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Design and Construction of a Waste Oil Burner

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***Abstract**: Waste lubrication oil (WLO) discharged from automobiles, generators and other machineries are often disposed of in the surroundings, this activity frequently leads to contamination of soil and underground water; causes devastating explosions and fires. This paper presents the design and construction of a waste oil burner, which utilizes WLO as a source of fuel for an aluminum metal melting furnace. The criterial for the waste oil burner design and selection of auxiliary equipment were based on the stoichiometric air/fuel ratio, feed mechanism and the maximum flame temperature attainable. A sampled SAE 20W-50 WLO was considered and its thermodynamic properties relevant to this studies include: viscousity, flash point and calorific value. Performance test carried out on the waste oil burner reveals a peak temperature of 919^{o}C at an oil flow rate of 630 kg/hr with a firepower of 723 kW capable of melting 10kg of aluminum cans within a time interval of 9 minutes.*

Keywords—Lubrication oil, Furnace, Calorific value, Thermal energy, Flame temperature, Viscousity and Firepower**.**

1. Introduction

Any petroleum-based oil that is unfit for use after performing its intended purpose and has lost its original qualities is considered waste oil. Large amounts of lubricating products are used in our automobiles, generators, farm machinery and industrial operations, necessitating a solution to the problem of what to do with them when their useful life is up. A waste oil burner is designed for the purpose of heat treatment and melting of metals in a furnace. According to a study by Kristin (2019), over 1.3 billion gallons of waste lubrication oil (WLO) are generated from the crankcases of millions of cars and trucks every time the oil is changed and are not properly disposed of. WLO does not degrade with use but it simply becomes dirty. As a result, the environmental impact of uncontrolled dumping and land filling of used oil in the environment is significant (Abu-etella et al., 2015).
Lead, cadmium, chromium, arsenic, dioxins, benzene and polycyclic aromatics are all present in WLO. Navaneenth et al. (2019), asserted that Water, barium, carbon, sulphur, dirt and ash are among the metal particles and chemicals found in waste oil; majority of them are highly poisonous in nature. Elisa and Mauro (2015), stated that because recycling is expensive and involves numerous processes and costs, waste oil burners or furnaces can be a cost-effective option to recycling. Waste oil furnaces provide an infinite quantity of energy, which can be utilized for heating processes– heating hot water and melting. There are various types of waste oil heaters or furnaces available in which used oil such as recycled oil, hydraulic fluids, transmission fluid and vegetable oils are burned in them.
Lubricating oils, according to Udonne et al. (2016), are viscous liquids that comprise roughly 90% base oil and fewer than 10% additives. These viscous solutions are used to protect machine and engine moving parts from getting worn out. Polycyclic aromatic hydrocarbons and polycyclic compounds are produced and gathered in the oil with metal from the wear and tear of moving parts in the machine being lubricated, as well as the chemical breakdown of the additives during use. These components in the waste or used oils are toxic and extremely harmful to humans and aquatic life (Chung et al., 2007).
Salah (2008), reported that WLO is valuable because it can be used to power plants, cement kilns, incinerators and some other manufacturing devices. When filtered and combined with diesel fuel up to 1%, WLO can be utilized for heating in industrial heaters and in heavy-duty engines. It can be used for chainsaws, lawnmowers, diesel-powered leaf blowers and wood splitters, if it is suitably filtered. WLO can be recycled and utilized to lubricate mechanical devices such as frozen bolts and rusty bits of screws.
Madu et al. (2014) designed, built and tested a burner for foundry applications that uses an admixture of spent engine oil and kerosene. The following are the outcomes of their investigation: Loss due to Friction, h_f = 2.9 x 10^{-5} m/s, Re = 1388 (Laminar flow), Loss at pipe entry = 1.313 x 10^{-3} Pa, Loss due to Nozzle = 1.05 x 10^{-4} Pa, Pressure in fluid = 180.504N/m^2. Other outcomes include the air fuel ratio, burner thermal efficiency and so on.
The aim of this study is to design and fabricate a waste oil burner that can be used as source of heat for a furnace. Thus, to achieve this aim the following objectives are projected:

i Determination of thermodynamic properties of the waste oil
ii Determination of air/fuel ratio
iii Selection of air blower

The waste engine oil considered for the present work is disused lubrication engine oil for automobiles and generators with the specification: Society of Automotive Engineers (SAE) 20W-50.

