J. Agric. & Env. Sci. (Damanhour University) 2024, 23 (1): 372-386
Print: ISSN 1687-1464 Online: 2735-5098

ACHIEVING SUSTAINABILITY AND OCCUPATIONAL SAFETY AND HEALTH STANDARDS TOWARDS IMPROVING THE EMISSION OF AGRICULTURAL MACHINE ENGINES TO RUN ON HYDROGEN INSTEAD OF DIESEL FUEL

Ahmed G. Mohamed [1], Ahmed M. Ibrahem [1], and Moataz A. Mahfouz [1]
[1] Arab Academy for science, technology and maritime transport.

*Corresponding Author: ahmed.ibrahem799@egypt.aast.edu

ABSTRACT:

With the increasing demand for a sustainable environment free of pollution and emissions from internal combustion engines in agricultural machinery, researchers are exploring innovative methods to enhance efficiency and reduce the environmental impact of these machines. This research deals with the utilization of used hydrogen as supplementary fuel in diesel engines aiming to maximize engine efficiency and minimize emissions. This research implemented and operated in green power H_2o factory to investigates experimentally using hydrogen fuel instead of diesel fuel on a diesel engine pump set Machine. The experimental measure of the emissions percentage while using diesel and hydrogen fuel in the engine, applied, and committed by safety standards when using hydrogen fuel, the test operates at engine load between 30% to 70%. The research achieves using hydrogen instead of diesel by 100 % and an improvement in emissions when using hydrogen fuel 100 % and the prevention of carbon monoxide, carbon dioxide, and sulfur dioxide totally, Increasing the exhaust speed with increasing hydrogen pressure to 4 m/s and finally, increasing the water discharge rate when using hydrogen to 56 m^3 / hr at the same engine loading.

Keywords: Used hydrogen, diesel engine, supplementary fuel, energy efficiency, emissions reduction, sustainability.

https://doi.org/ 10.21608/jaesj.2024.284553.1164

J. Agric. & Env. Sci. (Damanhour University) 2024, 23 (1): 372-386
Print: ISSN 1687-1464 Online: 2735-5098

INTRODUCTION:

Achieving sustainability in the agricultural field has several aspects as the Conservation of resources, soil health, water management, climate change, and the surrounding environment (Sara et al.,2023; Nicoleta,2021). Agriculture machinery increases and develops agricultural productivity and improves the agricultural scale portion, but most of this machinery operates with diesel engines (Lin, 2023). Diesel engines once source air pollution in internal combustion engine due to high emissions to the environment, the exhaust approximately 25 % of waste heat losses from diesel engine (Yousri et al, 2013; Ahmed et al., 2020), the emissions contents carbon dioxide 3 % of air pollution in the world (AA Banawan et al.,2013) the others polluted are nitrous oxides (NOx) as well as sulfur oxides (SOx) and Particulate Matter (PM) (Nader et al., 2017; Nader,2019; Nader,2018). These emissions leading to transient climate response to accumulated carbon emissions represents a great deal of political interest in climate science, noting that the primary focus of sustainability is to provide a clean, emission-free energy source to preserve the environment and make it safer, (Mohamed et al.,2019; Peterson et al.,2022; Sajan ,2021), where the global vision is to provide more sustainable and environmentally friendly fuel. (Priya et al., 2024) Despite numerous research on using lower emission and safer energy sources instead. Another environmentally friendly energy source, some research has attempted to reduce overall emissions by reducing the use of fossil fuels such as coal and natural gas. Fossil fuels pose a threat to the Earth's environment and biological systems. The use of these types of fuel leads to high carbon dioxide levels. (Jenni bai et al., 2023; Aravindan et al., 2023) Other researchers have followed the same thought for safe energy sustainability. (Pravin et al., 2015) where the road map comes the future fuel is used hydrogen to ensure the effective implementation of hydrogen incentives to evaluate its production methods to achieve better sustainability. ((Ibrahim and , Canan, 2015; Ahmed et al., 2023) and (Asim et 0al., 2023) Through this experiment, the researchers seek to Achieve the vision of the Arab Republic of Egypt 2030 in preserving

the environment and making its climate free of emissions, by replacing diesel fuel in agricultural engines with hydrogen and presenting amazing results of free the carbon emission rate from diesel fuel and hydrogen fuel.

MATERIALS AND METHODS:

In this research mix and replace hydrogen fuel with diesel fuel in a Diesel engine pump set Machine, table 1 shows the specifications of the pump set (https://www.man.eu/engines/en/products/on-road/busses-and-special-vehicles/busses-and-special-vehicles.html).

