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10th International Congress

Motor Vehicles & Motors 2024

ECOLOGY - VEHICLE AND ROAD SAFETY - EFFICIENCY

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PREDGOVOR

U oktobru se na Fakultetu inženjerskih nauka Univerziteta u Kragujevcu tradicionalno održava skup istraživača i naučnika koji se bave proučavanjem motornih vozila, motora i drumskog saobraćaja. Od 1979. do 2004. godine održano je trinaest bienalnih MVM simpozijuma koji su 2006. prerasli u Međunarodni kongres MVM. Od tada je održano devet MVM kongresa, a oktobra 2024. godine Fakultet inženjerskih nauka je organizovao deseti međunarodni kongres MVM od 10. do 11. oktobra 2024. godine.

Na deseti kongres Motorna vozila i motori, MVM2024 dostavljen je veliki broj naučnih radova iz Srbije i inostranstva. Kongres tradicionalno podržavaju Ministarstvo za nauku, tehnološki razvoj i inovacije Republike Srbije, Univerzitet u Kragujevcu, Fakultet inženjerskih nauka i međunarodni časopis „Mobility and Vehicle Mechanics“.

Tema Kongresa MVM 2024 bila je „Ekologija – Bezbednost vozila i na putevima – Efikasnost“. Tokom ovog istraživačkog putovanja, učesnici su puno naučili kroz rad na različitim sekcijama, koje su pokrivale širok spektar tema u vezi sa inženjerstvom u automobilskoj industirji, od fundamentalnih istraživanja do industrijskih primena, naglašavaju interakciju između vozača, vozila i životne sredine i stimulišući naučnu interakcije i saradnju.

Međunarodni naučni odbor u saradnji sa organizacionim odborom izradio je podsticajan naučni program. Program je ponudio preko 54 prezentacije radova, uključujući predavanja po pozivu i radove u sekcijama. Prezentacije na ovom kongresu obuhvatile su aktuelna istraživanja u oblasti motornih vozila i motora sprovedena u 12 zemalja iz celog sveta.

Zadovoljstvo nam je bilo što su nam uvodničari bili profesor Emrulah Hakan Kaleli (sa Tehničkog univerziteta Yıldız, Turska), profesor Ralph Putz (sa Univerziteta Landshut UAS, Nemačka) i profesori Nenad Miljić i Slobodan Popović (sa Univerziteta u Beogradu, Srbija). Izazovi i rešenja u korišćenju vodonika kao goriva za motore sa unutrašnjim sagorevanjem, korišćenje aditiva nanoborne kiseline dodatog u motorno ulje, kao i evropska politika o budućoj mobilnosti na putevima su bile teme uvodnih predavanja.

Sigurni smo da je ovaj program pokrenuo živu diskusiju i podstakao istraživače na nova dostignuća.

10. Kongres MVM 2024. finansijski je podržalo Ministarstvo za nauku, tehnološki razvoj i inovacije Republike Srbije.

Zahvaljujemo se iskusnim i mladim istraživačima koji su prisustvovali i prezentovali svoju stručnost i inovativne ideje na našem kongresu.

Posebnu zahvalnost dugujemo članovima međunarodnog naučnog odbora i svim recenzentima za njihov značajan doprinos visokom nivou kongresa.

Naučni i organizacioni komitet Kongresa MVM2024

FOREWARD

In October, the Faculty of Engineering University of Kragujevac traditionally holds gatherings of researchers and academics who study motor vehicles, engines and road traffic. From 1979 to 2004, thirteen, biennal MVM Symposiums have been held and they grew into an International Congress MVM in 2006. Since then, ninth MVM Congresses have been held, and in October 2024, the Faculty of Engineering organized the tenth International Congress MVM from 10th to 11th October 2024.

A large number of scientific papers from the Serbia and abroad were submitted to the tenth Congress “MVM2024”. Congress is traditionally supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, University of Kragujevac, Faculty of Engineering and the International Journal “Mobility and Vehicle Mechanics”.

The theme of the Congress MVM 2024 was "Ecology - Vehicle and Road Safety - Efficiency". Along this journey we learned from the various sessions, which broadly cover a wide range of topics related to automotive engineering from fundamental research to industrial applications, highlight the interaction between the driver, vehicle and environment and stimulate scientific interactions and collaborations.

The International Scientific Committee in collaboration with the Organising Committee built up a stimulating scientific program. The program offered over 54 presentations, including key-note speakers and paper sessions. The presentations to this conference covered current research in motor vehicle and motors conducted in 12 countries from all over the world.

We were pleased to have professor Emrullah Hakan Kaleli (from Yıldız Technical University, Türkiye), professor Ralph Pütz (from Landshut University UAS, Germany) and professors Nenad Miljić and Slobodan Popović (from University of Belgrade, Serbia) as the keynote speakers, addressing Challenges and solutions in using hydrogen as a fuel for internal combustion engines, using nanoboric acid (nBA) additive added in engine oil, as well as European policy on future road mobility.

We are sure this program will trigger lively discussion and will project researchers to new developments.

The 10th Congress MVM 2024 was financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

We would like to thank experienced and young researchers, for attending and bringing their expertise and innovative ideas to our conference.

Special thanks are due to the International Scientific Board Members and all reviewers for their significant contribution in the high level of the conference.

