

Preliminary Study on Utilization of Used Lubricant as Fuel Substitute for Metal Foundries

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Abstract: There are problems with too much waste of engine lubricants and expensive coke as raw materials and fuel for metal foundries. The research goal is investigating the possibility of exploiting used lubricants as fuel. Physical and chemical properties were considerably degraded due to high temperatures and pressures and severe friction. Therefore it was treated with the help of H₂SO₄ and Triethylamine (TEA). The treatment can significantly reduce specific gravity and kinematic viscosity, which makes the fuel easier to be sprayed and atomized while the calorific value increases. Some laboratory scale aluminum casting tests were conducted to investigate Combustion Temperatures, Fuel Consumptions, Flame lengths, and Melting Times. The burner is a vaporizing type with a double walled torch. The inner and outer diameters of the tubes are 50 mm and 60 mm. The fuel vaporization occurs in the concentric space between the tubes before it flows further through a nozzle into a combustion chamber. All experiments were carried with four variations of fuel pressure and two variations of fuel valve position. Thermocouples are placed in three points, i.e. base, midpoint and tip of stable flames. Temperatures go higher if higher fuel pressures are applied, due to more fuel supplied to the burner and more heat release. However the temperature increase is lesser at higher pressures. The influence of fuel valve opening is significant as well, where fully opened valve will generate the highest temperatures (up to 1120 °C). The highest temperatures are achievable in flame midpoints. However, at higher pressures the temperature difference between midpoints and bases is negligible. Fuel consumptions are measured for the same fuel pressure and valve opening variations. As expected, higher fuel pressures and wider valve openings will allow more fuel flow to the burner, but for lower pressures the influence of valve opening is small (around 18%) while for higher pressures the influence is very strong (around 63%). The next experiments are observations of melting time of 2 kg aluminum. As expected, higher pressures and wider valve opening will result in shorter melting times due to more intensive combustion heat. However the decrease is less substantial at higher pressures and wider openings. The next observations are finding out flame lengths as a function of fuel pressures and valve openings. It must be mentioned here that the air supply is kept constant. For the same fuel pressures, wider opening will normally lengthen the flame, due to more required time and space to oxidize the fuel. Flame length determines furnace dimension

Keywords: Combustion, Foundry, Fuel Substitution, Lubricant, Recycle

Introduction

Coke fired cupola furnaces remain the predominant unit for cast iron production. It is beneficial that the use of cheaper raw materials, such as steel scraps, is possible in these furnaces. Coke is especially used because it exercises the dual function of fuel and carburizing agent. Unfortunately coke becomes more rare and expensive in Indonesia, which makes approximately two third of the existing metal foundries in Ceper (Central Java) temporarily cease their production [1]. The solution to the problem could be cokeless cupola furnaces [2], however the substituting fuel must be cheaper than coke. In connection with this, environmental friendly cokeless cupola furnaces have been developed since 2003, where LDO (light diesel oil) or LPG (liquefied petroleum gas) is used to replace coke. The emission level, especially for particulate matters and sulfur dioxide, can be reduced. Moreover the SG (Spherodized Gray) number of foundry products will be better [3]. In Indonesia, nevertheless, the use of both alternative fuels is still considered to be uneconomical due to their high prices.

Lubrication is extremely required for all moving parts of energy systems, such as internal combustion engine pistons, plain bearings, ball bearings, roller bearings, meshing gear sets, etc. The right amount of lubricants in the right place at the right time will enormously prevent friction which will otherwise heat surfaces come into contact, and cause expansion and wear. It is claimed that over one third of the world's energy production is consumed in overcoming friction. The use of proper lubrication can effectively triple the life of a mechanical component [4]. Most lubricants are liquids, such as mineral oils, synthetic esters, silicon fluids, etc. Fluid film lubrication can completely separate two moving surfaces and frictional resistance to motion arises entirely from the shearing of the viscous fluid [5]. Since some liquid lubricants are derived from petroleum and synthetic oil, which consists of compounds of carbon and hydrogen, they can be burned relatively easy to extract its energy content. Along with continuous progress of industry and transportation sectors there will be serious environmental problems concerning too much engine lubricants which are disposed but not adequately treated previously.