Table 1 Engine specifications

Model	APAN diesel RTM
Bore	78 mm
Stroke	78.4 mm
Power	20 HP
Cooling	Air
Starting system	Manual
Cylinder NO.	1
Pump inlet	5 Inch
Pump outlet	5 Inch
Q	80 m^3/hr
Pressure	10 ar

The first step, operate the engine with pure diesel fuel and measure the emissions percentage that polluted the air by using an instrument E8500 gas analyzer as shows in figure 1 (https://site.jjstech.com/pdf/E-Instruments/E8500-Manual.pdf.), table 2 shows the specification and range of measurement of the device, the diesel fuel combustion equation shown in the following:

$$C_{13}H_{28} + 20\ O_2 \rightarrow 13\ CO_2 + 14\ H_2O$$

Figure (1) gas analyzer E8500

Table 2 gas analyzer specification

MODEL	E8500	
PHYSICAL	Material: ABS plastic case with internal aluminum shielding, Dimensions (analyzer): 11.42" x 10.24" x 4.88" / 29.0 x 26.0 x 12.4 cm, Weight: (analyzer): 11 lbs. / 5 kg Carrying case (analyzer & all accessories): Approx. 22 lbs. / 10 kg	
POWER	7.2 Volt, 8 AH rechargeable battery pack Operating time: 4 to 8 hours,110/240 VAC input, 12 V/2.5A fast charger Charging time: 6 hours minimum	
INSTRUMENT PUMPS	-Gas sample pump: high-quality diaphragm pump with long-life motor -CO dilution pump -Automatic condensate drain pump	
Gases-Range	CARBON MONOXIDE (CO)	0% - 10% 10% - 15%
	CARBON DIOXIDE (CO2)	0% - 20% 20% - 50%
	HYDROCARBONS (HC or CxHy)	0 - 0.40 % 0.40 – 1.00 % 1.00 – 3.00 %
	OXYGEN (O2)	0 – 25%
Temperature	0 – 2000 ºF (0 – 1100ºC)	
Velocity	10 – 300 ft/sec (3 – 100 m/sec)	

The second step is to operate the engine with hydrogen fuel. Inlet the hydrogen into the engine gradually with a decrease in the diesel fuel to reach pure hydrogen at pressures 3 PSI. but before injecting the hydrogen into the engine through the turbocharger must implement and commit safety instructions, the most common problem in hydrogen combustion in internal combustion engines is backfiring to avoid this problem fix the flashback arrestor between the hydrogen source and the engine as shown in figure 2. The hydrogen source in this experiment is an electrolyzer cell that generates the hydrogen directly to the engine figure 3 shows the electrolyzer cell and Table 3 presents its aspects. The electrolyzer is connected by a solar cell to provide electric power to the cell which assists in separating hydrogen and oxygen. The hydrogen goes into the hydrogen poplar then inlet to the engine for combustion as the following equation:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

