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# Effect of Temperature to Diesel (B0) and Biodiesel (B100) Fuel Deposits Forming

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**Abstract.** In this study, forming of deposits from biodiesel with different variation, that are Diesel (B0) and Biodiesel (B100) will be observed with hot surface plate method to find their characteristics and growth mechanisms, formed through repetitive process of deposition and evaporation that were done to every fuel variation. Growth was observed by using two methods of droplet testing, single droplet test and multi droplet test. This study program was created to finding the optimum temperature in order to control the forming of deposits in combustion chamber. Based on the results shown that Diesel (B0) evaporation time is faster than Biodiesel (B100). The growth of B0 deposit mass is smaller than B100 at temperatures 300°C and 350°C.



## INTRODUCTION

The need for fossil fuels have become a basic need of human life. However, fossil fuels include natural resources that require a long time to be renewed. Moreover, due to excessive exploitation, making fossil fuels become scarce and will run out completely. We can not depend on fossil fuels anymore. Indonesia actually has other potential for fuel needs. Indonesia is rich in natural vegetable resources that have the potential to be used as alternative fuels to replace fossil fuels. Biodiesel is an alternative fuel that has environmental advantages and can be renewed; help balance the emissions of carbon dioxide ($CO_2$) in nature and made from plant natural resources.

However, the use of biodiesel is still not used fully. Biodiesel must be mixed with diesel fuel derived from fossil fuels. The percentage of biodiesel is still not too large. This is caused by biodiesel problem in Diesel engines. The emergence of deposits or soot in some Diesel engine components such as combustion chambers and injectors is the main problem. One of the factors causing an increase in the amount of deposits on diesel engines come from the oxidation results or thermal degradation of FAME biodiesel.

As long as the engine is operating, there are many droplets inside the combustion chamber that occur during the atomization process, the droplets will experience evaporation and burning in the combustion chamber. However, there will be some droplets that hit the wall and stick, in many cases, especially in small diesel engines, high probability of rotation will be greater [1]. In an intensive study conducted by Werlberg and Cartetellieri, nearly 50% of the fuel hit the piston bowl. With the interaction between the fuel spray and the wall, it will increase the deposition of the fuel film [2]. There are several reasons for the rising tendency of a fuel spray collision on a hot surface to rise, including: 1). Increased injection pressure for consideration of engine design for spray atomization optimization. 2). long ignition delay [2], 3). The distance between the injector and the cylinder head is too close [3]. 4). Droplet of unburned fuel is perfect as in biodiesel [4].

Deposits forming on the combustion chamber wall will affect heat transfer on the combustion chamber wall, thereby increasing Nox and HC emissions [5]. Deposits also have a significant impact on engine performance too such as changes in spray injector characteristics, reduced power, increased fuel consumption, increased exhaust

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emissions, increased noise, even up to plug injectors. At high temperatures (> 550 $^{o}$C) the deposits formed are very thin, soft and dry and easily carried by gas flow in the combustion chamber. Deposits come from carbon. At temperatures below 200 $^{0}$C the deposit comes from fuel, adhesive, and carbon. Based on Leperhoff the structure of the resulting deposits <200 $^{o}$C, dark carbon (dark carbon), wet carbon and soot is seen in this study [5]. The speed of evaporation of fuel droplets attached to the heat wall is the most important factor of excessive deposit formation. The speed of evaporating droplets in reference fuels only around 1 millisecond, while biodiesel reached 9 milli second [6]. However, research from Yusmady eliminates the effect of combustion chamber temperature, so that the results are considered less valid. Until now the study of deposits is still small. How growth and characteristics cannot be explained correctly.

