydrocarbon) causing health and environmental hazards. These pollutants find their way into plant tissues, animals and human beings by the movement of hazardous constituents in the environment (Abdulyekeen *et al.*,2016; Bamiro and Osibanjo,2004; Wang *et. al.* 2000).

Locally, the incessant fluctuations and rise in fossil fuel pump price have had negative effects on the national economy especially the manufacturing sector. With continual depletion of crude oil resources in recent times, and the ever imminent need to maintain clean and healthy environment, alternative fuel source must be found. It is imperative that modern energy solutions must not place unsustainable demands on the available natural resources, affect the environment adversely and must primarily not compete with the basic human needs (Onabanjo *et al.*, 2016).

To achieve this, efficient utilization of the available resources is imperative. Necessary efforts must be in place to ensure that energy utilization systems are modified or constructed

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in forms that best employs the available resources. For example, when SEO could be said to have completely depleted its capacity for effective lubrication, they are becoming useful as additives in concrete for concrete composition based on analysis by Akchurin *et al.* (2016) and Beddu *et al.* (2016). While the works of Al-Omari (2008), Al-Omari *et al.* (2010) and Fakolujo *et al.* (2007) suggested that SEO could be used as fuel for furnaces moreover pre-mixture with kerosene or liquified petroleum gas (LPG) could be considered.

Lubricating oils ordinarily consist of 80 to 90% of base oil, which is a complex mixture of some hydrocarbons. While the remainder is made up of performance enhancing additives. Crankcase oil composition becomes altered during use because of breakdown of additives and contamination with products of combustion making its chemical composition difficult to itemized in chemical terms (Irwin *et. al*. 1997; Lale et al.,2014; Salam,2016). Mechanical systems require lubrication to prolong their lifespan. Lubricants help to convey away heat generated as a result of metal to metal contacts of parts in relative motion. It also helps to wash away iron filing and other particles that could cause abrasion to the moving parts. During service, the spent engine oil (SEO) or used lubricating oil is usually drained and replaced with fresh ones.

Atuanya (1987) reported that Nigeria accounted for more than 87 million litres of spent SEO annually. This quantity increased to about 150 million litres per year in 2004 out of which about 90 million litres was collectible for reprocessing (Bamiro and Osibanjo,2004). Various efforts directed at regeneration of SEO are documented in Danane *et al.* (2014), Olugboji and Ogunwole (2008) and Abro *et al.* (2013).

Mbachu *et al.* (2016), Abdulyekeen *et al.* (2016), Dindar *et al*. (2016) and Salam (2016) have also documented the isolation of micro-organisms for bio-degradation of SEO. These efforts are largely on laboratory scale therefore unable to tackle the real life pollution challenge caused by indiscriminate disposal of SEO.

Indiscriminate disposal of SEO makes it to end in water drains or on open lands where they constitute pollution sources. Wang *et. al.* (2000) and Obini *et. al.* (2012) showed that the relatively large amount of hydrocarbons present in the used oil includes the highly toxic polycyclic aromatic hydrocarbons. Most heavy metals such as Vanadium, Lead, Aluminium, Nickel and Iron which were rarely detectable in fresh lubricating oil have been reported to be indicated in high proportions in used oil (Whisman *et. al.*, 1974; Vwioko *et. al.*, 2006). The heavy metals may be retained in the soil in form of oxides, hydroxides, carbonates and exchange cations which are bound to organic matter in the soil (Yong *et. al.*, 1992; Fernandes and Henriques, 1991). Nevertheless, this is dependent on local conditions and on the kind of soil constituents available. Direct effect of these metals on the metabolism and growth of some plants have been demonstrated in (Okonokhua et. al., 2007; Anoliefo and Vwioko, 2001; Ekundayo *et. al.*, 1989). Effects of freshwater petroleum contamination on amphibians has also been documented in (Mahaney, 1994).