2. METHODOLOGY

The methodology proposed in this work gives the contextual framework for the research and comprises of the material selection, detail design as well as the performance evaluation.

2.1 Thermo-Chemical Properties of the Waste Oil

The analysis of the thermo-chemical properties of the waste oil was carried out and the result is shown in Table 2.1.

Table 2.1: Thermo-Chemical Properties of the Waste Oil

a	Apparatus	Results
Flash point	Pensky Martin	112ºC
Fire Point	Pensky Martin	143ºC
Calorific Value	Bomb Calorimeter	38,000 kJ/kg
Viscosity	Redwood Viscometer	68.2 cs
Density		714 kg/m^3
Specific Gravity		0.724

2.2 Determination of Air/Fuel Ratio

The determination of air/fuel ratio was done by applying the combustion equation using 125% excess air.

$C_{16}H_{34} + (1.25)(24.5)O_2 + 1.25[24.5(79/21)]N_2 \rightarrow$
$\rightarrow 16CO_2 + 6.125O_2 + 17H_2O + 1.25[24.5(79/21)]N_2$

From the above equation 226 kg of waste oil requires 980 kg of oxygen for combustion, therefore 1 kg of waste oil requires 18,87 kg of air for actual combustion.
Hence, the air/fuel ratio is **1:18.9**

2.3 Material Selection

The material selection required for the construction of the waste oil burner is given in Table 2.2.

Table 2.2: Material Selection

Part	Material Selected	Material Properties
Frame	Mild Steel	High strength
Fuel Tank	10L Cylinder	Corrosion resistance
Hose	Polymer	Durable and oil resistance texture
Nozzle	Aluminium, Mild Steel	Ability to atomize the fuel
Combustion Chamber	Galvanised Steel Pipe	High fusion temperature

2.4 The Selection of Air Blower

The air blower used to introduce combustion air into the combustion chamber was selected based on the specification presented in Table 2.3.

Table 2.3: Specification of Air Blower

Specification	Value
Capacity	600 W
Flow rate	3.3 m^3/min
Pressure	190 mBar
Speed	6000 rev/min
Power source	Electric
Type	Centrifugal

2.5 Conceptual Design of the Waste Oil Burner

The conceptual design of the waste engine oil burner envisages a hollow galvanized metal pipe with two opening for admitting drip oil and combustion air. It also has provision for automatic ignition given by a torch. The diagram is shown in Figure 2.1.

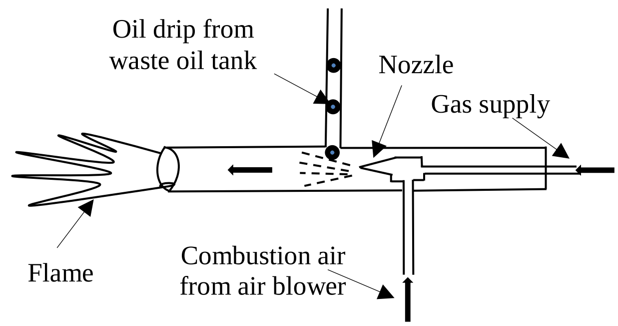

Fig. 2.1: Schematic diagram of the waste oil burner

2.6 Design and Technical Specification of the Waste Oil Burner

The design and technical specification of the waste oil burner is given in Table 2.4.

