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Survey of invest fuel magnetization in developing internal combustion engine characteristics

Hasanain A. Abdul-Wahhab*, Hussain H. Al-Kayiem, A. Rashid A. Aziz, Mohammad S. Nasif

Mechanical Engineering Department, Universiti Teknologi PETRONAS, Malaysia

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ABSTRACT

This document reviews the history of previous attempts on the behaviour of performance and emissions of internal combustion engines (ICE) by invest fuel magnetization. Engine designers are currently confronting serious challenges related to the reduction of emissions in ICE by refining their fuel consumption and performance. In the past, numerous efforts have been materialized to lessen the emissions and upsurge the combustion efficiency. It is important to realise and characterise the influence of the combustion parameters when a magnetic field is applied to hydrocarbons. The need for a better understanding of the interaction between the magnetic fields and combustion processes has been clearly brought out in this review paper.

1. Introduction

The internal combustion engine (ICE) started to develop by the end of the 19th century followed by a steady but slow progress in the succeeding hundred years [1]. The idea of around 97% enhancement in tailpipe emission appeared unimaginable around mid-seventies when emission control was in its early stages. However, in the present day, this is attainable without any difficulty though fuel emissions (ICE) have constantly been evolving and improving in order to comply with the ever-changing power requirements, exhaust and economy. During this time, several variations and concepts have emanated and disappeared, but for all modes of automotive applications, the conventional four-stroke engine continually remained as the most substantial power plant. Nowadays, ICE engines are implemented universally for power generation, construction, transportation, farming and manufacturing. Fig. 1 shows the general energy distribution where it is seen that road transportation demands almost 16% of the available fuel sources [2]. In the subsequent five years, additionally there would be a minimum of 70% enhancement to contribute to a total benefit of superior to 99%. Hence, in the coming 30 years, the idea of near-zero emissions from ICEs probably would not be a fantasy anymore and become a realistically achievable target [3]. Though some of the combustion catalysts could lessen emissions, however, in reality there is no such assessable influence on fuel economy. In order to be efficient in refining fuel economy, a catalyst must cause the engine to burn fuel entirely. Though, not much enhancement is possible. The efficiency of ICE engine combustion is usually more than 98%. Numerous continuing design enhancements for the lessening of emissions could have some potential for the improvement of fuel economy. Nevertheless, various modern emissions control strategies evidently reduce fuel economy, equal to quite a lot of percentage at times. Nowadays, designers are confronting the biggest challenges about the reduction of emissions in ICE by refining their fuel consumption and performance. Due to this reason, it was previously believed that engine design is more imperative than fuel properties. Nevertheless, for a given engine that is meant to be used for a specific task, fuel economy is linked to the heating value of the fuel, though a current conventional engine undergoes relatively high combustion noise, a low specific power output and a high degree of exhaust emissions. To accomplish this goal, at present, numerous solutions have been employed in recent years [4].

Those solutions include the improvement of fuel combustion by blending liquid fuel or gas [5–7], by improving the injection system [8], modification of the exhaust gas recirculation (EGR), combustion chamber as well as piston head design [9,10], by the use of Bio-diesel fuel [11,12], and by the use of magnetic field to change the orientation of hydrocarbons and molecules of hydrocarbons by modifying their configuration, and by utilising the exhaust gas extracted from the treatment systems (fuel oxidation catalysts along with fuel particulate filters or selective catalytic reduction systems). This paper outlines the extent to which the investment in the magnetization of fuel is required in order to improve the characteristics of internal combustion engine and the extent of reduction of emissions.

* Corresponding author.
E-mail address: Abu_ameer5@yahoo.com (H.A. Abdul-Wahhab).

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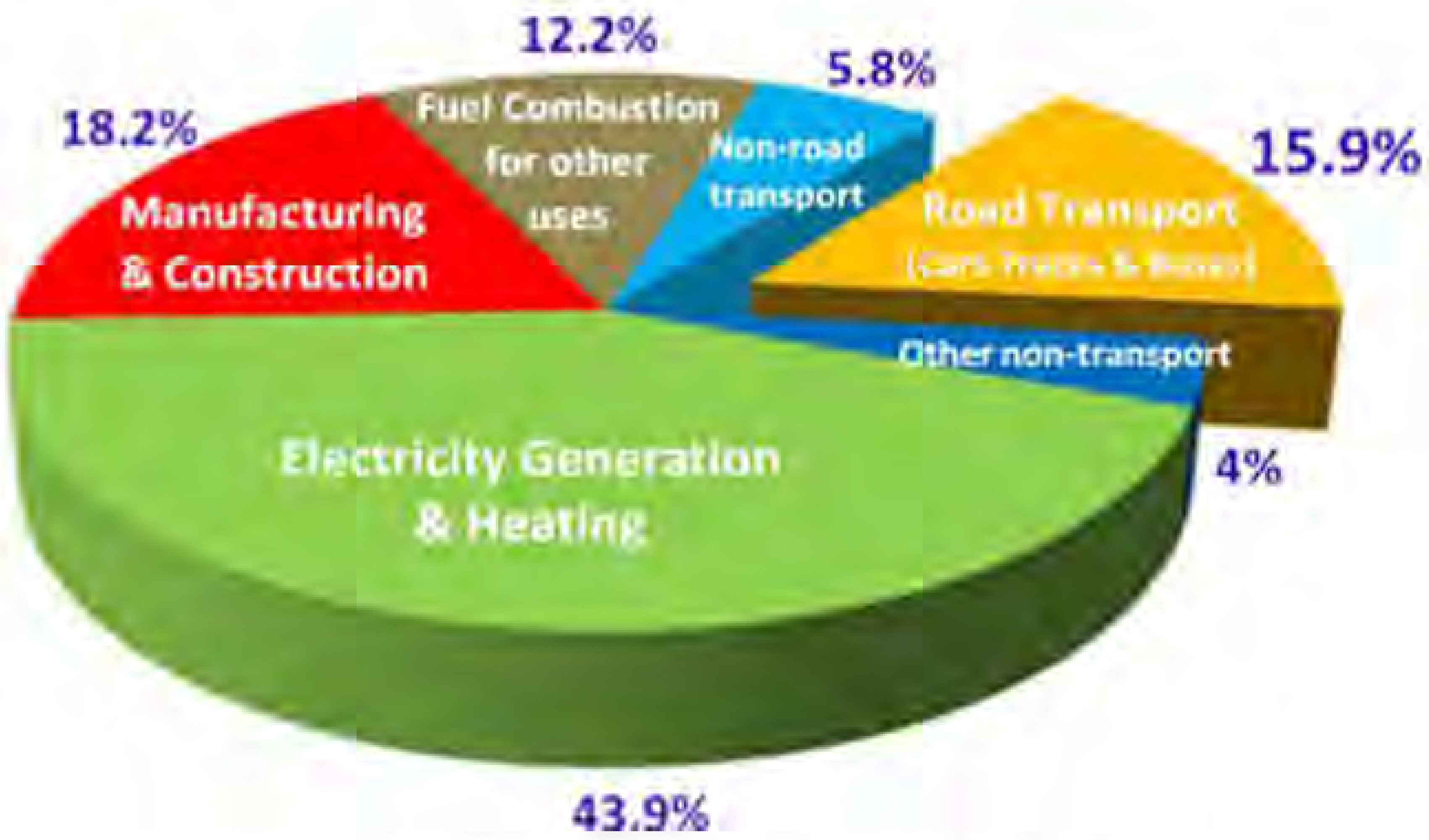


Fig. 1. General energy distribution [5].

2. Magnetization of hydrocarbon fuels

2.1. Background

Most of the fuels for ICE are in liquid phase; do not undergo combustion until they are combined with air after vaporization. On the other hand, emission from motor vehicles contains oxides of nitrogen, unburned hydrocarbons along with carbon monoxide [13]. Oxides of nitrogen along with unburned hydrocarbon react together in the atmosphere and generate smog [13–15]. Normally, the fuel required for ICE is a compound of molecules. According to Zhao and Ladommatos [16] and Wakayama and Sugie [17], every individual molecule comprises of many atoms made up of many electrons along with neutrons orbiting around their nucleus. There exists a presence of the magnetic movements inside their molecules; furthermore, they also contain electrical charges which are negative as well as positive. However, during the process combustion, the fuel is not combined with oxygen vigorously, and molecules are not realigned. Moreover, the hydrocarbon chains or the fuel molecules should be both realigned as well as ionized [18–20]. The process of realignment along with ionisation is accomplished by applying a magnetic field [21,22]. Treatment carried out of hydrocarbons molecules in the presence of high magnetic field would likely cause them to lose their cluster form and take the form of tiny associates having a larger definite surface area in order to carry out reaction involving oxygen which ends up in enhanced combustion. As per Van Der Waals invention of the weak force of clustering, there exists a strong binding between oxygen as well as hydrocarbons in this magnetised field, which make sure of best possible burning of both them inside the engine chamber [23,24].

