PREDICTING ENGINE PERFORMANCE AND EXHAUST EMISSIONS OF A SPARK IGNITION ENGINE FUELLED WITH 2-BUTANOL-GASOLINE BLENDS USING RSM AND ANN MODELS

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Penyelidikan eksperimen dalam pengujian enjin menggunakan bahan bakar alternatif selalunya tertakluk kepada operasi enjin, yang memerlukan masa dan pembiayaan kos bahan yang mahal. Atas sebab-sebab ini, kajian ini bertujuan untuk meramalkan prestasi enjin dan pelepasan ekzos menggunakan 2-butanol-gasoline bahan api yang dicampur dengan nisbah peratusan 5:95 (GBu5), 10:90 (GBu10) dan gasoline 15:85 (GBU-15) kepada 2-butanol, masing-masing, yang dikendalikan dalam empat silinder, empat lejang bahan api 4G93 Mitsubishi pada kedudukan pendikit lebar 30%, 50% dan 70% menggunakan metodologi permukaan tindak balas (RSM) dan rangkaian saraf tiruan (ANN). Berdasarkan eksperimen penyiasatan tersebut, pada 30%, 50% dan 70% daripada kedudukan pendikit lebar, 2-butanol-gasoline bahan api dicampur menunjukkan peningkatan kuasa brek enjin, brek tork dan kecekapan haba brek dengan peningkatkan kandungan 2-butanol dalam bahan api petrol. Prestasi enjin menunjukkan peningkatan dalam kuasa brek, brek tork dan brek thermal kecekapan dalam purata 2% hingga 15% dan 0.2% kepada 1.5%, masing-masing, untuk semua kedudukan pendikit diuji berkenaan dengan meningkatkan kandungan 2-butanol dalam bahan api petrol. Untuk pelepasan ekzos, ianya telah dicatatkan, penurunan yang sekata bagi nitrogen oksida (NO_x), carbon monoksida (CO), carbon dioksida (CO_2) dan hydrocarbon yang tidak terbakar (HC) untuk GBu5, GBu10 dan GBU-15, secara purata sebanyak 7.1%, 13.7%, dan 19.8% daripada G100, masing-masing, lebih jarak kelajuan 1000 hingga 4000 RPM. Kandungan pelepasan lain menunjukkan CO dan HC lebih rendah tetapi CO_2 lebih tinggi dari 2500 hingga 4000 RPM untuk bahan api campuran. Seterusnya, kelajuan enjin, bahan api campuran 2-butanol dan kedudukan pendikit enjin dan hasil dari prestasi enjin dan ekzos ciri-ciri pelepasan telah digunakan sebagai input dan output untuk metodologi RSM dan ANN. Berdasarkan model RSM, ciri-ciri prestasi mendedahkan bahawa kenaikan 2-butanol dalam bahan api yang dicampurkan membawa kepada peningkatan aliran kuasa brek, brek tork dan kecekapan terma brek. Bagaimanapun, bahan api brek didapati sedikit lebih tinggi diperhatikan. Tambahan pula, RSM model ini mencadang bahawa kehadiran 2-butanol mempamerkan trend penurunan kepada NO_x, CO dan HC, bagaimanapun trend yang lebih tinggi dapat diperhatikan untuk pelepasan CO_2 dimana keputusan ini adalah selari dengan keputusan eksperimen. Sementara itu, bagi ANN pula, kedua-dua lapisan tersembunyi model ANN dilatih tansig-logsig gabungan fungsi pengaktifan menghasilkan koefisien korelasi terbaik, R pada nilai 0.9995 terhadap gabungan fungsi pengaktifan lain yang dinilai. Walau bagaimanapun, untuk mencapai model ramalan yang lebih tepat, semua konfigurasi dinilai lebih lanjut oleh tambahan analisis kesilapan statistik dan korelasi metrik, iaitu Mean Absolute Percentage Error (MAPE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Theil U2, Nash-Sutcliffe Efficiency (NSE) and Kling–Gupta Efficiency (KGE). Penilaian, gabungan fungsi pengaktifan terbaik untuk kuasa brek, BSFC, BTE, NOx, CO, dan model ANN bagi CO_2 adalah konfigurasi tansig-logsig. Bagi tork Brek dan HC, kombinasi tansig memberikan ramalan yang lebih baik. Ia boleh ditunjukkan dengan tepat daripada kajian bahawa model ANN yang maju mempunyai ketepatan ramalan yang lebih tinggi berbanding dengan model RSM.

ABSTRACT

Experimental investigation in engine testing using alternative fuels always subjected to more engine operation, time-consuming and require expensive cost of materials. For these reasons, this study is aimed to predict the engine performance and exhaust emissions using 2-butanol-gasoline blended fuels with percentage volume ratios of 5:95 (GBu5), 10:90 (GBu10) and 15:85 (GBu15) of gasoline to 2-butanol, respectively, operated in a four-cylinder, four-stroke port fuel 4G93 Mitsubishi spark ignition engine at 30%, 50% and 70% of throttle position using artificial neural network and response surface methodology techniques. Based on the experimental investigation, at 30%, 50% and 70% of throttle position, 2-butanol–gasoline blended fuels indicated an improvement in engine brake power, brake torque and brake thermal efficiency with increasing 2-butanol content in the gasoline fuels. The engine performance indicated improvement in brake power, brake torque and brake thermal efficiency in the average of 2 to 15% and 0.2% to 1.5%,respectively, for all of the tested throttle position with respect to increasing the 2-butanol content in the gasoline fuel. For exhaust emissions, it was recorded that, a significant decreased of NO_x, CO, CO_2 and HC for GBu5, GBu10 and GBu15, by an average of 7.1%, 13.7%, and 19.8% than G100, respectively, over a speed range of 1000 to 4000 RPM. Other emission contents indicate lower CO and HC but higher CO_2 from 2500 to 4000 RPM for the blended fuels. The engine speeds, 2-butanol blended fuels and engine throttle position and results from the engine performance and exhaust emissions characteristics was then used as the input and output for the for the artificial neural network and response surface methodology. Based on the RSM model, performance characteristics revealed that the increment of 2-butanol in the blended fuels lead to the increasing trends of brake power, brake torque and brake thermal efficiency. Nonetheless, a marginally higher brake specific fuel consumption was observed. Furthermore, the RSM model suggests that the presence of 2-butanol exhibits a decreasing trend of NO_x, CO, and HC, however, a higher trend was observed for CO_2 exhaust emissions, which are in accordance with the experimental results. Meanwhile, for ANN it was shown that the two hidden layer ANN model trained with the tansig-logsig activation function combination yields the best correlation coefficient, R at a value of 0.9995 against other activation function combinations evaluated. However, to attain a higher fidelity prediction model, all the configurations are further assessed by additional statistical error and correlation metrics, namely Mean Absolute Percentage Error (MAPE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Theil U2, Nash-Sutcliffe Efficiency (NSE) and Kling–Gupta Efficiency (KGE). Following the evaluation, the best activation function combination for the brake power, BSFC, BTE, NO_x, CO, and CO_2 ANN predictive models is the tansig-logsig configuration. As for Brake torque and HC, the tansig combination provides a better prediction. It can be conclusively shown from the study that the developed ANN models have a higher predictive accuracy as compared to the RSM model.

