UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FACULTY OF MECHANICAL AND MANUFACTURING ENGINEERING TECHNOLOGY

PARAMETRIC AND COMBUSTION CHARACTERISTICS OF DIESEL AND WATER IN OIL EMULSIFIER MIXTURE

LOH CHI PEI

B091810492

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE TECHNOLOGY) WITH HONOURS

2022

Faculty of Mechanical and Manufacturing Engineering Technology

PARAMETRIC AND COMBUSTION CHARACTERISTICS OF DIESEL AND WATER IN OIL EMULSIFIER MIXTURE

LOH CHI PEI

Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honors

2022

PARAMETRIC AND COMBUSTION CHARACTERISTICS OF DIESEL AND WATER IN OIL EMULSIFIER MIXTURE

LOH CHI PEI B091810492

A thesis submitted in fulfillment of the requirements for the degree of Bachelor of Mechanical and Manufacturing Engineering Technology (Automotive Technology) with Honors

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this thesis entitled "PARAMETRIC AND COMBUSTION CHARACTERISTICS OF DIESEL AND WATER IN OIL EMULSIFIER MIXTURE " is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : *LOH CHI PEI*

Date : 17/1/2022

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

Signature :

Supervisor Name : DR. AHMAD FUAD BIN ABDUL RASID

Date : 18/1/2022

DEDICATION

I would like to express my sincere gratitude to Dr Ahmad Fuad Bin Abdul Rasid, Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM), for all his help, guidance and inspiration. His unwavering patience in mentoring and offering invaluable insights will be remembered by everyone who have supported my path. Prof. Madya is Dr. Lau Kok Tee, the chairman of PSM1 deserves special appreciation for all of his assistance and guidance with Chapters 1, 2 and 3.

Take this opportunity to thank of my heart to my buddy, Hamzi Bahari, who has selected the same supervisor as me for his encouragements and has been a pillar of strength during all of my projects. He constantly explains and advises me about my work. Finally, I’d want to express my gratitude to everyone who has helped, supported and encouraged me to continue my education.

Abstract

This report deals with propose of diesel and water in oil emulsifier mixtures which are to be improved by manipulating the percentage of emulsifier added in the mixer. The objective of this project is to analyse water-in-oil emulsions addition to the base fuel in terms of burning rate, lifetime and stability. The method that will be use is quantitative measurement on high speed imaging of evaporating diesel and emulsifier mixture. After the emulsion fuels are produced, the mixture is later on be analysed using laboratory analysis in FTKMP lab. Data and results of the experiment are observed and recorded. Quantitative analysis will be done based on the regression of D2-law and the change of combustion characteristics will be justified by cross-comparing the surface regression trend with the change of fuel properties. By the end of the report, the emulsion fuels where able to be produced by the mixer and the mixtures produced can be analysed. The expected result is the viscosity of emulsified diesel would increase since the viscosity of the emulsifier is higher than diesel. It is expected that the surface of the droplet would be enveloped by a layer of viscous emulsifier. Since there is a slightly increase in viscosity, vapour bubble will emerge from homogeneous and even heterogeneous nucleation would need a stronger internal pressure to rupture the droplet surface upon escaping thus producing stronger puffing or even micro explosion. However, there also a possibility of added emulsifier to stabilize the evaporation with reduced liquid-gas diffusion. This is due to addition of emulsifier will forms an elastic protective layer which would prevent early phase separation and also the suppressive action of the emulsifier layer formed on the surface of the droplet. Therefore, the layer requires higher heat to be evaporated, thus more time is needed to absorb the surrounding heat energy rather than to be used for evaporation. In the conclusion, this project had been expected successfully done and achieved all of the objectives. First of all, the effect of oil-in-water emulsions addition to the base fuel in terms of burning rate, lifetime and stability had been analysed. Besides, the second objective was to investigate the change of combustion phases in increasing water loading of emulsion fuel from 10% to 30% with 10% increment. Last but not least, the relationship of changes in combustion characteristics between diesel and water-in-oil emulsions had been determined.