Scientific and Organizational committee of Congress MVM2024

CONTENT

INTRODUCTORY LECTURES

SECTION A
Power Train Technology

SECTION B
Vehicle Design and Manufacturing

SECTION C
Vehicle Dynamics and Intelligent Control Systems

SECTION D
Driver/Vehicle Interface, Information and Assistance Systems

SECTION E
Transport Challenges in Emerging Economies

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Motor Vehicles & Motors 2024
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Motor Vehicles & Motors

MVM2024-026

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APPLICATION OF WASTE PLASTIC OIL IN THE MODERN AUTOMOTIVE INDUSTRY

ABSTRACT: During the burning of fossil fuels, harmful gases are emitted that contribute to global warming and air pollution. This phenomenon has serious consequences for the environment and human health. The development of technologies for more efficient production and use of alternative fuels is crucial for the future of energy and environmental protection. Alternative fuels represent an increasingly important part of global energy solutions. In addition to biogas, biodiesel, bioethanol and hydrogen, plastic oil represents an interesting alternative to fossil fuels. This oil is obtained by recycling used vegetable oils or fats, as well as plastics that are processed into liquid fuel. It is used as a substitute for fuel in some diesel engines, and can also be used as a heating fuel. The use of plastic oil in the automotive industry can reduce CO_2 emissions due to a smaller carbon footprint compared to traditional fossil fuels. However, there are concerns about the emission of other harmful gases and particles during combustion, so adequate control of this process is needed to reduce potential negative impacts on the environment. This paper presents an overview of the use and achievements in the development of plastic oil in the modern automotive industry.

KEYWORDS: alternative fuels, automotive industry, waste plastic oil, environmental protection.

INTRODUCTION

Fuels are a key source of energy worldwide, used in transportation, industry, and electricity generation. However, most fuels such as fossil fuels emit harmful gases like CO_2 and other pollutants when burned. These gases contribute to global warming and air pollution, which have serious consequences for environmental quality and human health. The current pace of economic growth is unsustainable without conserving fossil fuels such as crude oil, natural gas, and coal. According to the International Energy Outlook 2010, global consumption of liquid and petroleum products is projected to increase from 86.1 million barrels per day in 2007 to 92.1 million barrels per day by 2020 and 110.6 million barrels per day by 2035. Similarly, natural gas consumption is expected to rise from 108 trillion cubic feet in 2007 to 156 trillion cubic feet by 2035. Consequently, the existing oil and gas reserves are estimated to last only 43 and 167 more years, respectively [1]. Therefore, humanity must turn to alternative and renewable energy sources such as biomass, hydropower, geothermal energy, wind energy, solar energy, and nuclear energy. Alternative fuels are becoming an increasingly significant part of global energy solutions, aiming to reduce dependence on fossil fuels and their negative impact on the environment.

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Plastic has emerged as a global environmental adversary, rivaling fossil fuels in its detrimental impact on the planet. It has become an integral part of modern life, found in countless products and applications due to its versatility and durability. The low cost of production has led to a dramatic rise in plastic consumption each year. In 2015, global plastic production reached 322 million tons [2]. Currently, waste plastic constitutes a significant portion of municipal solid waste, and its volume is increasing daily. The global production of polyethylene is approximately 80 million tons per year, with primary uses in plastic bags, toys, oil containers, bottles, and packaging films [3]. However, the excessive use of plastic has led to significant environmental challenges. Only about 18% of single-use plastic waste is recycled, while 71% ends up in landfills and 11% escapes into the environment, ultimately reaching the oceans [4]. The mass production and consumption of plastic have resulted in an overwhelming amount of plastic waste, which is often not disposed of properly. This waste accumulates in landfills and oceans, causing severe harm to ecosystems and wildlife. It will pose a severe problem if no solution is found. The current popular approaches to tackling plastic waste include 4R solution, Reuse, Reduce, Recycle and Recover [5]. Another approach currently being studied and developed for managing plastic waste is converting it into fuel oil. This method addresses two major issues simultaneously: the accumulation of plastic waste and the creation of fuel oil from plastic materials. Several methods have been employed to produce waste plastic oil (WPO), including pyrolysis, thermochemical treatment and catalytic conversion. Among these, the pyrolysis process has proven to be the most effective in producing WPO [6]. Figure 1 shows transformation process of waste plastics into oil. It starts with the collection of plastic waste from various sources, including rivers, households, industries, and commercial establishments. Once waste plastics are collected from various sources, it is crucial to remove any impurities and other materials from the plastic.