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Abbreviations

°CA	degree of crank angle
AP_e	average effective pressure
$CH_3CH_2CH_2CH_2OH$	n-butanol
$CH_3CH_2CHOHCH_3$	2-butanol
$C_nH_{2n+1}OH$	alcohol structure formula
CH_3OH	methanol structure formula
C_2H_5OH	ethanol
C_3H_7OH	propanol
C_4H_9OH	butanol
$(CH_3)_2CH_2CHOH$	iso-butanol
$(CH_3)_3COH$	tert-butanol
P_e	effective power
P_{max}	maximum pressure
Nm	newton metre
R	correlation coefficient
R^2	coefficient of determination
Te_x	exhaust gas temperature
rpm	revolutions per minute
-OH	hydroxyl group

LIST OF ABBREVIATIONS

Abbreviations

AFR	air fuel-ratio
ANN	artificial neural network
AI	artificial intelligence
bTDC	before top dead centre
BDC	bottom dead centre
BMEP	brake mean effective pressure
BSFC	brake specific fuel consumption
BTE	brake thermal efficiency
BVP	butanol Volume Percentage
CI	compression ignition
CO	carbon monoxide
CO_2	carbon dioxide
COP21	Conference of the Parties
COV	coefficient of variation
DA	direction accuracy
DLS	damped least-squares
ECI-multi	electronically controlled multi-point fuel injection
EU	european union
FF	feedforward
FIT	fuel injection timing
FIP	fuel injection pressure
G100	Gasoline
GBu5	5% 2-butanol + 95 gasoline
GBu10	10% 2-butanol + 90% gasoline
GBu15	15% 2-butanol + 85% gasoline
GNA	gauss–newton algorithm
GHG	greenhouse gasses
H_nOME	honne oil methyl ester
IMEP	indicated mean effective pressure
HC	unburned hydrocarbon
HCCI	homogenous charge compression ignition engine

KGE	kling–gupta efficiency
LR	linear regression
LHV	lower heating value
Logsig	hyperbolic log-sigmoid
MAPE	mean absolute percentage error
CAD HRRmax	location of heat release rate
CAD P_{max}	location of maximum pressure
CuHRR	cumulative heat release rate
CI	compression ignition
MLP	multilayer perceptron
MSE	mean square error
MSRE	mean square root error
NO_x	nitrogen oxides
PME	peanut methyl ester
ppm	parts per million
purelin	linear function
RBF	radial basis function
RSM	response surface method
RSE	relative standard error
RMSE	root mean square error
rpm	revolutions per minute
SI	spark ignition
SHL	single hidden layer
SOHC	single overhead camshaft
Tansig	hyperbolic tangent sigmoid
TDC	top dead centre
THL	two hidden layer
trainbfg	quasi-Newton backpropagation
trainrp	resilient backpropagation
trainscg	scaled conjugate gradient
traingdx	variable learning rate
UN	united nation
WCO	waste cooking oil
WTO	wide throttle open

NSE	nash–sutcliffe coefficient of efficiency
n-butanol	primary butyl alcohol
2-butanol	secondary butyl alcohol

REFERENCES

Abedin, M. J., Masjuki, H. H., Kalam, M. A., Sanjid, A., Rahman, S. M. A., & Fattah, I. M. R. (2014). Performance, emissions, and heat losses of palm and jatropha biodiesel blends in a diesel engine. *Industrial Crops and Products, 59,* 96-104. doi: 10.1016/j.indcrop.2014.05.001

Alasfour, F. (1998a). NOx Emission from a spark ignition engine using 30% Iso-butanol–gasoline blend: part 1—preheating inlet air. *Applied Thermal Engineering, 18*(5), 245-256.

Alasfour, F. (1998b). NOx emission from a spark ignition engine using 30% iso-butanol–gasoline blend: Part 2—ignition timing. *Applied Thermal Engineering, 18*(8), 609-618.

Alasfour, F. (1999). The effect of using 30% iso-butanol-gasoline blend on hydrocarbon emissions from a spark-ignition engine. *Energy Sources, 21*(5), 379-394.

Alasfour, F. N. (1997). Butanol - A single-engine study: Availability analysis. *Applied Thermal Engineering, 17*(6), 537-549.

Alyamac, K. E., Ghafari, E., & Ince, R. (2016). Development of eco-efficient self-compacting concrete with waste marble powder using the response surface method. *Journal of Cleaner Production*.

Anderson, J., DiCicco, D., Ginder, J., Kramer, U., Leone, T., Raney-Pablo, H., & Wallington, T. (2012). High octane number ethanol–gasoline blends: Quantifying the potential benefits in the United States. *Fuel, 97*, 585-594.

Asghar, A., Abdul Raman, A. A., & Daud, W. M. A. W. (2014). A comparison of central composite design and Taguchi method for optimizing Fenton process. *The Scientific World Journal, 2014*.

Atmanli, A., Ileri, E., & Yilmaz, N. (2016). Optimization of diesel–butanol–vegetable oil blend ratios based on engine operating parameters. *Energy, 96,* 569-580.

Atmanlı, A., Yüksel, B., İleri, E., & Karaoglan, A. D. (2015). Response surface methodology based optimization of diesel–n-butanol–cotton oil ternary blend ratios to improve engine performance and exhaust emission characteristics. *Energy Conversion and Management, 90*, 383-394.

