

Future Fuels for a Better Future

Hiren Patel¹, Sourabh Singh², Ankit Panchal³

Students^{1,2}, Associate Professor³

Department of Mechanical Engineering

Sri Ganganagar Engineering College

Corresponding Author's Email: -hirenpatel845@gmail.com

Abstract

The world is keen on developing clean fuels for future usage in autos and other gadgets. More hazardous gas emissions will not contribute to survival in this climate. To maintain our environment, several visible modifications should be done immediately in our power producing equipment, whether fixed or portable. This study investigates current advances in electric cars and conventional engines. The research also examines recent and future technology utilised to make power-generating units more efficient and less emissive.

Keywords: *Electric vehicles, hydrogen, internal combustion engines, alternative fuels, emissions, fuel cell*

INTRODUCTION

The greatest environmental challenge that humanity is now experiencing is air pollution, and the major source of air pollution is emissions from our cars. The current modes of transportation rely heavily on finite fossil fuels. The development of both developed and emerging countries raises the need for fossil fuels, particularly in the transportation sector. Furthermore,

increased use of fossil fuels results in increased emissions of harmful gases (GHG). These gases eventually cause global warming and other major environmental problems.

This topic has piqued the interest of numerous academics, who are working to find alternative fuels with minimal or no environmental impact. Alternative fuel cars are those that operate on fuels other

than petroleum fuels (AFV). The following alternative fuels are available: hydrogen, electric, biodiesel, electric-hybrid, and hydrogen fuel cell.

In this assessment, the emphasis is on using hydrogen as a fuel, electric cars, and other alternative fuels to improve the future. Specifically, the transportation sector is responsible for a large percentage of air pollution. This article discusses several superior fuels, their emissions, and their use.

Some fuels require more research before they may be used more often, whereas others can simply replace traditional fuels and minimise air pollution. The transportation industry contributes to air pollution.

LITERATURE REVIEW

Power was created by steam engines throughout the nineteenth century. Energy was created by internal combustion engines utilising fossil fuels such as gasoline, diesel, and so on in the twentieth century, and the twenty-first century is expected to be the century of hydrogen as a fuel, whether utilised in internal combustion engines or as fuel cells [1].

Because the emissions of traditional power producing units, such as I.C. engines, have had a negative impact on our environment and climate, we must devise some strategic strategies to develop hydrogen and other alternative fuels as future energy sources [2].

Hydrogen has the potential to supply energy with little or no environmental effect when compared to carbon-based fossil fuels. Nevertheless, there are several technological and scientific limitations that can be overcome with future hydrogen research [3].

Fuel cells will play an important part in future energy sources. Fuel cells offer excellent electrical efficiency and clean emissions, and they have the potential to solve economic and environmental problems if additional studies are conducted [4].

Electric cars have the potential to cut greenhouse gas emissions as well as exhaust pollution. Recent studies in Europe show that electric and hybrid vehicles cut 10–24% of global warming. However, electric vehicles have significant limitations, such as battery replacement, vehicle lifetime, and so on, but they are

still more beneficial than traditional vehicles [5].

Fuel cell cars solve the challenges associated with battery vehicles. Fuel cell cars have a large range (contingent on hydrogen depository). Many automakers agree that fuel cell cars are the only sophisticated alternative that offers long-range, zero-emission mobility with a tolerable refuelling time [6].

Bio-diesel is another solution that is simple to apply and will help to lessen the effects of greenhouse gases (GHG) on our environment. A lot of agricultural waste is used to make biodiesel, and many cheap oils are also used [7].

Alternate Fuels

The sustainability of renewable resources will benefit both humans and the environment. To make this conceivable, we must create some alternative fuels. Some of these are listed below[8]. Biodiesel is made from agricultural waste, and numerous low-cost oils are employed in the creation of biodiesel [7]. Hydrogen as an Alternative Fuel Hydrogen is the most abundant element on the planet. It is also non-toxic and does not contaminate groundwater. Hydrogen may be used in

traditional engines as is, or it can be used in fuel cells, which create electricity [9].

