MATHEMATICAL MODELING ON THE EFFECT OF EQUIVALENCE RATIO IN EMISSION CHARACTERISTICS OF SPARK IGNITION ENGINE WITH HYDROGEN PEROXIDE ADDITION

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A report submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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2022

DECLARATION

I declare that this project entitled “Mathematical Modeling on The Effect of Equivalence Ratio in Emission Characteristics of Spark Ignition Engine with Hydrogen Peroxide Addition” is the result of my own work except as cited in the references.

Signature : ……..

Name : ……..

Date : ……..

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature : ……..

Supervisor's Name : ……..

Date : ……..

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ABSTRACT

The project of “Mathematical Modeling on the Effect of Equivalence Ratio on Emission Characteristics of Spark Ignition Engine with Hydrogen peroxide Addition” aims to investigate the effect of equivalence ratio on the emission characteristics of combustion product of a spark ignition engine. The fuel used is gasoline and it is mixed with hydrogen peroxide. Hydrogen peroxide acts as an oxidizing agent that helps to reduce the emission of harmful and toxic combustion products. Mathematical modelling is used to calculate the mole fraction for each combustion products and graphs on the effect of equivalence ratio to the emission characteristics will be generate. MATLAB simulation programme will be used to obtain the data.

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ABSTRAK

Projek "Pemodelan Matematik terhadap Kesan Nisbah Kesetaraan terhadap Ciri-ciri Pelepasan Enjin Pencucuhan Percikan dengan Penambahan Hidrogen peroksida" bertujuan untuk menyiasat kesan nisbah kesetaraan ke atas ciri-ciri pelepasan hasil pembakaran enjin pencucuh percikan. Bahan api yang digunakan ialah gasolin dan ia dicampur dengan hidrogen peroksida. Hidrogen peroksida bertindak sebagai agen pengoksidaan yang membantu mengurangkan pelepasan produk pembakaran yang berbahaya dan toksik. Pemodelan matematik digunakan untuk mengira pecahan mol bagi setiap hasil pembakaran dan graf tentang kesan nisbah kesetaraan kepada ciri-ciri pelepasan yang akan dijana. Program simulasi MATLAB akan digunakan untuk mendapatkan data.

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LIST OF ABBREVITIONS

COx	-	Carbon Oxide
NOx	-	Nitrogen Oxide
COPD	-	Chronic Obstructive Pulmonary Disease
H_2O_2	-	Hydrogen Peroxide
SI	-	Spark Ignition
CI	-	Compressed Ignition
LNG	-	Liquid Natural Gas
RFG	-	Reformulated Gasoline
HC	-	Hydrocarbon
UHC	-	Unburned Hydrocarbon
CO_2	-	Carbon Dioxide
H_2O	-	Water (Hydrogen Dioxide)
N_2	-	Nitrogen gas
O_2	-	Oxygen gas
CO	-	Carbon Monoxide
H_2	-	Hydrogen gas
H	-	Hydrogen atom
O	-	Oxygen atom
OH	-	Hydroxide
NO	-	Nitrogen Oxide

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CHAPTER 1

INTRODUCTION

1.1 Background

The world now lives in fear because of the pollution created by human themselves. This created problems that causing not only human, but all living things such as the animals, plants, and microorganism are affected by it. Various pollution exists but in the field of road transport, air pollution is the one that created the most problems. Common spark ignition engines produced toxic products such as Carbon Oxide (COx), Nitrogen Oxide (NOx), soot, and particulate matters and released it to the environment through the exhaust (Muhammad Saad Khan et al., 2009). The pollutant combined with the existing air composed of oxygen, hydrogen and other particle and created harmful gaseous that potentially enter the respiratory system of humans and animal and causing various type of diseases such as lung cancer, chronic obstructive pulmonary disease (COPD) and asthma (Jiang et al., 2016).