Balat, M. (2011). Production of bioethanol from lignocellulosic materials via the biochemical pathway: A review. *Energy Conversion and Management, 52*(2), 858-875. doi: 10.1016/j.enconman.2010.08.013

Balki, M. K., & Sayin, C. (2014). The effect of compression ratio on the performance, emissions and combustion of an SI (spark ignition) engine fueled with pure ethanol, methanol and unleaded gasoline. *Energy, 71*, 194-201. doi: 10.1016/j.energy.2014.04.074

Balki, M. K., Sayin, C., & Canakci, M. (2014). The effect of different alcohol fuels on the performance, emission and combustion characteristics of a gasoline engine. *Fuel, 115*, 901-906.

Basheer, I., & Hajmeer, M. (2000). Artificial neural networks: fundamentals, computing, design, and application. *Journal of microbiological methods, 43*(1), 3-31.

Bejaoui, M. A., Beltran, G., Aguilera, M. P., & Jimenez, A. (2016). Continuous conditioning of olive paste by high power ultrasounds: Response surface methodology to predict temperature and its effect on oil yield and virgin olive oil characteristics. *LWT-Food Science and Technology, 69*, 175-184.

Beşikçi, E. B., Arslan, O., Turan, O., & Ölçer, A. (2016). An artificial neural network based decision support system for energy efficient ship operations. *Computers & Operations Research, 66*, 393-401.

Bezerra, M. A., Santelli, R. E., Oliveira, E. P., Villar, L. S., & Escaleira, L. A. (2008). Response surface methodology (RSM) as a tool for optimization in analytical chemistry. *Talanta, 76*(5), 965-977.

Bharadwaz, Y. D., Rao, B. G., Rao, V. D., & Anusha, C. (2016). Improvement of biodiesel methanol blends performance in a variable compression ratio engine using response surface methodology. *Alexandria Engineering Journal, 55*(2), 1201–1209.

Binetti, G., Del Coco, L., Ragone, R., Zelasco, S., Perri, E., Montemurro, C., . . . Schena, F. P. (2017). Cultivar classification of Apulian olive oils: Use of artificial neural networks for comparing NMR, NIR and merceological data. *Food Chemistry, 219*, 131-138.

Bose, P. K., Bodkhe, V. N., Barma, B. D., & Banerjee, R. (2017). Response Surface Methodology Based Multi-objective Optimization of the Performance-Emission Profile of a CI Engine Running on Ethanol in Blends with Diesel *Biofuels* (pp. 201-228): Springer.

Box, G. E., & Behnken, D. W. (1960). Some new three level designs for the study of quantitative variables. *Technometrics, 2*(4), 455-475.

Box, G. E., & Draper, N. R. (1987). *Empirical model-building and response surfaces* (Vol. 424): Wiley New York.

Božnar, M. Z., Grašič, B., de Oliveira, A. P., Soares, J., & Mlakar, P. (2017). Spatially transferable regional model for half-hourly values of diffuse solar radiation for general sky conditions based on perceptron artificial neural networks. *Renewable Energy, 103*, 794-810.

Broustail, G., Halter, F., Seers, P., Moréac, G., & Mounaim-Rousselle, C. (2012). Comparison of regulated and non-regulated pollutants with iso-octane/butanol and iso-octane/ethanol blends in a port-fuel injection spark-ignition engine. *Fuel, 94*, 251-261.

Canakci, M., Ozsezen, A. N., Arcaklioglu, E., & Erdil, A. (2009). Prediction of performance and exhaust emissions of a diesel engine fueled with biodiesel produced from waste frying palm oil. *Expert systems with Applications, 36*(5), 9268-9280.

Carden, E. P., & Fanning, P. (2004). Vibration based condition monitoring: a review. *Structural health monitoring, 3*(4), 355-377.

Cavazzuti, M. (2012). Optimization methods: from theory to design scientific and technological aspects in mechanics: Springer Science & Business Media.

Cay, Y., Cicek, A., Kara, F., & Sağiroğlu, S. (2012). Prediction of engine performance for an alternative fuel using artificial neural network. *Applied Thermal Engineering, 37*, 217-225.

Çay, Y., Korkmaz, I., Çiçek, A., & Kara, F. (2013). Prediction of engine performance and exhaust emissions for gasoline and methanol using artificial neural network. *Energy, 50*, 177-186.

Chakraborty, A., Roy, S., & Banerjee, R. (2016). An experimental based ANN approach in mapping performance-emission characteristics of a diesel engine operating in dual-fuel mode with LPG. *Journal of Natural Gas Science and Engineering, 28*, 15-30.

Channapattana, S., Pawar, A. A., & Kamble, P. G. (2017). Optimisation of operating parameters of DI-CI engine fueled with second generation Bio-fuel and development of ANN based prediction model. *Applied Energy, 187*, 84-95.

Chen, Y.-L., Chen, S., Tsai, J.-M., Tsai, C.-Y., Fang, H.-H., Yang, I.-C., & Liu, S.-Y. (2012). Optimization of suitable ethanol blend ratio for motorcycle engine using response surface method. *Journal of Environmental Science and Health, Part A, 47*(1), 101-108.

Chen, Z., Wu, Y., Huang, J., & Liu, D. (2015a). Metabolic engineering of Klebsiella pneumoniae for the de novo production of 2-butanol as a potential biofuel. *Bioresource technology, 197*, 260-265.

Chen, Z., Wu, Y., Huang, J., & Liu, D. (2015b). Metabolic engineering of Klebsiella pneumoniae for the de novo production of 2-butanol as a potential biofuel. *Bioresour Technol, 197*, 260-265. doi: 10.1016/j.biortech.2015.08.086

Chen, Z., Wu, Z., Liu, J., & Lee, C. (2014). Combustion and emissions characteristics of high n-butanol/diesel ratio blend in a heavy-duty diesel engine and EGR impact. *Energy Conversion and Management, 78*, 787-795. doi: 10.1016/j.enconman.2013.11.037

Chen, Z., Yang, F., Xue, S., Wu, Z., & Liu, J. (2015c). Impact of higher n-butanol addition on combustion and performance of GDI engine in stoichiometric combustion. *Energy Conversion and Management, 106*, 385-392. doi: 10.1016/j.enconman.2015.09.051

Cooper, C. D., & Alley, F. C. (2010). *Air pollution control: A design approach*: Waveland Press.