Olugboji and Oladeji (2008) established that spent engine oil refined using activated clay compared favourably with fresh engine oil but depleted additives may need to be replenished. This imply that the calorific properties of the base oil constituent remains, thus spent engine oil could effectively serve as combustion fuel. It however remains necessary to ascertain the economic suitability for various applications. Studies have however shown that secondary fuels can be added to Nigerian SEOs to enhance its effective spray combustion properties (Yahaya and Diso, 2014). Yahaya and Diso (2012) and Fakolujo *et al.* (2007) recommended mixing SEO 85.7% and 70% kerosene but their analysis focused on only financial gains without relations to other parameters.

Olalere (2015) demonstrated that the SEO obtained after the routine service of automobile and generator engines could be effectively employed as the fuel for combustion in the crucible furnace he locally built for research purposes. The focus of this work is to estimate the optimal mixture ratio for SEO and kerosene, and SEO and diesel for the most economic firing of the crucible furnace. Through this, improved financial savings and environmental protection can be achieved.

MATERIALS AND METHODS

Spent engine oil was collected from several automobile service workshops within Akure Metropolis. Akure is located within the humid region of south-western Nigeria on latitude 7° 16'N and longitude 5° 13'N. Physico-chemical analysis of the SEO fuel were carried out in accordance with American Society for Testing and Materials (ASTM) stipulations (ASTM D445-15, 2015; ASTM D287-12b, 2012; ASTM D92-12b, 2013). The design and construction details for the crucible furnace used is documented in (Olalere, 2015). The physico-chemical properties of SEO, diesel and kerosene are shown in Table 1.

Experimental Procedure

The furnace was preheated for about 10 minutes. 12 litre of SEO was boiled (to remove water molecules) and filtered to remove iron fillings and other debris or particles in the oil. The mixtures of the fuels were metered into 10 clean bottles based on ratio designations in Table 2. Each bottle therefore contained 450 ml mixture which is made up of six 75ml part according to the designations in Table 2. For example, the ratio designated S_1D_5 implies a mixture with 1 part of SEO to 5 parts of Diesel mixed together to make 450 ml, each part being 75 ml each. This arrangement holds for all the other nine ratio designations.

The fuel sample mixtures were shaken vigorously to ensure proper mixing and evaluated for the physico-chemical properties enumerated in Tables 3 and 4. All the samples were in liquid state at room temperature (taken to be 25°C) and dark brown in colour.

The blower was turned on, air and fuel regulators were opened as combustion was initiated. The time taken to completely combust 450 ml of the fuel was monitored each time on a stop watch. The maximum temperature attained within this period was also measured using K-type thermocouple. Afterward, the fuel regulator was closed and the blowers turned off. The little traces of the fuel remaining were wiped clean before repeating the procedure for a new fuel sample.

Table 1: Physico-chemical Properties of the Spent Engine Oil, Diesel and Kerosene Fuel

Fuel	Colour	State at room temperature (i.e. at 25°C)	Flash point (°C)	Fire point (°C)	Specific gravity	Kinematic viscosity (mm²/s)	Calorific value (kJ/kg)
SEO	Dark brown	Liquid	260	300	0.8882	206.60	41,870
Diesel	Clear but yellowish brown	Liquid	52	59	0.8670	5.80	44,800
Kerosene	Pale yellow	Liquid	38	40	0.8000	2.00	35,000

Table 2: Admixture Ratios in 450 ml Fuel Samples

Designations	Spent engine oil (SEO)	Diesel	Designations	Spent engine oil (SEO)	Kerosene
S_1D_5	1	5	S_1K_5	1	5
S_1D_2	1	2	S_1K_2	1	2
S_1D_1	1	1	S_1K_1	1	1
S_2D_1	2	1	S_2K_1	2	1
S_5D_1	5	1	S_5K_1	5	1

Table 3: Physico-chemical Properties of the Admixed Spent Engine Oil Fuel with Diesel

Fuel	Flash point (°C)	Fire point (°C)	Specific gravity	Kinematic viscosity (mm^2/s)
S_1D_5	62	69	0.8533	3.9193
S_1D_2	84	96	0.8539	6.9316
S_1D_1	98	110	0.8604	9.7089
S_2D_1	102	112	0.8614	20.2090
S_5D_1	110	142	0.8832	50.3221

Table 4: Physico-chemical Properties of the Admixed Spent Engine Oil Fuel with Kerosene