Initially, hydrogen utilisation should be promoted in major cities with the highest levels of air pollution [10]. The transportation industry contributes significantly to global warming.

Vehicle emissions have been determined to contribute 13.5% of total global warming[11]. Hydrogen may be used in both diesel engines and gasoline engines [9].

Properties of Hydrogen

Hydrogen is the most plentiful and basic element on the planet. Hydrogen, on the other hand, is not a naturally separate substance. It is mainly found bonded with other elements, including carbon, oxygen, and others[12].

Wide range of flammability

With a wide variety of stoichiometric air-fuel mixtures, hydrogen can provide minimal emissions. The standard gasoline engine has an air-to-fuel ratio of 14.7:1, but hydrogen-powered cars have a ratio of 34:1. (air-to-fuel ratio). A broad range of flammability results in combustion within a range. A lean mixture also improves fuel efficiency [13]. Minimum ignition source

energy required In the case of hydrogen, less energy is required to ignite the air-fuel mixture. It is 0.24 mj in the case of normal petrol engines, but 0.02 mj in the case of hydrogen engines. So, in hydrogen engines, a simple glow plug may be used, but in petrol engines, a spark plug is required, which consumes more energy[13].

Low density

In comparison to other fuels such as gasoline and diesel, hydrogen has an extremely low density. Because of its low density, we can carry more gas in the same capacity tank, and our maximum driving range increases[12].

High diffusivity

Because hydrogen diffuses more in the air than other fuels, its high diffusivity reduces the likelihood of hazardous circumstances. In other words, hazardous conditions can be reduced or avoided. In addition, when compared to other fuels, it produces a more consistent air-fuel mixture[12].

Techniques to use Hydrogen in Internal Combustion Engines

Hydrogen can be induced into a cylinder by three different methods-

- Fuel carburetion method.

- Inlet manifold port injection.
- Direct injection into engine cylinder.

Fuel carburetion method

It is relatively simple to convert our regular gasoline engine to a hydrogen engine. However, as we all know, hydrogen exists in nature as a gas. So it takes up less space than petrol, occupying just 1.7% of the entire capacity of the cylinder, resulting in a 15% lower power output in hydrogen-carburized engines than in petrol engines. To compensate for this loss, we employ various ways such as injecting higher pressures of hydrogen into the cylinder, resulting in increased power[9].

Inlet manifold port injection

We employ electrically or physically driven injectors to inject hydrogen into the input manifold port injection system. It is 85% more efficient than a gasoline engine. We may also employ liquid hydrogen (higher pressure) in the input manifold port injection system, which takes up more capacity. It is 115% more efficient than a gasoline engine[9].

Direct injection

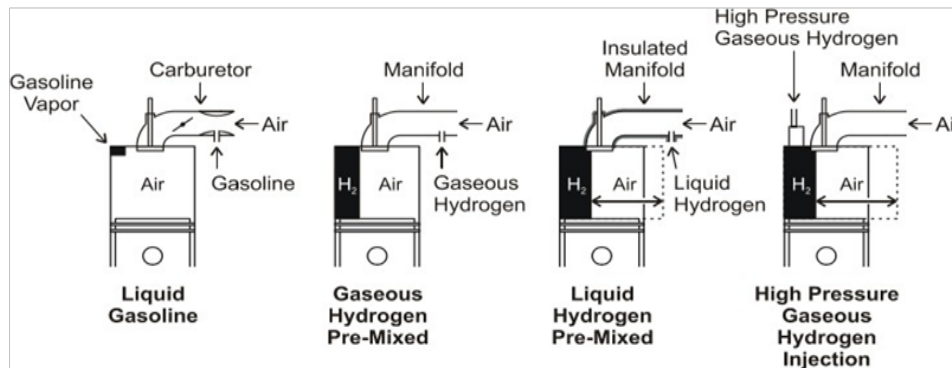


Fig. 1: Different Types of the Mixture of Hydrogen in I.C Engine [9].

As indicated in the image, direct injection involves injecting hydrogen straight into the cylinder (1). Power loss in the input manifold port injection system is eliminated in the direct injection system. It is 120% more efficient than a petrol engine and 42% more efficient than a carbureted hydrogen engine[14].