ABSTRAK

Laporan ini berkaitan dengan campuran bahan bakar iaitu bahan bakar emulsi minyak-air yang harus dipertingkatkan dengan memanipulasikan peratusan emulsi yang dicampur di dalam pengadun. Objektif projek ini adalah untuk menganalisis penambahan emulsi air dalam minyak kepada bahan api asas dari segi kadar pembakaran, jangka hayat dan kestabilan. Cara yang dipilih untuk menjalankan eksperimen ini ialah pengukuran kuantitatif pada pengimejan berkelajuan tinggi campuran diesel dan pengemulsi penyejat. Setelah bahan bakar emulsi siap dihasilkan, kajian di atas akan dilakukan menggunakan analisis makmal di makmal FTKMP. Data dan keputusan dari kajian diamati dan direkodkan. Analisis kuantitatif akan dilakukan berdasarkan regresi undang-undang D2 dan perubahan ciri pembakaran akan dibenarkan dengan membandingkan silang arus regresi permukaan dengan perubahan sifat bahan bakar. Pada akhir laporan, bahan bakar emulsi telah dapat dihasilkan oleh pengadun dan campuran yang dihasilkan boleh dianalisis. Hasil yang diharapkan adalah kelikatan diesel pengemulsi akan meningkat kerana kelikatan pengemulsi lebih tinggi daripada diesel. Diharapkan permukaan titisan akan diselimuti oleh lapisan pengemulsi likat. Oleh kerana terdapat sedikit peningkatan kelikatan, gelembung wap akan muncul dari nukleasi yang homogen dan bahkan heterogen memerlukan tekanan dalaman yang lebih kuat untuk pecah permukaan titisan ketika melarikan diri sehingga menghasilkan pembengkakan yang kuat atau bahkan ledakan mikro. Namun, terdapat juga kemungkinan pengemulsi tambahan untuk menstabilkan penyejatan dengan penyebaran gas-gas yang berkurang. Ini kerana penambahan pengemulsi akan membentuk lapisan pelindung elastik yang akan mencegah pemisahan fasa awal dan juga tindakan penekanan lapisan pengemulsi yang terbentuk di permukaan titisan. Oleh itu, lapisan memerlukan haba yang lebih tinggi untuk disejat, oleh itu lebih banyak masa diperlukan untuk menyerap tenaga haba di sekitar daripada digunakan untuk penyejatan. Kesimpulannya, projek ini diharapkan berjaya dilaksanakan dan mencapai semua objektif. Pertama sekali, kesan emulsi minyak dalam air terhadap bahan bakar dasar dari segi kadar pembakaran, jangka hayat dan kestabilan telah dianalisis. Selain itu, objektif kedua adalah untuk menyiasat perubahan fasa pembakaran dalam meningkatkan muatan air bahan api emulsi daripada 10% kepada 30% dengan kenaikan 10%. Akhir sekali, hubungan perubahan dalam ciri-ciri pembakaran antara diesel dan emulsi air dalam minyak telah ditentukan.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank and praise to my god, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation to Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform.

My utmost appreciation goes to my main supervisor, Dr Ahmad Fuad Bin Abdul Rasid, Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM) for all his support, advice and inspiration. His constant patience for guiding and providing priceless insights will forever be remembered. My special thanks go to Prof. Madya is Dr. Lau Kok Tee, the chairman of PSM1 and PSM2 for all of his assistance and guidance with Chapter 1, Chapter 2, Chapter 3, Chapter 4 and Chapter 5.