Costagliola, M. A., De Simio, L., Iannaccone, S., & Prati, M. V. (2013). Combustion efficiency and engine out emissions of a S.I. engine fueled with alcohol/gasoline blends. *Applied Energy, 111*, 1162-1171. doi: 10.1016/j.apenergy.2012.09.042

Daniel, R., Tian, G., Xu, H., Wyszynski, M. L., Wu, X., & Huang, Z. (2011). Effect of spark timing and load on a DISI engine fuelled with 2, 5-dimethylfuran. *Fuel, 90*(2), 449-458.

Dawson, C. W., Abrahart, R. J., & See, L. M. (2007). HydroTest: a web-based toolbox of evaluation metrics for the standardised assessment of hydrological forecasts. *Environmental Modelling & Software, 22*(7), 1034-1052.

Deb, M., Majumder, P., Majumder, A., Roy, S., & Banerjee, R. (2016). Application of artificial intelligence (AI) in characterization of the performance–emission profile of a single cylinder CI engine operating with hydrogen in dual fuel mode: An ANN approach with fuzzy-logic based topology optimization. *international journal of hydrogen energy, 41*(32), 14330-14350.

Debnath, B. K., Saha, U. K., & Sahoo, N. (2015). A comprehensive review on the application of emulsions as an alternative fuel for diesel engines. *Renewable and Sustainable Energy Reviews, 42*, 196-211. doi: 10.1016/j.rser.2014.10.023

Demirbas, A., & Demirbas, M. F. (2011). Importance of algae oil as a source of biodiesel. *Energy Conversion and Management, 52*(1), 163-170.

Dernotte, J., Mounaim-Rousselle, C., Halter, F., & Seers, P. (2009). Evaluation of butanol–gasoline blends in a port fuel-injection, spark-ignition engine. *Oil & Gas Science and Technology – Revue de l'Institut Français du Pétrole, 65*(2), 345-351. doi: 10.2516/ogst/2009034

Dharma, S., Masjuki, H., Ong, H. C., Sebayang, A., Silitonga, A., Kusumo, F., & Mahlia, T. (2016). Optimization of biodiesel production process for mixed Jatropha curcas–Ceiba pentandra biodiesel using response surface methodology. *Energy Conversion and Management, 115*, 178-190.

Dhingra, S., Bhushan, G., & Dubey, K. K. (2014). Multi-objective optimization of combustion, performance and emission parameters in a jatropha biodiesel engine using Non-dominated sorting genetic algorithm-II. *Frontiers of Mechanical Engineering, 9*(1), 81-94.

Dhole, A., Yarasu, R., Lata, D., & Baraskar, S. (2014). Mathematical modeling for the performance and emission parameters of dual fuel diesel engine using hydrogen as secondary fuel. *International Journal of Hydrogen Energy, 39*(24), 12991-13001.

Dhole, A., Yarasu, R., Lata, D., Baraskar, S., & Shaw, D. (2015). Mathematical modeling for the performance and emission parameters of dual-fuel diesel engine using producer gas as secondary fuel. *Biomass Conversion and Biorefinery, 5*(3), 257-270.

Dias, M. O. d. S., Maciel Filho, R., Mantelatto, P. E., Cavalett, O., Rossell, C. E. V., Bonomi, A., & Leal, M. R. L. V. (2015). Sugarcane processing for ethanol and sugar in Brazil. *Environmental Development, 15*, 35-51. doi: 10.1016/j.envdev.2015.03.004

Dimopoulos, P., Rechsteiner, C., Soltic, P., Laemmle, C., & Boulouchos, K. (2007). Increase of passenger car engine efficiency with low engine-out emissions using hydrogen–natural gas mixtures: a thermodynamic analysis. *International Journal of Hydrogen Energy, 32*(14), 3073-3083.

Doğan, O. (2011). The influence of n-butanol/diesel fuel blends utilization on a small diesel engine performance and emissions. *Fuel, 90*(7), 2467-2472. doi: 10.1016/j.fuel.2011.02.033

Elfasakhany, A. (2014). Experimental study on emissions and performance of an internal combustion engine fueled with gasoline and gasoline/n-butanol blends. *Energy Conversion and Management, 88*, 277-283. doi: 10.1016/j.enconman.2014.08.031

Elfasakhany, A. (2015). Experimental investigation on SI engine using gasoline and a hybrid iso-butanol/gasoline fuel. *Energy Conversion and Management, 95*, 398-405. doi: 10.1016/j.enconman.2015.02.022

Elfasakhany, A. (2016). Experimental study of dual n-butanol and iso-butanol additives on spark-ignition engine performance and emissions. *Fuel, 163*, 166-174. doi: 10.1016/j.fuel.2015.09.059

Elfghi, F. (2016). A Hybrid Statistical Approach for Modeling and Optimization of RON; A Comparative Study and Combined Application of Response Surface Methodology (RSM) and Artificial Neural Network (ANN) based on Design of Experiment (DOE). *Chemical Engineering Research and Design*.

Fattah, I. R., Masjuki, H., Kalam, M., Mofijur, M., & Abedin, M. (2014). Effect of antioxidant on the performance and emission characteristics of a diesel engine fueled with palm biodiesel blends. *Energy Conversion and Management, 79*, 265-272.

Feng, R., Fu, J., Yang, J., Wang, Y., Li, Y., Deng, B., . . . Zhang, D. (2015). Combustion and emissions study on motorcycle engine fueled with butanol-gasoline blend. *Renewable Energy, 81*, 113-122.

Ferreira, S. C., Bruns, R., Ferreira, H., Matos, G., David, J., Brandao, G., . . . Souza, A. (2007). Box-Behnken design: an alternative for the optimization of analytical methods. *Analytica chimica acta, 597*(2), 179-186.

Frassoldati, A., Cuoci, A., Faravelli, T., Niemann, U., Ranzi, E., Seiser, R., & Seshadri, K. (2010). An experimental and kinetic modeling study of n-propanol and iso-propanol combustion. *Combustion and Flame, 157*(1), 2-16.

Ganesan, V. (2012). *Internal combustion engines*: McGraw Hill Education (India) Pvt Ltd.

Gani, P., Mohamed Sunar, N., Matias-Peralta, H., Abdul Latiff, A. A., & Mohamad Fuzi, S. F. Z. (2017). Growth of microalgae Botryococcus sp. in domestic wastewater and application of statistical analysis for the optimization of flocculation using alum and chitosan. *Preparative Biochemistry and Biotechnology*, 1-9.

