Calculation of the Exhaust Gas Temperature in Diesel Engines Using Biodiesel Blends

Shaik Abdul Farid[1], Yuvarajan D[2]*

[1]Research Scholar, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu. India. Pincode: 602105.

[2]*Project Guide, Corresponding Author, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu. India. Pincode: 602105.

ABSTRACT:

AIM: This work examines the exhaust gas temperature of a diesel engine fuelled with biodiesel blends. A measure of the heat created by combustion in the form of exhaust gas temperature is known as EGT. **MATERIALS AND METHOD:** In this work the engine used was a four-cylinder 4 stroke diesel engine which is mounted by the eddy current dynamometer. The blend is obtained by the combination of a biodiesel blend and neat diesel. Diesel engine exhaust gases vary with speed and load. High speed and high load result in a higher temperature in the exhaust gas. **RESULTS:** The EGT calculated by the blend of cashew nut shell oil and the diesel at 0% load is calculated as the 9.8%, at 20% load is 1.7%, at the load 50% the is 1.3%, at 80% of the load is 1.7% and at the 100% the difference is 6.85%. **CONCLUSION:** The exhaust gas temperature varies with the engine types, fuels, ignition quality, compression ratio, and other factors. When the engine is at the full of 100% load the exhaust gases rises. Exhaust gases reach temperatures up to 500^{o} C - 700^{o} C, while at minimal load (40% - 30% load), the gases are produced at temperatures of 200^{o}C - 300^{o} C. The exhaust gas temperature of the cashew nut shell oil was 20% more than the neat diesel exhaust gas temperature.

Keywords: Diesel**,** Cashew nut shell oil, Exhaust gas temperature, Biodiesel blend, Combustion, CI engine.

INTRODUCTION:

Diesel engines are becoming a more important part of the world economy. The diesel engines are capable of producing more torque and they operate in a high compression ratio hence they are used in power generators, automobile sectors, and mechanical sectors (Verma 2020). Exhaust gas temperature is a measure of the temperature of the exhaust gases at the exhaust manifold of an engine. It is the temperature of the engine exhaust gases as they leave the engine until the gas temperature is measured by several thermocouples mounted in the exhaust steam and is presented as a deck gauge in either degree Fahrenheit or degree Celsius (Méndez-Carmona et al. 2021). The high exhaust gas temperature is due to the more flow of fuel and the less flow of the air into the cylinders(Anwar and Manikandan 2020).

There are more than 10,600 researches on “google scholar” and there are over 33,180 researches in the “science direct” on the “EXHAUST GAS TEMPERATURE” from the year 2010 to 2015. At the less air, the exhaust gas temperature will be increased and may be decreased by the variance of fuel mixture(Harrison and Hester 2017). The exhaust gas temperature can be reduced by adjusting the combusting rate of the fuel. This is due to the expansion rate of the diesel engine being much better than the gasoline engine. In diesel engines, NOx

formation is a highly temperature-dependent phenomenon and takes place when the temperature in the combustion chamber exceeds 2000 Kelvin (Lakshminarayanan and Agarwal 2019). Biodiesel is a renewable fuel and biodegradable fuel which is made from waste vegetables and other items which are thrown away as waste (Hossain, Sharif Hossain, and AlEissa 2016). The biodiesel is represented by the B100 as neat biodiesel and can be blended with the neat diesel. Like diesel, biodiesel is also used for the combustion process in the IC engine. The percentage of the energy destruction due to the combustion process decreases as the EGT level increases since the higher combustion temperature due to higher EGT level reduces the energy destruction (Agarwal et al. 2018). Among these papers, the best paper is given by Agarwal in 2018 stating that the percentage of energy destruction by combustion leads to an increase in EGT.(Bhavikatti et al. 2021; Karobari et al. 2021; Shanmugam et al. 2021; Sawant et al. 2021; Muthukrishnan 2021; Preethi et al. 2021; Karthigadevi et al. 2021; Bhanu Teja et al. 2021; Veerasimman et al. 2021; Baskar et al. 2021)

Inference from the previous studies conclude that the performance parameters of diesel engines were inspected for lower blends and loads. However, no significant studies were focussed on evaluating the EGT of diesel engines at higher biodiesel blends and higher loads. This study focuses on examining the EGT of stationary diesel engines fuelled with 20 % biodiesel blend and at various loads.