Considering those problems a research should be conducted in order to investigate the possibility of exploiting used lubricants as a fuel substitute in cupola furnaces of Indonesian metal foundries

Methodology

All experiments, but not including the treatment of used lubricants, were carried with four variations of fuel pressure, i.e. 0.5 bar, 1 bar, 1.5 bar and 2 bar, and also two variations of fuel valve position (half opened and fully opened). It must be mentioned here that the air supply is kept constant during the observations, because the blower setting was unchanged.

Treatment of used lubricants

Physical and chemical properties (including heating value) of used lubricants were considerably degraded due to high temperatures and pressures and also severe friction. Therefore it was treated according to the following steps :

- heating until 180°C to evaporate water content, then cooling until 30°C,
- pouring small amount of H₂SO₄ into the lubricants (with a ratio of 1:7) and stirring for about 90 minutes to obtain red liquid, then let dark colored residues settle for 24 hours,
- separating the clear upper fraction from the settling dark fraction and addition of small amount of *Triethylamine* (TEA) into the clear fraction with the ratios of 1: 25, 1: 30, 1: 35 and 1: 40, then stirring for approximately 90 minutes to obtain green liquid and finally settling for 24 hours,
- recovering the clear upper portion which now can be used as fuel

Combustion temperatures

The burner is a vaporizing type with a double walled torch. The inner and outer diameters of the annulus are 50 mm and 60 mm. The fuel is fed with the help of a pump. The fuel vaporization occurs in the concentric space between the tubes before it flows further through a nozzle into a combustion chamber. Thermocouples are placed in three points, i.e. base, midpoint and tip of stable flames in order to observe combustion temperatures, as seen in Figure 1.

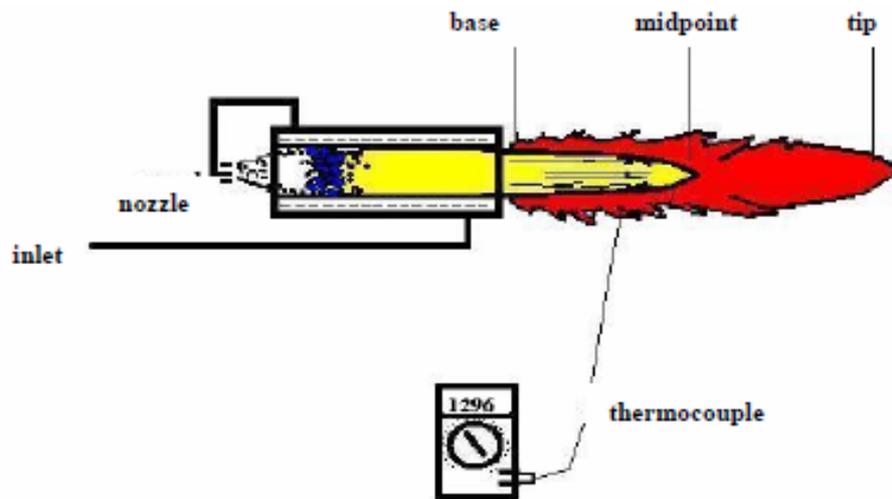


Fig.1 Schematic of Temperature measurements

Thermocouples are connected to a multimeter which functions as a temperature reader. All required air is primary air, since there is no secondary air.

Fuel consumption

Fuel consumptions are observed for the same fuel pressure and valve opening variations. The measurement is carried out by investigating the rate of fuel surface drop inside a cylindrical fuel tank with a capacity of 20 liters. The level of fuel upper surface is recorded for each minute. Multiplying the decrease rate with the cross sectional area of the tank and the oil density will yield the sought fuel consumption.