Gentry, T. W., Wiliamowski, B. M., & Weatherford, L. R. (1995). A comparison of traditional forecasting techniques and neural networks. *Intelligent Engineering Systems Through Artificial Neural Networks, 5*, 765-770.

Ghafari, S., Aziz, H. A., Isa, M. H., & Zinatizadeh, A. A. (2009). Application of response surface methodology (RSM) to optimize coagulation–flocculation treatment of leachate using poly-aluminum chloride (PAC) and alum. *Journal of hazardous materials, 163*(2), 650-656.

Ghobadian, B., Rahimi, H., Nikbakht, A., Najafi, G., & Yusaf, T. (2009). Diesel engine performance and exhaust emission analysis using waste cooking biodiesel fuel with an artificial neural network. *Renewable Energy, 34*(4), 976-982.

Gu, X., Huang, Z., Cai, J., Gong, J., Wu, X., & Lee, C.-F. (2012). Emission characteristics of a spark-ignition engine fuelled with gasoline-n-butanol blends in combination with EGR. *Fuel, 93*, 611-617. doi: 10.1016/j.fuel.2011.11.040

Guarieiro, L. L. N., de Souza, A. F., Torres, E. A., & de Andrade, J. B. (2009). Emission profile of 18 carbonyl compounds, CO, CO 2, and NO x emitted by a diesel engine fuelled with diesel and ternary blends containing diesel, ethanol and biodiesel or vegetable oils. *Atmospheric Environment, 43*(17), 2754-2761.

Hamad, K., Khalil, M. A., & Shanableh, A. (2017). Modeling roadway traffic noise in a hot climate using artificial neural networks. *Transportation Research Part D: Transport and Environment, 53*, 161-177.

Hatami, M., Cuijpers, M. C. M., & Boot, M. D. (2015). Experimental optimization of the vanes geometry for a variable geometry turbocharger (VGT) using a Design of Experiment (DoE) approach. *Energy Conversion and Management, 106*, 1057-1070. doi: 10.1016/j.enconman.2015.10.040

Haykin, S., & Network, N. (2004). A comprehensive foundation. *Neural Networks, 2*(2004), 41.

He, B.-Q., Liu, M.-B., & Zhao, H. (2015). Comparison of combustion characteristics of n-butanol/ethanol–gasoline blends in a HCCI engine. *Energy Conversion and Management, 95*, 101-109. doi: 10.1016/j.enconman.2015.02.019

Hirkude, J. B., & Padalkar, A. S. (2014). Performance optimization of CI engine fuelled with waste fried oil methyl ester-diesel blend using response surface methodology. *Fuel, 119*, 266-273.

Ho, T., & Karri, V. (2010). Basic tuning of hydrogen powered car and artificial intelligent prediction of hydrogen engine characteristics. *International Journal of Hydrogen Energy, 35*(18), 10004-10012.

Ho, T., Karri, V., Lim, D., & Barret, D. (2008). An investigation of engine performance parameters and artificial intelligent emission prediction of hydrogen powered car. *International Journal of Hydrogen Energy, 33*(14), 3837-3846.

Hosmath, R., Banapurmath, N., Khandal, S., Gaitonde, V., Basavarajappa, Y., & Yaliwal, V. (2016). Effect of compression ratio, CNG flow rate and injection timing on the performance of dual fuel engine operated on honge oil methyl ester (HOME) and compressed natural gas (CNG). *Renewable Energy, 93,* 579-590.

Hossain, M. S., Chao, O. Z., Ismail, Z., Noroozi, S., & Yee, K. S. (2016). Artificial Neural Networks for Vibration Based Inverse Parametric Identifications: A Review. *Applied Soft Computing*.

Hosseinpour, S., Aghbashlo, M., Tabatabaei, M., & Khalife, E. (2016). Exact estimation of biodiesel cetane number (CN) from its fatty acid methyl esters (FAMEs) profile using partial least square (PLS) adapted by artificial neural network (ANN). *Energy Conversion and Management, 124*, 389-398.

http://www.bbc.com/news/business-33114119 Brazil biofuel industry finds new seetspot 02/08/2015.

Hubadillah, S. K., Othman, M. H. D., Harun, Z., Ismail, A., Iwamoto, Y., Honda, S., . . . Sokri, M. N. M. (2016). Effect of fabrication parameters on physical properties of metakaolin-based ceramic hollow fibre membrane (CHFM). *Ceramics International, 42*(14), 15547–15558.

Ileri, E., Karaoglan, A. D., & Atmanli, A. (2013). Response surface methodology based prediction of engine performance and exhaust emissions of a diesel engine fuelled with canola oil methyl ester. *Journal of Renewable and Sustainable Energy, 5*(3), 1-19.

Ismail, H. M., Ng, H. K., Queck, C. W., & Gan, S. (2012). Artificial neural networks modelling of engine-out responses for a light-duty diesel engine fuelled with biodiesel blends. *Applied Energy, 92*, 769-777.

Javed, S., Murthy, Y. S., Baig, R. U., & Rao, D. P. (2015). Development of ANN model for prediction of performance and emission characteristics of hydrogen dual fueled diesel engine with Jatropha Methyl Ester biodiesel blends. *Journal of Natural Gas Science and Engineering, 26*, 549-557.

Jin, C., Yao, M., Liu, H., Lee, C.-F. F., & Ji, J. (2011). Progress in the production and application of n-butanol as a biofuel. *Renewable and Sustainable Energy Reviews, 15*(8), 4080-4106. doi: 10.1016/j.rser.2011.06.001

Joo, Y. C., & Park, S. Y. (2017). Oil prices and stock markets: Does the effect of uncertainty change over time? *Energy Economics, 61*, 42-51.

Jouzdani, S., Zhou, A., & Akih-Kumgeh, B. (2017). Propanol isomers: Investigation of ignition and pyrolysis time scales. *Combustion and Flame, 176*, 229-244.

Kapusuz, M., Ozcan, H., & Yamin, J. A. (2015). Research of performance on a spark ignition engine fueled by alcohol–gasoline blends using artificial neural networks. *Applied Thermal Engineering, 91*, 525-534.