MATERIALS AND METHOD:

The experiment investigation on the performance of blend of cashew nut shell oil in CI engine was done in the thermal engineering laboratory, Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, Totally two groups were considered: experimental group of blend of 20% cashew nut shell oil (B20) and control group consisting of neat diesel. From previous studies the mean BTE and standard deviation values for the experimental group is 95% and 0.51 whereas for the control group the mean and standard deviation values are 92% and 1.0 (Verma 2020).

Neat diesel was brought from the nearby HP pump near to the SIMATS, Thandalam, Chennai. The neat diesel does not contain any of the blends. The amount of diesel was 5 litres.

The cashew nut shell oil was bought from the ‘menaka chemicals’ in choolaimedu, chennai. The cashew nut shell was made from the process of transesterification and hot rolling process. The common method used for the extraction of cashew nut shell oil was through mechanical pressing and transesterification, hot oil and roasting method. The cashew nut shell liquid as extracted has a strong blistering action. Before this liquid is utilized for preparation of resins, it requires treatment to get rid of metallic impurities as well as traces of sulphur compounds. Cashew nut shell oil has innumerable applications, such as friction linings, paints, laminating resins, rubber compounding resins, cashew cements, polyurethane based polymers, surfactants, epoxy resins, foundry chemicals, and intermediates for chemical industry. The properties of the cashew nut shell oil are presented in Table 1.

The CNSO20D80 is composed of cashew nut shell oil and the diesel with the

ratio of 1:4. The addition of 80% diesel and 20% of cashew nut shell oil to form the composition of CNSO20D80. The diesel was made by the digging process on a large scale in an industrialist manner. The composition of the diesel and cashew nut shell oil was being added a negligible amount of SPAN 80 to reduce the surface viscosity of the cashew nut shell oil to get mixed by the diesel compound.

The engine which is used in the process is a four cylinder 4 stroke engine, the bore length is 87.5mm, stroke length is 110mm, compression ratio is 16.5:1. The engine is powered by the 670 cc with a speed of 1500 rpm, rated power of the engine is 5HP. Lubrication used in the engine is SAE40. The values and the readings were taken from the digital meter and the sensors fixed on the setup as shown in the figure 2. The load was supplied in the form of hydraulic dynamometer loading. , fuel supply direct injection type. The engine was a water cooled system engine and the level of water was controlled accordingly. The difference between the CNSO20D80 and neat diesel values are noted in the table.

Statistic Analysis

IBM - SPSS applications are used to study the analytical table with the experimental table. In the comparison with the diesel the CNSO shows the better results The test of the binary blend experimented with a four-cylinder CI diesel engine and thereafter it was compared with diesel fuel, which showed a confirmatory result condition when compared with diesel.

RESULT:

At 0% the EGT with biodiesel is 164^{o}C and with the diesel 148^{o}C in which the exhaust gas temperature is so high in biodiesel blend. At the load of 20% the biodiesel EGT is 182^{o}C and the diesel EGT is 181^{o}C comparatively both the values are equal. When with the load of 80% the biodiesel blend EGT is at 303^{o}C and the diesel is 298^{o}C. The complete load of 100% the values varies as 408^{o}C and 344^{o}C.

DISCUSSION:

EGT increases with load for all fuels. This is due to the fuel being more in the combustion chamber while the air was not sufficient with the required amount for the good air-fuel. If the air-fuel mixture is with a stoichiometric value of 14.7:1 the EGT can be maintained as low as the required level. EGT is slightly higher than diesel. This is due to the following factors. (i) incomplete combustion and (ii) peak combustion happening at the end of the power stroke(World Health Organization 2014). In addition, the viscous number is more for the biodiesel; the exhaust gas temperature is high as compared to the diesel-run exhaust gas temperature(Jung, Hwang, and Bae 2016).

Inference from a previous study states that EGT varies with the engine's speed and load. At high speeds and high loads, diesel exhaust gases reach high temperatures(Pielecha, Borowski, and Cieslik 2014). In general, exhaust gases from diesel-cycle engines produce temperatures in the range of 500°C to 700°C at 100% load, and 200°C to 300°C at no load(Lietti and Castoldi 2018). The temperature of exhaust gases discharged is normally around 420°C (788°F) (Cojocaru 2021). A diesel engine exhaust will be higher even when the working temperature of a diesel engine is high its exhaust gas temperature will be lower than that of a gasoline engine (Viskup 2020). The EGT

calculated by the blend of cashew nut shell oil and the diesel at 0% load is calculated as the 9.8%, at 20% load is 1.7%, at the load 50% the value is 1.3% at 80% of the load 1.7% and the 100% 6.85%.