J. Agric. & Env. Sci. (Damanhour University) 2024, 23 (1): 372-386
Print: ISSN 1687-1464 Online: 2735-5098

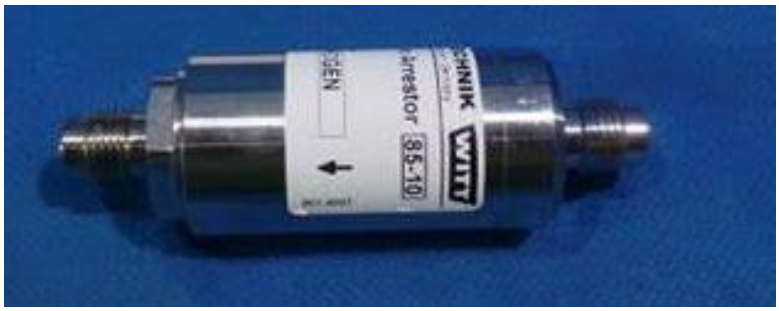

Figure (2) flashback arrestor

Table 3 Electrolyzer aspects

Dimension	20*20*15 cm
Pressure	4 PSI
Rate	0.2 L/min
Solar cell	12 V & 30 A

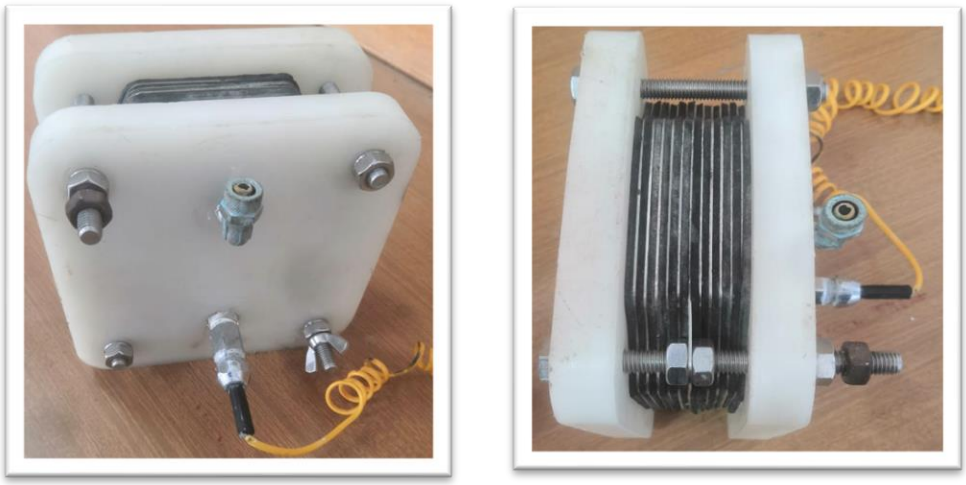

Figure (3) hydrogen electrolyzer

Results:

The results of this experiment show that the following curves illustrate the relation between the engine loading and variable parameters

such as fuel consumption, exhaust temperature, emissions percentage, and exhaust velocity for both two fuels.

Figure 4 illustrates the relationship between engine loading and diesel fuel consumption when using both fuel types, it found that an increase in diesel fuel with the increase from 0.008 Kg/sec to 0.08 Kg/sec at engine loading 30 % to 70 ^ respectively and fixed consumption at zero approximately when using hydrogen fuel.

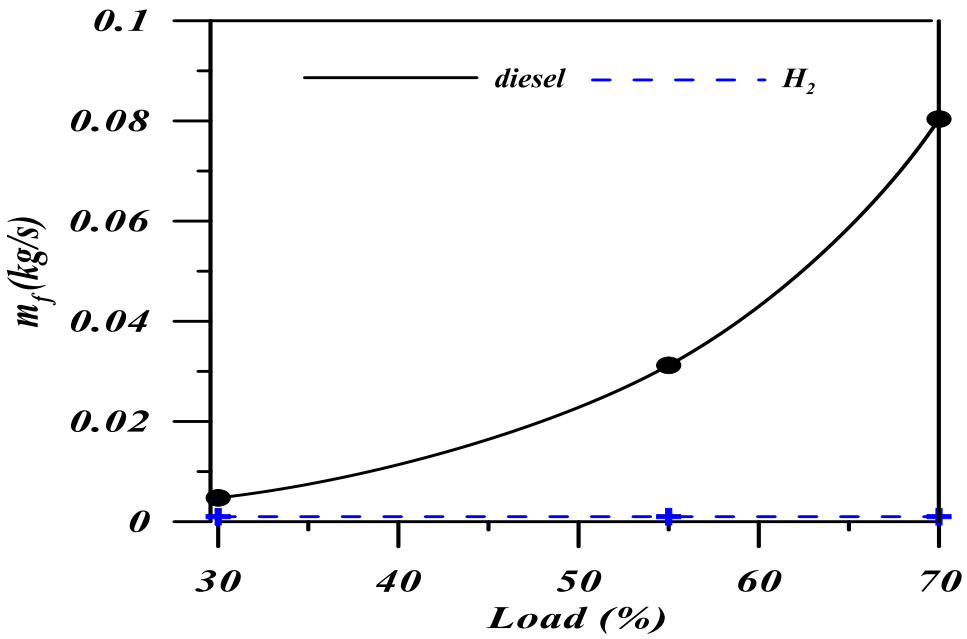

Figure (4): engine loading VS fuel consumption.

Figure 5 presents the relationship between engine loading and carbon monoxide (CO) emission percentage when using both fuel types, the carbon monoxide decreases from 340 ppm to 270 ppm with increased engine loading when used diesel fuel. And carbon monoxide decreases from 150 ppm to 130 ppm when using hydrogen fuel than diesel fuel. Finally, the percentage of carbon monoxide better when using hydrogen fuel than diesel fuel.