Last but not least, from the bottom of my heart a gratitude to my friend, Hamzi Bahari, for his encouragements and who have been the pillar of strength in all my projects. I would also like to thank my beloved parents for their endless support, love and prayers. Finally, thank you to everyone who had provided me the assistance, support and inspiration to embark on my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

Droplet combustion characteristics are a component of stratification via liquid fuel sprays therefore, the current study path is useful. As a result, a better understanding of the ignition and combustion characteristics of fuel droplets would provide a better understanding of spray combustions [7]. Because the size of a liquid fuel spray is sufficiently reduced, a scaling approach to the relativity of isolated droplet and spray combustion would provide useful data for numerical and modelling studies [2]. Furthermore, in terms of droplet evaporation, ignition mechanism, and droplet evolution dynamics, it was discovered that the combustion behaviour of a single isolated droplet and droplets inside fuel sprays are quite comparable [3], [4]. As a result, studies of isolated droplets with simple mass and energy transmission are relevant to the complicated spray environment in combustion.

Godsave [8] and Spalding [9] proposed the classic quasi-steady model, which anticipated that a liquid fuel droplet would undergo a steady gasification process throughout its lifetime. The droplet is assumed to be spherically symmetric with a uniform and constant droplet temperature in the model prediction. The effects of droplet heating and fuel vapour accumulation were ignored [10], [11], resulting in one-dimensional mass and energy transmission during the evaporation process [12]. However, in the actual evaporation process, liquid fuel droplets go through a number of transitory evaporation processes, including droplet heating, fuel vapour buildup, and disruptive dynamics in liquid-phase evolution [13], [14]. As a result, the experimental results, particularly during the evaporation of a fuel droplet under normal gravity, are discovered to be non-one-dimensional. Several scholars have used analytical methods to adapt the quasi-steady model in order to enhance prediction accuracy [7]–[13].

Quantitative measurements of isolated and grouped droplet combustion studies include detailed dynamics throughout droplet lifetime in high speed imaging [15], [16], ignition and combustion behaviour of binary mixtures [17], [18], droplet group interactions [19]–[21], and droplet flame spread mechanism [22]–[24]. These types of research methods are quite useful in supporting the analytical assessments of various studies [19], [25], which aim to accurately mimic actual fuel burning. Years of quantitative and analytical research have gone into reducing the variation and error between calculated and measured outcomes. More investigation into these areas, using more precise measuring techniques, will yield more specific information on the fuel evaporation processes.

Emulsified fuels are water-based emulsions containing a combustible liquid, such as oil or fuel. Emulsions are a type of dispersion that includes both a continuous and dispersed phase. Water-in-diesel emulsion is the most commonly used emulsion fuel. [26] Both phases of an emulsion are immiscible liquids, such as oil and water. Emulsion fuels might be microemulsions or traditional emulsions. The main differences between the two are stability (microemulsions are thermodynamically stable systems, whereas macroemulsions are kinetically stabilized) and particle size distribution (microemulsions are thermodynamically stable systems, whereas macroemulsions are kinetically stabilized) (microemulsions are formed spontaneously and have dimensions of 10 to 200 nm, whereas macroemulsions are formed by a shearing process and have dimensions of 100 nm to over 1 micrometre). Macroemulsions are prone to settling (or creaming) and changes in particle size over time, whereas microemulsions are isotropic. Both use surfactants (also known as emulsifiers) and can be water-in-oil (invert emulsions) or oil-in-water (oil-in-water emulsions) (regular emulsions).

The goal of this research is to see how adding an emulsifier to diesel affects combustion characteristics. The method that will be used is quantitative measurement of evaporating diesel and emulsifier mixtures using high-speed imaging. The change in combustion characteristics will be justified by cross-comparing the surface regression trend with the change in fuel properties in a quantitative analysis based on the regression of the D2-law.

1.2 Problem Statement

The fuel qualities and combustion characteristics of the diesel and emulsifier mixture will alter as they are mixed. To avoid major changes in the fuel qualities of the base fuel as well as the production of a protective layer around the suspended soot particles, no surfactant was added. [1] However, there was no mention of the rate of change, relation properties, or combustion characteristics in the literature review.

A relationship study is required as a result of these issues. The goal of this research is to see how adding an emulsifier to diesel affects combustion characteristics. However, there are a few reservations about completing this project. It was uncertain what relationship existed between changes in combustion characteristics between diesel and water in oil emulsions. Aside from that, the impact of adding oil-in-water emulsions to a base fuel in terms of burning rate, life time, and stability is unknown. Finally, the effects of adding an emulsifier on fuel characteristics are unknown.