In 2015, Indonesian Ministry of Energy and Mineral Resources made a policy regarding the use of biodiesel. The use of biodiesel starting from 2015 must have reached a level of 15% or B15 must have begun to be used as fuel. This will encourage the industry to be able to develop Diesel engine designs that are suitable for B15 fuels. But high percentage of biodiesel will cause a deposit growth problem on the engine and the solution to this problem is still not found. Therefore, it is necessary to conduct a comprehensive study to answer the high percentage of biodiesel use. This study approaches the process of forming deposits in the engine with the deposition process and evaporation of the fuel repeatedly on the hot plate. This method is used to overcome the complexity of deposit testing on engines; and saves time, cost and fuel tested. This method has also been carried out by researchers in reference [6, 7]. However, the researcher on the reference uses a rig test in the form of an open system in testing the hot plate. The results obtained by researchers are still not better compared to testing the deposit on the engine. This is due to the conditions of deposit formation on the research rig test which is less close to the deposit growth conditions inside the engine. It is necessary to design a test rig that is closer to the real condition of the engine. However, an engine certainly has many parameters and is a complicated process starting from fuel injection to the growth process of the deposit. It should be noted that research on the formation of deposits in combustion chambers and injectors basically includes measurement of deposit thickness in engine components in response to the application of test and reference fuels [8, 9].

In this study, the real engine condition is simplified to only one parameter, temperature. The study was conducted with hot plates placed in a closed room so that the temperature of the room and the hot plate can be homogeneous while the pressure in the room remains constant. This condition is close to the real condition of the engine where the hot plate in this study is analogous to the engine component surface with closed system conditions. The purpose of this research is to analyze deposits forming characteristic at various temperatures and various fuels, using hot chamber deposition test rigs. The effect of temperature on the formation of diesel fuel (B0) and biodiesel (B100) deposits is done by comparing the deposit results of the two fuels. Characteristics of deposit formation in this study are limited to evaporation process and deposition process.



## SYSTEM DESCRIPTION

### Hot Chamber Deposition Test Rig

Fuel was tested using a hot chamber with different plate temperatures to obtain a deposit sample. This method is an approximation for real conditions of deposit formation on the surface of the engine components. This method is used to overcome the complexity to know the characteristics of deposit formation on the surface of engine components. Some parameters in the engine are considered constant and only one parameter is taken, temperature. The temperature can be adjusted to be similar to the wall temperature of an engine component.

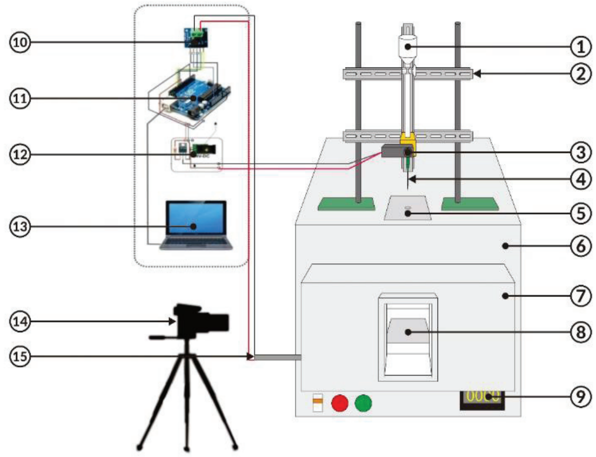


**FIGURE 1.** Hot Chamber Deposition Test Rig.

**TABLE 1**. Caption of Hot Chamber Deposition Test Rig method.

| Number | Caption of Hot Chamber Temperature Test Rig method |
|---|---|
| 1 | Fuel tank / container |
| 2 | Buffer fuel container |
| 3 | Solenoid Valve Shako PU220AR02-24V |
| 4 | Needle |
| 5 | The droplet entry holes into the furnace |
| 6 | Furnace with heater capacity up to 1200°C |
| 7 | Furnace door |
| 8 | Drip plate / heat plate (AISI 304) |
| 9 | Furnace temperature control |
| 10 | K type thermocouple module (Max6675) |
| 11 | Arduino Uno R3 Microcontroller |
| 12 | Power Supply 24 V DC & Relay Solenoid |
| 13 | Laptop, temperature data display & microcontroller programming |
| 14 | Video camera |
| 15 | K type thermocouple |



## Evaporation Process (Single Droplet)

In this process, the hot plates inside the Hot Chamber Deposition Test Rig are dripped with fuel which is tested once for each temperature. Diesel fuel (B0) and biodiesel (B100) used in this experiment are Pertamina B0 and FAME biodiesel (Fatty Acid Methyl Ester). The process of fuel evaporation is recorded using a video camera from before fuel injection until the fuel evaporation is complete.

