FILTER SYSTEM DESIGNED TO REDUCE THE EMISSION OF GASOLINE MOTORCYCLE POLLUTANTS

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Abstract

Clean, healthy air is a major topic worldwide. It is because poor air quality hurts human health and is even responsible for the deaths of millions of people. This work develops exhaust pipes with filters to reduce pollutants emitted by motorcycles. Three pollutant concentrations are measured here: CO_2, CO, and HC. The measurements were taken before and after the filter system to calculate pollutant reduction. The maximum pollutant reduction of the filter system: 6.1 % of CO_2, 8.0 % of CO, and 651.0 ppm of HC. The main mechanism of this filter is the physical trapping of pollutants. When the gas flows through the exhaust pipe, pollutants in the stream are captured by the filter through direct contact. This could be observed visually by the change in the filter color, which darkens after use in the exhaust pipe. However, the limitation of this work is the short-term experiment, lasting only 5 minutes, which is a key for the next research. It is also necessary to have alternative filters that are sustainable and can work properly in high-temperature conditions.

Key words : *filter, pollutant, air quality, physical trapping, high temperature.*

INTRODUCTION

Air pollution is one of the biggest crises, deteriorating human well-being worldwide. As reported by the *World Health Organization* (WHO), millions of people died, directly or indirectly, due to poor air quality. [1]. It is the second primary factor of death risk in the world [2]. A study by J. Rentschler and N. Leonova even found a disproportionate impact between low and high-income countries [3], and unfortunately, the low-income population suffers more from poor air quality. Frequently, their job requires outdoor activities that directly expose them to poor air quality. Therefore, poor air quality is a complex issue that needs to be considered by future urban planners and policymakers [4]. Those facts show that air pollution needs to be solved as soon as possible.

There are many sources of air pollution. It can happen naturally (wildfires, dust storms, and volcanic eruptions) or in human activities (combustion, agriculture, and waste production). One of the largest sources of human activity-related air pollution is the transportation sector. Many attempts have already been made to minimize air pollution, either by advancing the technology to have more efficient transportation systems or enacting policies to support mass transportation modes [5]. Another attempt to reduce emissions could be made by developing technology that produces pollutants, such as the open burning of fields of rice straw [6]. Those efforts are necessary to prevent harmful consequences in the future [7]. In other words, a comprehensive approach is needed to tackle air pollution from the transportation sector.

A WHO global air quality guidelines report shows that the transportation sector remains the dominant source of air pollution. For many cities in developing countries, traffic congestion and poor vehicle regulations even make the air quality worse [8]. A common approach for reducing pollutants from the street is tree planting. Unfortunately, the impact of street trees on air quality depends heavily on specific conditions. For some conditions, even that approach does not help the situation at all [9]. Therefore, it is necessary to develop technology that directly reduces pollutants from the transportation sector.

In the Southeast Asia region, the transportation sector is dominated by motorcycles (almost 80%) [10]. This mode of transportation offers affordable mobility and is much more flexible than other modes. That makes motorcycles the favorite mode of transportation for urban cities in developed countries and contributes to a greater amount of air pollution [11]. The problem is not only when the motorcycle works on the road, which produces pollutants, but also the idle condition of the bike adds contaminants to the air [12].

Pollutants inevitably occur from the combustion engine transportation system. Working in optimal conditions, the Air-Fuel Ratio (AFR) of 14.7:1 for gasoline, is normally hard to achieve in the real world. Rich/lean mixtures and poor ignition occur frequently, contributing to air pollution [13]. Motorcycles as sources of pollution need to be addressed. Many attempts have already been made to solve the problem. One of the most common ways is to redesign the gas pipe to provide additional functional benefits, such as acoustic improvement and emission control [14].

The exhaust pipe is the biggest source of pollutants emitted from a motorcycle [15]. This study aims to add a filter system to a motorcycle's exhaust pipe for CO, CO_2, and HC. The filter geometry is designed to match the exhaust pipe of gasoline-engine motorcycles and is also shaped to contain the filter.