Table 2.4: Product Specification

S/N	Items	Details
	A. Air blower	
1	Type	Centrifugal
2	capacity	600kW
	B. Feed system	
3	Mechanism	Gravity
4	Hose type and diameter	Polymer / 5 mm
5	Storage tank	10 L cylinder
	C. Auxiliary fuel	
6	Type	Methane gas
7	Calorific	50,000kJ/kg
	D. Casing	
8	Material type	Galvanized steel pipe
9	Internal/External dia.	60 mm / 64 mm
	E. Frame	
10	Material	Steel angle bar
11	size	40 mm

2.7 Working Principle of the Waste Oil Burner

The waste oil burner operates by an initial ignition provided by a methane gas line and air supplied by an air blower. After a steady combustion is maintained by this process, the waste oil valve is opened to allow waste oil drip at the tip of the nozzle. The oil undergoes combustion and when a steady flame is achieved, the methane gas supply is cut off.

2.8 Performance Test

Figure 2.2 shows the prototype waste oil burner that was fabricated. Performance test was carried out on it, in order to the determine the following:

1) The flame temperature for a given mass flow rate.
2) The flame length.

3) The firepower of the waste oil upon combustion process.

Fig. 2.2: The prototype waste oil burner connected to a furnace

3. RESULTS AND DISCUSSION

The results of the performance test carried out on the waste oil burner is presented in Table 2.5.

Table 2.5: Result of Performance Test

Mass flow rate (kg/hr)	Flame temperature (ºC)	Fire power (kW)
5.00	870	5.92
5.30	890	6.12
5.50	895	6.75
5.65	900	6.90
6.00	910	7.05
6.30	919	7.23

The WLO calorific value and test length were both constant in the experiments, leaving the mass flow rate of the oil consumed as the only variable. As a result, the mass of fuel used in 300 seconds was meant to measure the firepower. Between the minimum and maximum flow rates, there was a significant increase in firepower. Secondly, the firepower and the amount of oil burned were related, so an increase in the amount of fuel burned implied an increase in firepower, as seen in the data presented in the Table 2.5. The improvement in firepower with increasing fuel flow rate was attributed to finer fuel atomization, which improved reactant mixing and combustion efficiency.

During the waste oil combustion, the temperature of the flame was recorded. Temperatures were measured and graphed at various fuel flow rates, as shown in Table 2.5. The temperature of the flame was measured by inserting a K-type thermocouple into the core of the flame. Temperature increased with fuel flow rate at all stoichiometric ratio (SR) levels, as shown in Table 2.5. This can be attributed to the fact that flow pressures were insufficient to atomize fuel into very small sprays for efficient burning at lower fuel flow rates. As a result, fuel/air mixing was insufficient, and combustion was less efficient than planned. The fact that unburnt hydrocarbon (UHC) was highest for the same flow rate further confirmed this. The temperature of the flame in combustion is determined by the type of fuel utilized, the amount of excess air present and the degree of atomization and oxidation in the process. Flame temperatures of over 1200ºC are possible using liquid and gaseous fuels. The greatest flame temperature attained in this study was 919.2ºC, which was due to better fuel atomization caused by high pressure fuel flow rates. Improved atomization leads to improved fuel oxidation, which leads to near-complete combustion. The temperature of the flame increased as well as the amount of air supplied. An increase in combustion air oxygen concentration allows for more stable combustion, resulting in greater combustion and flame temperatures, which improve heat transfer and combustion thermal efficiency (Lalovi et al., 2011).

4. CONCLUSIONS

Based on the findings, it can be concluded that waste engine oil can be burned to generate process heat to supplement energy demand in small to medium industries. This can help to cut down on the costs of energy production. This confirmed that WLO contains a significant amount of unused energy that is discarded. When compared to WLO, conventional fuels such as coal, which are mostly used for energy generation, have very low heating values (between 25 and 35 kJ/kg). As a result, WLO should be used for energy generation.

The WLO burner's ability to supply process heat for steam boilers is demonstrated by the maximum flame temperature of 919.7ºC achieved in open space combustion. When a WLO burner is used to provide process heat in the above-mentioned equipment, it can save a significant amount of energy when compared to when conventional electricity is used exclusively. When compared to a 3 kW electric heater, heating 100 L of bath water with a WLO burner can save up to 75% on energy. Waste lubrication oils are excellent liquid fuels, and with the right burner design and manufacturing, they may be a stable source of energy to complement our country's energy supply.

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