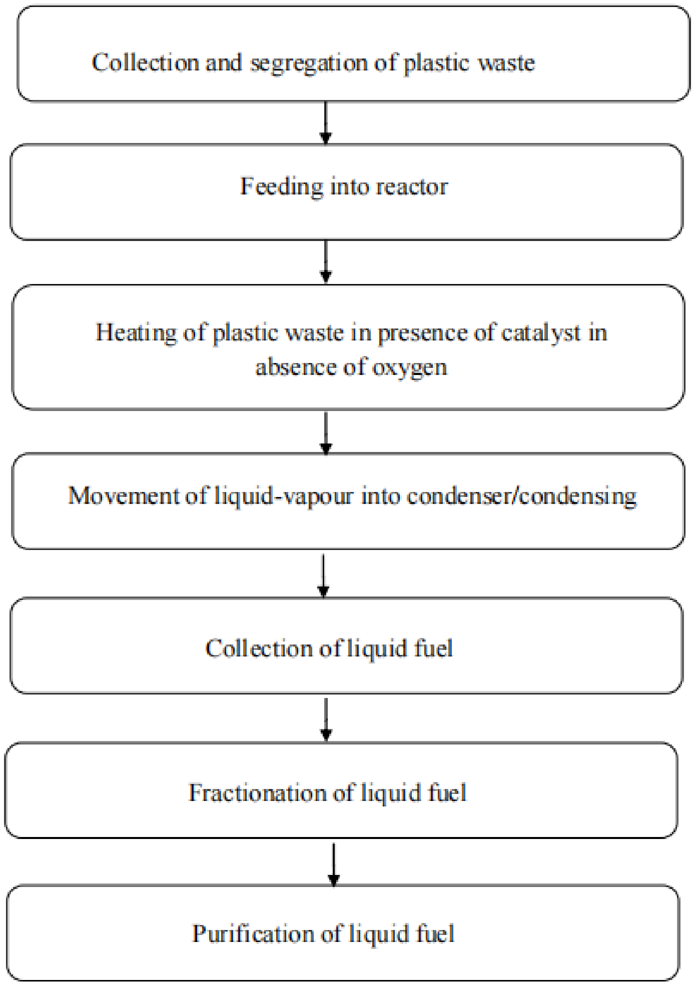

Figure 1 Transformation of waste plastics into oil [7]

Pyrolysis involves the thermal degradation of long-chain polymer molecules into smaller, simpler molecules using heat and pressure [8]. Figure 2 presents breaking of hydrocarbon chain with pyrolysis process. This process yields three primary products: oil, gas, and char. The quantity of waste plastic oil produced is influenced by various factors, including pyrolysis temperature, reactor type, residence time, catalyst type, and the type and flow rate of the fluidizing gas. The schematic diagram of the pyrolysis plant utilized is presented in Figure 3. The literature review indicates that the pyrolysis of EVA (ethylene-vinyl acetate) has not been extensively studied, and the fundamental properties of the resulting oil have yet to be reported. Conversely, the pyrolysis of polyethylene has been thoroughly researched by various authors, and the composition of the produced oil suggests it is a promising fuel for power and heat generation [9].

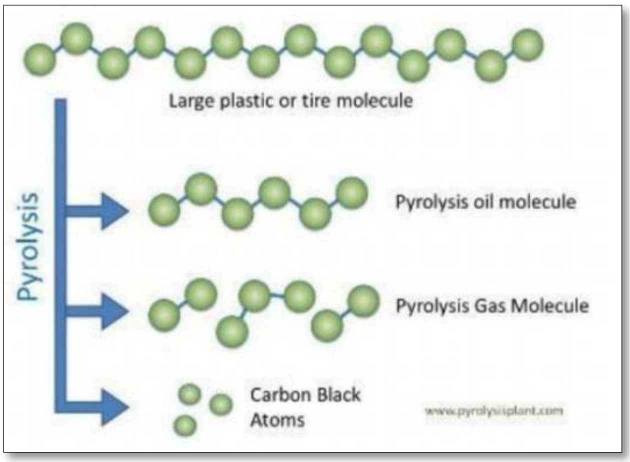

Figure 2 Breaking of hydrocarbon chain with pyrolysis process [7]

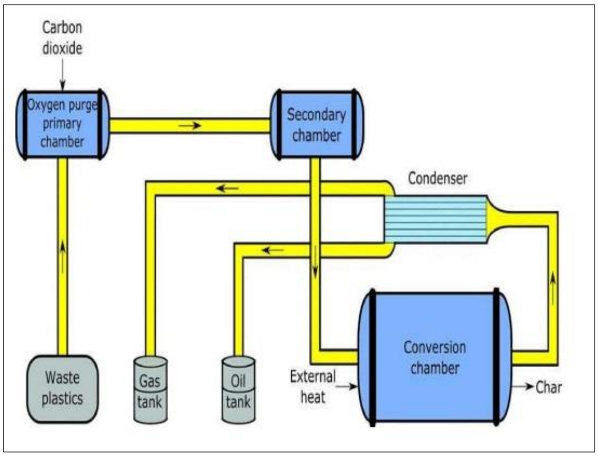

Figure 3 Schematic diagram of the pyrolysis plant [9]

WPO exhibits thermal properties that are both favorable and comparable to petrol. A comparison of various thermal properties—including density, gross calorific value, viscosity, flash point, and fire point — is presented in the table 1 below.

Table 1 Comparison of the properties of WPO with Petrol and Diesel [1]

Sl. No.	Properties	WPO	Petrol	Diesel
1.	Density (kg/m3)	760	742	850
2.	Gross calorific value (MJ/kg)	45,226	45,5	42,6
3.	Viscosity (cst) at 25°C	2,8	2,42	3,05
4.	Flash point (°C)	35	23	50
5.	Fire point (°C)	45	29	56

Miskolczi conducted a study on the pyrolysis of actual waste plastics using a pilot-scale horizontal tube reactor at 520°C, both with and without the presence of a Zeolite Socony Mobil–5 catalyst (ZSM-5 catalyst), type of zeolite catalyst. The results indicated that the presence of the catalyst increased the yields of gases, gasoline, and light oil. The study also concluded that plastic waste could be converted into gasoline and light oil with yields ranging from 20-48% and 17-36%, respectively, depending on the parameters used [10]. Gungor et al. conducted research using oil derived from the pyrolysis of high density polyethylene (HDPE) blended with diesel at a 5% blend ratio in a four-cylinder diesel engine. Their findings indicated that the use of HDPE resulted in lower brake thermal efficiency and cetane number, as well as higher emissions of carbon dioxide and nitrogen compared to diesel operation [11]. In their study Aditya Machiraju et al. concluded that the pyrolysis method is both environmentally friendly and cost-effective. They found that 1 kg of waste plastics can be converted into 75% of useful liquid hydrocarbon fuels without emitting pollutants. This approach not only addresses hazardous plastic waste but also reduces the need for importing crude oil. The properties of the produced plastic liquid fuel closely resemble those of diesel fuel, making it a viable alternative [12]. Dr. D. Subramanyam et al. conducted a performance investigation on single-cylinder four-stroke diesel engines using blends of waste plastic oil and diesel as an alternative fuel. They found that the brake thermal efficiency of the waste plastic oil blend was 26.24% at 3.67 kW bp, which was higher than that of diesel, at 24.85% [13].