Melting time

The next experiments are focused to obtain the melting time of 2 kg of aluminum. A 27 cm diameter cylindrical crucible is used to melt aluminum. It is made from cast iron and covered with refractory brick. The observed melting time is the required period to increase the material temperature from ambient up to its melting temperature, therefore each measurement begins when stable flames from the burner is directed and contacted to the metal inside the crucible and terminates when the metal commences to melt, as seen through an opening in the crucible mouth.

Flame length

The next observations are finding out flame lengths as a function of fuel pressures and valve openings. The measurement was conducted simply with the help of a ruler which is longitudinally positioned in the same direction as the flame jet. The recorded length is the utmost distance that can be achieved by the flame. Pictures were taken for different cases in order to make analysis easy.

Results and Discussion

Treatment of used lubricants

After various treatments the physical and combustion characteristics of the lubricants are measured [1 and 6] and summarized in the following Table 1. It was obvious that the treatment can significantly reduce specific gravity and kinematic viscosity, which makes the fuel easier to be sprayed and atomized. If HHV (higher heating value) is a negative function of specific gravity, according to the Eq. (1)

$$HHV = 22320 - (3780 \times SG^2) \text{ Btu/lb}, \quad (1)$$

it means that the treatment can increase its calorific value.

Table 1 Lubricant characteristics, without and after various treatments

No	Characteristics	Treatment types				
		Used lubricant	1:25	1:30	1:35	1:40
1	Specific gravity 60/60°F	0.9056	0.8866	0.8926	0.8886	0.8762
2	Kinematic Viscosity 40 °C, cSt	85.05	63.23	71.95	58.78	55.19
3	Kinematic Viscosity 100 °C, cSt	10.58	9.374	9.904	8.649	8.604
4	Residual Carbon, %wt	1.780	1.055	1.691	1.359	0.339
5	Water Content, % vol	0.2	0.7	1.0	1.1	0.4
6	Residue, %wt	0.368	0.266	0.294	0.278	0.331
7	Higher Heating Value (kcal/kg)	10684.9	10756.5	10734.0	10749.0	10795.0