Karuppasamy, K., Thaheer, A. S. A., Basha, C. A., & Manivannan, A. (2012). The effect of biodiesel blends on single cylinder DI diesel engine and optimization using response surface methodology. *European Journal of Scientific Research, 84*(3), 365-376.

Khattree, R., & Rao, C. R. (2003). *Statistics in industry* (Vol. 22): Gulf Professional Publishing.

Khoobbakht, G., Najafi, G., Karimi, M., & Akram, A. (2016). Optimization of operating factors and blended levels of diesel, biodiesel and ethanol fuels to minimize exhaust emissions of diesel engine using response surface methodology. *Applied Thermal Engineering, 99*, 1006-1017.

Kiani, M. K. D., Ghobadian, B., Ommi, F., Najafi, G., & Yusaf, T. (2012). *Artificial neural networks approach for the prediction of thermal balance of SI engine using ethanol-gasoline blends.* Paper presented at the International Conference on Availability, Reliability, and Security.

Kiran, B., Pathak, K., Kumar, R., & Deshmukh, D. (2016). Statistical optimization using Central Composite Design for biomass and lipid productivity of microalga: A step towards enhanced biodiesel production. *Ecological Engineering, 92*, 73-81.

Koç, M., Sekmen, Y., Topgül, T., & Yücesu, H. S. (2009). The effects of ethanol–unleaded gasoline blends on engine performance and exhaust emissions in a spark-ignition engine. *Renewable Energy, 34*(10), 2101-2106.

Kshirsagar, C. M., & Anand, R. (2017). Artificial neural network applied forecast on a parametric study of Calophyllum inophyllum methyl ester-diesel engine out responses. *Applied energy, 189*, 555-567.

Kumar, B. R., Saravanan, S., Rana, D., & Nagendran, A. (2016). Combined effect of injection timing and exhaust gas recirculation (EGR) on performance and emissions of a DI diesel engine fuelled with next-generation advanced biofuel–diesel blends using response surface methodology. *Energy Conversion and Management, 123*, 470-486.

Kumar, D. V., Kumar, P. R., & Kumari, M. S. (2013). Prediction of performance and emissions of a biodiesel fueled lanthanum zirconate coated direct injection diesel engine using artificial neural networks. *Procedia engineering, 64*, 993-1002.

Laurini, M. P. (2017). The spatio-temporal dynamics of ethanol/gasoline price ratio in Brazil. *Renewable and Sustainable Energy Reviews, 70*, 1-12.

Lee, T., & Reitz, R. D. (2003). Response surface method optimization of a high-speed direct-injection diesel engine equipped with a common rail injection system. *TRANSACTIONS-AMERICAN SOCIETY OF MECHANICAL ENGINEERS JOURNAL OF ENGINEERING FOR GAS TURBINES AND POWER, 125*(2), 541-546.

Lu, J.-G., Lu, C.-T., Chen, Y., Gao, L., Zhao, X., Zhang, H., & Xu, Z.-W. (2014). CO 2 capture by membrane absorption coupling process: application of ionic liquids. *Applied Energy, 115*, 573-581.

Ma, F., Wang, J., Wang, Y., Wang, Y., Zhong, Z., Ding, S., & Zhao, S. (2008). An investigation of optimum control of a spark ignition engine fueled by NG and hydrogen mixtures. *International Journal of Hydrogen Energy, 33*(24), 7592-7606.

MacLean, H. L., & Lave, L. B. (2003). Evaluating automobile fuel/propulsion system technologies. *Progress in Energy and combustion Science, 29*(1), 1-69.

Masum, B., Kalam, M., Masjuki, H., Palash, S., & Fattah, I. R. (2014a). Performance and emission analysis of a multi cylinder gasoline engine operating at different alcohol–gasoline blends. *Rsc Advances, 4*(53), 27898-27904.

Masum, B. M., Masjuki, H. H., Kalam, M. A., Palash, S. M., Wakil, M. A., & Imtenan, S. (2014b). Tailoring the key fuel properties using different alcohols (C2–C6) and their evaluation in gasoline engine. *Energy Conversion and Management, 88*, 382-390. doi: 10.1016/j.enconman.2014.08.050

Masumn, B. M., Masjuki, H. H., Kalam, M. A., Fattah, I. M. R., Palash, S. M., & Abedin, M. J. (2013). Effect of ethanol–gasoline blend on NOx emission in SI engine. *Renewable and Sustainable Energy Reviews, 24*, 209-222. doi: 10.1016/j.rser.2013.03.046

Mat Yasin, M. H., Yusaf, T., Mamat, R., & Fitri Yusop, A. (2014). Characterization of a diesel engine operating with a small proportion of methanol as a fuel additive in biodiesel blend. *Applied Energy, 114*, 865-873. doi: 10.1016/j.apenergy.2013.06.012

McCulloch, W. S., & Pitts, W. (1990). A logical calculus of the ideas immanent in nervous activity. *Bulletin of mathematical biology, 52*(1), 99-115.

Montgomery, D. C. (2008). *Design and analysis of experiments*: John Wiley & Sons.

Myers, R., & Montgomery, D. (2002). Response Surface Methodology, John Wiley&Sons. *Inc., USA*.

Najafi, G., Ghobadian, B., Tavakoli, T., Buttsworth, D. R., Yusaf, T. F., & Faizollahnejad, M. (2009). Performance and exhaust emissions of a gasoline engine with ethanol blended gasoline fuels using artificial neural network. *Applied Energy, 86*(5), 630-639. doi: 10.1016/j.apenergy.2008.09.017

Najafi, G., Ghobadian, B., Yusaf, T., Ardebili, S. M. S., & Mamat, R. (2015). Optimization of performance and exhaust emission parameters of a SI (spark ignition) engine with gasoline–ethanol blended fuels using response surface methodology. *Energy, 90*, 1815-1829.

Namvar-Asl, M., Soltanieh, M., Rashidi, A., & Irandoukht, A. (2008). Modeling and preparation of activated carbon for methane storage I. Modeling of activated carbon characteristics with neural networks and response surface method. *Energy Conversion and Management, 49*(9), 2471-2477.

Negnevitsky, M. (2005). Artificial intelligence: a guide to intelligent systems: Pearson Education.

Nigam, P. S., & Singh, A. (2011). Production of liquid biofuels from renewable resources. *Progress in energy and combustion science, 37*(1), 52-68.