1.3 Objective

The following are the objectives of this research:

a) To analyse water-in-oil emulsions addition to the base fuel in terms of burning rate, lifetime and stability.
b) To investigate the change of combustion phases in increasing water loading of emulsion fuel from 10% to 30% with 10% increment.
c) To determine the relationship of changes in combustion characteristics between diesel and water-in-oil emulsions.

1.4 Project Scopes

The scopes of the project are:

- Focuses on the processing of readily acquired combustion image of emulsified droplet.
- Emulsifier loading ranges between 10% to 30% with 10% increment by volume.
- Analyse burning rate and stability of emulsified diesel fuel from droplet analysis.

1.5 Hypothesis

Because the emulsifier has a higher viscosity than diesel, the viscosity of the emulsified diesel should increase. A coating of viscous emulsifier is expected to surround the droplet's surface. Vapour bubbles will arise from homogeneous and even heterogeneous nucleation, requiring a higher internal pressure to breach the droplet surface when departing, resulting in stronger puffing or even mini explosion.

However, an emulsifier might be added to help stabilize evaporation and minimize liquid-gas diffusion. This is due to the presence of an emulsifier, which produces an elastic protective barrier on the droplet's surface, preventing early phase separation and suppressing the suppressive activity of the emulsifier layer. As a result, the layer takes more heat to evaporate, requiring longer time to absorb rather than use the ambient heat energy for evaporation.

CHAPTER 2

LITERATURE REVIEW

2.1 Droplet Combustion

The research on spray combustion can be divided into two categories. The first portion is based on a detailed examination of the actual combustion process, beginning with the combustion of a single fuel droplet. The second section involves first-hand observations of spray combustion in order to explore several associated phenomena such as flame length. Aside from that, spray combustion can theoretically be examined utilizing data from a single fuel droplet. Furthermore, a significant quantity of fine droplets necessitates droplet combustion studies. To begin, it's critical to distinguish between the many types of droplet combustion. The first type of droplet combustion is monopropellant droplet combustion, in which the fuel and oxidizer are combined into a single material. The second type of droplet combustion is bipropellant droplet combustion, which is significantly more common in practical applications involving fuel droplet burning in an oxidizing media (usually air).

2.2 Principle of Oil-water emulsion fuel

An emulsion is a mixture of two or more immiscible liquids, one of which is present as a droplet, or dispersed phase, which is disseminated throughout the other, or continuous phase. For stability, it is created by mechanical agitation in the presence of surface active chemicals, also known as emulsifiers or surfactants. The surfactants have a hydrophilic (polar) head and a hydrophobic (nonpolar) tail. It's in there to make the surface tension of the medium it dissolves weaker. The polar groups orient towards the water and the nonpolar groups orient towards the oil when it is placed in an oil-water mixture, lowering the interfacial tension between the oil and water phases. Based on the type of polar group on the surfactant, they are classed as cationic, anionic, amphoteric, and non-ionic. Hydrophilic-lipophilic balance, or HLB (water liking-oil liking) score, is established for the optimal synthesis of appropriate surfactant. Low HLB results in a water-in-oil emulsion, whereas high HLB results in an oil-in-water emulsion. HLB has a range of values from 1 to 20.

Because emulsion is used as a fuel in diesel engines, it is important that it be stable, which can be achieved with the employment of appropriate surfactants. Surfactants should burn cleanly, producing no soot and containing no sulphur or nitrogen. Additionally, they should have no effect on the fuel's physiochemical qualities. In most cases, the amount incorporated in the emulsion process is between 0.5 and 5% by volume ratio. Sorbitan monooleate [9, 17, 30, 32] and polyethylene glycol sorbitan monooleate mixture [13, 24], polyethylene glycol sorbitan monooleate (polysorbate 80) and sorbitol sesquiplane (SSO) mixture [22], sorbitan monolaurate [27], gemini [32], polyoxymethylene nonylphenol ether [15], solgen 40, and noigen TDS-30.