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The higher the pollution level, the chances of getting sick by the polluted air is increased. For example, in Bandar Tun Razak, Kuala Lumpur, an experiment is conducted to study the average concentration of air pollutants recorded for a period of 2010-2014 because the city is congested with moving vehicles. From that long period of time, the result showed that amount of COx and NOx does not have the potential to decline. This means the probability of people getting sick due to the polluted air keep increasing and do not have an end to it. Numerous people will get sick if this problem still continues and it can also threaten the ecosystem. (Tajudin et al., 2019)

To solve the problems, engineers all around the globe try to undergo continuous changes and improvements to reduce the pollutants emitted by the vehicles. One of the ideas is by adding fuel additive to the existing fuel to create a safer product of combustion released by the engine. This brilliant idea does not focus only on the emission products but also the effect of the fuel additive to the fuel itself. Engineers wanted the fuel additive to give a boost to the fuel so it can burn efficiently without wasting any component. Hydrogen is one of the most suitable agents for the job. It is renewable, highly efficient, clean fuel, fast burning speed, high diffusion coefficient, wide firing range and low ignition energy that can bring a lot of advantages to the diesel-type engine. The same result also applied to hydrogen peroxide(H_2O_2) that it also gives the equal advantages just like the hydrogen. It also stated that hydrogen peroxide has led to a better combustion(Adnan et al., 2018). But not all vehicle using the same diesel-fuel type engine. Some other vehicle uses gasoline as it fuels and they give out the same problem just like the diesel-type vehicles, that is they emitted harmful gaseous to the atmosphere. Fortunately, hydrogen peroxide also works well as a fuel additive to the gasoline. With the help of hydrogen peroxide, the spark-ignition engine can work at its best and perform better compared to the engine when gasoline only is being used. The engine's peak pressure, thermal efficiency, indicated power and heat release rate showed that the engine give the best result when hydrogen peroxide is added into the fuel. (Adlan et al., 2018)

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1.2 Problem Statement

When dealing with spark-ignition engine, it is not only about the power it gives to the vehicles, but also the product of the combustion that is released into the environment. This problem occurs because the transportation industry is getting bigger day by day and the numbers of vehicles on the road increases dramatically. Although at first the emission of toxic gaseous from the fossil fuel combustion such as NOx, COx and soot does not do much effect to the ecosystem, but eventually it will cause a lot of problems if it is not overcome immediately. Our respiratory system will face a great threat if air pollutants had entered the body through the respiratory organ. Studies have validated the relationship between traffic air pollution and chronic obstructive pulmonary disease. It has been shown that the damaged respiratory system is as dangerous as damages caused by ingestion of toxic chemicals(El Morabet, 2019). Researchers are trying to come out with the solution to improve the combustion products so the concentration of toxic components in combustion products will be lowered.(Adlan et al., 2018)

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Studies had been made but the most of it is about compression ignition engine with injection of hydrogen peroxide. Only a few studies that are about spark ignition engine since it is not as hype as its brother. Although the fuel being used is different where compressed ignition engine uses diesel fuel while spark ignition engine uses gasoline for combustion, there is minor differences in term of combustion product as both fuels shares the same source of origin. Diesel powered vehicles have more torque while gasoline powered vehicles are suitable for city driving. With the help of hydrogen peroxide, each fuel improves the combustion process as stated that hydrogen-fuelled engine potentially create a low emission (Lee, 2001).

Studies has been made to proof the capability of hydrogen peroxide as a fuel additive practically but theoretically it has not yet been proven. Mathematical model can be used as

the evidence to strengthen the researchers' studies of the hydrogen peroxide as fuel additives. The mathematical model can calculate the mole fraction for the emission products and from the simulation, we can see the effect of adding hydrogen peroxide on the emission of combustion products (Yusof et al., 2015).

1.3 Objective

The objectives of this project are as follows:

1. To construct a mathematical model to obtain mole fraction of each combustion products for spark ignition engine with hydrogen peroxide addition.
2. To study the effect of equivalence ratio to the mole fraction of the emission products.