EXPERIMENTAL METHOD

In this work, a 4-stroke gasoline engine from a motorcycle with a displacement of 1103.3 cc was used as the source of pollutants. This engine has been in use since 2009 and still functions well as a motorcycle during the experiment. The pollutant is emitted from the exhaust gas pipe connected to the filter system before being released to the air. The contaminants measured in this research are Carbon Dioxide (CO_2), Carbon Monoxide (CO), and Hydrocarbons (HC). They are measured by a gas analyzer to determine the extent of the decrease in the pollutant's concentration. The tool used to measure pollutant concentration in this research was a Heshbon Exhaust Gas Analyzer HG-520, made in Korea. The experimental setup is described in the schematic figure below.

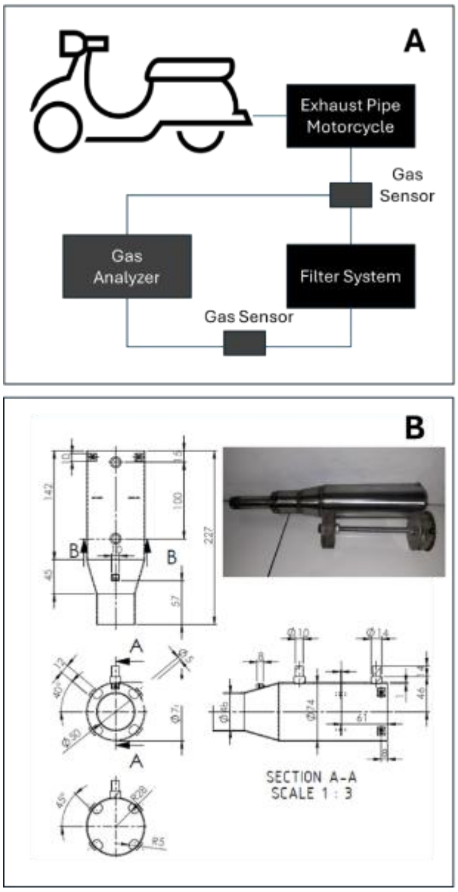

Figure 1. Experimental setup: 1A) Schematic picture; and 1B) filter system design

The filters used here are commercial car engine air filters with multi-layer pleated nonwoven fiber structures and glass wool. The experiment begins by turning on the motorcycle and setting it to a constant speed of 60 km/h. The sensors were placed at two locations: before and after the filter system. Sensor. Then the pollutant concentration data is displayed on the gas analyzer and recorded. Each data point is recorded after 5 minutes to ensure the flow is already in a steady state.

RESULT AND DISCUSSION

The main cause of pollutant generation from conventional motorcycles is incomplete combustion. This can happen when the reaction between fuel and air is either above or below the stoichiometric ratio. In the real world, achieving the perfect air-to-fuel ratio is hard. Even to get closer to that adding many tools and techniques is necessary [16]. Therefore, pollutants are inevitable when using motorcycles.

Three pollutant concentration measures in the exhaust pipe namely CO_2, CO, and HC. When complete combustion happens, CO_2 is the primary product with water (H_2O) as described in the chemical reaction:

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

The engine's high efficiency could be indicated by a higher CO_2 concentration relative to other carbon species in the exhaust pipe. As mentioned before, it is impossible to achieve a perfect combustion reaction in the engine's combustion chamber. A lack of oxygen prevents carbon atoms from oxidizing fully, leading to the formation of CO rather than CO_2. The CO molecules are more dangerous when exposed directly to humans compared to CO_2 [17]. On the other hand, when the fuel molecules burn partially, HC is formed, indicating wasted fuel. These pollutants contribute to greenhouse gases and lead to poor air quality [18].

The velocity of the pollutant exiting the exhaust pipe decreased as more filter mass was added. This becomes one of the constraints when designing a filter system. Back pressure should be avoided as much as possible to maintain low exhaust emissions [19]. The figure below displays the pollutant concentration to show the effectiveness of the filter system.

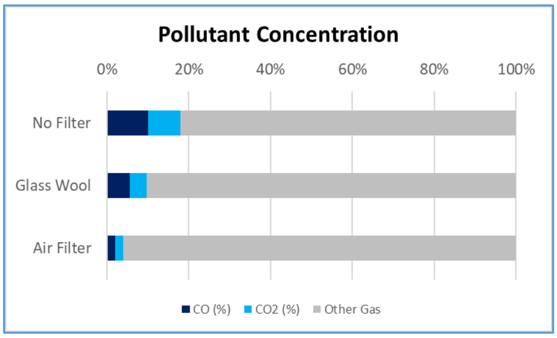

Figure 2. The reduction of pollutants CO and CO_2

The graph shows three schemes: no filter, glass wool filter, and air filter. This filter system can reduce the concentration of pollutants emitted from the exhaust pipe. Glas wool reduces CO and CO_2 concentrations by 4.4% and 3.9%, respectively.