PERFORMANCE CHARACTERSTICS

The performance parameters brake thermal efficiency, brake specific fuel consumption, and exhaust gas temperature are summarized as follows.

Brake specific fuel consumption

The brake specific fuel consumption measures (BSFC) how efficiently an engine uses the supplied fuel to perform work. It is inversely proportional to thermal efficiency. BSFC of WPO and petrol is shown in Figure 4. The brake specific fuel consumption for the 80% and 100% petrol-grade waste plastic oil ranges from 1.28 kg/kWh to 0.59 kg/kWh at 64% load, while for petrol engines it varies from 1.474 kg/kWh to 0.598 kg/kWh [7].

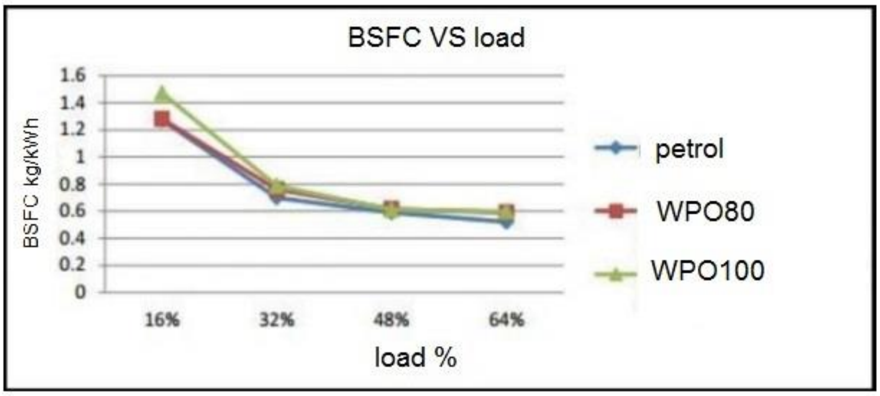

Figure 4 BSFC vs Petrol Load [7]

Figure 5 illustrates that WPO blends exhibit higher specific fuel consumption compared to diesel at 80% load. This discrepancy can be attributed to the fact that the fuel requirement increases at a lower rate than the increase in brake power, as heat losses tend to be reduced at higher loads [7].

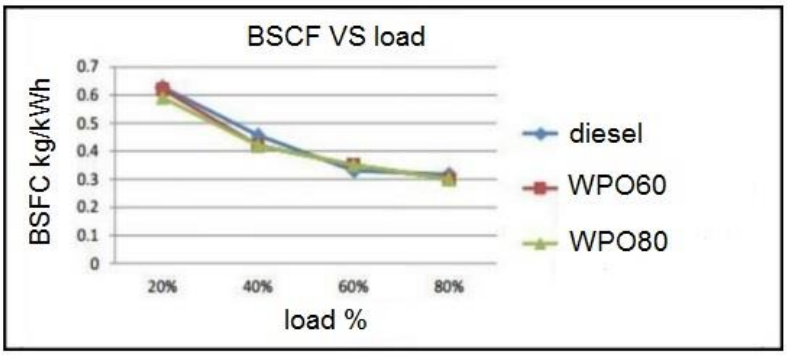

Figure 5 BSFC vs Diesel Load [7]

An experimental investigation of a diesel engine using blends of diesel fuel and plastic pyrolysis oil reveals that BSFC rises with increasing load for WPPO 50, WPPO 70, and diesel fuel. Nonetheless, with further load increments, BSFC declines across all fuel blends. At maximum load, WPPO blends demonstrate a higher specific fuel consumption compared to diesel fuel. This observation may be primarily attributed to the proportionate increase in brake power due to relatively reduced heat losses at elevated loads. The brake specific fuel consumption for the waste plastic oil ranges from 0.574 g/kWh at no load to 10.297 g/kWh at full load with standard injection timing, and from 0.514 g/kWh at no load to 0.235 g/kWh at full load with retarded injection timing [8].

Exhaust gas temperature

The increase in exhaust gas temperature (EGT) is primarily attributed to the heat released during the diffusion combustion phase. However, this heat exits the engine as waste and can not be harnessed to produce useful power [14]. Figure 6 shows that the exhaust gas temperature is higher for diesel fuel compared to PPO across varying brake power levels. This suggests that the combustion of PPO in the engine cylinder is more efficient than that of diesel, likely due to better atomization which enhances combustion. When PPO is blended with diesel in various ratios, the exhaust gas temperatures tend to be higher than those of pure diesel. This is attributed to the longer ignition delay, accelerated combustion of the blend, and the engine's reduced thermal efficiency relative to diesel [17].