J. Agric. & Env. Sci. (Damanhour University) 2024, 23 (1): 372-386
Print: ISSN 1687-1464 Online: 2735-5098

Figure 6 shows the relationship between engine loading and carbon dioxide (CO_2) percentage when using both fuel types, the carbon dioxide increases from 1 % to 2 % with increased engine loading when using diesel fuel, but when using hydrogen fuel carbon dioxide decreases from 0.9 % to 0.7 % with increased engine loading. So, it big improvement in the percentage of carbon monoxide when using hydrogen fuel than diesel fuel.

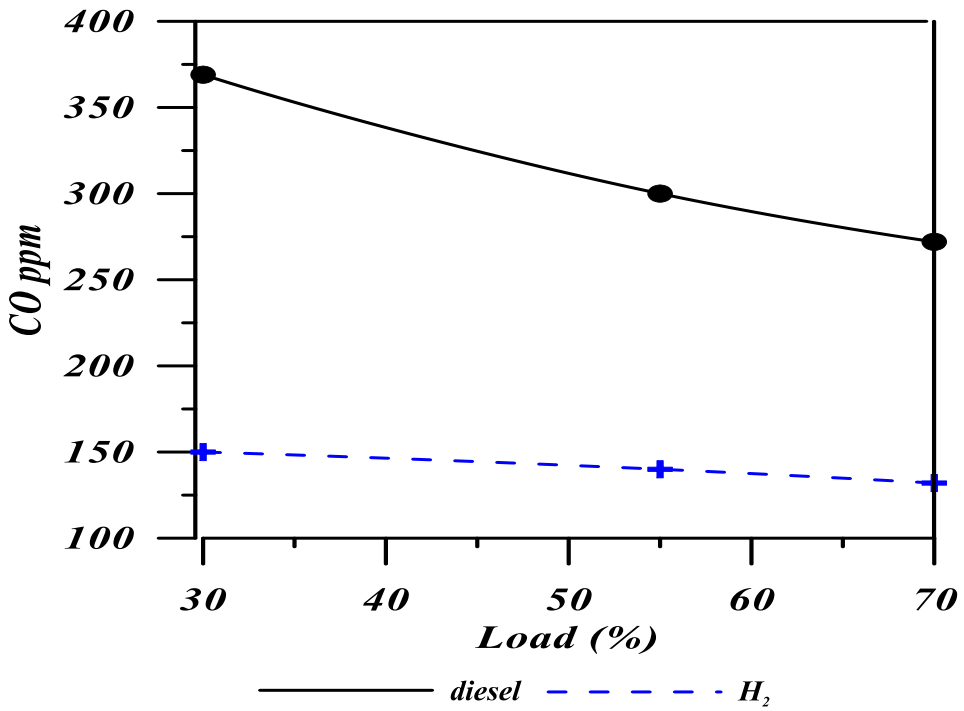

Figure (5): Engine loading VS carbon monoxide percentage.

J. Agric. & Env. Sci. (Damanhour University) 2024, 23 (1): 372-386
Print: ISSN 1687-1464 Online: 2735-5098

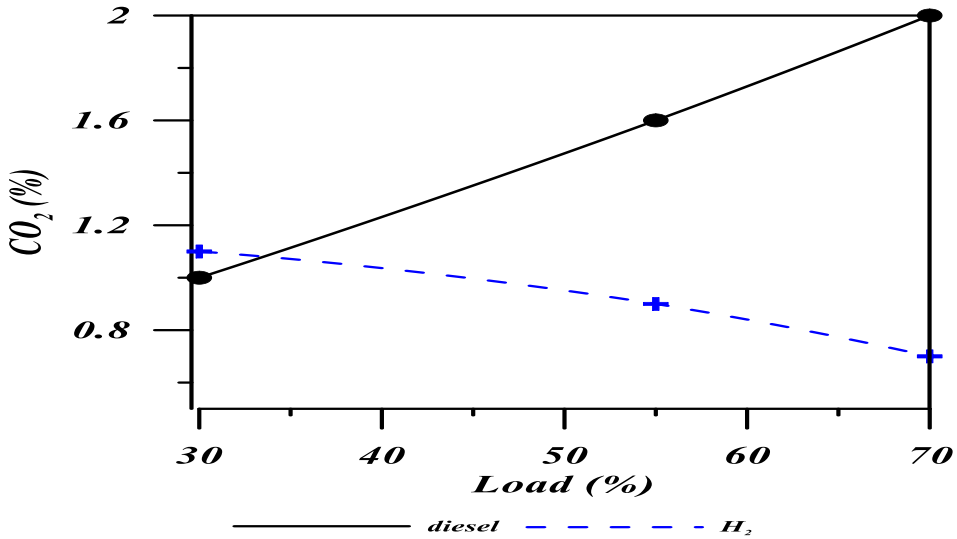

Figure (6): Engine loading VS carbon dioxide percentage.