The limitation of this work is that a large amount of blended biofuel cannot be used in unmodified engines because of the property changes between plain diesel and cashew nut shell oil (B20). Adding more blends to the unmodified engine can affect the overall performance of the engine (Prabhu and Venkata Ramanan 2020). So engine modification has to be done for using excess blends.

CONCLUSION:

In this work, the diesel exhaust gas temperature is lesser than the biodiesel derived from the cashew nutshell. The exhaust gas temperature is being reduced by the adjustment of the viscosity of the biodiesel blend in the combustion process, complete combustion. Diesel generates 23% less EGT than biodiesel.

DECLARATIONS

Conflict of Interests

There is no conflict of interest in this manuscript

Author Contributions

Author SAF was involved in data collection,data analysis and manuscript writing. Author YD was involved in data validation and review of manuscripts.

Acknowledgement:

The authors would like to express their gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (Formerly known as Saveetha University)for providing the necessary infrastructure to carry out this work successfully.

Funding

We thank our financial sponsors for the following organizations for providing financial support.

1. Menaka chemicals
2. Saveetha University
3. Saveetha Institute of Medical and Technical Sciences
4. Saveetha School of Engineering.

REFERENCES:

1. Agarwal, Avinash Kumar, Anirudh Gautam, Nikhil Sharma, and Akhilendra Pratap Singh. 2018. *Methanol and the Alternate Fuel Economy*. Springer.
2. Anwar, Zeeshan, and Arumugampillai Manikandan. 2020. “Case Study: Trouble Shooting of Gas Turbine Generator GTG Trips Due to Gas Turbine High Exhaust Temperature Spread While Operating on Liquid Fuel.” *Day 2 Wed, October 30, 2019*. https://doi.org/10.2118/196350-ms.
3. Baskar, M., R. Renuka Devi, J. Ramkumar, P. Kalyanasundaram, M. Suchithra, and B. Amutha. 2021. “Region Centric Minutiae Propagation Measure Orient Forgery Detection with Finger Print Analysis in Health Care Systems.” *Neural Processing Letters*, January. https://doi.org/10.1007/s11063-020-10407-4.
4. Bhanu Teja, N., Yuvarajan Devarajan, Ruby Mishra, S. Sivasaravanan, and D. Thanikaivel Murugan. 2021. “Detailed Analysis on Sterculia Foetida Kernel Oil as Renewable Fuel in Compression Ignition Engine.” *Biomass Conversion and Biorefinery*, February. https://doi.org/10.1007/s13399-021-01328-w.
5. Bhavikatti, Shaeesta Khaleelahmed,

Mohmed Isaqali Karobari, Siti Lailatul Akmar Zainuddin, Anand Marya, Sameer J. Nadaf, Vijay J. Sawant, Sandeep B. Patil, Adith Venugopal, Pietro Messina, and Giuseppe Alessandro Scardina. 2021. "Investigating the Antioxidant and Cytocompatibility of Mimusops Elengi Linn Extract over Human Gingival Fibroblast Cells." *International Journal of Environmental Research and Public Health* 18 (13). https://doi.org/10.3390/ijerph18137162.