The Fuel generally contains hydrocarbon, and during the flow of fuel around the magnetic field, the arrangement of hydrocarbons is altered [15]. Similarly, the inter-molecular force is significantly lowered or depressed. Such methods are said to assist in dispersing the oil molecules to divide finely [14]. It causes an effect that makes sure that the fuel vigorously combines with oxygen and results in complete burning process inside the combustion chamber as shown in Fig. 2 [16]. The outcomes are decreased in carbon monoxide, oxides of nitrogen and hydrocarbons which are emitted by the exhaust and improved economy of the fuels. The ionisation of fuel assists in the dissolving of carbon which is build up in the combustion chamber, carburettor, fuel injector and jets, as a result, it maintains the condition of the fuel magnet which is fitted on trucks and car engines instantly before the injector or carburettor is on the fuel line. For the locating of the South Pole on adjacent of fuel line and the North Pole spaced apart from the fuel line the orientation is set for the magnet in order to make the magnetic field [16].

2.2. Magnetization for simplest hydrocarbons fuel

The simplest form of hydrocarbon is methane having the chemical formula (CH_4), is a significant provider of hydrogen which is the main element of natural gas. Molecules of methane are made up of one carbon atoms and four hydrogen atoms as well as it is neutral electrically [15,18]. With regard to energy, the largest amount of energy which can be released is contained in the hydrogen atom, since the amount of carbon in octane is 84.2%. The carbon part of the molecule when undergoes combustion produces 28479.544 kJ/kg amount of energy. Similarly, the hydrogen consists of 15.8% as its molecular weight, is said to produce (22797.126 kJ/kg). Hydrogen is the simplest and least heavy element and is identified as the main component of hydrocarbon fuels (excluding less amount of sulphur along with inert gases and carbon) [17].

The hydrogen atom consists of two charges as shown in Fig. 3 [18], a negative charge known as an electron and a positive charge known as a proton. Moreover, it contains a dipole moment. In addition to this; it can be both paramagnetic and diamagnetic in reaction to the magnetic field relying on its nucleus spin orientation. As a result, it takes place in two different isomeric range forms known as ortho and para, which are characterised by various opposite spins of the nucleus. The ortho molecule takes the rotational levels which are odd when the spins are parallel with similar orientation for two atoms. As a result, it acts as a paramagnet and is used as a catalyst for various reactions. The parahydrogen molecule occupies the rotational level which is even, and the state of spin is in opposite direction of one atom as compared other, thereby making it diamagnetic.

A marked effect on the physical properties such as vapour pressure, specific heat and the behaviour of the gas molecules has been caused by the spin orientation. Ortho hydrogen becomes unstable due to coincident spins, despite the fact that para hydrogen is less reactive than ortho hydrogen counterpart. The magnitude of internal field strength inside a material which is subjected to an external field is represented by the magnetic field density [21]. Magnetic flux density is measured in gauss or tesla where 1 $T=10^4$ gauss. The magnitude of magnetic strength is an indicator of which magnetic energy can be provided by a magnetic source [23]. The magnetic field density which is supposed to be passed onto the fuel fluctuates according to the equipment of combustion as well as the rate of combustion [20]. The distance between magnetization and combustion area is also important. To obtain good a magnetic effect, it should be as close as possible. However the temperature of the magnetic material should be maintained under the critical temperature of magnetic properties in a magnetic material [25]. On the other hand, the magnetic field which satisfies Maxwell's equations and the electrical conductivity gave this behaviour [26] while the electrical conductivity of fuel decreases as sulphur is removed during the refining process. Most fuel such as diesel which is produced prior to 2006 having higher sulphur content and commonly exhibits electrical conductivity between 150 and 250 (ps/m), depends on the sulphur content of the fuel [27].

2.3. Effect of magnetic field on combustion behaviour

The fact that magnetic fields affect flames behaviour has been proved. Some research has been performed on the effect caused by the magnetic field on the gas flows along with flames [28–30]. The modifications of the gas-flow, as well as the shape of the flame, are understood to be the result of the role of oxygen. Oxygen is paramagnetic, and it aligns with the magnetic field in order to construct a layer of oxygen. The layer of oxygen causes the other gases and flames to press back [30]. Ueno et al. [28] found that combustion velocity was modified if the combustion reaction site is exposed to a magnetic field. Salamandra and Shlyakman [31] applied an electric field to a homogeneous fuel-air mixture. The results indicated that the electric field intensity increases as the flame velocity increases. Some other results

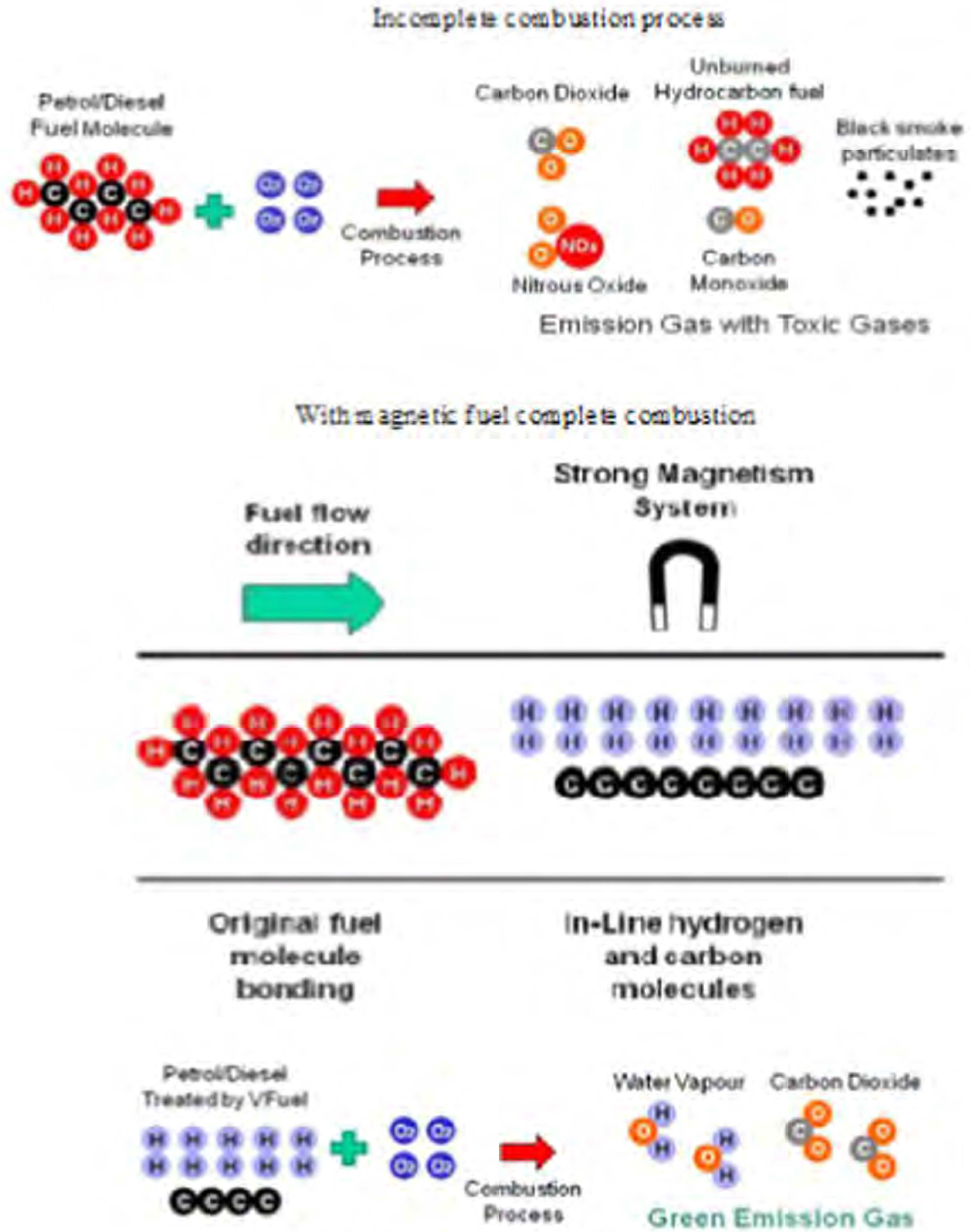


Fig. 2. Schematic view of the magnetic field [20].