Figure 7 demonstrates the relationship between engine loading and nitrogen monoxide (NO) amount when using both fuel types, the nitrogen monoxide increases from 5 ppm to 12.5 ppm with increased engine loading when using diesel fuel, but when using hydrogen fuel nitrogen dioxide decreases from 23 ppm to 18.6 ppm with increased engine loading. And the amount of nitrogen monoxide is better when using diesel fuel than hydrogen fuel.

J. Agric. & Env. Sci. (Damanhour University) 2024, 23 (1): 372-386
Print: ISSN 1687-1464 Online: 2735-5098

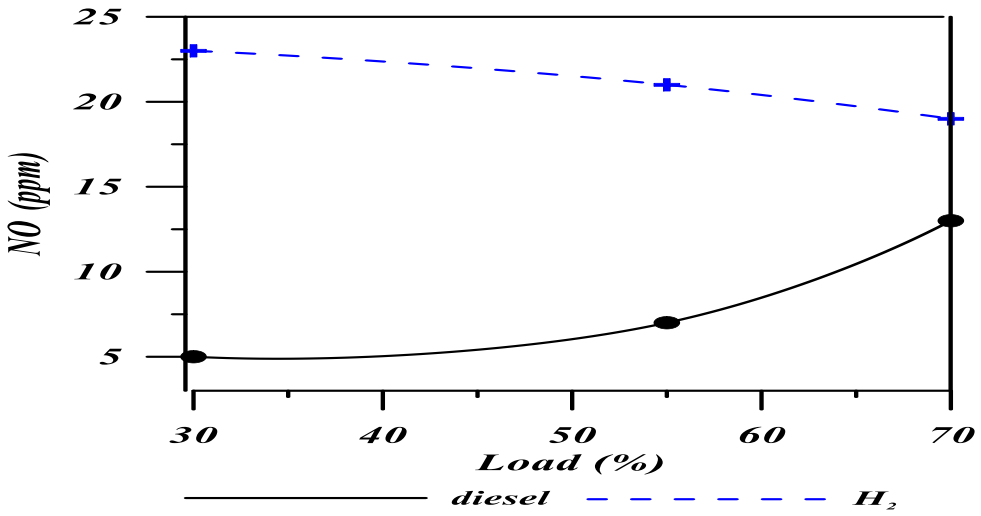

Figure (7): Engine loading VS Nitrogen monoxide percentage.

Figure 8 shows the relationship between engine loading and exhaust temperature increases from 145°C to 150°C when using diesel and increases also when using hydrogen fuel from 131°C to 133°C with increase engine loading. But when using hydrogen fuel the temperature is lower than when using diesel fuel.

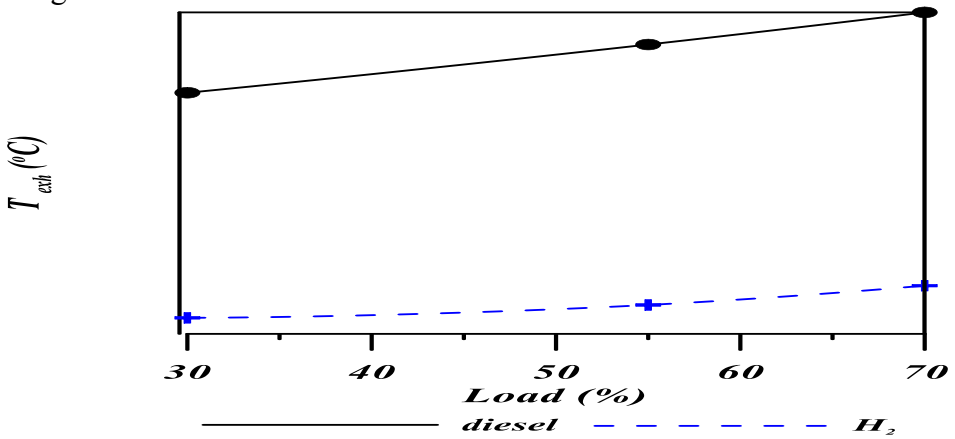

Figure (8): Engine loading VS exhaust temperature.