Normann, F., Andersson, K., Leckner, B., & Johnsson, F. (2009). Emission control of nitrogen oxides in the oxy-fuel process. *Progress in Energy and combustion Science, 35*(5), 385-397.

Oğuz, H., Sarıtas, I., & Baydan, H. E. (2010). Prediction of diesel engine performance using biofuels with artificial neural network. *Expert systems with Applications, 37*(9), 6579-6586.

Olah, G. A., Goeppert, A., & Prakash, G. S. (2008). Chemical recycling of carbon dioxide to methanol and dimethyl ether: from greenhouse gas to renewable, environmentally carbon neutral fuels and synthetic hydrocarbons. *The Journal of organic chemistry, 74*(2), 487-498.

Pai, P. S., & Rao, B. S. (2011). Artificial neural network based prediction of performance and emission characteristics of a variable compression ratio CI engine using WCO as a biodiesel at different injection timings. *Applied energy, 88*(7), 2344-2354.

Pandian, M., Sivapirakasam, S., & Udayakumar, M. (2011). Investigation on the effect of injection system parameters on performance and emission characteristics of a twin cylinder compression ignition direct injection engine fuelled with pongamia biodiesel–diesel blend using response surface methodology. *Applied Energy, 88*(8), 2663-2676.

Paul, A., Bose, P. K., Panua, R. S., & Banerjee, R. (2013). An experimental investigation of performance-emission trade off of a CI engine fueled by diesel–compressed natural gas (CNG) combination and diesel–ethanol blends with CNG enrichment. *Energy, 55*, 787-802.

Poompipatpong, C., & Kengpol, A. (2015). Design of a decision support methodology using response surface for torque comparison: An empirical study on an engine fueled with waste plastic pyrolysis oil. *Energy, 82*, 850-856.

Puli, D., & Ravi Kumar, P. (2015). Performance and emission characteristics of Tertiary Butyl Alcohol gasoline blends on a spark ignition engine. *Biofuels, 6*(1-2), 71-78.

Raith, S., Vogel, E. P., Anees, N., Keul, C., Güth, J.-F., Edelhoff, D., & Fischer, H. (2017). Artificial Neural Networks as a powerful numerical tool to classify specific features of a tooth based on 3D scan data. *Computers in Biology and Medicine, 80*, 65-76.

Rao, K. P., Babu, T. V., Anuradha, G., & Rao, B. A. (2016). IDI diesel engine performance and exhaust emission analysis using biodiesel with an artificial neural network (ANN). *Egyptian Journal of Petroleum*.

Rezaei, J., Shahbakhti, M., Bahri, B., & Aziz, A. A. (2015). Performance prediction of HCCI engines with oxygenated fuels using artificial neural networks. *Applied Energy, 138*, 460-473.

Rosenblatt, F. (1958). The perceptron: A probabilistic model for information storage and organization in the brain. *Psychological review, 65*(6), 386.

Roy, S., Banerjee, R., & Bose, P. K. (2014a). Performance and exhaust emissions prediction of a CRDI assisted single cylinder diesel engine coupled with EGR using artificial neural network. *Applied Energy, 119*, 330-340.

Roy, S., Banerjee, R., Das, A. K., & Bose, P. K. (2014b). Development of an ANN based system identification tool to estimate the performance-emission characteristics of a CRDI assisted CNG dual fuel diesel engine. *Journal of Natural Gas Science and Engineering, 21*, 147-158.

Saeidi, S., Jouybanpour, P., Mirvakilli, A., Iranshahi, D., & Klemeš, J. J. (2016). A comparative study between Modified Data Envelopment Analysis and Response Surface Methodology for optimisation of heterogeneous biodiesel production from waste cooking palm oil. *Journal of Cleaner Production, 136*, 23-30.

Saidur, R., Jahirul, M., Hasanuzzaman, M., & Masjuki, H. (2008). Analysis of exhaust emissions of natural gas engine by using response surface methodology. *Journal of Applied Sciences, 8*(19), 3328-3339.

Salvi, B., Subramanian, K., & Panwar, N. (2013). Alternative fuels for transportation vehicles: a technical review. *Renewable and Sustainable Energy Reviews, 25*, 404-419.

Sant'Anna, A. C., Bergtold, J., Featherstone, A., Caldas, M., & Granco, G. (2017). *Does Vertical Integration Increase Efficiency? A Look at Ethanol Plants in the Center-South of Brazil.* Paper presented at the 2017 Annual Meeting, February 4-7, 2017, Mobile, Alabama.

Saraee, H. S., Taghavifar, H., & Jafarmadar, S. (2017). Experimental and numerical consideration of the effect of CeO 2 nanoparticles on diesel engine performance and exhaust emission with the aid of artificial neural network. *Applied Thermal Engineering, 113*, 663-672.

Satake, K., Monaka, T., Yamada, S., Endo, H., Yanagisawa, M., & Abe, T. (2008). The Rapid Development of Diesel Engines Using an Optimization of the Fuel Injection Control. *Mitsubishi Heavy Industries, Ltd. Tech. Review, 45*(3).

Savaliya, M. L., Dhorajiya, B. D., & Dholakiya, B. Z. (2015). Recent advancement in production of liquid biofuels from renewable resources: a review. *Research on Chemical Intermediates, 41*(2), 475-509.

Sayin, C., Ertunc, H. M., Hosoz, M., Kilicaslan, I., & Canakci, M. (2007). Performance and exhaust emissions of a gasoline engine using artificial neural network. *Applied Thermal Engineering, 27*(1), 46-54.

Sayin, C., Uslu, K., & Canakci, M. (2008). Influence of injection timing on the exhaust emissions of a dual-fuel CI engine. *Renewable Energy, 33*(6), 1314-1323.

Shabanpour, H., Yousefi, S., & Saen, R. F. (2017). Forecasting efficiency of green suppliers by dynamic data envelopment analysis and artificial neural networks. *Journal of Cleaner Production, 142*, 1098-1107.

Shahbaz, M., Yusup, S., Inayat, A., Patrick, D. O., & Pratama, A. (2016). Application of response surface methodology to investigate the effect of different variables on conversion of palm kernel shell in steam gasification using coal bottom ash. *Applied Energy, 184*, 1306-1315.

Sharon, H., Jayaprakash, R., Sundaresan, A., & Karuppasamy, K. (2012). Biodiesel production and prediction of engine performance using SIMULINK model of trained neural network. *Fuel, 99*, 197-203.