6. Cojocaru, Remus-Cristinel. 2021. "EVALUATION OF THE QUALITY STANDARDS OF THE WATER DISCHARGED INTO THE SEA AFTER WASHING THE EXHAUST GASES." *Journal of Marine Technology and Environment*. https://doi.org/10.53464/jmte.01.2021.03.
7. Harrison, R. M., and R. E. Hester. 2017. *Environmental Impacts of Road Vehicles: Past, Present and Future*. Royal Society of Chemistry.
8. Hossain, A. Sharif, A. Sharif Hossain, and Mohammed AlEissa. 2016. "Biodiesel Fuel Production from Palm, Sunflower Waste Cooking Oil and Fish Byproduct Waste as Renewable Energy and Environmental Recycling Process." *British Biotechnology Journal*. https://doi.org/10.9734/bbj/2016/22338.
9. Jung, Yongjin, Joonsik Hwang, and Choongsik Bae. 2016. "Assessment of Particulate Matter in Exhaust Gas for Biodiesel and Diesel under Conventional and Low Temperature Combustion in a Compression Ignition Engine." *Fuel*. https://doi.org/10.1016/j.fuel.2015.10.076.
10. Karobari, Mohmed Isaqali, Syed Nahid Basheer, Fazlur Rahman Sayed, Sufiyan Shaikh, Muhammad Atif Saleem Agwan, Anand Marya, Pietro Messina, and Giuseppe Alessandro Scardina. 2021. "An In Vitro Stereomicroscopic Evaluation of Bioactivity between Neo MTA Plus, Pro Root MTA, BIODENTINE & Glass Ionomer Cement Using Dye Penetration Method." *Materials* 14 (12). https://doi.org/10.3390/ma14123159.
11. Karthigadevi, Guruviah, Sivasubramanian Manikandan, NatchimuthuKarmegam, Ramasamy Subbaiya, SivasankaranChozhavendhan, Balasubramani Ravindran, Soon Woong Chang, and Mukesh Kumar Awasthi. 2021. "Chemico-Nanotreatment Methods for the Removal of Persistent Organic Pollutants and Xenobiotics in Water - A Review." *Bioresource Technology* 324 (March): 124678.
12. Lakshminarayanan, P. A., and Avinash Kumar Agarwal. 2019. *Design and Development of Heavy Duty Diesel Engines: A Handbook*. Springer Nature.
13. Lietti, Luca, and Lidia Castoldi. 2018. *NOx Trap Catalysts and Technologies: Fundamentals and Industrial Applications*. Royal Society of Chemistry.
14. Méndez-Carmona, Natalia, Rahel K. Wyss, Maria Arnold, Adrian Segiser, Nina Kalbermatter, Anna Joachimbauer, Thierry P. Carrel, and Sarah L. Longnus. 2021. "Effects of

Graft Preservation Conditions on Coronary Endothelium and Cardiac Functional Recovery in a Rat Model of Donation after Circulatory Death." *The Journal of Heart and Lung Transplantation: The Official Publication of the International Society for Heart Transplantation* 40 (11): 1396–1407.

15. Muthukrishnan, Lakshmipathy. 2021. "Nanotechnology for Cleaner Leather Production: A Review." *Environmental Chemistry Letters* 19 (3): 2527–49.
16. Pielecha, Ireneusz, Przemyslaw Borowski, and Wojciech Cieslik. 2014. "Investigations into High-Pressure Diesel Spray-Wall Interaction on Reduction of Exhaust Emission from DI Diesel Engine." *SAE Technical Paper Series*. https://doi.org/10.4271/2014-01-1250.
17. Prabhu, A., and M. Venkata Ramanan. 2020. "Emission and Performance Analysis of Pentanol-Diesel Blends in Unmodified Diesel Engine." *International Journal of Ambient Energy*. https://doi.org/10.1080/01430750.2018.1490356.
18. Preethi, K. Auxzilia, K. Auxzilia Preethi, Ganesh Lakshmanan, and Durairaj Sekar. 2021. "Antagomir Technology in the Treatment of Different Types of Cancer." *Epigenomics*. https://doi.org/10.2217/epi-2020-0439.
19. Sawant, Kashmira, Ajinkya M. Pawar, Kulvinder Singh Banga, Ricardo Machado, Mohmed IsaqaliKarobari, Anand Marya, Pietro Messina, and Giuseppe Alessandro Scardina. 2021. "Dentinal Microcracks after Root Canal Instrumentation Using Instruments Manufactured with Different NiTi Alloys and the SAF System: A Systematic Review." *NATO Advanced Science Institutes Series E: Applied Sciences* 11 (11): 4984.
20. Shanmugam, Vigneshwaran, Rhoda Afriyie Mensah, Michael Försth, Gabriel Sas, ÁgostonRestás, Cyrus Addy, Qiang Xu, et al. 2021. "Circular Economy in Biocomposite Development: State-of-the-Art, Challenges and Emerging Trends." *Composites Part C: Open Access* 5 (July): 100138.
21. Veerasimman, Arumugaprabu, Vigneshwaran Shanmugam, Sundarakannan Rajendran, Deepak Joel Johnson, Ajith Subbiah, John Koilpichai, and UthayakumarMarimuthu. 2021. "Thermal Properties of Natural Fiber Sisal Based Hybrid Composites – A Brief Review." *Journal of Natural Fibers*, January, 1–11.
22. Verma, Mohdfazil Khan AkshaygargSiddharthjain. 2020. "Optimization of Low-Temperature Transesterification of Low FFA Blend of Sunflower Oil and Algae Oil." *Fuel* 279 (November): 118459.
23. Viskup, Richard. 2020. *Diesel and Gasoline Engines*.
24. World Health Organization. 2014. *WHO Guidelines for Indoor Air Quality: Household Fuel Combustion*. World Health Organization.