Emissions

The main components of air are oxygen, hydrogen, nitrogen and some other gases are also present in traces. When hydrogen burns in the internal combustion engine, it only generates H_2O , traces of NO_x (oxides of nitrogen), traces of CO (carbon monoxide)[15]. The amount of emission depends upon following factors

- Air fuel ratio.
- Compression ratio.
- Ignition timing.
- Engine speed [9].

Current Status of Hydrogen Fueled IC Engine Vehicles

A few automotive manufacturers are currently working on the development of hydrogen-powered vehicles. Ford and BMW have announced the development of production-ready hydrogen-powered automobiles [16].

Hydrogen fuel cell

A fuel cell is a device that produces energy through a chemical process. Our typical batteries, like fuel cells, create power by employing metal ions and oxides[17]. The sole difference between hydrogen fuel cells and ordinary batteries or cells is that hydrogen fuel cells may create power indefinitely as long as there is a sufficient supply of fuel, i.e. hydrogen. Figure 2 depicts the operation of a hydrogen fuel cell [18]. Recent advances in hydrogen fuel cell technology enable clean development and resource utilisation. [19]

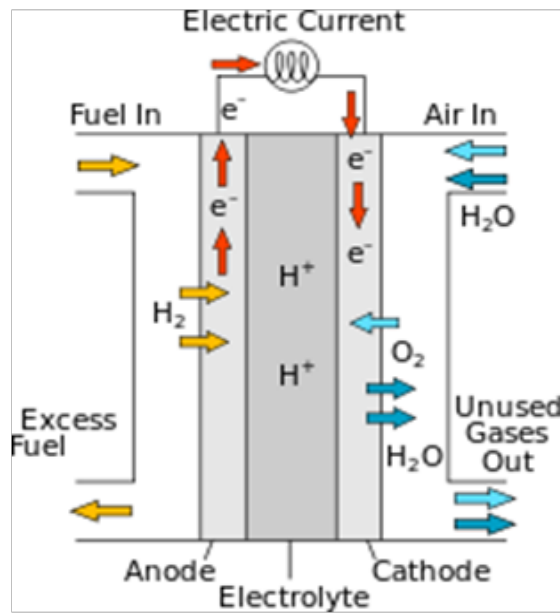


Fig. 2: Hydrogen Fuel cell. [18]

Utilization of hydrogen in fuel cell

We employ a fuel (hydrogen) and an oxidising agent in the hydrogen fuel cell (oxygen). Hydrogen is employed in hydrogen fuel cells because its by-product is merely water, whereas other electrochemical cells produce hazardous by-products that contaminate our environment [18].

Uses of hydrogen fuel cell

The hydrogen fuel cell is nowadays most commonly used in vehicles. Many countries have made filling stations and started using fuel cells on regular basis.

shuttles as well as liquid hydrogen to fuel rockets [20].

- NASA is the principal user of hydrogen fuel cells, using them to power electrical systems in space
- Our cars emit no tailpipe emissions, protecting the environment from dangerous greenhouse gases[17].
- Hydrogen fuel cells are also used in permanent power stations such as generators, as well as portable power stations such as cars. [18] Several countries, for example, have begun to use hydrogen fuel cell vehicles for transportation. On June 27, 2019, France launched its first hydrogen fuel cell bus refuelling station, which was completed by McPhy Technologies. Several other businesses, including Shell, are also involved [21].

Electric/Hybrid Vehicles

As a result of rapid technical advancement, electric cars are being developed. Electric cars are a more advanced variant of hybrid automobiles. More study is needed to reduce the uncertainty around new vehicles[22].

Electric vehicles

As a result of rapid technical advancement, electric cars are being developed. Electric cars are a more advanced variant of hybrid automobiles. More study is needed to reduce the uncertainty around new vehicles[22].

Hybrid vehicles

Hybrid cars employ both electric motors and traditional engines as power units. Hybrid cars are classified into two types: mild hybrids and complete hybrids. Full hybrid cars are those that operate the automobile without a conventional engine, while mild hybrid vehicles are those that do not run without a conventional engine[25]. Because GHG (greenhouse gas) emissions are minimised, both hybrid and electric cars are suitable for usage. Electric vehicles may save up to 0% [24].

