

COMBUSTION VISUALIZATION AND MEASUREMENT IN A CLOSED
VESSEL

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To my beloved husband Mohd Ismail Shazli,
son Muhammad Harraz Ismail,
mother Rosnani Zainal and
father Aznam Yahya.

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ABSTRAK

Dalam mendalami kajian kadar pembakaran, terdapat banyak kajian telad dibuat menggunakan kaedah merekod tekanan dan teknik fotografi schlieren. Kedua-dua kaedah tersebut telah diamati secara meluas pada keadaan api berbentuk sfera. Hal ini telah membuatkan pelbagai perbandingan diantara pengoksida dan minyak bersandarkan kajian-kajian sebelum ini. Walaubagaimanapun pada pengetahuan penulis, belum ada data eksperimen yang dijalankan di Malaysia. Lantas mewujudkan peluang untuk kajian yang lebih mendalam. Sebuah pendandang berbentuk siliner yang menghasilkan api berbentuk sfera digunakan dalam eksperimen ini. Eksperimen dijalankan hanya untuk metana-udara pada lima keadaan keserataan kadar (ϕ) iaitu pada keadaan lebihan udara (0.7, 0.8), stoichiometri (1.0) dan keadaan lebih metana (1.2, 1.4). bacaan maksima yang direkod di nilai. Pada masa yang sama teknik fotografi 'schlieren' juga digunakan pada keadaan stoichiometri. Gambar 'schlieren' tersebut memberi maklumat pandangan kasar pada jelaga yang terbentuk. Keputusan profile tekanan pada stoichiometry di bandingkan degan kajian penyelidik terdahulu. Berdasarkan eksperimen yang dijalankan, bentuk profil data yang direkod dan juga kadar pembakaran adalah mirip kajian yang sebelumnya. Kadar pembakaran yang diperoleh bagi campuran awal metana-udara adalah 6.328 cm/sec bagi $\phi=0.7$, 9.718 cm/sec bagi $\phi=0.8$, 26.415cm/sec bagi $\phi=1.0$, 18.081 cm/sec untuk $\phi=1.2$ dan 5.026 cm/sec untuk $\phi=1.4$.

ABSTRACT

In accessing the research of burning velocity, it was found that a wide range of determination on burning velocity by pressure record method and schlieren photography technique research exists. Both method has been observed broadly in expanding spherical flame in gaseous phase. Therefore various oxidizer-fuel mixture comparison were made based on their accuracy. However, in the author's knowledge there has not been an extensive experimental data develop locally. Thus a gap exists for further research in this area. A cylindrical vessel combustor that correspond to spherically expanding flame is used in this experiment. The experiment is subjected for only premixed methane-air of five equivalence ratio (ϕ) which are lean (0.7, 0.8), stoichiometric (1.0) and rich (1.2, 1.4). The maximum pressure recorded was examined. Simultaneously a schlieren photography technique was employed during the combustion at stoichiometric condition. The schlieren image provide the visualization of the propagating flames. The result of pressure profile at stoichiometry condition was compared with the previous work by other researcher. Based on the experimental investigation, the trend line of the recorded pressure profile and the burning velocity at various equivalence ratio in this experiment is similar as obtain in previous work done. The burning velocity of premixed methane-air were 6.328 cm/sec for $\phi = 0.7$, 9.718 cm/sec for $\phi = 0.8$, 26.415 cm/sec for $\phi = 1.0$, 18.081 cm/sec for $\phi = 1.2$ and 5.026 cm/sec for $\phi = 1.4$ respectively.

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LIST OF SYMBOLS

D, d	–	Diameter
L	–	Length
P	–	Pressure
R	–	Radius
T	–	Temperature
V	–	Velocity
ρ	–	Density
S_L	–	Flame speed
S_u	–	Burning velocity
γ	–	Specific heat ratio
ϕ	–	Equivalence ratio
t	–	Time

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CHAPTER 1

INTRODUCTION

1.1 Background

Combustion is a process formed when there are a source of fuel, air (oxidizer) and heat. From combustion process, fire, heat and light were obtained. These products of combustion process are useful for many applications. Simple burning of woods to obtain heat during winter time, or for cooking has evolved to burning of coal to obtain lights and electricity, and burning of diesel to operate ships and vehicles. Therefore combustion processes something that very closed to our daily activity. In control used of combustion can be benefitted to human. However it is dangerous when simple combustion becomes out of control and turn out to be explosion.

Combustion is a self-propagating mechanism, meaning once it ignited it will continue and sustained by the high temperatures until either the fuel or the oxidiser practically diminish. Woods, coal, and diesel are a form of fuel or in combustion it is refer as reactant. The air that responds with the reactants is called oxidizer. When the two combined, with the present of energy in a form of heat, combustion will happen. The source of heat can comes from spark ignition like in the example of internal combustion engine of a car. However in order for a combustion to occur, the three elements, fuel and air must be in adequate mixture and heat must be sufficient. This sufficient mixture is measured as equivalence ratio of the air and fuel.