The drop plate is inserted into the furnace, the furnace temperature is adjusted as desired then after reaching the temperature, the furnace temperature is left stable first by waiting for 10 minutes. It ensures the same temperature of the hot plate with the furnace chamber. After hot plate conditioning is complete, the new hot plate is dripped with fuel. After recording is complete, the plate is immediately removed and the other plate is inserted into the furnace for testing at the next temperature.

The resulting video starts when the fuel droplets fall into the hot plate until the fuel is completely evaporated. This is marked by the drying process starting from the middle to the edge of the thin film that has been finished. At the temperature of the transition boiling tested fuel regime, the resulting video starts when the fuel droplets fall onto the hot plate until the fuel droplets finish "rolling". Thin films are only formed for a short time at this temperature. At the temperature at which the fuel tested is burned, the resulting video starts when the fuel droplets fall onto the hot plate until the combustion reaction is complete. There are no thin films formed at this temperature. Evaporation time can be obtained by viewing the video of the test results from the evaporation process of the fuel being tested.

## Deposition Process (Multi Droplet)

In this process, the hot plate inside the Hot Chamber Deposition Test Rig is dripped with fuel which is tested continuously with a certain time lag for each drop. Multidroplet biodiesel variations are only taken at temperatures of 250 °C, 300 °C, and 350 °C.The heat plate is dripped 2,000 - 6,000 times for each temperature. At the test of 6,000 drops, the dropping was done 3 times (per 2,000 drops) while for 2,000 drops only 1 drop was made.

The time lag from the first drop to the second drop and so on is 3 seconds. This figure is determined by reason of not being too long and not too fast from the time of evaporation of fuel. If the time lag is too long, it will take a lot of time for this research and based on literature, the resulting deposits will be less and in dry conditions[6]. If the time lag is too fast, then it is estimated that the fuel will wet the hot plate and make thin films with an area that can be larger than the hot plate.

Before the drop plate is inserted into the furnace, the furnace temperature is left stable first. Then the drop plate is inserted and conditioned with furnace temperature for 10 minutes. This is done to ensure the temperature of the hot plate with the furnace chamber is the same. After hot plate conditioning is complete, the new hot plate is dripped with fuel.

After the drip (per 2,000 times) is complete, the plate is left idle for 10 minutes in the furnace with the heater furnace turned off. This is done so that the deposit does not experience a drastic temperature change when released from the furnace and to facilitate the removal of the hot plate from the furnace. A heat plate with a deposit produced after the deposition process, goes straight to the process of mass deposit measurement. Mass deposit measurement were carried out using ADAM digital analytical scale PW 254.



# RESULT AND DISCUSSION

## Evaporation Process (Single Droplet)

The process of evaporation of fuel in the hot plate is observed by its evaporating character at each temperature. The evaporation time of the fuel, temperature and appearance of fire is obtained from this process