J. Agric. & Env. Sci. (Damanhour University) 2024, 23 (1): 372-386
Print: ISSN 1687-1464 Online: 2735-5098

Figure 9 presents the relationship between engine loading and exhaust velocity for both diesel and hydrogen fuel. the exhaust velocity increases from 0.001 m/s to 0.2 m/s with engine loading when using diesel fuel. And the exhaust velocity increases from 3.95 m/s to 4.15 m/s with engine loading when using hydrogen fuel but when using hydrogen fuel the velocity is higher than using diesel fuel.

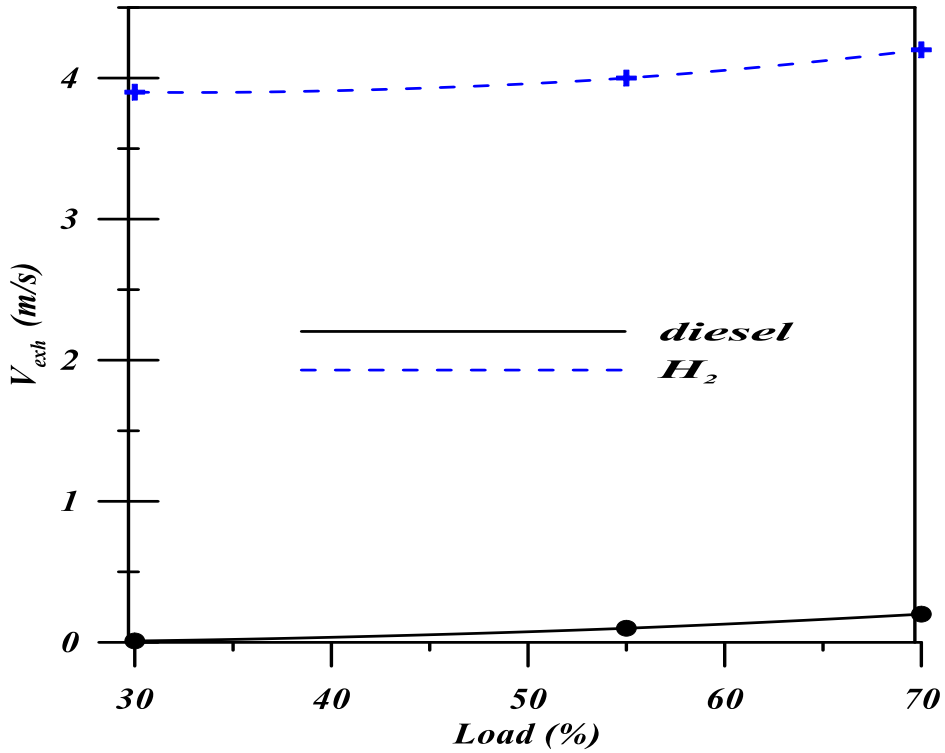

Figure (9): Engine loading VS exhaust velocity.

Figure 10 illustrates the relationship between engine loading and pump discharge rate for both diesel and hydrogen fuel. the pump discharge rate increases from 28 m^3/hr to 54.6 m^3/hr with engine loading when using diesel engine. And the pump discharge rate increases from 32 m^3/hr to 56

m^3/hr with engine loading when using diesel engine. But when using hydrogen fuel the pump discharge rate is higher than using diesel fuel and improvement in discharge rate in the same engine loading.