TABLES AND FIGURES:

Table 1 specifications of Engine.

S.NO	SPECIFICATION	RESULTS
1	BHP	10 (de-rated)
2	No. of. Cylinders	Four
3	Compression Ratio	23:1
4	Bore	73mm
5	Stoke length	88.9mm
6	Orifice diameter	20mm
7	Type of ignition	Compression ignition
8	Type of cooling	Water-cooled
9	Type of starting	Self start
10	Method of loading	Hydraulic dynamometer
11	Speed	1500 rpm

Table 2. Properties of diesel.

S.no	**Specification**	**Value**
1	Density at 15^{o}C	0.8116
2	Flash point ^{o}C	59
3	Kinematic viscosity at 15^{o}C	4.6818
4	Conventional viscosity at 15^{o}C	1.321^{o}C
5	Freezing point, ^{o}C	-11
6	Pour point, ^{o}C	-2
7	Diesel index	30
8	Flame temperature, ^{o}C	2054

Table 3 Specifications of cashew nut shell oil.

SPECIFICATION	RESULTS
SPECIFIC GRAVITY AT 30 ^{0}c	0.950-0.970
Varrarity at 30 ^{0}c	550.0
Moisture % by weight max	1.0%
Matter insoluble in toluene %by weight max	1.08
Less in weight on heating% by weight max	2.0
Ash% by weight max	1.0
Iodine value min	1.0
Wifs method	250
Catalytic methods	375
Viscosity at 30 ^{0}c cps min	30
Viscosity after acid washing at 30^{0}c cps min	200
Acid value max	14

Table 4 Specifications of CNSO20D80

S.NO	SPECIFICATIONS	RESULTS
1	Saponification value	145-160
2	Water (kf)	Max 1%
3	Boiling point	463.43^{0}c
4	Colour	Pale yellow
5	Solution form	Viscous liquid
6	Vapour pressure	Greater than 1.4 hPa (20^{0}c)
7	Refractive index	n20/D 1.48(litre)
8	Flashpoint	Greater than 230 f
9	Specific gravity	0.986
10	Storage temperature	Room temperature
11	Acidic value	10 of maximum
12	Span 80 molecular formula	C24H44O6

13	Molecular weight	428.62

Table 5. Comparison of EGT using both CNSO20D80 and Diesel.

S.no	CNSO20D80	Diesel
1	408	380
2	400	378
3	405	375
4	402	384
5	410	389
6	408	386
7	400	380
8	405	375
9	402	376
10	410	384
11	408	389
12	400	386
13	405	380
14	402	370
15	410	375
16	408	384
17	400	389
18	405	386
19	402	384
20	410	386

Table 6. Group statistics mean standard deviation and standard mean error of both fuels.

GROUPS	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
CNSO20D80	20	405.0000	3.78362	0.84604
Diesel	20	381.8000	5.53078	1.23672

Table 7. Independent T test significance value.

EGT	**F**	**Sig**	**t**	**df**
Equal variances assumed	**4.328**	**0.44**	**15.483**	**38**
Equal variances not assumed			**15.483**	**33.589**