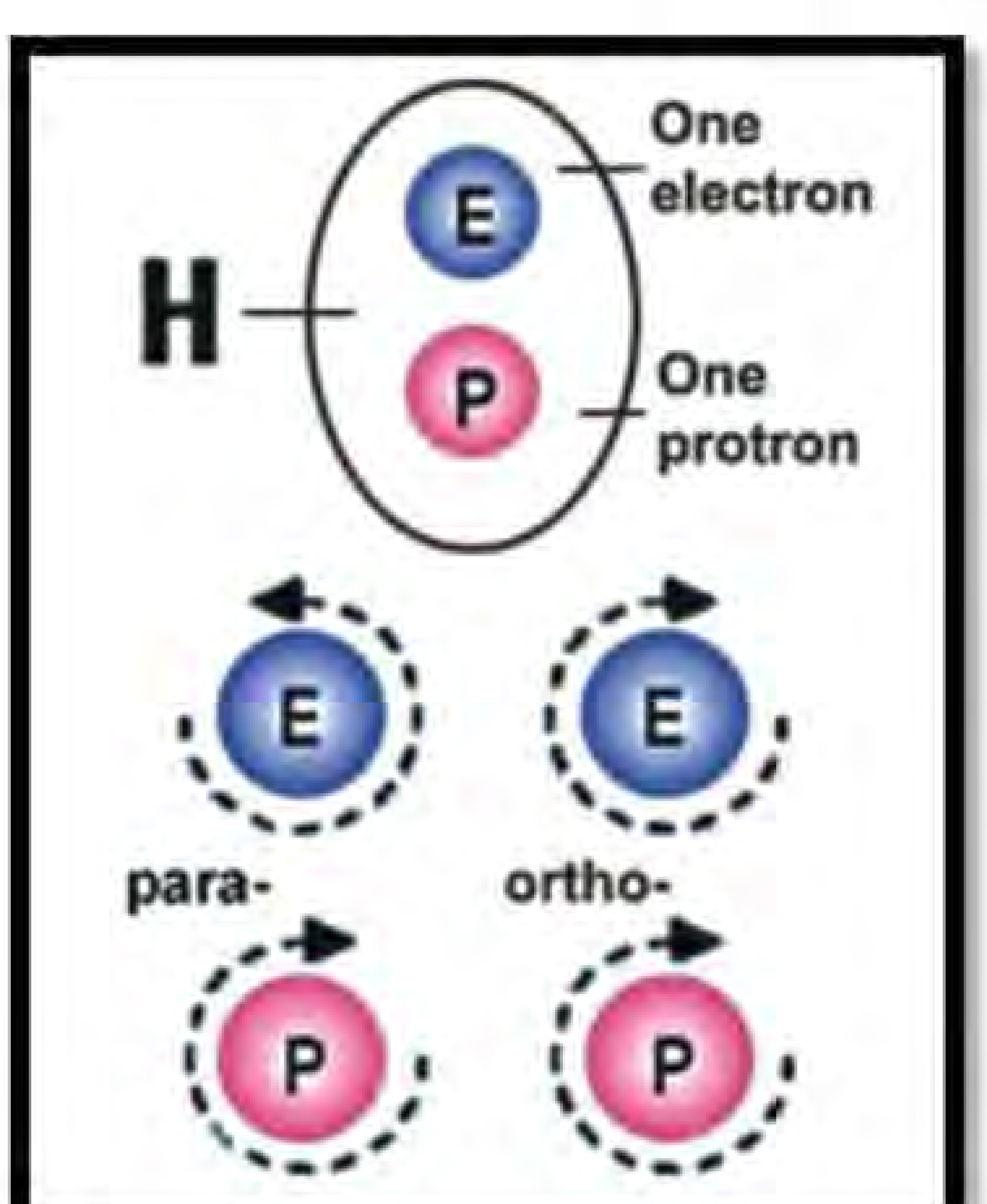


Fig. 3. Atomic orientation [22].

suggested the possibility of magnetic control of combustion and air flow [32].

Hydrocarbons are regarded as a significant resource of energy for people since the olden times. The significance of combustion cannot be ignored. However, the huge and unrestrained chemical modifications which occur in this reaction cause a difficulty in determining the mechanistic paths [33–35]. The rate at which consumption of fuel takes place is reduced to improve the quality of the fuel. With regard to thermodynamics initiatives to make the enthalpy of combustion higher are considered as the greatest advances to attain this objective. A schematic sight of the effect of magnetic field on the process of combustion is displayed in Fig. 4 [33], it is believed that energy that is free, is unaffected as all the primary bonds are broken to make new bonds during the process of combustion. As a result, the products avoid the effects of the magnetic field. Hence, combustion heat or combustion enthalpy is increased causing improvement in the quality of the fuel along with a decrease in the consumption of fuel after that. These explanations supported the reports provided by the companies which were involved in the manufacturing of the magnetic fuel saver. Though several designs were proposed, they were unsuccessful as the conditions demanded to apply the magnetic field, for instance strength were not fulfilled. Earlier empirical studies produced outcomes with a chance of decrease in the consumption of fuel because of application of the magnetic field to add fuel before the process of combustion. Despite the fact that the studies having scientific approach were hardly made in order to understand the features of this phenomenon [33,36,37]. In what manner these modifications affect the combustion

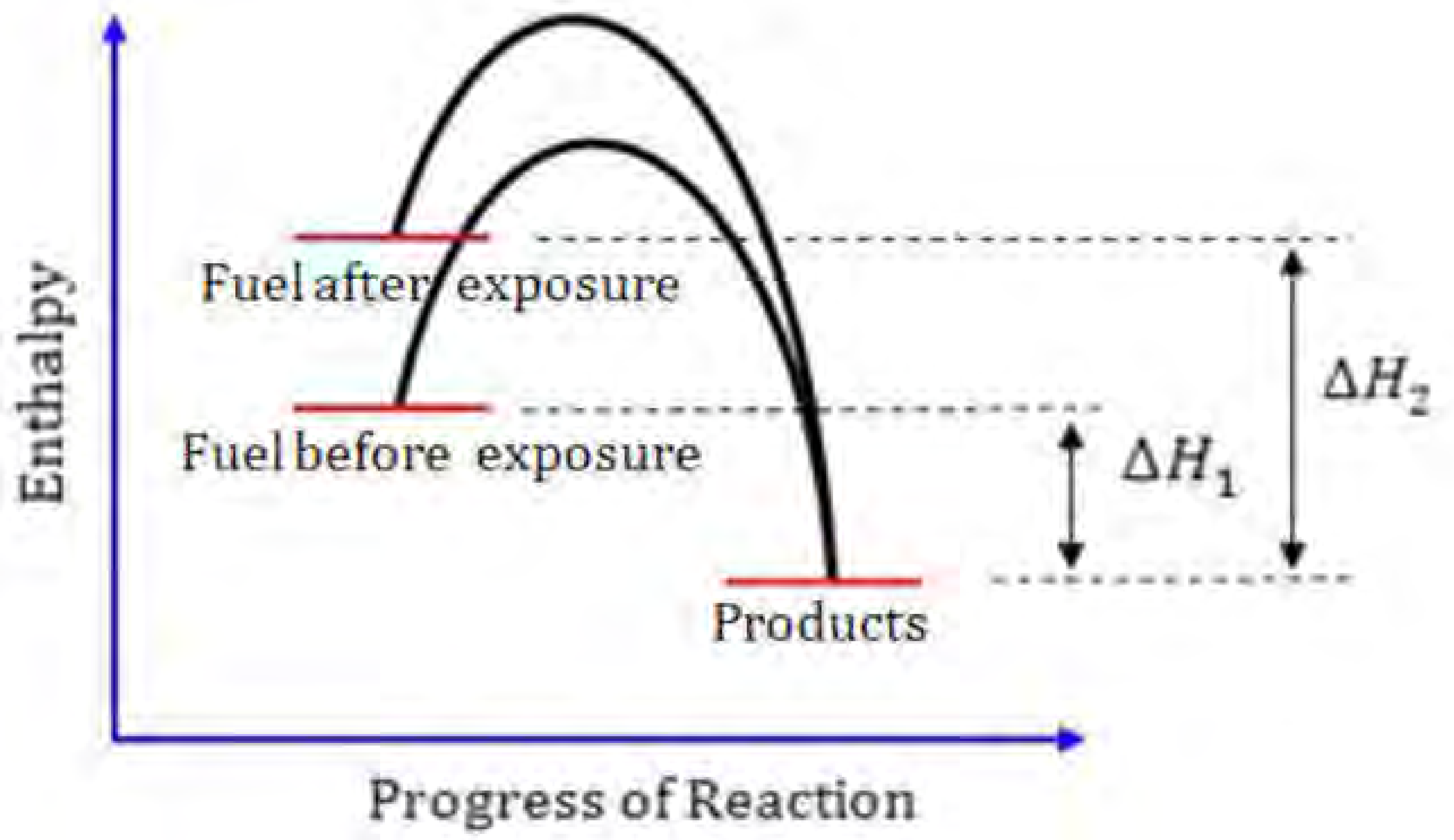


Fig. 4. Schematic view of magnetic field effect on the combustion behaviour [37].

enthalpy of fuel is shown in Fig. 4.