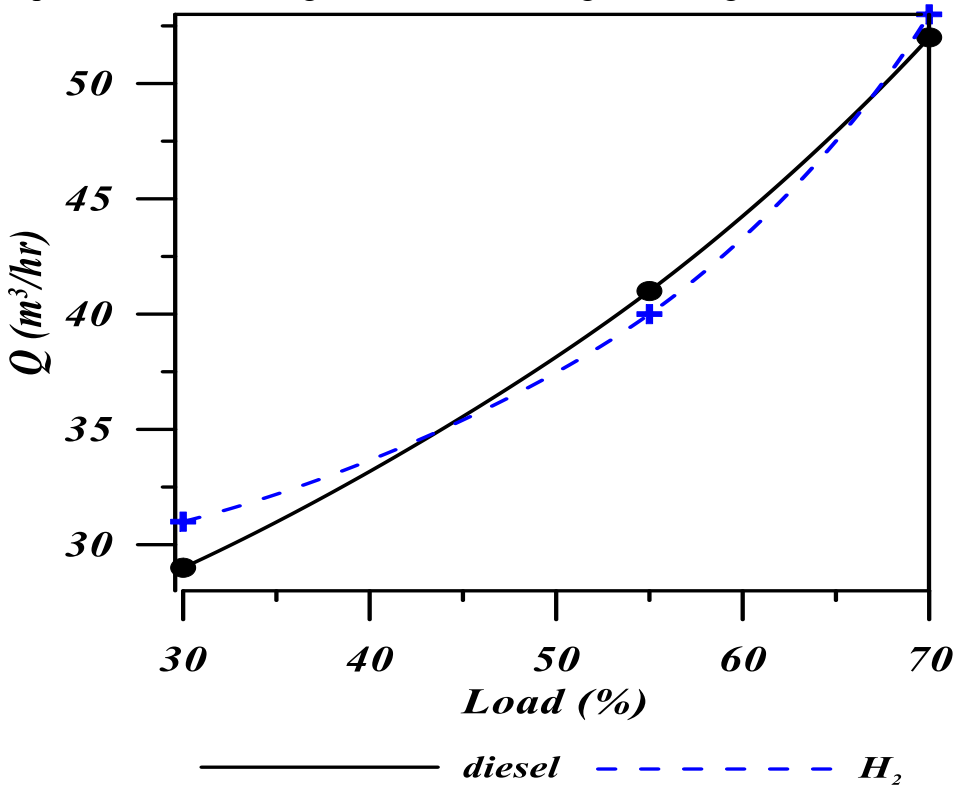

Figure (10): Engine loading VS pump discharge rate.

Conclusion:

At the end of the experiments found that:

1- Emission rates with diesel fuel are high, especially carbon dioxide.
2- An improvement in emissions occurred when used hydrogen instead of diesel.
3- Operating the engine with 100% hydrogen fuel.

4- The emission rate improved with the use of hydrogen by 100% and the prevention of carbon monoxide, carbon dioxide, and sulfur dioxide.
5- Increasing the rate of improvement in emissions with increasing hydrogen pressure.
6- Increase the exhaust speed with increasing hydrogen pressure.
7- Decrease in exhaust temperature when using hydrogen.
8- Increase pump flow rate when using hydrogen fuel.
9- Finally, improve performance and emission when using hydrogen fuel at the same engine loading.

REFERENCES:

- Adel .B, M. Mosleh, I.S Seddiek. 2013. Prediction of the fuel saving and emissions reduction by decreasing speed of a catamaran, Journal of Marine Engineering & Technology, issue 12, PP. 40-48.
- Ahmed. G. M, A. A. El bauomy. 2023. Green Hydrogen Toward Sustainable Marine Fuel, 4th International Conference of Chemical, Energy and Environmental Engineering 2023.
- Ahmed .G. M, M. Mosleh, W. M. El-Maghlany, N. R. Ammar. 2020. Performance analysis of supercritical ORC utilizing marine diesel engine waste heat recovery, Alexandria Engineering Journal, issue 2, PP893-904.
- Ana-Maria .T, M. MATACHE, I. GRIGORE, L. C. VLĂDUŢOIU, N. UNGUREANU, S. S. BIRI.2021, environmental pollution caused by agricultural activities. acta technica corviniensis – Bulletin of Engineering Tome XIV [2021] | Fascicule 2 [April – June]
- Aravindan M, K, G, Praveen.2023. Hydrogen towards sustainable transition: A review of the production, economic, environmental impact, and scaling factors. Elsevier B.V. This is an open-access article under the CC, page 2.
- Asim. K. S, A .Azad, M. G. Rasul, and A.T. Doppalapudi,2023, Prospect of Green Hydrogen Generation from Hybrid Renewable Energy Sources: A Review, vol. 16, issue 3, 1-17.

- Choudhuri. S.2021.Research on sustainable development; International Journal of Recent Technology and Engineering (IJRTE), pages10,1211.
- Canan. A, I. Dincer. 2015. Review and evaluation of hydrogen production methods for better sustainability; International Journal of Hydrogen Energy, Volume 40, pages 11094-11111.
- https://www.man.eu/engines/en/products/on-road/busses-and-special-vehicles/busses-and-special-vehicles.html.
- https://site.jjstech.com/pdf/E-Instruments/E8500-Manual.pdf.
- Jennie .B, H. Ru. 2023. Carbon Emissions Trading and Environmental Protection: International Evidence. Georgetown University and NBER, 3700 O St., Washington DC, 20057, USA, Nanyang Business School, Nanyang Technological University, 50 Nanyang Avenue, Singapore; pages 2:6.
- Jorge. O. G. P, A .H . Abdalla, C. I. Oseghale, P. J. Hall. 2016. Multiple regression analysis in the development of NiFe cells as energy storage solutions for intermittent power sources such as wind or solar, Official Journal of the International Association for Hydrogen Energy; volume 41, pages 16330,16331.
- Lin .J. X. Z, and Q. Wang. 2023, Effects of Agricultural Machinery Operations on PM2.5, PM10, and TSP in Farmland under Different Tillage Patterns Agriculture 13, 930
- Mohamed. M. E, 2008. Design of marine hydrogen internal combustion engine. Alexandria Engineering Journal, Vol. 47 (2008), No. 1, 57-65
- Nader. R. A, 2018. Energy- and cost-efficiency analysis of greenhouse gas emission reduction using slow steaming of ships: case study RO-RO cargo vessel. Volume 13 PP. 868-876.
- Nader. R. A, 2019. An environmental and economic analysis of methanol fuel for a cellular container ship. Volume 69. PP. 66-76.
- Nader. R. A, I. S. Seddiek, 2017. Eco-environmental analysis of ship emission control methods: Case study RO-RO cargo vessel. Ocean Engineering. Volume 137. PP1166-173.