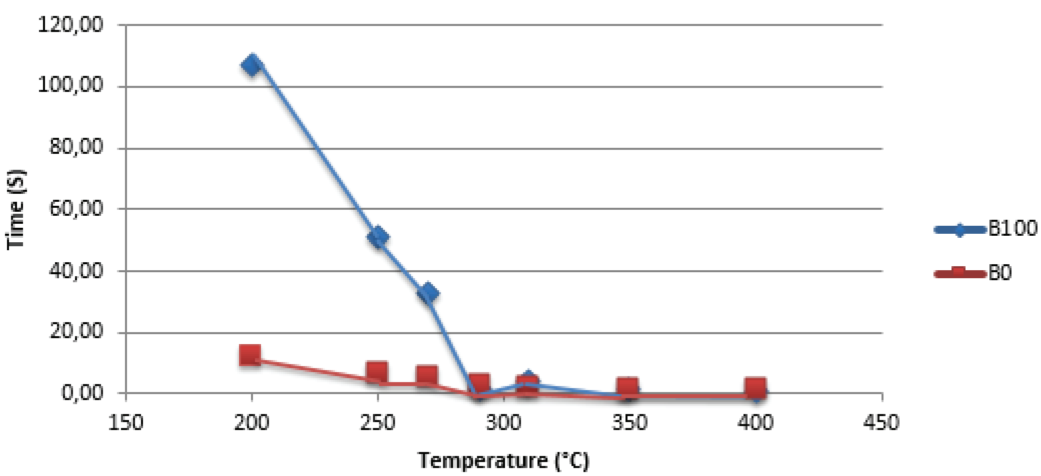


**FIGURE 2**. Evaporation Time B0 and B100 at Specific Temperatures

B0 requires faster evaporation time than B100. Starting from 200°C, B0 is 6-8 times faster than B100. Evaporation time affects the area of the deposit and mass deposits produced. The resulting area becomes wide or narrow due to the plate which is affected by the evaporation of the fuel.

## Deposition Process (Multi Droplet)

The process of deposition of fuel in the hot plate produces the character and growth of deposits at each temperature. Deposit growth can be obtained by measuring the mass deposit (deposit amount). The results of the deposition process are as follows.

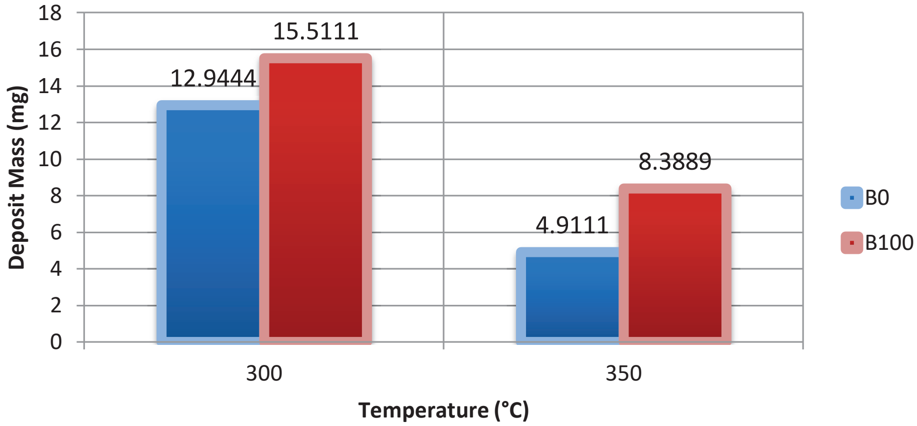


**FIGURE 3.** Mass Growth Deposits of B0 and B100 at temperatures of 300 °C and 350 °C



From the test results presented in Figure 3, B100 fuel has a higher deposit growth compared to B0 fuel. The mass at B0 is still below 15 mg, while the mass of B100 is in the range of 15 mg. This certainly shows that the mass of deposits produced by B100 is greater both at 300°C and at 350°C. The nature of the deposit is strongly influenced by the temperature where deposit is formed. With a temperature difference the deposit structure is also different. Quality of deposits is influenced by the temperature of the walls [10].

The data in figure 3 also shows formation of deposit decreases with the higher temperature used. The deposits produced by both fuels decrease when the temperature used is 350°C. However, the large difference in the mass of deposits produced is still higher than B100 compared to B0. Through figure 4, it can be seen that the amount of deposit produced at both temperatures is quite different, where B100 has higher amount of deposit produced.