Fig 1 ENGINE USED IN THE PROCESS

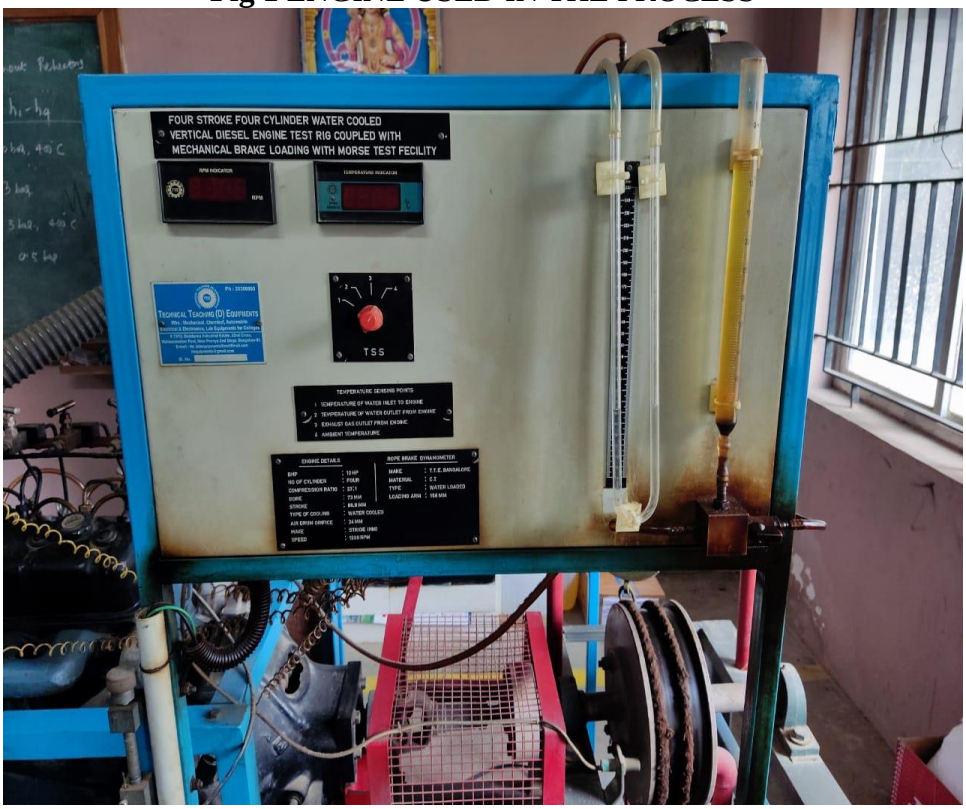

Fig 2 METRE TO NOTE LOAD VALUES

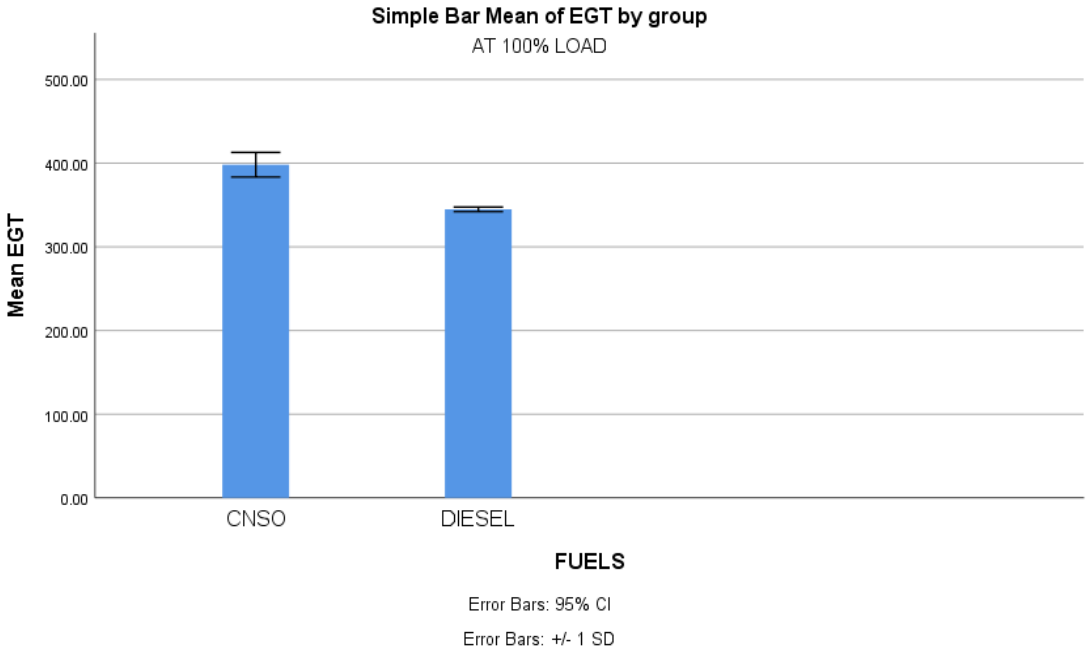

Fig 3: The X-axis the fuels are mentioned and on the Y-axis the mean of EGT is mentioned. The mean of EGT is compared in between the cashew nut shell oil and the diesel on the 100% load and the EGT of diesel is 344ºC and the EGT of cashew nut shell oil is 408ºC. The graph is made with the error bars 95% CI and the standard deviation of ± 1 SD.