Fuel	Flash point (°C)	Fire point (°C)	Specific gravity	Kinematic viscosity (mm^2/s)
S_1K_5	75	89	0.8270	2.0689
S_1K_2	84	96	0.8371	3.3268
S_1K_1	92	100	0.8521	8.4477
S_2K_1	88	92	0.8654	12.3240
S_5K_1	102	122	0.8757	43.7811

RESULTS AND DISCUSSION

Physical properties of various admixture ratios of the spent engine oil with diesel and kerosene fuel are presented in Tables 3 and 4. It could be observed that all the properties evaluated for (that is, flash point, fire point, specific gravity and kinematic viscosity) increased and the proportion of diesel and kerosene in mixture was reduced. This is expected because diesel and kerosene are less dense and viscous than the spent engine oil.

Figure 1 presents the temperature built up in the furnace due to the combustion of the 450 ml of the various fuel admixtures. The furnace was preheated before initiating combustion each time. The maximum temperature build up of about 190 °C attained was achieved when the ratio of kerosene to spent engine oil was 2:1. The maximum temperature build up attained using the spent engine oil and diesel mixture was 124 °C, this was achieved with equal proportions of spent engine oil and diesel. The temperature build up achieved when the admixture contained kerosene superseded the ones for mixture containing diesel for all the ratios except when the mixture had diesel and spent engine oil in equal proportions.

The time taken for the combustion of the fuel mixtures increased in exponential pattern for both cases, but the mixture with diesel took longer time to burn off. This is expected because of its relative volatility compared to kerosene. Also, Tables 3 and 4 showed that flash and fire points for all the mixtures were much lower than that of the spent engine oil in Table 1. The high flammability of kerosene and diesel can therefore be said to be a major influence on trends in Figures 1 and 2.

In Figure 3, the estimated cost of the fuel samples declined as the quantity of the spent engine oil in the mixtures increased. The cost of the admixtures with kerosene is lower than those for diesel because of the higher market demand for diesel than kerosene (kerosene being largely used for domestic cooking and heating). This makes the kerosene admixtures to be preferred to those of diesel, and the preferred admixture ratio being 1 part of spent engine oil to 2 parts of kerosene.

Cheaper mixtures moreover produces carburizing flames which does not attain high temperatures quickly making it difficult to attain the objective of melting the metal in the shortest time possible.