Combustion temperature

The measurement results are displayed graphically in Figures 2 and 3

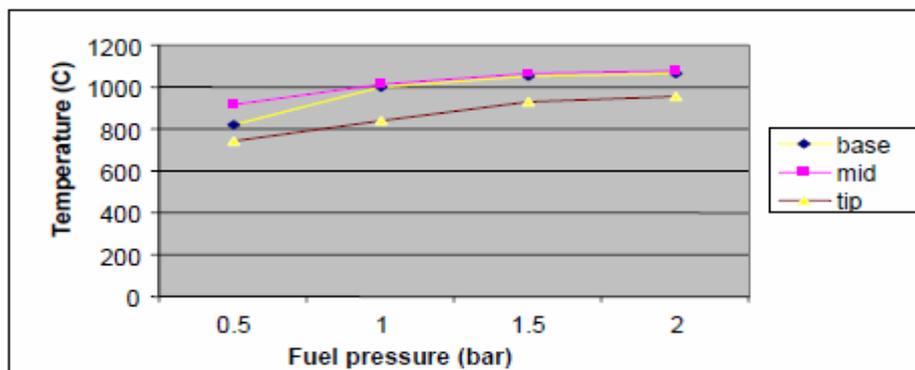


Fig. 2 Combustion temperatures for half opened fuel valve

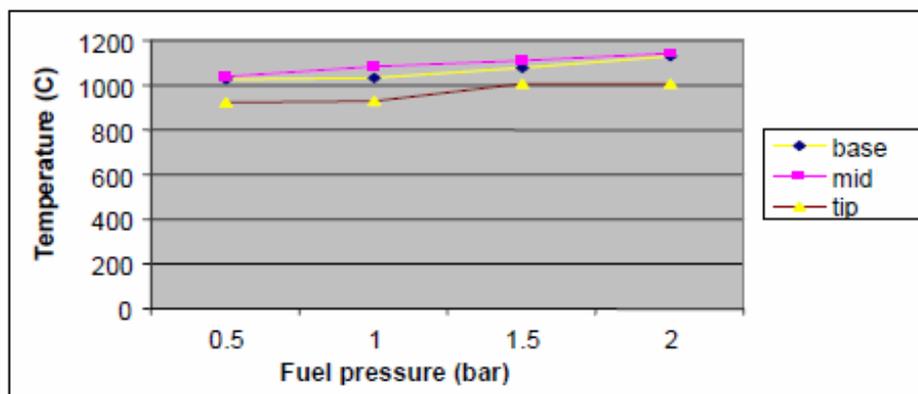


Fig.3 Combustion temperatures for fully opened fuel valve

Temperatures go higher if higher fuel pressures are applied, due to more fuel supplied to the burner and consequently more heat release. However the temperature increase is less significant at higher pressures because more fuel is not accompanied with more supplied air, therefore the mixtures become richer. The influence of fuel valve opening is significant as well, where fully opened valve will generate higher temperatures. The highest temperature (at 1120 °C) occurs in the midpoint at the fuel pressure of 2 bar and fully opened valve. The highest temperatures are always attainable in flame midpoints where combustion intensity achieves the highest rate, while the lower temperatures occur in flame bases and tips. Near the flame base, evaporation and mixing of fuel with air still take place, so the combustion has not really begun. Meanwhile in the flame tip the amount of combustibles has been reduced significantly, so the reaction rate will be lower. However, at higher pressures the temperature difference between midpoints and bases is negligible. It seems that the stoichiometric condition has not been achieved in the experiments, because more fuel supply still tends to increase the temperature.

Fuel consumption

The measurement results are displayed graphically in the following Figure 4.

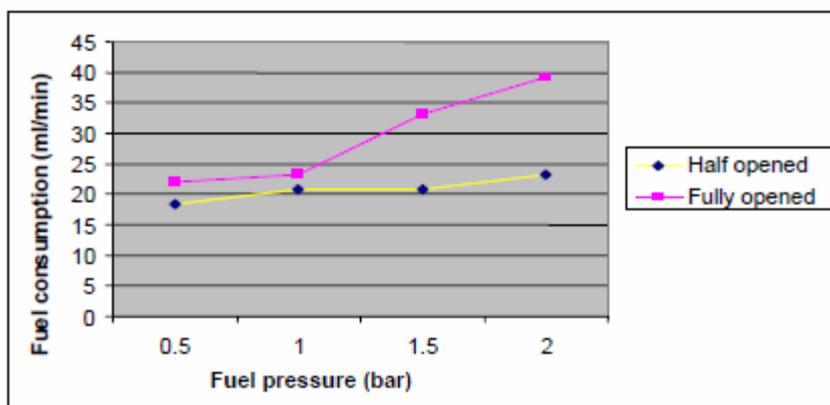


Fig.4 Fuel consumption

As expected, higher fuel pressures and wider valve openings will allow more fuel quantity to the burner due to less flow resistance. If the valve is only partially opened, the fuel pressure seems to play negligible role in fuel flow, but at fully open mode, the fuel amount is highly dictated by the fuel pressure. For lower pressures the influence of valve opening is small (around 18% increase), while for higher pressures the effect is very strong (around 63% escalation).