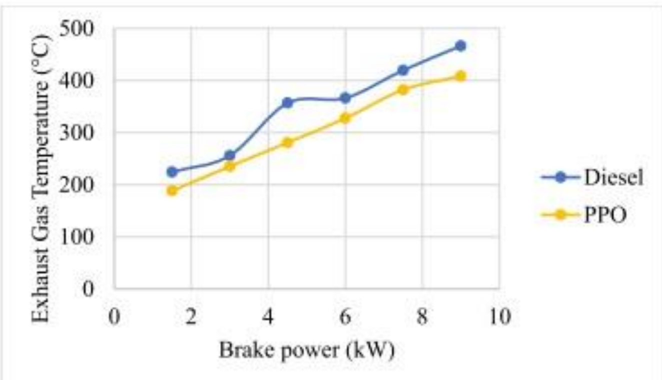

Figure 6 Exhaust gas temperature vs. brake power [17]

An experimental study on a CI engine using blends of diesel and waste plastic oil demonstrated that, as load increases, more fuel is burned to meet the power requirement, resulting in higher exhaust gas temperatures. The study observed that for pure plastic oil, exhaust gas temperatures range from 240°C at low load to 450°C at full load. Additionally, in the CI engine, increasing the proportion of plastic oil in the blend leads to a continuous rise in exhaust gas temperature [15].

Brake thermal efficiency

Brake thermal efficiency (BTE) reflects the engine's ability to efficiently convert the chemical energy in fuel into useful mechanical work [14]. The experiment utilized a single-cylinder, four-stroke, air-cooled DI diesel engine and an air-cooled spark ignition engine running on waste plastic oil. Diesel and gasoline proved to be more efficient under full load conditions. This is attributed to the slightly higher exhaust gas temperature and heat release rate of waste plastic oil compared to diesel and gasoline at full load. Study examining blends of waste plastic oil and petrol in a spark ignition engine revealed that petrol achieved a thermal efficiency of 16.4% at 64% load which is shown on Figure 7. At the same load, the brake thermal efficiency of the engine using 100% WPO and an 80% WPO-petrol blend was 12.6% and 12.2%, respectively [7].

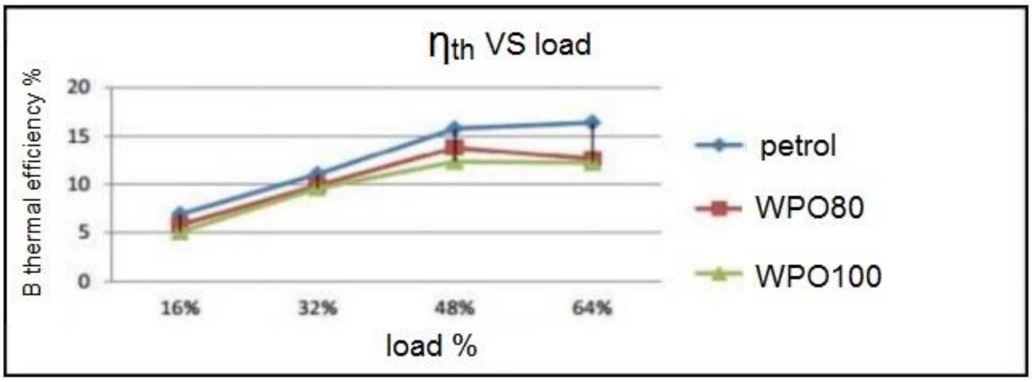

Figure 7 Brake thermal efficiency vs Petrol load [7]

An experimental study on waste plastic oil and diesel fuel blends in compression ignition engines demonstrated a thermal efficiency of 27.5% at full load, as illustrated in Figure 8. At the same load, the engine running on WPO60 and WPO80 diesel-grade blends achieved brake thermal efficiencies of 24% and 25.3%, respectively [7].

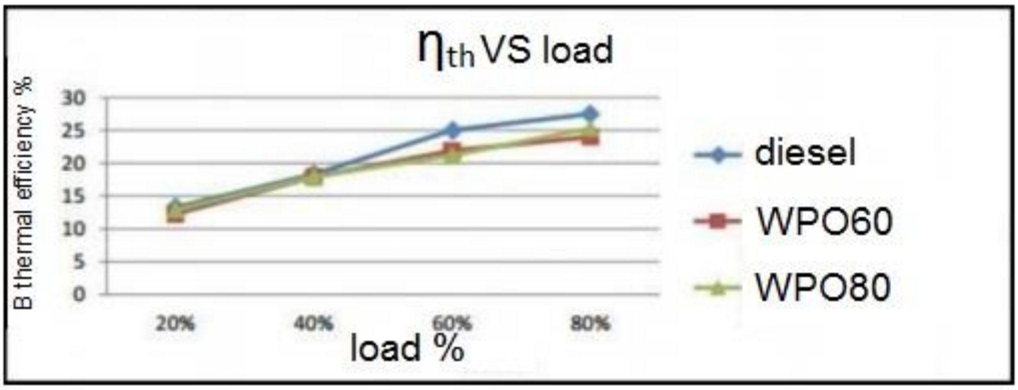

Figure 8 Brake thermal efficiency vs Diesel load [7]

Using a single-cylinder, four-stroke, air-cooled direct injection diesel engine with waste plastic oil, the experimental study found that thermal efficiency was 28.2% at rated power for diesel and 27.4% for waste plastic oil [8]. Moreover, the brake thermal efficiency of waste plastic oil closely matches that of diesel up to 75% of rated power, beyond which it decreases. Diesel fuel exhibits higher efficiency at full load due to slightly higher exhaust gas temperatures and heat release rates for waste plastic oil compared to diesel. Another experimental study on waste plastic oil with varying injection timing revealed a thermal efficiency of 28.2% at full load for standard injection timing and 32.25% for retarded injection timing of waste plastic oil. Retarding the injection timing accelerates combustion initiation and sustains combustion during the power stroke, resulting in a lower peak heat release rate and increased effective pressure for work output. As a result, work output is higher with retarded injection timing, thereby increasing brake thermal efficiency [16].