1.4 Scope of The Project

The scope of the project that will be discussed are:

1. This project has been specific to the use of hydrogen peroxide as fuel additive that is used in spark-ignition engine.
2. This project is only required to obtain mole fraction for the combustion products of hydrogen peroxide mixed with gasoline.
3. All the calculation can be calculated manually by using every possible step that is needed in certain formula used to solve the equations.
4. MATLAB program can be used to solve all the calculation and graphs can be obtained from it that may help in the project purpose.

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1.5 General Methodology

For the project, several methods will be used to achieve the objectives in this project and are listed below:

1. Literature review

   Journals, articles, or any suitable materials will be used as the guideline and references in order to complete the project. Most of the sources are related to the title of the project.

2. Calculation

   Method of calculation such as Newton Raphson method is conducted to obtain the mole fraction of the components of the combustion products of the project.

3. Simulation

   Computational simulation is generated to obtain the values of the combustion product will be made based on the calculation.

4. Report writing

   At the end of the study, a full complete report will be written

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Spark Ignition engine with Hydrogen peroxide Addition

New era of technologies is now focusing more on inventing various types of products that will create a better earth for the people. The sustainability of the earth can be well preserved if all products are created eco-friendly. From power generation, power consumption, and daily essential products should be used without giving harmful side effects to the environment. Countries such as India and United States of America have invested in the usage of geothermal energy resources from existing thermal spring of which there are found a lot in their country instead on generating power using old-fashioned way that is by using fossil fuels. This alternative way is very worthwhile as India is currently standing among top five countries whose uses maximum energy that is expected to increase by three times by 2023 (Kumar et al., 2019). Automobile industry has also created an alternative way to reduce the emission of harmful gaseous to the surrounding. Both spark-ignition (SI) engine and compressed-ignition (CI) engine has been releasing various hazardous gaseous since day one of the engines' usage until today that resulting in the thinning of the ozone layer and global warming. Greenhouse gases, carbon oxides, nitrogen oxides and other harmful gaseous are the reason of the problem. In China, the transport pollution has becoming a major threat to the air quality of the country and the problem may becoming even worse as the increase of ownership of personal vehicles (HE & QIU, 2016). More vehicles on the road will emit more amount of toxic emission to the environment and this

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will not only be affecting China but the whole world will also receive the effects of global warming.

So, renewable fuels such as bioethanol or biodiesel are produced to remove the side effect that has been the major problems to the existing fuels. Bioethanol is proven to reduce the emission of carbon dioxide of a compressed-ignition engine, giving the automobile industry a better hope in reducing air pollution. (Damyanov & Hofmann, 2019). However, the existing hydrocarbon fuels such as gasoline and diesel are still being used worldwide and there is no stopping sign on the usage of these fuels. Since the introduction of the biofuels to the automobile industry are still new, the popularity is still superiorly far compared with the existing hydrocarbon fuels. While the hydrocarbon fuels economy steadily increased and becoming one of the sources of national income, biofuels is known only by certain people. Thus, for now this is not the best answer to the global warming problems.

Another possible solution that might be as efficient as the usage of biofuels is by creating an eco-friendly combustion product for both CI engines and SI engines from existing fuels. This can be achieved by adding fuel additive to the existing fuel to create a new combustion product that will reduce or even better fully eliminate the emission of harmful gaseous to the environment. Hydrogen peroxide is one of the fuel additives that can be use besides formaldehyde (CH_2O) that can relate to the improvement of the autoignition (Manias et al., 2016). (Adnan et al., 2018) stated that gasoline with hydrogen peroxide addition perform better compared to gasoline alone. Better combustion is the result of mixed solution, creating an effective spark-ignition engine. With the mixed solution of gasoline and hydrogen peroxide with the suitable ratio of 95% of gasoline and 5% of hydrogen peroxide has created the best outcome in term of fuel consumption, indicated power, and heat release rate.

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