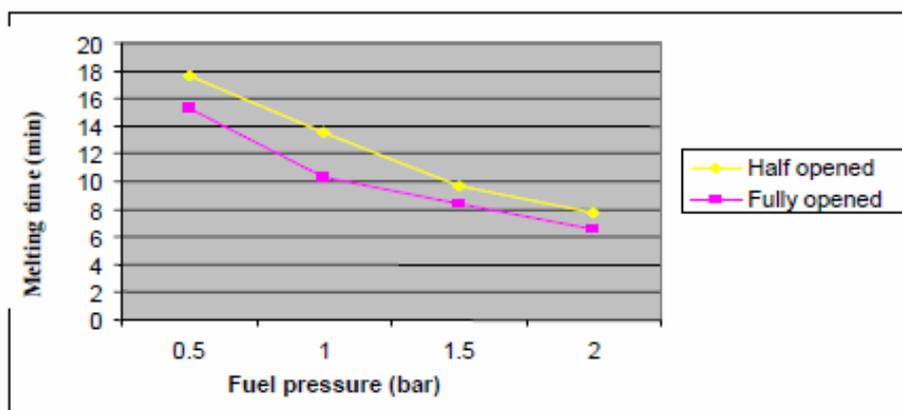


Fig. 5 Melting time of 2 kg aluminum

It is not surprising that higher pressures and wider valve opening will result in shorter melting times due to more fuel flow and more intensive combustion heat. However the decrease is less substantial at higher pressures and wider openings. It is probably caused by non linearity of supplied fuel with generated heat required for melting. In spite of remarkable increase of fuel flow at higher fuel pressures, the decrease of melting time is not as much as expected. The reason is that combustion air is not supplied in the proper amount according to fuel supply but always kept unchanged, therefore the released heat is limited by the incoming air quantity.

Flame length

The observation results are presented in the Table 2, while the pictures are shown in Figures 6 and 7.

Table 2 Flame lengths and flame colors

Fuel pressures (bar)	Half opened		Fully opened	
	Lengths (cm)	Flame color at burner mouth	Lengths (cm)	Flame color at burner mouth
0.5	19	Red	27	Yellow
1.0	32	Yellow	29	Blue
1.5	25	Light blue	45	Bright yellow
2.0	24	Blue	50	Bright yellow

For the same fuel pressures, wider opening will normally lengthen the flame, due to more required time and space to completely oxidize the higher fuel flow rates. Flame length is important to be investigated for almost all combustion applications because it determines furnace dimension or distance of heated materials. Furthermore, it seems that the colors represent the temperature or released heat, where red indicates the observed lowest temperature, while bright yellow corresponds to the measured highest temperature.