ENGINE EMISSION CHARACTERSTICS

Emissions from internal combustion engines have been a significant contributor to air pollution, with regulated pollutants being carbon monoxide, Nox, unburned hydrocarbon and smoke opacity.

Carbon mono-oxide (CO) and carbon dioxide emission (CO_2)

CO is produced due to insufficient oxygen, inadequate air entrainment, poor mixture preparation, and incomplete combustion of hydrocarbon fuel. CO is toxic and an intermediate product of hydrocarbon fuel combustion that needs to be controlled. CO emissions can be reduced by increasing the temperature of the combustion chamber to 1200°C, which promotes more complete combustion and oxidation to CO_2 [17]. Some researches documented higher CO emission for WPO compared to diesel fuel [18-21]. Figure 9 shows CO emission with varying load. J. Devaraj et al. attributed the higher CO levels in WPO to lower cylinder temperatures [20]. Similarly, Singh et al. reported higher CO emissions when using WPO and diesel blends compared to diesel alone [22]. An experiment was conducted on a single-cylinder, four-stroke, air-cooled diesel engine using waste plastic oil. For the diesel engine, CO concentration ranged from 14.14 g/kWh to 5.75 g/kWh at 25% of rated power, while for waste plastic oil, it ranged from 18.51 g/kWh to 6.19 g/kWh. Therefore, it was concluded that CO emissions are higher for waste plastic oil. The lower cylinder temperature is the cause of incomplete combustion [15].

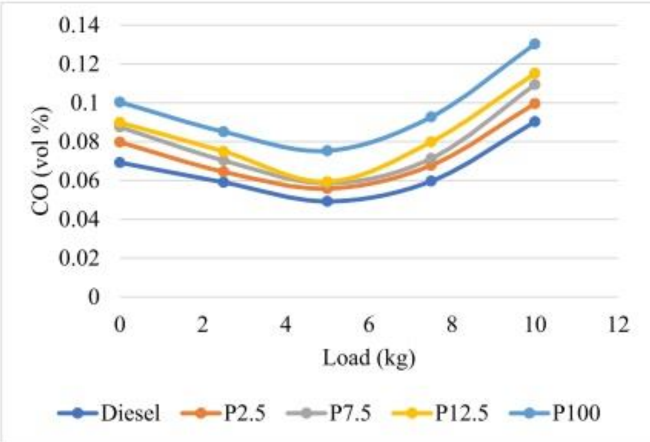

Figure 9 CO emission with varying load [19]

Conversely, some researchers have found that WPO produces lower CO emissions compared to diesel [23,24]. CO emissions decrease with an increase in compression ratio due to the resulting higher combustion temperatures [19]. Additionally, Güngör et al. [25] observed a 20% reduction in CO emissions when using a blend of 5% PPO with diesel. However, some researchers have reported higher CO emissions for WPO-diesel blends compared to diesel alone. The reasons cited include poor mixture preparation, locally rich regions, and the absence of oxygenated compounds in waste plastic oil [15].

After nitrogen oxide, CO_2 is the second most significant component of exhaust gases, comprising 12% of emissions [19]. Some researches documented that CO_2 emission in WPO is lower compared to diesel fuel [19, 23, 26]. The natural higher heat capacity of CO_2 reduces peak combustion temperatures by absorbing heat [27]. Studies have attributed the lower CO_2 emissions from PPO compared to diesel to combustion instability and reduced oxygen levels [23,28], as well as higher viscosity leading to incomplete combustion [19]. The CO_2 emissions in the exhaust can be minimized by employing an EGR (Exhaust Gas Recirculation) system, in contrast to using solely WPO without EGR. This is due to issues such as combustion instability and reduced oxygen levels in the engine cylinder [28].

Nitrogen oxide emission

NOx consists of nitric oxide (NO) and nitrogen dioxide (NO2) and is generated by the oxidation of nitrogen during combustion [17]. NOx emissions in engine exhaust are influenced by the combustion temperature, the duration of chemical reactions, and the presence of oxygen-rich areas inside the cylinder [14]. Additionally, proper combustion raises the temperature and increases the number of free oxygen atoms, which can react with nitrogen to form NOx [15]. An experimental study on blends of waste plastic oil and diesel fuel in a compression ignition engine shows that NOx concentration ranges from 12.15 g/kWh to 7.61 g/kWh for diesel fuel as the load increases, and from 14.68 g/kWh to 8.23 g/kWh for WPO as the load increases. It was also noted that increasing the proportion of waste plastic oil in the blend leads to higher NOx emissions [15]. Figure 10 illustrates the variations in NOx emissions for WPO and its blends with DEE (at 5 wt% and 10 wt%, denoted as WD05 and WD10, respectively) under different load conditions. These results are compared with those obtained using commercial diesel. It is observed that NOx emissions increase with the load for all tested fuel samples [20].

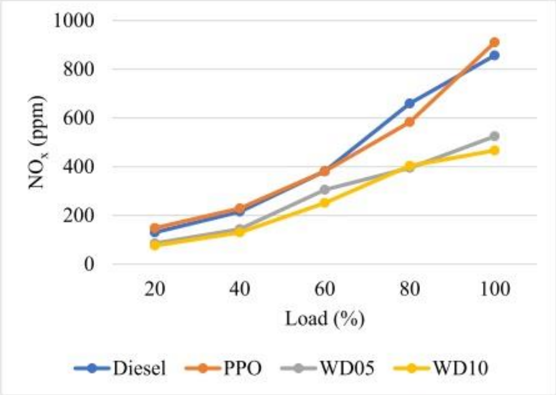

Figure 10 Variation in NOx emission with respect to load [20]

Many researchers also mentioned NOx emission higher for WPO than diesel fuel at all loads [21, 24, 28, 29, 30]. The reason for this is the greater heat release associated with waste plastic oil [15]. Several researchers have attributed the higher NOx emissions of PPO compared to diesel to increased peak cylinder pressure and greater heat release [27, 30]. Khatha et al. [29] cited the higher nitrogen content in PPO as the reason for its elevated NOx emissions compared to diesel. Experimental studies on waste plastic oil with exhaust gas recirculation (EGR) in a direct injection diesel engine show that NOx emissions decrease continuously with increasing load and with higher amounts of EGR. The decrease in NOx concentration is due to the presence of inert gases in the EGR, which absorb the heat released during combustion, thereby reducing the cylinder temperature and replacing the oxygen in the chamber [28].