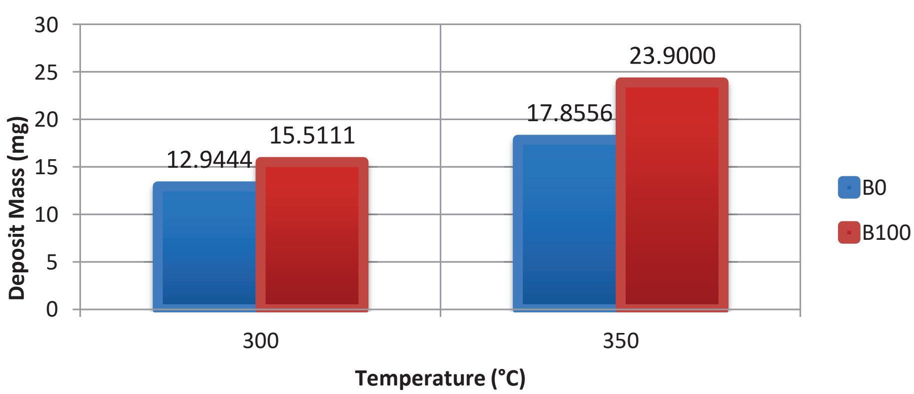


**FIGURE 4.** Total Mass Deposit of B0 and B100

## CONCLUSION

In this paper, forming of deposits from biodiesel with different variation temperature will be observed with hot surface plate methode to find their characteristics and growth mechanisms of deposits. Based on the results shown above, it can concluded that Diesel (B0) evaporation time is faster than Biodiesel (B100) because at B0 it occurs earlier or at a temperature lower than B100. Evaporation time affects the area of deposit that is generated and the amount of deposit formed. The faster evaporation time, the smaller the deposit area produced. At temperatures 300$^{o}$C and 350$^{o}$C the growth of B0 deposit mass is smaller than B100.

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## REFERENCES

1. S. Choi and Y. Oh, A study on spray characteristics of non-esterified biodiesel fuel, Science Asia **37**, 174-177 (2007).
2. H. Tang, A. Wang, S. O. Salley and K. S. Ng, The effect of natural and synthetic antioxidants on the oxidative stability of biodiesel, Journal of the American Oil Chemists' Society **85** (4), 373-382 (2008).
3. C. F. Taylor, *The Internal-combustion Engine in Theory and Practice: Combustion, fuels, materials, design*. (MIT press, 1985).
4. T. R. Sem, Effect of various lubricating oils on piston deposits in biodiesel fueled engines, 0148-7191, (2004).
5. G. Lepperhoff and M. Houben, Mechanisms of deposit formation in internal combustion engines and heat exchangers, (1993).
6. Y. B. M. Arifin, Diesel and Bio-diesel Fuel Deposits on a Hot wall Surface, (2009).
7. Y.-S. Lin and H.-P. Lin, Spray characteristics of emulsified castor biodiesel on engine emissions and deposit formation, Renewable energy **36** (12), 3507-3516 (2011).
8. M. T. Suryantoro, B. Sugiarto, D. Chistian, B. Samudra and Z. Gusfa, Deposit characterization of a diesel engine combustion chamber by droplets at hot chamber temperature: Effect of temperature on evaporation time and deposit structure, Internasional Journal of Technology **7**, 1372-1380 (2016).
9. M. T. Suryantoro, B. Sugiarto and F. Mulyadi, Growth and characterization of deposits in the combustion chamber of a diesel engine fueled with B50 and Indonesian biodiesel fuel (IBF), Biofuel Research Journal **3** (4), 521-527 (2016).
10. F. NAGAO, M. IKEGAMI and A. TOKUNAGA, Temperature Dependence of Carbon Deposit in a Diesel Combustion Chamber, Bulletin of JSME **9** (35), 573-579 (1966).