In terms of combustion and emissions, there is a limited literature on the effect of surfactant on the properties of water-in-diesel emulsions. By fuelling it in a four stroke and four cylinder engine test bed, Nadeem and coworkers investigated water-in-diesel emulsion with conventional (sorbitan monooleate) and gemini surfactants for main pollutant emissions and found that for 15% water content, there is a 71 percent reduction in PM emission with geminin surfactant water in diesel emulsion fuel.

There are two types of emulsification techniques: two-phase (also known as primary) and three-phase (also known as secondary) (sometimes called multiphase or secondary emulsion to include complex emulsions with more than three liquid ingredients). One continuous phase and one dispersed phase liquids make up a two-phase emulsion, while a three-phase emulsion comprises one continuous phase and two or more dispersed phase liquids. Although the focus of this work is on the water-in-diesel emulsion, which is a two-phase emulsion, it is necessary to discuss three-phase emulsion studies, particularly those that are compared to two-phase emulsions. As a result, research into three-phase emulsion techniques has been examined.

2.3 Three-Phase Emulsion

The three-phase emulsification technique can create two different forms of three-phase emulsions. The inner and outer phases have an impact. Oil-in-water-in-oil and water-in-oil-in-water emulsions are the two types. Oil-in-water-in-oil emulsions are used in the internal combustion engine for fueling, while water-in-oil-in-water emulsions are used in cosmetics, food, and pharmaceutical manufacture. Phase inversion, mechanical agitation, and two-stage emulsion are the three techniques that can be used to make a three-phase emulsion. In a three-phase emulsion, the most typical technique is two-stage emulsification, which uses both lipophilic and hydrophilic surfactants. Using a hydrophilic type surfactant and a mechanical homogenizer machine, a two-phase oil-in-water emulsion is first created. The two-phase oil-in-water emulsion is then further emulsified in oil with a lipophilic kind of surfactant to generate a three-phase oil-in-water-in-oil emulsion.

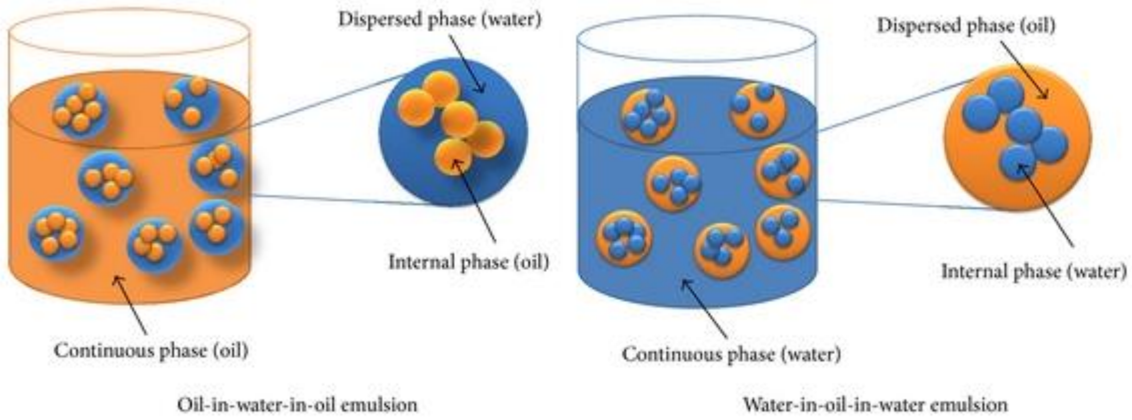

Figure 2.1

Concept of three-phase oil-in-water-in-oil and water-in-oil-in-water emulsions.