Smoke opacity

Smoke opacity indirectly measures the amount of soot particles in the exhaust gas. Smoke formation is a complex process primarily influenced by the fuel composition and the air-fuel ratio [14]. Figure 11 illustrates the variation in smoke opacity across different fuel samples as a function of BMEP. The data indicate that smoke opacity increases with engine load for all tested fuels. Among the fuels evaluated, D100 (100% diesel) exhibits the highest smoke emission, which can be attributed to its higher aromatic content and poorer ignition properties. In contrast, fuel blends containing WCO and WPPO, which have minimal aromatic content and more efficient combustion, show a significant reduction in smoke opacity. Specifically, at full load, smoke opacity decreases by 8.7%, 13%, and 22.7% for blends D80B20 (80% diesel, 20% biodisel), D70B20P10 (70% diesel, 20% biodiesel, 10% WPO) and D60B20P20 (60% diesel, 20% biodiesel, 20% WPO), respectively, compared to pure diesel [14].

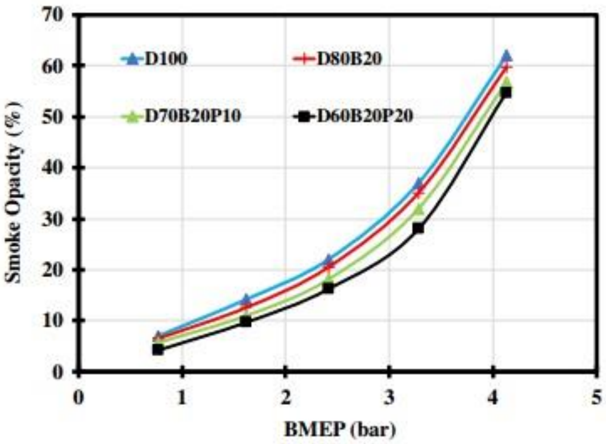

Figure 11 Changes in smoke opacity with respect to BMEP for various fuel samples [14]

Some researchers documented that smoke emission is higher for WPO than diesel [18, 21]. Also, some experiments for WPO blends and diesel come to conclusion that smoke emission is higher than just diesel due to uneven fuel distribution within the engine cylinder, shortened combustion periods and rapid flame spread [31]. As the proportion of WPO in the blend with diesel increases, smoke emissions rise due to the higher viscosity and lower volatility of WPO, which affect spray properties and mixture formation, ultimately reducing combustion efficiency [19, 21].

Unburnt hydrocarbon

Hydrocarbons refer to organic compounds that exist in the gaseous state, while solid hydrocarbons contribute to particulate matter. Unburned hydrocarbons result from incomplete combustion. In CI engines, higher loads exacerbate the issue of unburned hydrocarbons. During lighter loads, less fuel is injected, which can lead to incomplete combustion due to poor fuel distribution, low exhaust temperatures, and regions with lean air-fuel mixtures that may allow unburned hydrocarbons to escape into the exhaust [32]. Higher emissions of unburned hydrocarbons (UHC) were also documented by Geo et al. [26]; Kalargaris et al. [33]; Singh et al. [22] for blends of WPO and diesel compared to diesel alone. This is attributed to incomplete combustion, unreacted hydrocarbons and the higher aromatic content of WPO [34]. Figure 12 presents the results of experiments where WPO was obtained at two different temperatures, 700 °C and 900 °C (designated as PPO700 and PPO900, respectively). The study also examined blends of these PPOs with 25% commercial diesel (PPO700 75 and PPO900 75). The findings indicate that unburned hydrocarbon (UHC) emissions are higher for PPO and its blends compared to pure diesel. This increase is likely due to a longer ignition delay and higher aromatic content, which contribute to a reduced combustion duration. However, PPO and its blends produced at 700 °C showed lower UHC emissions. Additionally, the data suggest that UHC emissions are lower in blends of PPO and diesel compared to neat PPO. This improvement is attributed to the lower aromatic content of diesel, which enhances combustion efficiency when blended with PPO [33].

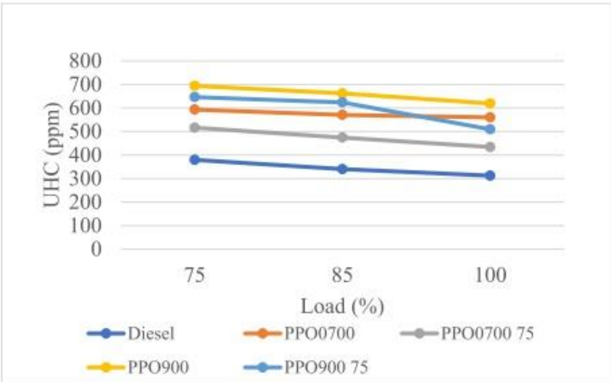

Figure 12 Unburnt hydrocarbon emission vs. Load [33]

Another factor contributing to the higher concentration of unburned hydrocarbons in WPO and WPO-diesel blends compared to diesel fuel is the presence of unsaturated hydrocarbons in WPO that do not fully combust [35]. Additionally, higher fumigation rates, fuel leakage through injector nozzles due to the lower viscosity of WPO-diesel blends and inadequate propagation of fuel spray into the combustion chamber also play roles [18, 20, 36].