3. Effect of magnetic field on emissions in spark ignition engine along with fuel consumption

A procedure and an instrument was demonstrated by Sanderson [38], in order to treat the liquid fuel inside the internal combustion engines through passing it by a magnetic field before combining it with air in the fuel injector or the carburettor [39], whereas an experimental test was performed by Janezak and Krensel [40]. In order to treat gasoline with the magnetic field for the purpose of effective pollution as well as combustion, their discovery considered a unit of permanent magnet mountable as retrofit adaptors outside the fuel line is causing no separation or alteration between the ignition system and fuel [41,42]. Govindasamy and Dhandapani [43], reported that the usage of strong magnetic charge obtained from the magnet input to the fuel line two-stroke spark ignition engine results in full burning, in order to increase the power and lessen the expenses of the process. Fig. 5 demonstrates the following: (a) variation of brake thermal efficiency along with air-fuel ratio (b) magnetic field on the fuel line. In addition to this, the magnetic flux on the fuel line considerably decreases the

(a)

(b)

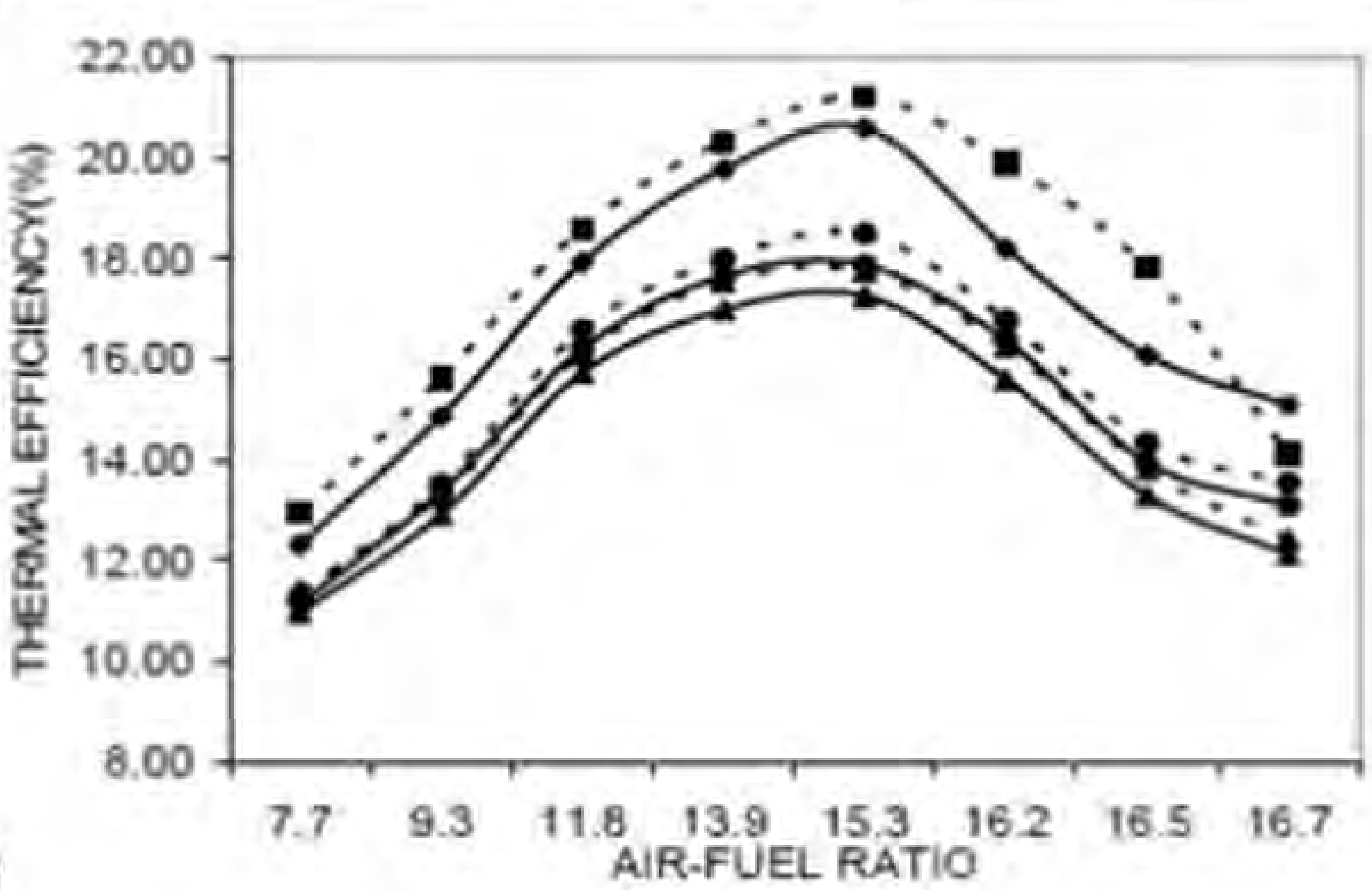


Fig. 5. Show (a) magnetic field on the fuel line, (b) Variation of brake thermal efficiency with the air-fuel ratio [48].

Table 1
Changes in performance and emission parameters due to different magnetic field strength [48].

Parameters	Base engine %	Copper-coated engine, %	Zirconia coated engine, %
Increase in brake thermal efficiency	3.2	6.6	11.2
Reduction in cyclic variation	8.6	8.8	12.1
Reduction in CO emission	13.3	23.5	29.5
Reduction in HC emission	22.1	37.3	44.2

destructive emissions from the exhaust at the same time increasing the mileage and enhancing the performance of the engine [44–46]. Moreover, the efficiency of the process of combustion increases and provides an increased performance of octane.

The engine was made to work in a mode of constant speed, and the following cases were considered to acquire results: the base engine, the engine with a permanent magnetic field with different intensity (3000, 4500, and 9000) gauss, Copper coated engine with 9000 gauss magnetic flux and Zirconia. Modifications in various parameters with an engine having a coating of Zirconium, base and Copper having 9000 gauss magnetic flux are shown in Table 1 [43]. It was shown in the experimental results that the magnetic flux in the fuel decreases the emission of carbon monoxide till 23% in copper coated engine (situated in the cylinder head), till 13% for the base engine along with 29% in zirconium coated (situated in cylinder head) engine having 9000 gauss magnetic flux [47,48]. While Al-Ali et al. [49] used two types of magnetic device, the first type was fixed inside the fuel tank, and the other one was fixed in the fuel line. The outcomes showed a decrease of 18% in average consumption of fuel and 70% decrease in emissions of HC and CO_2 and a decrease of 68% of NO_X was measured.

The effect caused by the magnetic field on the internal combustion engines was studied by Al-Dossary [50]. This magnetic field was produced by the electromagnets with the help of a car battery of 12 V through fluctuating the configuration along with the strength of the magnetic field. The magnetic effect produced a decrease in specific consumption of fuel that was constantly noticeable only at the least load measuring 20 N m along with highest and lowest speed of 1000 rpm and 3000 rpm by utilising one magnet. The most noticeable decrease was the effect on CO as compared to entire emissions occurred at the speed and load of the engine specifically at the speed of 1000 rpm which was the lowest by using a total of five magnets. The most constant decrease in HC was also considerable at the speed of 1000 rpm by using a total of four magnets, whereas, different configurations along with magnetic field strengths showed reasonable decrease in the speed as well as loads of most engines [51].