Performance of Electric Vehicles

We know that the efficiency of internal combustion engines may range from 15%

to 18%, but the efficiency of electric cars can range from 60-70%. This difference is significant, and driving electric vehicles has less negative consequences[26]. Electric cars have more efficiency than internal combustion engines since they have fewer losses such as heat losses and so on [27].

An Ecological Perspective of Electric/Hybrid Vehicles

We are aware of the advantages of electric vehicles, such as environmental friendliness and lower emissions, but we must not overlook the negative effects of batteries. Although batteries may be recycled, hazardous compounds are still discharged into our environment[28].

Some emission data is provided below.

- 0.24 kg slag and 30 gm toxic solids.
- <0.1 kg Sb, Hg, Ni, Pb, Cd to water.
- <5gm Pb, Cd, Cu, Zu, As, Ni to air

Current Difficulties and Issues Further study is needed in this area. Electric cars are still not totally trustworthy. The energy management system, motors, battery lifespan, and some other criteria that must be considered are described below[29].

- Cost of electric/hybrid vehicles is still high.

- Cost to implant infrastructure for refuelling stations is high.
- Companies have developed fast charging systems but still, there are some challenges.
- Also, the distance travelled in one charge is less as compared to conventional vehicles [30].

Biodiesel

Biodiesel is a petroleum-like fuel that is made from vegetable oil, animal fats, and waste cooking oil. The growing petroleum problem and higher greenhouse gas emissions (GHG) drive the development of biodiesel [31].

Biodiesel is made from vegetable oils that, when burned, emit practically minimal sulphur and only recyclable CO₂ [32]. Vegetable oils are a rich source of energy and have a high heating capacity [33].

Production of biodiesel

Transesterification is the primary method of producing biodiesel. Triglycerides contained in oil react with alcohol in the presence of a catalyst to create fatty acids alkyl esters. Biodiesel emits less hydrocarbons (HC), less carbon monoxide

(CO), but more nitrogen oxides (NO_x) than fossil diesel[34].

However, NO_x emissions can be lowered by adding water to it through the emulsification process. It is the most cost-effective and straightforward approach of reducing dangerous and hazardous gas emissions.

Source of biodiesel production

Biodiesel may be made from fatty acid-containing sources. Fatty acids can exist as mixed or free forms [36]. Because vegetable oils are high in fatty acids, they may be used as a feedstock for biodiesel manufacturing. There are around 350 oil-producing crops, including sunflower, cottonseed, soybeans, rapeseed, and peanuts [33].

As a result, the blends are abbreviated as B5, B10, B100, and so on, indicating the proportion of biodiesel, for example. "B10" denotes 10% biodiesel and 80% fossil fuel[37]. Scientists have found that when we use biodiesel in our traditional diesel engines, the power output of biodiesel is less than that of fossil fuel, but the torque production is greater, and the pollutants are lower. In fact, B20 outperforms all other biodiesel blends in terms of efficiency [38].

Comparison of biodiesel with conventional diesel

Biodiesel is an excellent source of energy.

Biodiesel can also be blended with fossil diesel. In practice, it is mixed with fossil fuel to get optimal performance.

Some Other Alternate Fuels

Some alternative fuels that can be used immediately have been created by researchers. Some of them are as follows: [39]

Dimethyl Ether (DME)

Dimethyl ether (DME), like LPG, is a liquefied gas. It may be produced from both renewable and nonrenewable sources by utilising a range of feedstock. It may be employed in our standard I.C. engines with minor injection system modifications[40]. The sole difference is that the volume to be injected is more than in a traditional

diesel engine due to the low density of dimethyl ether (DME)[41].

The advantage of employing dimethyl ether (DME) is that it emits fewer hazardous emissions than traditional engines. Because of the low density, greater mixing occurs, resulting in smokeless emissions [42].