Sharudin, H., Abdullah, N. R., Najafi, G., Mamat, R., & Masjuki, H. (2017). Investigation of the effects of iso-butanol additives on spark ignition engine fuelled with methanol-gasoline blends. *Applied Thermal Engineering, 114*, 593-600.

Shen, P., & Lukes, J. R. (2015). Impact of global warming on performance of ground source heat pumps in US climate zones. *Energy Conversion and Management, 101*, 632-643. doi: 10.1016/j.enconman.2015.06.027

Shiguemori, É. H., Da Silva, J. D. S., & de Campos Velho, H. F. (2004). Estimation of initial condition in heat conduction by neural network. *Inverse Problems in Science and Engineering, 12*(3), 317-328.

Singh, S. B., Dhar, A., & Agarwal, A. K. (2015). Technical feasibility study of butanol–gasoline blends for powering medium-duty transportation spark ignition engine. *Renewable Energy, 76*, 706-716. doi: 10.1016/j.renene.2014.11.095

Smith, P., Cheng, W. K., & Heywood, J. (2014). Crevice Volume Effect on Spark Ignition Engine Efficiency: SAE Technical Paper.

Surisetty, V. R., Dalai, A. K., & Kozinski, J. (2011). Alcohols as alternative fuels: An overview. *Applied Catalysis A: General, 404*(1–2), 1–11. doi: 10.1016/j.apcata.2011.07.021

Szwaja, S., & Naber, J. D. (2010). Combustion of n-butanol in a spark-ignition IC engine. *Fuel, 89*(7), 1573-1582. doi: 10.1016/j.fuel.2009.08.043

Tan, Y. H., Abdullah, M. O., Nolasco-Hipolito, C., Zauzi, N. S. A., & Abdullah, G. W. (2017). Engine performance and emissions characteristics of a diesel engine fueled with diesel-biodiesel-bioethanol emulsions. *Energy Conversion and Management, 132*, 54-64.

Thewes, M., Müther, M., Brassat, A., Pischinger, S., & Sehr, A. (2012). Analysis of the effect of bio-fuels on the combustion in a downsized DI SI Engine *SAE International Journal of Fuels and Lubricants*.

Thirugnanasambandham, K., Sivakumar, V., & Shine, K. (2016). Studies on treatment of egg processing industry wastewater using electrocoagulation method: optimization using response surface methodology. *Desalination and Water Treatment, 57*(46), 21721-21729.

Tosun, E., Aydin, K., & Bilgili, M. (2016). Comparison of linear regression and artificial neural network model of a diesel engine fueled with biodiesel-alcohol mixtures. *Alexandria Engineering Journal*.

Turkson, R. F., Yan, F., Ali, M. K. A., & Hu, J. (2016). Artificial neural network applications in the calibration of spark-ignition engines: An overview. *Engineering Science and Technology, an International Journal, 19*(3), 1346-1359.

Varol, Y., Öner, C., Öztop, H., & Altun, Ş. (2014). Comparison of methanol, ethanol, or n-butanol blending with unleaded gasoline on exhaust emissions of an SI engine. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 36*(9), 938-948.

Wallner, T., Miers, S. A., & McConnell, S. (2009). A comparison of ethanol and butanol as oxygenates using a spark ignition direct injection, spark ignition engine. *Journal of Engineering for Gas Turbines and Power, 131*. doi: 10.1115/1.3043810

Walther, T., & François, J. M. (2016). Microbial production of propanol. *Biotechnology advances, 34*(5), 984-996.

Wigg, B., Coverdill, R., Lee, C.-F., & Kyritsis, D. (2011). Emissions characteristics of neat butanol fuel using a port fuel-injected, spark-ignition engine: SAE Technical Paper.

Win, Z., Gakkhar, R., Jain, S., & Bhattacharya, M. (2005). Parameter optimization of a diesel engine to reduce noise, fuel consumption, and exhaust emissions using response surface methodology. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 219*(10), 1181-1192.

Witek-Krowiak, A., Chojnacka, K., Podstawczyk, D., Dawiec, A., & Pokomeda, K. (2014). Application of response surface methodology and artificial neural network methods in modelling and optimization of biosorption process. *Bioresour Technol, 160,* 150-160.

Worden, K., & Dulieu-Barton, J. M. (2004). An overview of intelligent fault detection in systems and structures. *Structural health monitoring, 3*(1), 85-98.

Yap, W. K., Ho, T., & Karri, V. (2012). Exhaust emissions control and engine parameters optimization using artificial neural network virtual sensors for a hydrogen-powered vehicle. *International Journal of Hydrogen Energy, 37*(10), 8704-8715.

Younis, S. A., El-Azab, W. I., El-Gendy, N. S., Aziz, S. Q., Moustafa, Y. M., Aziz, H. A., & Amr, S. S. A. (2014). Application of response surface methodology to enhance phenol removal from refinery wastewater by microwave process. *International Journal of Microwave Science and Technology, 2014*.

Yusaf, T., Saleh, K., & Said, M. (2011). Engine performance and emission analysis of LPG-SI engine with the aid of artificial neural network. *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, 225*(5), 591-600.

Yusaf, T. F., Buttsworth, D., Saleh, K. H., & Yousif, B. (2010). CNG-diesel engine performance and exhaust emission analysis with the aid of artificial neural network. *Applied Energy, 87*(5), 1661-1669.

Yusri, I. M., Mamat, R., Azmi, W. H., Najafi, G., Sidik, N. A. C., & Awad, O. I. (2016). Experimental investigation of combustion, emissions and thermal balance of secondary butyl alcohol-gasoline blends in a spark ignition engine. *Energy Conversion and Management, 123,* 1-14. doi: 10.1016/j.enconman.2016.05.082

Yusri, I. M., Mamat, R., Azmi, W. H., Najafi, G., Sidik, N. A. C., & Awad, O. I. (2017). Application of response surface methodology in optimization of performance and exhaust emissions of secondary butyl alcohol-gasoline blends in SI engine. *Energy Conversion and Management, 133,* 178-195.

Zhang, Q., Meng, F., Zha, L., Wang, X., & Zhang, G. (2015). A sensitive cataluminescence-based sensor using a SrCO 3/graphene composite for n-propanol. *Rsc Advances*, *5*(71), 57482-57489.