Effect caused by the magnetic field on the internal combustion engines was studied by Farrag and Saber [22]. This study focused on the parameters that are measured for the performance of the engine, like exhaust emissions along with fuel consumption. Application of magnetic field was carried out on the SI engine by making use of gasoline fuel. In addition to this, the fuel was exposed to a permanent magnet which was mounted on inlet lines of the fuel. At different idling engine speeds, experiments were done. The emissions from exhaust gas were analysed with the help of an exhaust gas analyser. The effect of the magnet with a decrease in consumption of fuel was around 15% decrease in CO at every idling speed; in the range of around 7%. The decrease in effect caused by emissions of NO was around 30%.

The effect caused on the performance of spark ignition engine due to magnetised fuel was studied by Habbo et al. [52]. The performance of the engine was studied carefully by studying the four parameters which were the thermal efficiency (η_{th}), brake power of the engine (bp), exhaust emissions along with the specific fuel consumption (*SFC*). The fuel was exposed to a magnetic field that was kept to fuel supply line in order to magnetise the fuel prior to its placement in the engine cylinder. The outcomes displayed a noticeable enhancement in the performance of the engine. The engine power, along with the thermal efficiency was increased by 3.3% and 4%, during the use of a magnetic coil of 1000 gauss. Moreover, a decrease in the specific consumption of fuel was accomplished. Though this brake power was increased approximately by 16.4% and the thermal efficiency was increased by 7.6%, and specific consumption of fuel was reduced by 21.3% when the magnetic coil of 2000 gauss was used with no magnetic field. The emissions from gas exhaust displayed a decrease of approximately 44% of HC and 80% of CO when the magnetic coil of 1000 Gauss was used. An additional decrease of approximately 58% of HC along with 90% of CO was seen when the magnetic coil of 2000 gauss was utilised [53,54].

Khalil [55] studied that application of magnetic field onto supply line of an internal combustion engine which was functioning with a mixture of 10% volume ethanol-gasoline (leaded) led to an efficient method of a decrease in the emissions from the polluting agents in the exhaust gases. Using magnetic field of 2000 Gauss resulted in a decrease of 68.8% at 30° bTDC in emission of carbon monoxide and decrease of 42.5% in the unburned hydrocarbons at 10° bTDC in addition to this a decrease of 15% in CO_2 at 25° bTDC together contributed to an increased performance of the engine, with 3.6% increase in thermal efficiency and 8.6% increase in thermal power of brake along with decrease of 3.2% in specific fuel consumption. The temperature of the exhaust gas was affected to a minor extent by the effect of magnetic field. Better outcomes regarding brake specific fuel consumption along with thermal efficiency were observed by operating the engine at 2000 gauss coil as compared to running it at 1000 gauss.

Research of Faris et al. [56] studied the usage of permanent magnets with various intensities such as 2000 gauss, 4000 gauss, 6000 gauss, along with 9000 gauss, which were fixed for a two-stroke engine. Moreover, the research also comprised of its effect on consumption of exhaust gases and gasoline. In order to compare the outcomes, it required carrying out research for experiment excluding the usage of the magnets. Fig. 6 displays the fuel magnetization unit [56].

The general performance of the test of exhaust emission displayed a better result, where the rate of decrease in consumption of gasoline ranged from 9-% and 14%. Fig. 7 shows that by decreasing the amount fuel consumed and by increasing magnetic field intensity a large decrease of 14% in the rate was observed by utilising magnetic field intensity of 6000 and 9000 gauss. It was seen that the percentage of components HC and CO of exhaust gas were reduced by 30% and 40%. However, the percentage of CO_2 was increased approximately by 10%. The absorption spectrum of ultraviolet radiation as well as infrared radiation demonstrated a modification in both chemical and physical properties of the structure of gasoline molecules under the effect of magnetic field. The surface tension of gasoline subjected to various intensities of the magnetic field was compared and measured with them without magnetization [43,56].

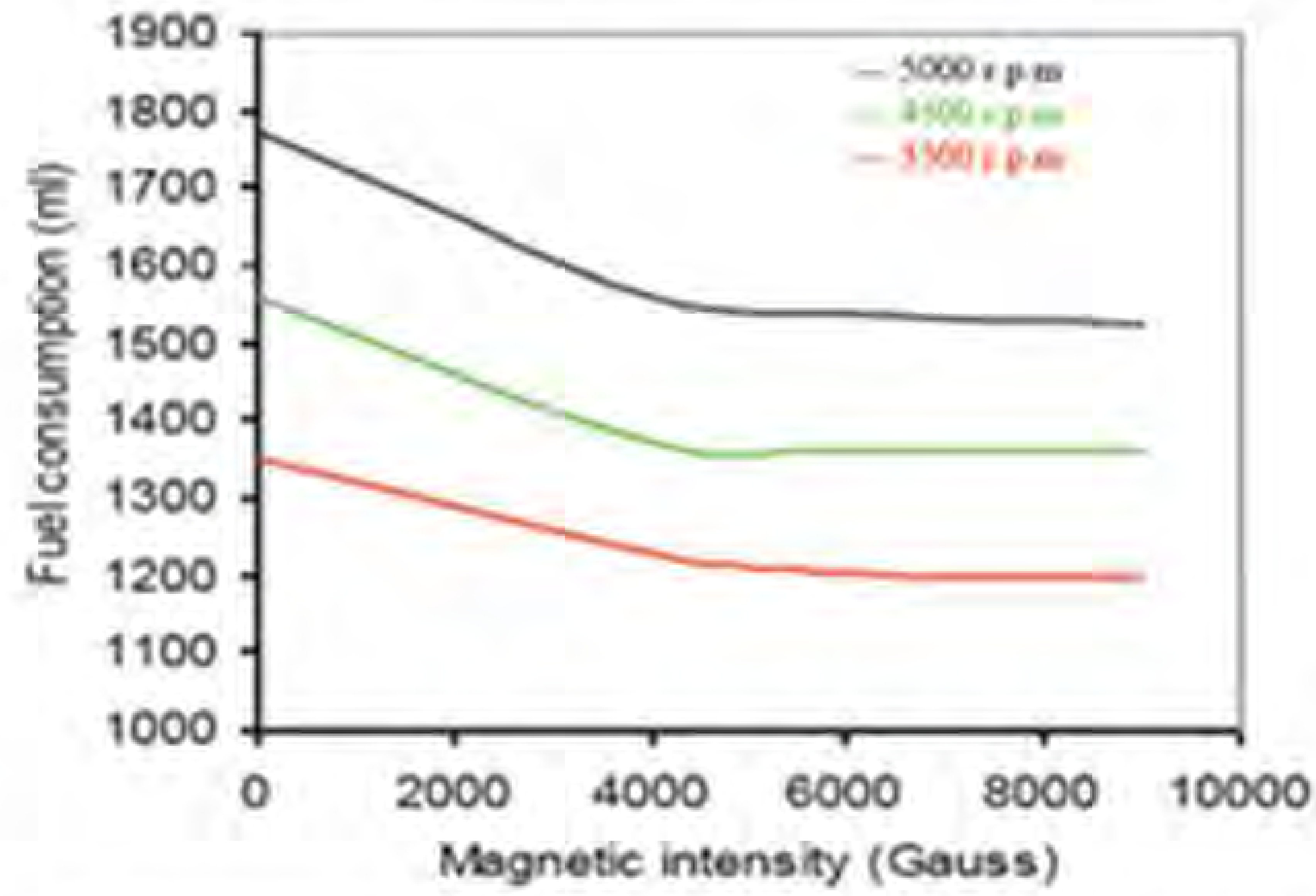


Fig. 7. Effect of reduction in the amount of consumed fuel with increasing magnetic field intensity [61].

4. Effect of magnetic field on fuel consumption and emissions in compression ignition engine

Jacob Almén [57] conducted a test known as Magnetic Emission Control which demonstrated the emission of nitrogen oxides (NO_X), carbon monoxide (CO), and hydrocarbons (HC) was not efficient. A considerable decrease in the emission of particles of 9% and a decrease of 3–7% was seen in consumption of fuel and CO_2.