Alcohol as a Fuel

Ethanol has been used as a fuel for many years. The octane number of alcohol fuels is greater than that of standard diesel and gasoline fuels[43]. Furthermore, alcohol fuel burns cleaner than gasoline and diesel fuel.

Alcohol fuels release fewer dangerous and hazardous gases such as CO, NO_x, and so on, and they may be used with little engine hardware adjustments.

Comparison of various properties of primary alcohols with gasoline and diesel

	Methane	Methanol	Dimethyl ether	Ethanol	Gasoline	Diesel
Formula	CH ₄	CH ₃ OH	CH ₃ OCH ₃	CH ₃ CH ₂ OH	C ₇ H ₁₆	C ₁₄ H ₃₀
Molecular weight (g/mol)	16.04	32.04	46.07	46.07	100.2	198.4
Density (g/cm ³)	0.00072 ^a	0.792	0.661 ^b	0.785	0.737	0.856
Normal boiling point (°C)	-162	64	-24.9	78	38-204	125-400
LHV (kJ/cm ³)	0.0346 ^a	15.82	18.92	21.09	32.05	35.66
LHV (kJ/g)	47.79	19.99	28.62	26.87	43.47	41.66
Exergy (MJ/l)	0.037	17.8	20.63	23.1	32.84	33.32
Exergy (MJ/kg)	51.76	22.36	30.75	29.4	47.46	46.94
Carbon Content (wt%)	74	37.5	52.2	52.2	85.5	87
Sulfur content (ppm)	~7-25	0	0	0	~200	~250

^aValues per cm³ of vapor at standard temperature and pressure.

^bDensity at $P = 1$ atm and $T = -25^{\circ}\text{C}$.

Fig. 3: Comparison of Different Types of Alcohol Fuels with Gasoline and Diesel [46].

In comparison to traditional fuels, these are the fuels with minimal emissions and high power output[44]. Among alcohol fuels, methanol is a simple chemical that lacks sulphur and other complicated compounds while having qualities similar to ethanol[45]. Because alcohol fuels are more reactive than other fuels, engine material changes should be undertaken to replace conventional fuels with alcohol fuels [46].

CONCLUSION

This research indicates that there are some fuels that can be utilized in the future and will assist in fulfilling future demands without diminishing our consumption. Our future automobiles will be electric.

- The properties of hydrogen are particularly beneficial for efficiently using hydrogen gas, and hydrogen may also be utilized in traditional engines with little adjustments.
- When compared to traditional fuels, hydrogen-powered cars emit no hazardous emissions.
- Hydrogen may also be utilised as a gas in a fuel cell to generate energy, which can then be used in our electric automobiles and other gadgets. These fuel cells may be employed in fixed

power plants as well as portable power generation devices.

- Electric vehicle research has been conducted, and dependable batteries for battery electric cars have been developed (BEVs). Fast charging is also accomplished to suit the requirements of the future.
- Other fuels are being developed that can be utilised in our standard internal combustion engine without modification, such as biodiesel, dimethyl ether, and alcohol as an additive.
- The efficiency of electric cars ranges from 60-70%, which is significantly higher than that of traditional engines.

REFERENCES

1. Lanz, Heffel J., Messer C. Hydrogen Use in Internal Combustion Engines. *Hydrog. Fuel Cell Engines Relat. Technol.* 2001, 3–23p..
2. Akansu S.O., Dulger Z., Kahraman N., Veziroä T.N. Internal combustion engines fueled by natural gas — hydrogen mixtures. 2004, 29, 1527– 1539p.