2.4 Two-Phase Emulsion

Two types of three-phase emulsions can be created using the three-phase emulsification technique. The inner and outer phases have an effect on each other. The two types of emulsions are oil-in-water-in-oil and water-in-oil-in-water. Water-in-oil-in-water emulsions are used in cosmetics, food, and pharmaceutical manufacturing, whereas oil-in-water-in-oil emulsions are utilized in internal combustion engine fueling. Three ways can be employed to make a three-phase emulsion: phase inversion, mechanical agitation, and two-stage emulsion. The most common way for making a three-phase emulsion is two-stage emulsification, which uses both lipophilic and hydrophilic surfactants. A two-phase oil-in-water emulsion is initially generated using a hydrophilic type surfactant and a mechanical homogenizer machine. A lipophilic surfactant is used to further emulsify the two-phase oil-in-water emulsion in oil, resulting in a three-phase oil-in-water-in-oil emulsion.

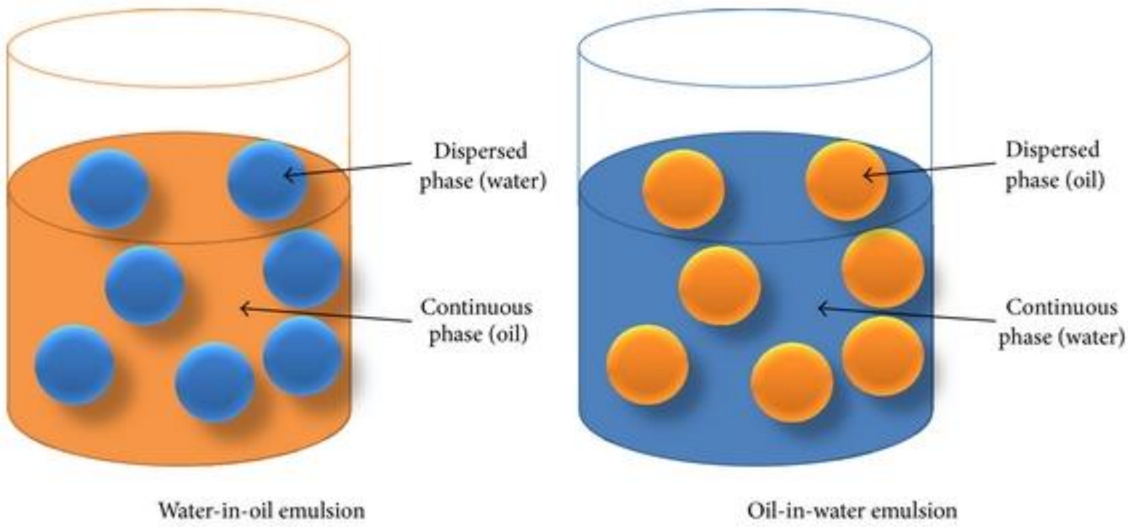

Figure 2.2

Concept of two-phase water-in-oil and oil-in- water emulsions.

For either type of stable emulsion to form, three basic conditions must be met:

(a) The two liquids must be immiscible or mutually insoluble in each other.

(b) Sufficient agitation must be applied to disperse one liquid into the other.

(c) An emulsifying agent (surfactant) or a combination of emulsifiers must be present.

2.5 Effect of oil-water emulsion on combustion process

With the help of surfactants in an oil-water emulsion, water remains embedded inside the diesel droplets. When this form of emulsion is sprayed into a heated combustion chamber, heat is transmitted to the surface of the fuel droplets by convection and radiation. Because water and diesel have different boiling temperatures, their evaporation rates will be different. As a result, the water molecules superheat quicker than the fuel molecules, causing vapor expansions to break off. It's at this point that the micro-explosion happens. The whole droplet splits up into small droplets swiftly in a micro-explosion, and water leaves the droplets in a fine mist (a part of the droplet break up).

These micro-explosions can generate a rapid breakdown, or secondary atomisation, of the fuel droplets, resulting in rapid evaporation of the fuel and hence enhanced air-fuel mixing, as seen in Figure 3. It's also crucial to understand the fundamentals of micro-explosion of water-in-diesel emulsions and the factors that influence them, as this plays a key role in improving combustion.