Testing of fuel ioniser type fuel max was effectively carried out in conditions of the laboratory by using a cylinder engine known as Hastz diesel, was demonstrated by John et al. [58]. Below are the major findings: saving of fuel was outstanding at a mid-range speed between 1700 rpm till 1800 rpm. Fuel max accomplished a saving of fuel of 1.6% on the whole with contrast to test cycle that was conducted without ionisation; in addition to this a higher and lower engine test outcome was not able to accomplish noticeable saving. As a result, it was a no load condition. When Govndasamy and Dhandapani [59] investigated the effect caused by magnetic field with decrease in emission of NO_X inside the Bio-diesel engine with recirculation of exhaust gas, they got to know that when magnetic field is present, the efficiency of brake is increased by 5%, and the values of HC as well as CO are decreased [60].

Al-Khaledy [61] studied the combustion efficiency for diesel fuel in an electrical generator for a time period of 4 weeks with and without

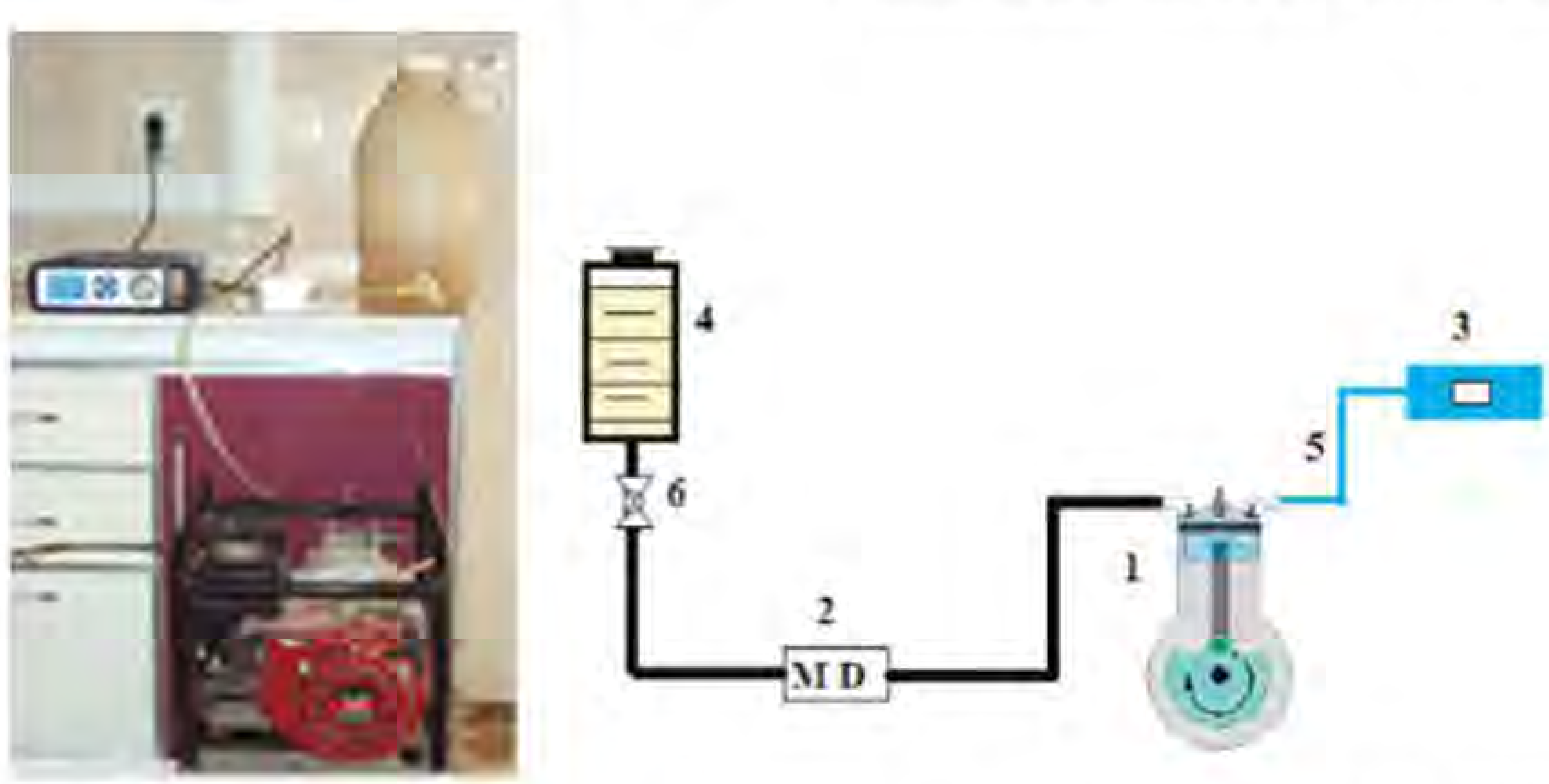


Fig. 6. A picture of the fuel magnetization unit. 1. Engine; 2. Magnetic device; 3. Measuring device for exhaust gases; 4. Fuel tank; 5. Gas sensor; 6. Valve [61].

the involvement of magnetic field and emissions from pollutant agents. A comparison was made between the data which resulted as an output for magnetised diesel fuel and the normal diesel fuel. A decline in the emissions from pollutant agents and an increase in combustion efficiency by using magnetic field unit was observed. The treatment using magnet decreased the generation of NO by 5%, NO_X by 20%, and an increase in CO by 2% was observed.

Jain and Deshmukh [62] explained the working of MFC along with the parameters and constraints by which emission, as well as the efficiency of MFC, is influenced. Magnets known as Ferret were used as MFC. A permanent magnet was mounted in the path of fuel lines, which improved the properties of fuel like its orients, molecules of hydrocarbon, improved atomisation of fuel and aligns. By using these properties, mileage was improved, and enhanced emission was obtained from the vehicle. The fuel burned entirely, hereby generating a higher output of the engine and good economy of fuel, most significantly it decreased the amount of NO_X, HC, smoke and CO from the exhaust. Furthermore, it increased the mileage of the vehicle by 10–40% and showed a decrease in the specific fuel consumption by 23.6% and break specific fuel consumption by 18.6% [63]. Variation of specific fuel consumption with load, and both with and without magnetic flux is shown in Fig. 8 [62].

The effect of magnetic field on hydrocarbon fuel flow was analysed by Attar et al. [64]. It was deduced that viscosity of the flowing hydrocarbon fluids reduces when a magnetic field is applied [65,66]. De-clustering of the fuel molecules of hydrocarbon has been proved to provide better atomisation of the fuel, Fig. 9(a) shows de-clustering of hydrocarbon molecules along with improved mixing of the mixture of the fuel and air which decrease the amount of unburnt fuel and, therefore, improving the thermal efficiency of the IC Engine. An experimental setup was done to carry out the analysis of the effect caused by the viscosity of petrol as shown by Fig. 9(b) [64]. It enhances the economy of the fuel of diesel engine and vehicles. The work is quite important with regard to its effect on the automobile market globally. As a result, ending up in less consumption of fuel and therefore, ensuring the conservation of non-renewable fuel. The percentage of CO is reduced in the exhaust gases through complete combustion [64,67]. The experiments in present research consist of usage of permanent magnets with various field intensity such as 2000 gauss, 4000 gauss, 6000 gauss and 8000 gauss, which is fixed on the fuel line of the diesel/petrol engine to study the impact on the consumption of gasoline.

5. Summary

The following observations are made on the above literature survey:

1. The magnetization of fuel can increase its internal energy and lead to particular modifications at a molecular level. In general, the magnetic treatment of the fuel decreases the fuel consumption in the engine and decreases the rate at which gas emissions are released into the environment, as a result causing less pollution. Clear changes were observed in the value of surface tension of the gasoline fuel, which were more as compared to changes in the diesel fuel. It led to a decrease fuel consumption in gasoline engines (up to 18%) more than what it was in the diesel engines (up to 14%). Fig. 10(a) shows those comparison between types of engines (decreasing fuel consumption 56% in gasoline engine and 44% in diesel engine) and change in some properties of the fuel (density, internal energy, etc.) by the magnetic field in gasoline fuel compared with diesel fuel, it let to achieve reduction of emissions in gasoline engines with higher ranges from diesel engines, Fig. 10(b) shows those results.
2. The success of this method in the development of the internal combustion engine is not restricted to the effect of the magnetic field on the molecular composition of the fuel but also extends control over some design features to be developed extensively and accurately. Fig. 11 describes the application of magnetic features, effect of magnetizer location (this means to test the impact of the installation site magnetised from the combustion chamber, while practical tests [49] showed the advantages of improved performance and emission reduction which are larger when influence is away from the combustion chamber), for this purpose the use of magnetic materials was proposed while designing and manufacturing both the top cylinder as well as the inlet manifold. Effect of increasing magnetizer intensity (increase the intensity of the magnetic field has a positive role in improving the performance characteristics dramatically so one must choose the appropriate values when adopting as part of routes design). In some previous literature, one had to use magnetization fuel to coincide with one of the ways to