3. Edwards P.P., Kuznetsov V.L., David W.I.F., Brandon N.P. Hydrogen and fuel cells : Towards a sustainable energy future \$. 2008, 36, 4356– 4362p.
4. Neef H.J. International overview of hydrogen and fuel cell research. Energy. 2009, 34(3), 327–333p.
5. Eberle U., Müller B., Helmolt R.V. Fuel cell electric vehicles and hydrogen infrastructure: Status 2012. Energy Environ. Sci. 2012, 5(10), 8780–8798p.
6. Hawkins T.R., Singh B., Majeau-Bettez G., Strømman A.H. Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles. J. Ind. Ecol. 2013, 17(1), 53–64p.
7. Demirbas M.F. Balat M. Recent advances on the production and utilization trends of bio-fuels: A global perspective. Energy Convers. Manag. 2006, 47(15–16), 2371– 2381p.
8. Demirbas A. Future fuels for internal combustion engines. Energy Sources, Part A Recover. Util. Environ. Eff. 2010, 32(14), 1273–1281p.
9. Sharma C.S.K. Hydrogen Usage in I.C. Engines. Int. J. Sci. Eng. Res. 2016, 7(8), 440–445p.
10. Sharma S., Ghoshal S.K. Hydrogen the future transportation fuel: From production to applications. Renew. Sustain. Energy Rev. 2015, 43, 1151– 1158p.
11. Ahmed A., Al-Amin A.Q., Ambrose A.F., Saidur R. Hydrogen fuel and transport system: A sustainable and environmental future. Int. J. Hydrogen Energy. 2016, 41(3), 1369–1380p.
12. Mazloomi K., Gomes C. Hydrogen as an energy carrier: Prospects and challenges. Renew. Sustain. Energy Rev. 2012, 16(5), 3024– 3033p.
13. Kumar V., Gupta D., Kumar N. Hydrogen Use in Internal Combustion Engine: a Review. Int. J. Adv. Cult. Technol. 2015, 3(2), 87–99p.
14. Gurz M., Baltacioglu E., Hames Y., Kaya K. The meeting of hydrogen and automotive: A review. Int. J. Hydrogen Energy. 2017, 42(36), 23334–23346p.
15. Karagöz Y., Sandalci T., Yüksek L., Dalkılıç A.S., Wongwises S. Effect of hydrogen-diesel dual-fuel usage on performance, emissions and diesel combustion in diesel engines. Adv. Mech. Eng. 2016, 8(8), 1–13p.

16. Bhaskar V., Prakash R.H., Prasad B.D. Hydrogen Fuelled I.C. Engine. *Int. J. Sci. Res.* 2013, 1(1), 46–53p.
17. Wilberforce T., Alaswad A., Palumbo A., et al. Advances in stationary and portable fuel cell applications. *Int. J. Hydrogen Energy.* 2016, 41(3)7, 16509–16522p.
18. Fuel cell. [Online]. Available: https://en.wikipedia.org/wiki/Fuel_cell
19. Garland N.L., Papageorgopoulos D.C., Stanford J.M. Hydrogen and fuel cell technology: Progress, challenges, and future directions. *Energy Procedia.* 2012, 28, 2–11p.
20. Details of fuel cell and its usage. [Online]. Available: <https://www.azocleantech.com/article.aspx?ArticleID=333>.
21. Current scenario of hydrogen fueled busses in France. [Online]. Available: <https://fuelcellsworks.com/news/mcph-y-energy-inauguration-of-frances-first-refueling-station-for-hydrogen-buses/>.
22. Fernández L.P., Román T.G.S., Cossent R., et al. Assessment of the impact of plug-in electric vehicles on distribution networks. *IEEE Trans. Power Syst.* 2011, 26(1), 206–213p.
23. Tie S.F., Tan C.W. A review of energy sources and energy management system in electric vehicles. *Renew. Sustain. Energy Rev.* 2013, 20, 82–102p.
24. Racz A.A., Muntean I., Stan S.D. A Look into Electric/Hybrid Cars from an Ecological Perspective. *Procedia Technol.* 2015, 19, 438–443p.
25. Al-Alawi B.M., Bradley T.H. Review of hybrid, plug-in hybrid, and electric vehicle market modeling Studies. *Renew. Sustain. Energy Rev.* 2013, 21, 190–203p.
26. Hawkins T.R., Gausen O.M., Strømman A.H. Environmental impacts of hybrid and electric vehicles-a review. *Int. J. Life Cycle Assess.* 2012, 17(8), 997–1014p.
27. Richardson D.B. Electric vehicles and the electric grid: A review of modeling approaches, Impacts, and renewable energy integration. *Renew. Sustain. Energy Rev.* 2013, 19, 247–254p.
28. Pasaoglu G., Honselaar M., Thiel C. Potential vehicle fleet CO₂ reductions and cost implications for various vehicle technology deployment scenarios in Europe.