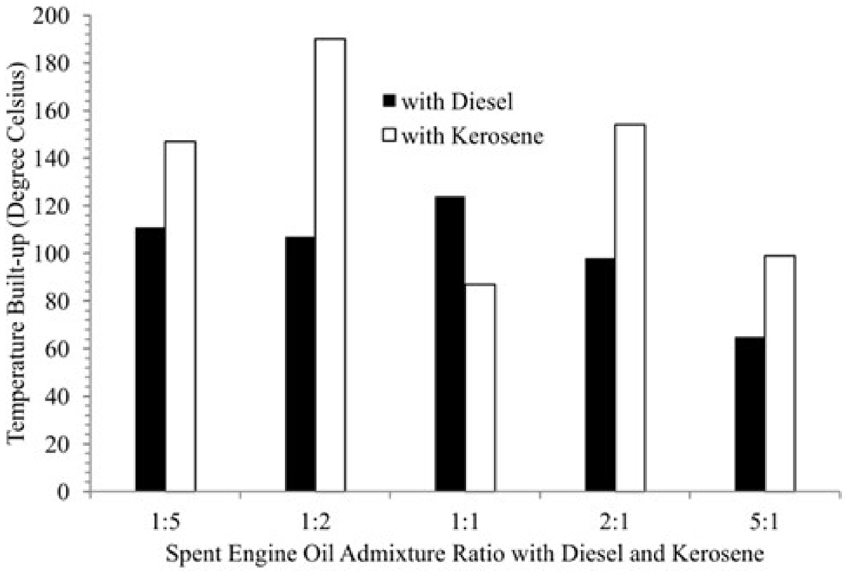

Figure 1: Temperature built up achieved for various fuel admixture ratio

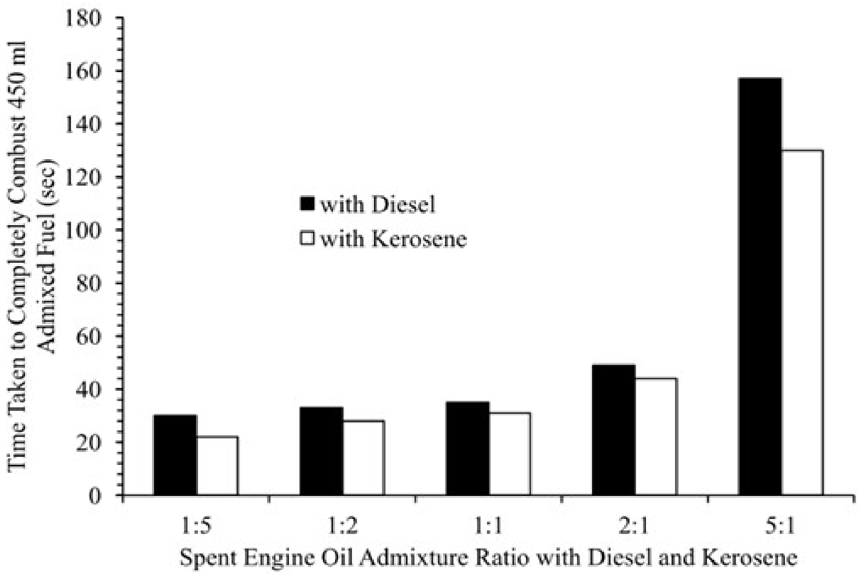

Figure 2: Time Taken to Completely Used Up 450 ml Admixed Fuel

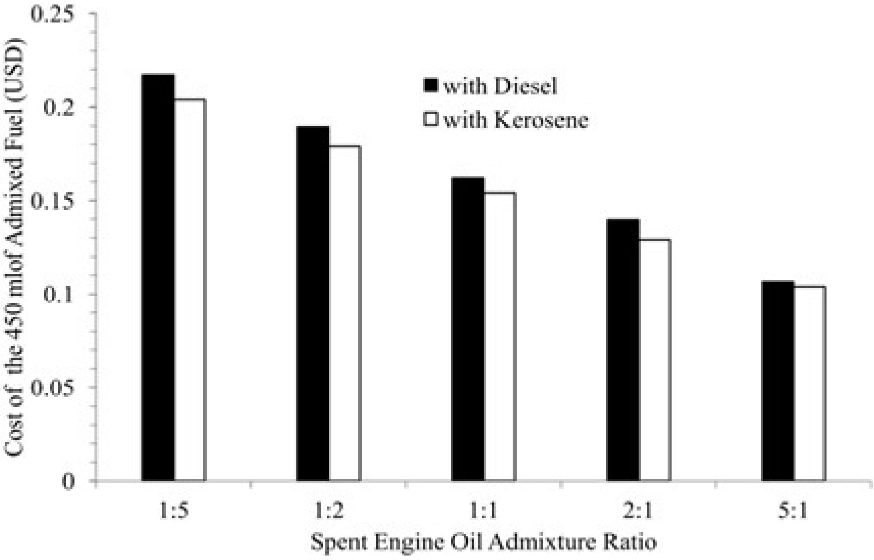

Figure 3: Cost of combustion of 450ml the different fuel admixtures

CONCLUSION

Various admixtures of spent engine oil with kerosene and diesel was evaluated for economic firing of a locally built crucible furnace. The cost of 450ml sample of each mixture, the temperature built up when combusting the sample and the time taken to completely combust the mixture sample was measured. Physical properties of the sample oil mixtures, like flash point, fire point, specific gravity and kinematic viscosity, were also measured. Generally, mixtures with kerosene had higher temperature built up and lower duration for combustion of the 450ml mixture samples. While kerosene is recommended on this basis, admixtures with diesel will be more suitable for melting purposes because of the latent heat that will be required. Diesel has higher calorific value and burns more slowly. Therefore, equal proportion of spent engine oil to diesel is proposed as optimal admixture ratio for melting in the crucible furnace.

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