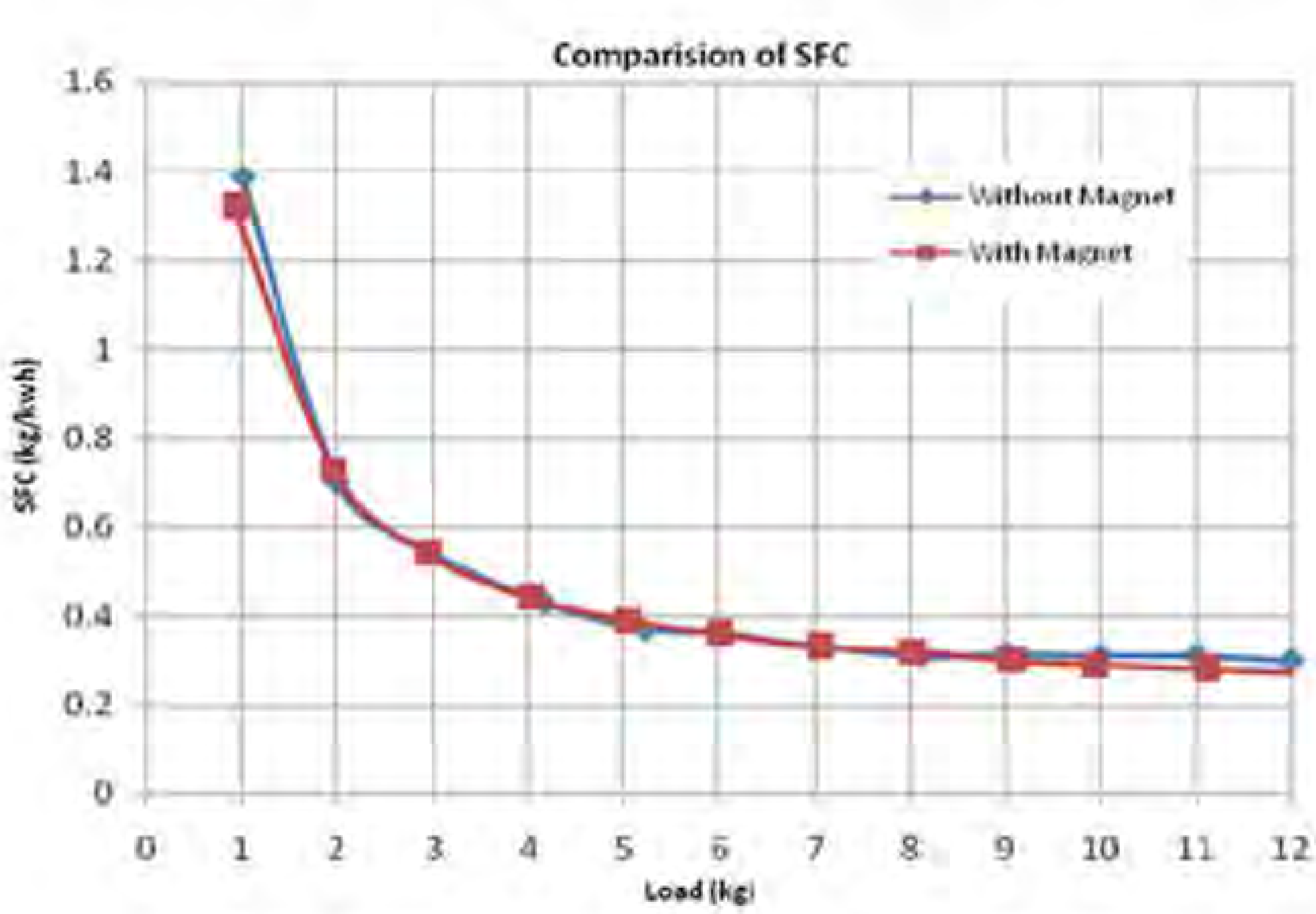


Fig. 8. Variation of Specific fuel consumption with load [68].