- Energy Policy. 2012, 40(1), 404–421p.
29. Sulaiman N., Hannan M.A., Mohamed A., et al. A review on energy management system for fuel cell hybrid electric vehicle: Issues and challenges. *Renew. Sustain. Energy Rev.* 2015, 52, 802–814p.
30. Hannan M.A., Azidin F.A., Mohamed Hybrid electric vehicles and their challenges: A review. *Renew. Sustain. Energy Rev.* 2014, 29, 135–150p.
31. Lin L., Cunshan Z., Vittayapadung S., et al. Opportunities and challenges for biodiesel fuel. *Appl. Energy.* 2011, 88(4), 1020–1031p.
32. Janaun J., Ellis N. Perspectives on biodiesel as a sustainable fuel. *Renew. Sustain. Energy Rev.* 2010, 14(4), 1312–1320p.
33. Balat M., Balat H. A critical review of bio-diesel as a vehicular fuel. *Energy Convers. Manag.* 2008, 49(10), 2727– 2741p.
34. Arai S., Nakashima K., Tanino T., et al. Production of biodiesel fuel from soybean oil catalyzed by fungus whole-cell biocatalysts in ionic liquids. *Enzyme Microb. Technol.* 2010, 46(1), 51–55p.
35. Dabhi Y., Brahmabhatt H., Kapadia H., Zalavadiya S. Emission Characteristic of Diesel and Biodiesel Fuelled. *C.I. Engine*, February, 2019.
36. Chattopadhyay S., Karemore A., Das S., et al. Biocatalytic production of biodiesel from cottonseed oil: Standardization of process parameters and comparison of fuel characteristics. *Appl. Energy.* 2011, 88(4), 1251–1256p..
37. Alptekin E., Canakci M. Determination of the density and the viscosities of biodiesel-diesel fuel blends. *Renew Energy.* 2008, 33(12), 2623–2630p.
38. Özener O., Yüksek L., Ergenç A.T. Özkan M. Effects of soybean biodiesel on a DI diesel engine performance, emission and combustion characteristics. *Fuel.* 2014, 115(10), 875–883.
39. Struben J., Sterman J.D. Transition challenges for alternative fuel vehicle and transportation systems. *Environ. Plan. B Plan. Des.* 2008, 35(6), 1070– 1097p.
40. Arcoumanis C., Bae C., Crookes R., Kinoshita E. The potential of di- methyl ether (DME) as an alternative fuel for compression-

- ignition engines: A review. *Fuel*. 2008, 87(7), 1014– 1030p.
41. Mittal G., Chaos M., Sung C.J., Dryer F.L. Dimethyl ether autoignition in a rapid compression machine: Experiments and chemical kinetic modeling. *Fuel Process. Technol.* 2008, 89(12), 1244–1254p.
42. Maji S., Ahmed S., Siddiqui W.A., et al. Impact of Di-methyl Ether (DME) as an Additive Fuel for Compression Ignition Engine in Reduction of Urban Air Pollution. *Am. J. Environ. Prot.* 2015, 3(2), 48–52p.
43. Eyidogan M., Ozsezen A.N., Canakci M., Turkcan A. Impact of alcohol- gasoline fuel blends on the performance and combustion characteristics of an SI engine. *Fuel*. 2010, 89(10), 2713–2720p.
44. Yasin M.H.M., Mamat R., Yusop A.F., et al. Fuel physical characteristics of biodiesel blend fuels with alcohol as additives. *Procedia Eng.* 2013, 53, 701–706p.
45. Liu H., Wang Z., Long Y., S., et al. Comparative study on alcohol-gasoline and gasoline-alcohol Dual- Fuel Spark Ignition (DFSI) combustion for engine particle number (PN) reduction. *Fuel*. 2015, 159, 250–258p.
46. Agarwal A.K. Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. *Prog. Energy Combust. Sci.* 2007, 33(3), 233-271p.