WASTE PLASTIC OIL FOR DIESEL ENGINE

The use of waste plastic oil as an alternative fuel for diesel engines is a pioneering innovation that offers significant environmental advantages. This method not only reduces plastic waste but also leverages the existing diesel engine infrastructure. Converting waste plastics into usable fuel aligns with sustainability initiatives and has the potential to considerably lower fuel costs. In the following section, collection of research studies will be presented exploring the use of waste plastic oil in diesel engines. These studies examine different aspects of engine performance, emissions, and fuel properties when incorporating WPO as a fuel source. The combined results highlight the potential of WPO as an environmentally friendly fuel alternative, emphasizing its contribution to reducing plastic waste and improving engine efficiency. Studies collectively highlight the increasing interest in utilizing waste plastic oil as a sustainable alternative fuel for diesel engines. These investigations show that WPO, produced from various plastic sources through different conversion methods, can be effectively integrated into diesel engines, providing key benefits such as enhanced brake thermal efficiency, reduced emissions of carbon monoxide (CO) and unburned hydrocarbons (UHC), and potential cost savings. Additionally, the use of catalysts in the pyrolysis process and blending WPO with diesel have been identified as strategies to improve combustion efficiency and overcome challenges associated with the direct use of WPO.

Various examples of the use of WPO are detailed in review paper of Amardeep et al [37]. Some of these examples will be discuss in order to illustrate the practical applications and benefits of WPO. Maithomklang et al. concluded that waste plastic oil (WPO) is not ideal for direct use in diesel engines but is better suited as a blending component. The study also highlighted that WPO has a lower soot oxidation temperature, which contributes to improved sustainability. Chowdhury et al. highlighted the challenges associated with biomass conversion through pyrolysis, stressing the importance of conducting comprehensive energy and material balances to improve the efficiency and effectiveness of the process [37]. Ghorpade et al. found that blends containing up to 50% waste plastic oil are effective, but higher percentages result in engine issues and increased emissions. Janarthanan and Sivanandi conducted a study on a diesel engine running on fuel derived from plastic pyrolysis, reporting a 6% improvement in brake thermal efficiency (BTE). Additionally, the study observed a reduction in emissions of unburned hydrocarbons (UBHC) and carbon monoxide (CO) [38]. Naima et al. found that the engine operates efficiently on 100% WPO, although it has a slightly longer ignition delay. Additionally, the study indicated that oil derived from waste engine oil is a viable fuel option for diesel engines [39].

In the next section, a summary of research focused on the performance of diesel engines fueled by WPO and its various blends with traditional diesel fuels is provided, as discussed in Amardeep et al [37]. These studies explore a range of factors, including engine efficiency, emissions, and combustion properties. Investigating the use of WPO and its blends in diesel engines presents a promising research area, highlighting potential environmental and economic benefits. Mohan et al. investigated a single-cylinder, 4-stroke, water-cooled engine operating at a variable speed of 1500-1800 rpm, with a fuel injection pressure of 220 bar. Their findings include a decrease in brake thermal efficiency (BTE), an increase in specific fuel consumption (SFC), and higher heat release rate (HRR) and exhaust gas temperature (EGT). Additionally, they observed an increase in ignition delay period (IDP), nitric oxide (NO), and carbon dioxide (CO_2), while smoke emissions decreased. Januszewicz et al. studied a single-cylinder, 4-stroke Common Rail engine with Bosch CP4.1 direct injection and a fuel injection pressure of 180 MPa. Their findings include a decrease in in-cylinder pressure, an increase in heat release rate (HRR), and higher emissions of carbon monoxide (CO) and hydrocarbons (HC). Mangesh et al. studied a 4-cylinder, in-line turbocharged (T/C), direct injection (DI) engine with a rated power of 70 kW, a compression ratio of 17.5:1, an injection timing of 12°CA before top dead center (bTDC), and a nozzle opening pressure of 23 MPa. Their findings include an increase in in-cylinder pressure, brake thermal efficiency (BTE), and heat release rate (HRR), along with a decrease in brake specific fuel consumption (BSFC). Additionally, they observed increases in carbon monoxide (CO) and nitrogen oxides (NOx) emissions [37].

CONCLUSIONS

Application of WPO in the modern automotive industry represents a significant step towards sustainable fuel solutions. The utilization of WPO not only addresses the pressing issue of plastic waste management but also offers potential benefits in terms of reducing dependence on conventional fossil fuels. The research highlights that WPO can be effectively integrated into diesel engines, leading to improvements in fuel efficiency and a reduction in certain emissions, thereby contributing to a more eco-friendly automotive sector.

However, while preliminary findings are promising, several challenges remain. It is imperative to conduct further research to comprehensively evaluate the long-term impacts of using WPO on engine performance, reliability, and overall vehicle operation. Additionally, optimizing the pyrolysis process to ensure consistent fuel quality and cost-effectiveness is crucial for broader adoption.
The ongoing development and refinement of WPO technology could pave the way for significant advancements in both waste management and automotive fuel efficiency. Continued interdisciplinary collaboration and innovation will be essential to overcoming existing barriers and fully harnessing the potential of waste plastic oil in achieving a greener and more sustainable automotive industry.

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