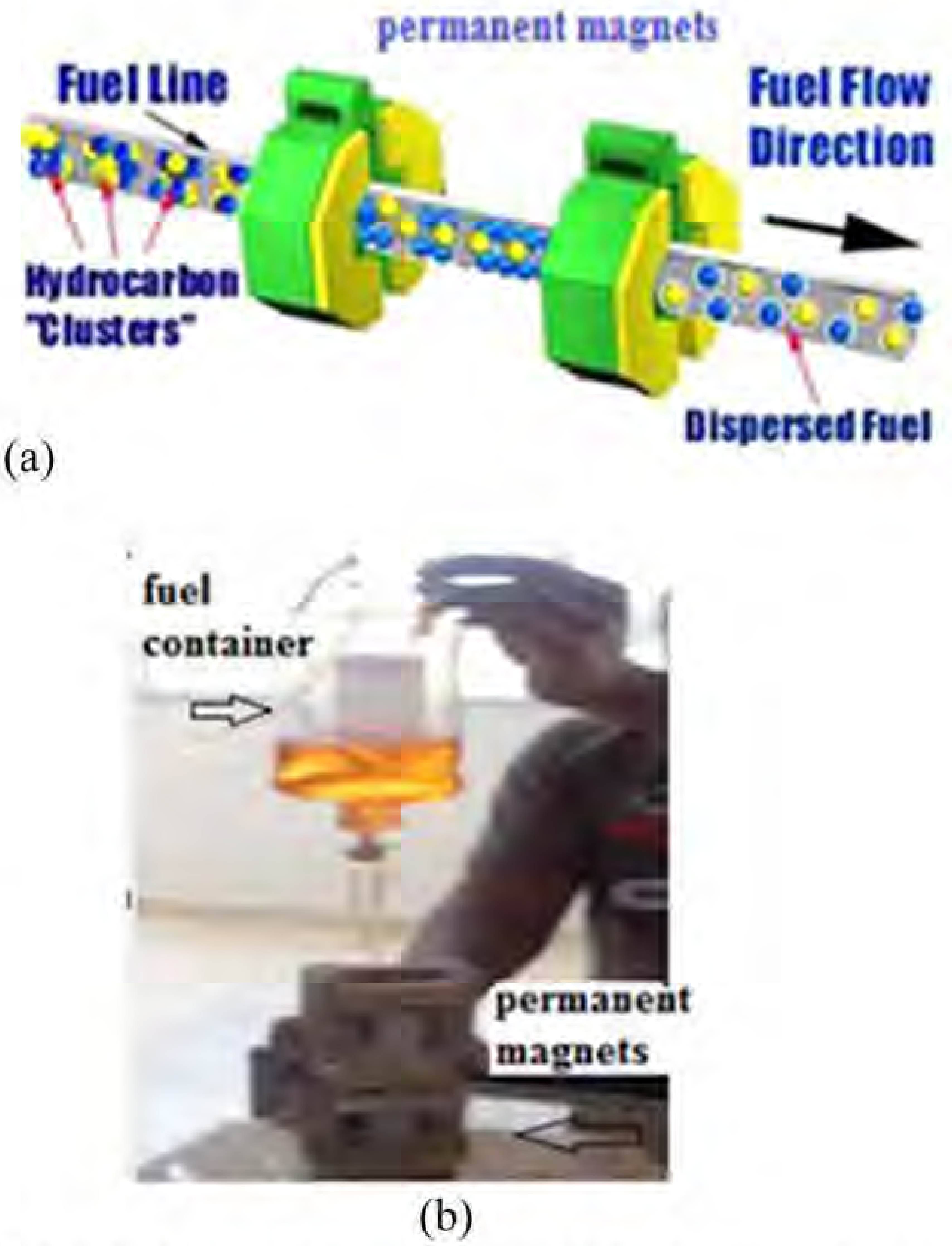
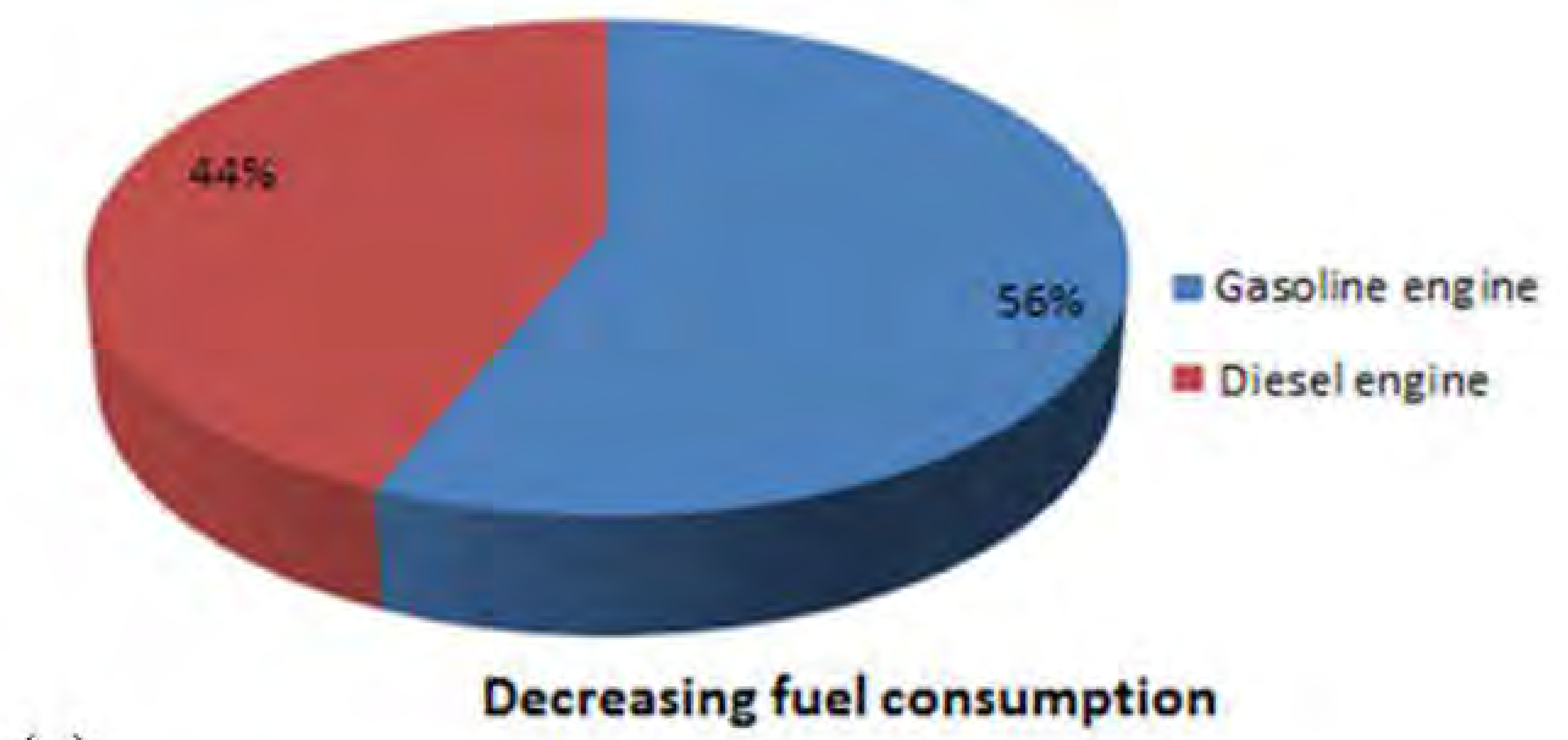
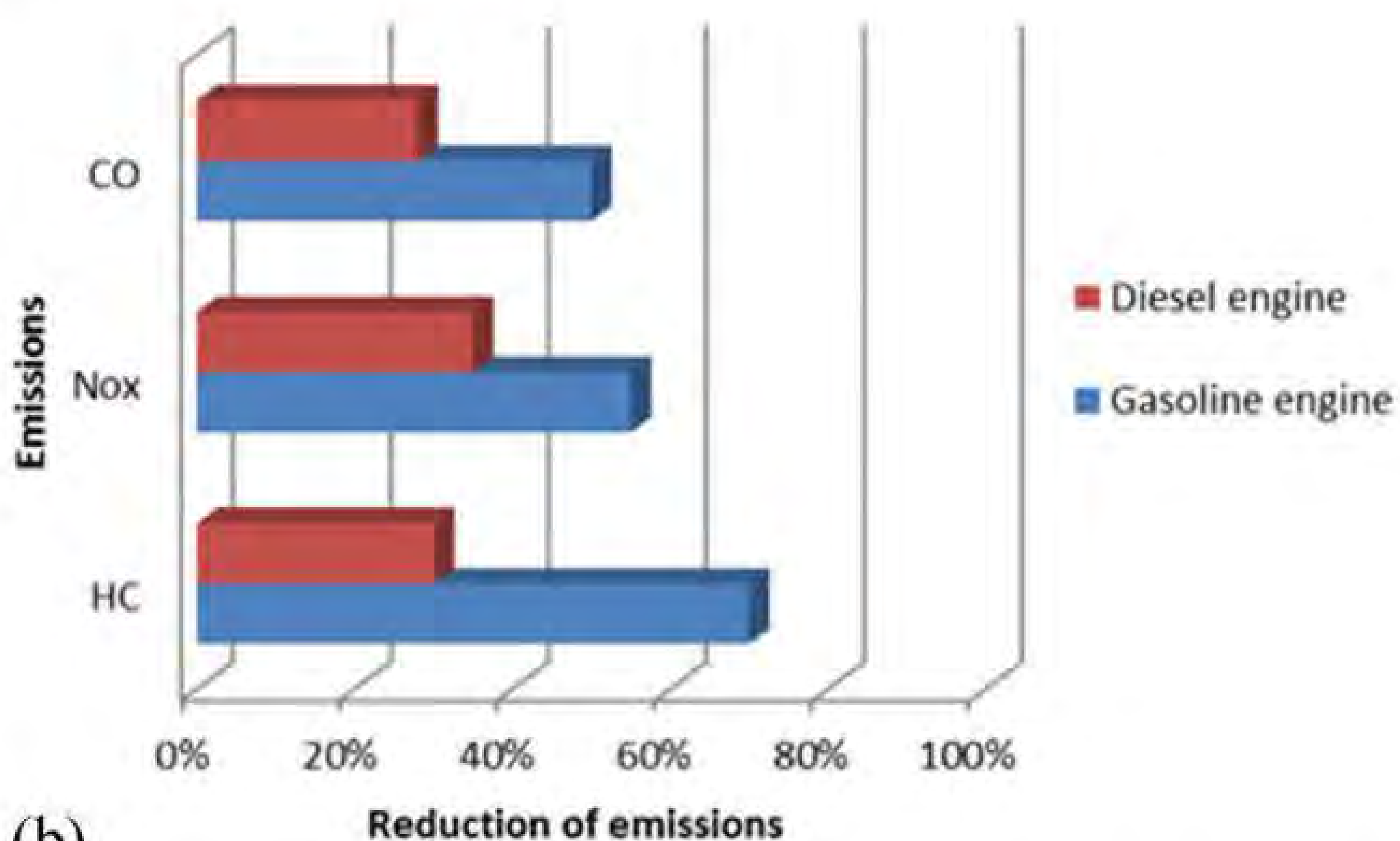


Fig. 9. (a) De-clustering of hydrocarbon molecules, (b) Experimental setup for analysis of the effect of magnetic field on the viscosity of petrol [70].



(a)



(b)

Fig. 10. A general comparison of (a) decreasing fuel consumption, (b) reduction of exhaust emissions, between gasoline and diesel engines.

develop the performance of the engine, for example, the use of biofuels. Further magnetic treatment does not require energy and, therefore, is considered economically feasible.

6. Conclusions

Based on the reviewed paper for the performance and emissions of internal combustion engines, it is concluded that the magnetic field represents a good way as an alternative for blending fuel (gasoline and Diesel) with gases and, therefore, must be taken into consideration in the future for transport purpose. Apart from the fuel storage and delivery mechanism, it delivers nearly similar performance as it has good combustion characteristics. In the short term, the magnetic field method has been coming a long way in resolving the emissions problem and with decreasing hydrocarbon resources and increasing the cost of the find; it is going to be "a method to reckon with." Through the establishment of right fuel burning parameters via adequate magnetic means (Fuel Energizer), it can be assumed that a combustion engine receives maximum energy per litre and the environment having the least possible level of toxic emission.

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