- Ozili, P, K. 2022. Sustainability and Sustainable Development Research around the World. Managing Global Transitions Online Volume 20 · Number 3, pages 259,260.
- Priya .S, D. Germinlou, A. B.Q. Lardi. 2024.sustinable hydrogen production, storage, and distribution – A systematic review for newfoundland and Labrador. Journal of sustainable development; vol.17, pages 1,2.
- Pravin .N, J.G. Suryawanshi.2016. Effects of MBT spark timing on performance emission and combustion characteristics of S.I engine using hydrogen-CNG blends, International Journal of Hydrogen Energy; volume 41, pages 666,667.
- Sara .L.O, S.R.M. El-Areed , M. T. Moreira , S.G .García. 2023. Improving environmental sustainability of agriculture in Egypt through a life-cycle perspective. Science of the Total Environment 890 (2023) 164335
- Thomas. L. F, D,J,Paynter. 2015. Extending the relationship between global warming and cumulative carbon emissions to multi-millennial timescales, Environmental Research Letters; Volume 10, Number 7, pages 2,4.
- Yousri MA. W, M Mosleh, N. R. Ammar, 2013. Energy analysis of a combined solid oxide fuel cell with a steam turbine power plant for marine applications. Journal of Marine Science and Application, Volume 12, pages 473–483.

J. Agric. & Env. Sci. (Damanhour University) 2024, 23 (1): 372-386
Print: ISSN 1687-1464 Online: 2735-5098

تحقيق معايير الاستدامة والسلامة والصحة المهنية نحو تحسين انبعاث محركات الآلات الزراعية لتعمل بالهيدروجين بدلا من وقود الديزل

أحمد جمعه محمد جمعه [1] وأحمد محمد محمد أحمد إبراهيم [1] ومعتز أحمد محفوظ [1]

1 الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري

الملخص:

مع تزايد الطلب على بيئة مستدامة خالية من التلوث والانبعاثات الناتجة عن محركات الاحتراق الداخلي في الآلات الزراعية، يستكشف الباحثون طرقًا مبتكرة لتعزيز الكفاءة وتقليل التأثير البيئي لهذه الآلات. يتناول هذا البحث استخدام الهيدروجين المستخدم كوقود تكميلي في محركات الديزل بهدف زيادة كفاءة المحرك وتقليل الانبعاثات. تم تنفيذ هذا البحث وإجراء التجربة في مصنع جرين باور أتش تو أوه لاستخدام وقود الهيدروجين بدلاً من وقود الديزل على آلة مضخة رفع المياه تعمل بمحرك الديزل. القياس التجريبي لنسبة الانبعاثات أثناء استخدام وقود الديزل والهيدروجين في المحرك، مطبق وملتزم بمعايير السلامة عند استخدام وقود الهيدروجين، ويعمل الاختبار عند حمل المحرك بين 30% إلى 70%. توصل البحث إلى استخدام الهيدروجين بدلاً من الديزل بنسبة 100% وتحسين الانبعاثات عند استخدام الوقود الهيدروجيني 100% والوقاية من أول أكسيد الكربون وثاني أكسيد الكربون وثاني أكسيد الكبريت تماماً، وزيادة سرعة العادم مع زيادة ضغط الهيدروجين إلى 4 م/ث. وأخيراً زيادة معدل تصريف الماء عند استخدام الهيدروجين إلى 56 م3/ساعة عند نفس تحميل المحرك.

الكلمات المفتاحية: الهيدروجين، محرك الديزل، الوقود التكميلي، كفاءة الطاقة، خفض الانبعاثات، الاستدامة.