When combustion takes place, there is very thin layer of bright yellowish in colour form surround the burning source. For example, when turning on the cooking stove at home, there is a formation of 'this' yellow sometimes bluish in colour emission. This emission of light is what we called flame. Flame is a thin reaction zone where the air-fuel mixtures get burn. The flame which propagates towards the unburnt mixture is called flame front which can be measured as flame speed. From the observation of flame front propagation and the flame speed gives opportunity to study the burning velocity. In any changes of combustion parameters namely pressure, temperature, air-fuel mixing condition and complexity of flow will definitely affect the measured burning velocity. Often there is a confusion between flame speed and burning velocity. Flame speed is define as flame front propagates normal to its surface trough the adjacent unburnt gas (Lewis and Elbe, 1987). Whereas the burning velocity is define as the movement of the surrounding unburned gasses towards the propagating flame front. The two can be related with the density of the burned and unburned mixture.

The determination of burning velocity is very important in a way that it gives the information on how fast the combustion process react if the combustion parameters varies. This value is significance in evaluating the performance of a system that applied combustion process. For example the performance of IC engine of a vehicle. The high efficiency of the engine can be achieve if a small amount of input to be used, which is the fuel. But of course, this is unique to only if the effect of air-fuel mixture is a concern. One of the most studied burning velocity condition is in gaseous phase of methane and air for difference parameter of equivalence ratio at atmospheric pressure and ambient temperature. It has been proven experimentally and numerically studied by various researchers that the burning velocity is highest at a slightly rich mixture conditions (Dobashi, 1997). The burning velocity value obtained experimentally can be used in the later simulation work as it gives the verification of the combustion model with the actual environment.

To study the burning velocity of combustion is not as simple as igniting it. Combustion process is very complex. It involves chemical kinetics reactions as it comprises chemical chains that form the hydrocarbon fuel and as well as the

oxidizer. It also involve the complexity of the flow. As when the flame front propagates, it probably experience the transitions from laminar to turbulent flows. This contribute to instability of the flame front due to chemical kinetics reaction of the mixtures (Dobashi, 1997). It is also important to take into account the state of the burned gas which the combustion parameters are concern. Last but not least the study of type of application in combustion for example in the IC engine and industrial heating.

In the works of Dahoe *et al.* pointed out that from 1953 up to 2003, experimental and numerical data on burning rate of methane and air mixture are not extensively presented. Therefore it is a concern to contribute experimental data on this burning velocity as a support to the existing data. Recognizing that combustion is a complex process, some consideration need to be taken into account in the study of burning rate. In order to obtain a reliable results, process need to be isolate from other influences, first. Following next is determination on what parameters to be observed. One of the prominent parameter is the measurement of burning velocity with several equivalence ratio of mixtures. Apart from that, selection of method used to calculate the burning velocity. From early study on burning velocity measurement, a pressure trace method had proven experimentally consistent (Rallis and Garfoth, 2001).

Realizing the importance of fundamental understanding of combustion specifically in burning velocity determination, therefore a plentiful of study should be address in this field. In this master project, it is aiming to calculate burning velocity by considering the effect of the various equivalence ratio of methane and air. The result obtain from the experimental work is then compared with the existing data available. It is in hope that the range of burning velocity obtained is coherent with the previous work done. Thus established reliable burning velocity data locally.

1.2 Problem Statement

Burning velocity of gaseous methane and air has been widely studied by various researcher. However throughout literature review it was found that there was a limited experimental data on burning velocity that derived from pressure measurement technique. One of the combustion performance that can be measured is the burning velocity. Thus this gives the opportunity to extend the burning velocity research area conducted locally and eventually provides supporting data in combustion.

In this project it is aimed to measure the burning velocity experimentally by means of pressure trace method in a closed cylindrical vessel that correspond to spherically expanding flame. The recorded pressure data will be used to compute the burning velocity and the results will be quantitative and qualitatively studied. It is expected that the burning velocity of gaseous methane at various equivalence ratio closed to the results obtain by other researchers.

1.3 Objectives

In the present work, it is aim;

- To measure the pressure build-up during combustion process as the function of time.
- To observe the image of spherical flame propagation trough out the combustion.
- To calculate the burning velocity of the spherical flame base on the recorded pressure build-up.

1.4 Scopes

In the present work the experimental works are subjected to several limitation as stated below;

- The experiment cover selected equivalent air fuel ratio at lean (0.7 and 0.8), stoichiometric (1.0) and rich mixtures (1.2 and 1.4).
- Limited only to combustion of methane gaseous fuel.
- Experiment is subjected to spherical flame only.

1.5 Significance of Study

The experiment has advantage in a way that it initiates experimental study of burning velocity locally by providing a compatible combustor that capable to measure built-up pressure. Begins with a simple reaction of hydrocarbon bond (methane) with the air in a gaseous form, the combustor can be extend and upgraded to study in a fluid and solid phase fuel. Thus a thorough study of burning velocity of various oxidizer-fuel mixture at different condition can be explored. This include the investigation of burning velocity from various alternative fuel source that derives from palm oil mill effluent (POME), sludge pond, municipal solid waste, agricultural waste and etc. Furthermore, it can be the starts of establishment of local data base on burning velocity for various type of mixture.

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