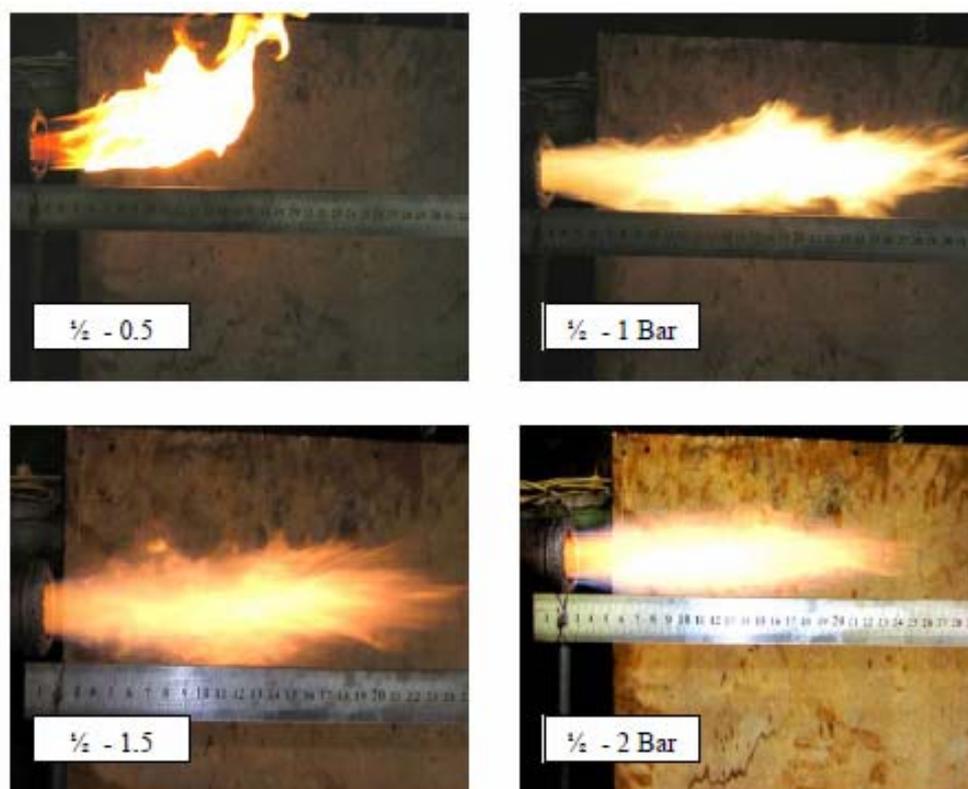


Fig. 6 Flames at half opened fuel valve

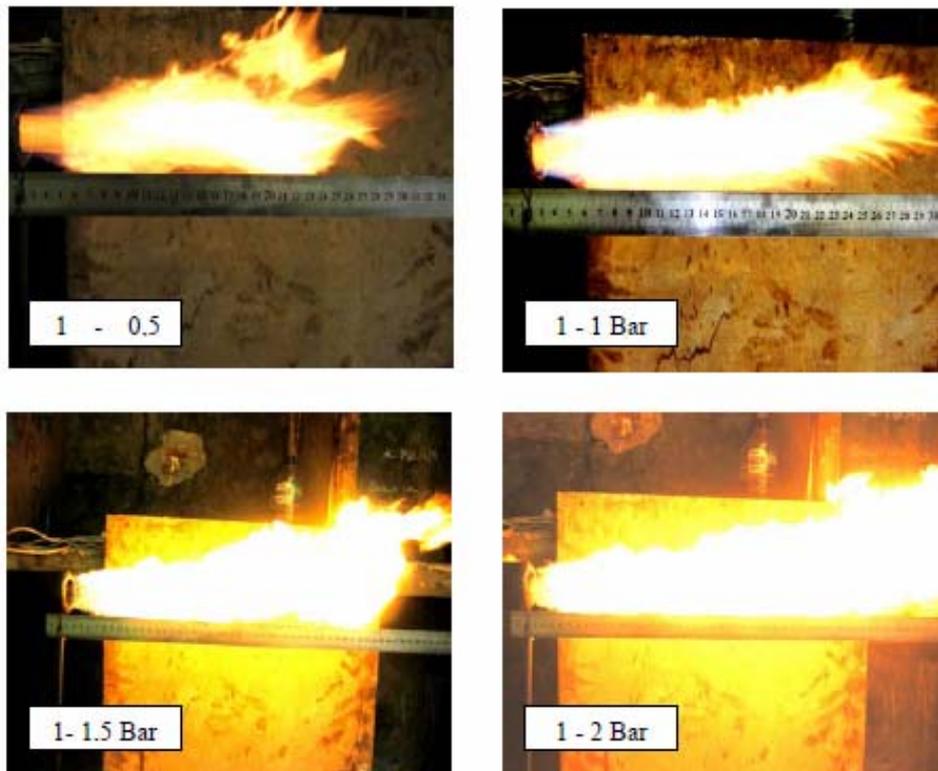


Fig.7 Flames at fully opened fuel valve

Conclusion

Based on those experiments, it can be concluded that:

1. Used lubricant can be utilized as fuel substitute in metal foundries, especially for metals with low melting temperature, such as aluminum.
2. In order to be more suitable used lubricant must be treated prior to usage to improve its combustion characteristics and remove its heavy metal content.
3. The designed burner is appropriate and satisfying
4. It is possible to generate high temperatures inside the furnace with some conditions, such as high fuel flow rate (achievable through higher fuel pressure and fully opened valve), appropriate air supply, etc.

Acknowledgments

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