On the other hand, the air filter system reduces CO concentrations by 8.0% and CO_2 concentrations by 6.1%. In this case, the air filter system performs better in reducing the CO and CO_2 than glass wool. Another pollutant measured in this work is hydrocarbons (HC). The figure below shows HC concentration in ppm.

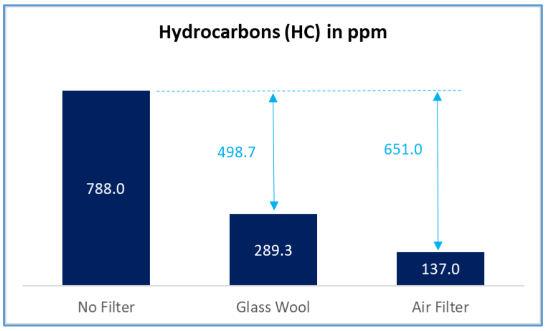

Figure 3. The reduction of HC pollutants

When filtering HC, glass wool reduces 498.7 ppm, and the air filter reduces 651.0 ppm. Here, the air filter system also works better than the glass wool.

The air filter and glass wool indeed reduced the pollutants CO, CO_2, and HC after the engine had been running for five minutes. When incomplete combustion occurs in the engine, fine particles are expelled into the exhaust pipe. Those particles are known as soot, a solid, black, and amorphous form of carbon. It can be observed that the filter color darkens after use. The color change is due to soot accumulation on the filter. These fine particles are trapped in the filter system which then reduces the concentration of pollutants emitted from the exhaust pipe.

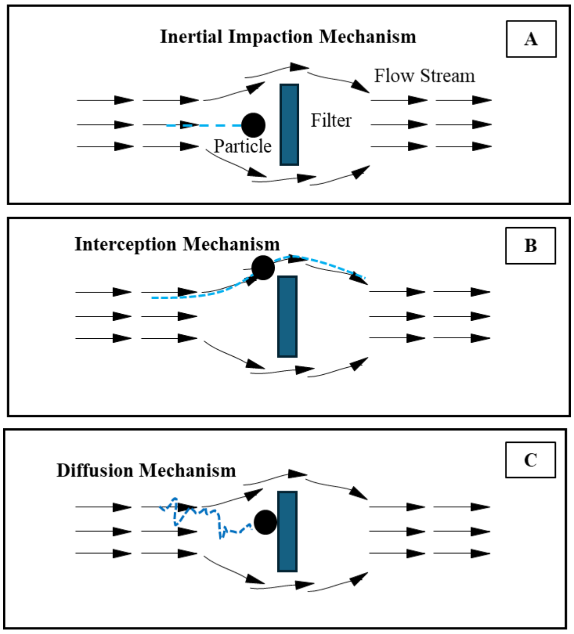

Figure 4. Filtration Mechanism: 4A) Inertial Impaction; 4B) Interception; 4C) Diffusion.

The mechanism for reducing pollutants in this filter system is mainly due to physical trapping as the gas flows and to contact with the filter [20]. During interaction between the gas stream and the filter, some of the gas particles are attached to the filter via inertial or interception mechanisms. When the filter system is working correctly, especially when the exhaust pipe temperature is still low, heavier hydrocarbons are absorbed by the filter. However, as the temperature increases, some of those pollutants may desorb and return to the gas stream. Since there is no charge involved in this experiment, the diffusion mechanism did not happen.

CONCLUSION

This filter system can reduce pollutants such as CO_2, CO, and HC. The air filter performs better in reducing pollutants. However, upon inspection after use, both materials are damaged and should be disposed of. The color changes significantly darker and cannot be used anymore. Therefore, future research needs to change the filter material. Furthermore, sustainable and eco-friendly materials should be prioritized so that when the filter is used and needs to be disposed of, it will not cause environmental issues.

Another limitation of this work is that the experiment only works for five to ten minutes, which needs to be extended to be more applicable in the real world. It is necessary to conduct experiments over a more extended period to assess the durability of the filter system.

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