The temperature of micro-explosions rises as the emulsifier content rises, as does the waiting duration. In the secondary atomization process of water-in-diesel emulsion fuels, micro-explosion is a common occurrence. The volatility of the base fuel, the type of emulsion, the water content, the diameter of the dispersed liquid, the position of the dispersed liquid, and ambient factors such as pressure and temperature all influence this occurrence.

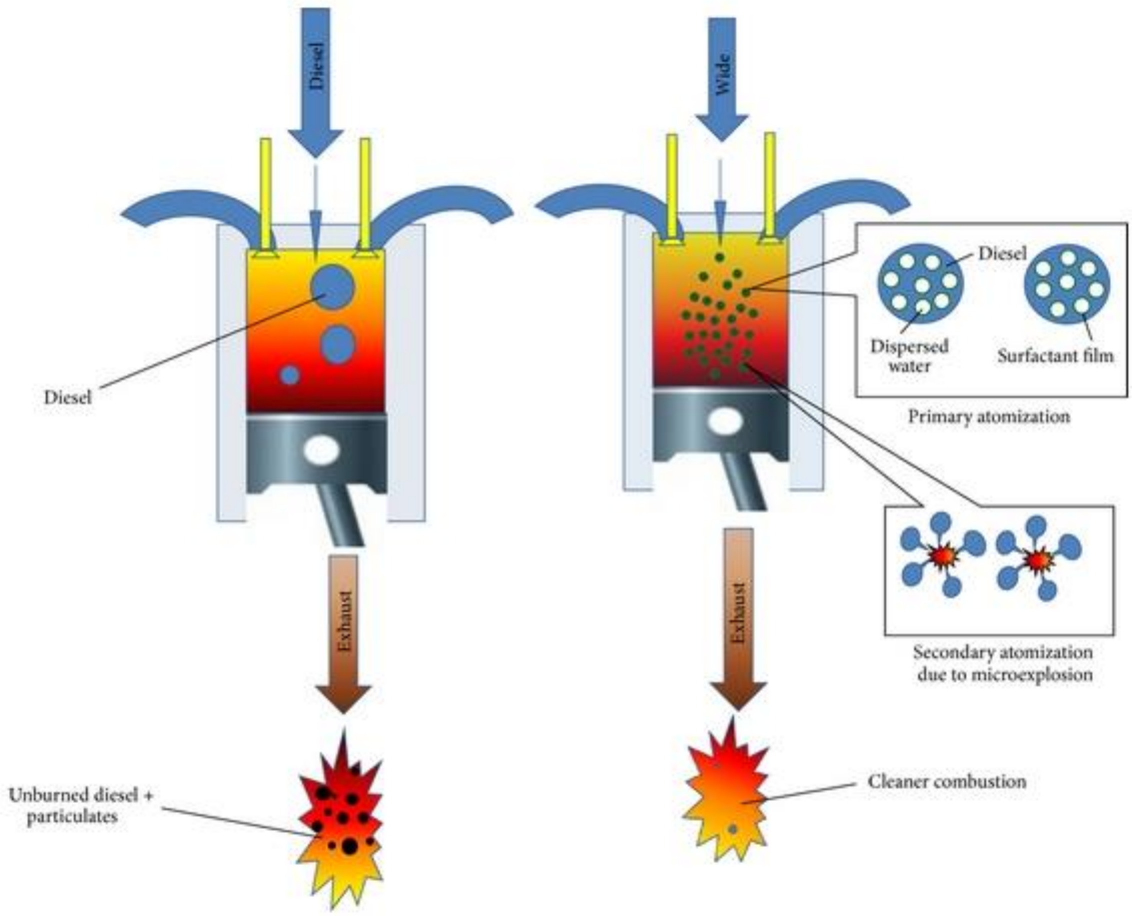

Figure 2.3

Primary and secondary atomisation in spray flame of emulsified fuel.