OPTIMIZATION OF SOLENOID DRIVER AND CONTROLLER FOR GASEOUS FUEL HIGH-PRESSURE DIRECT INJECTOR USING MODEL-BASED APPROACH

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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

Kajian ini memfokuskan kepada sistem Suntikan Langsung (DI) yang menggunakan Gas Asli Termampat (CNG) sebagai bahan bakar. Penyuntik Langsung Gasolin (GDI) yang konvensional telah diubah supaya boleh mengaplikasikan bahan bakar berbentuk gas. Salah satu masalah yang timbul ialah kadar turun naik aliran jisim penyuntik yang tidak menentu. Faktor penting yang membawa kepada masalah yang berlaku adalah pemacu dan pengawal penyuntik yang tidak optimal. Oleh itu, tujuan kajian ini ialah untuk mengenal pasti parameter penyuntik yang paling mempengaruhi, membina model penyuntik secara analitikal serta model berdasarkan data, melakukan pengoptimuman penyuntik berdasarkan model dan mengesahkan nilai saranan optimum penyuntik melalui simulasi dan eksperimen. Rig ujian penyuntik secara mandiri juga telah digunakan sebagai cara bereksperimentasi. Kajian parametrik dilakukan dengan menggunakan model penyuntik berprinsipkan Satu Dimensi (1D) yang dibina di dalam MATLAB Simulink. Pemodelan berdasarkan data menggunakan rancangan tahap satu dan model Interpolasi Fungsi Asas Jejari (RBF) telah diguna pakai berasaskan data yang dikumpul dari simulasi penyuntik. Satu kajian pengoptimuman telah dilakukan menggunakan algoritma Persimpangan Batas Biasa (NBI) dari dalam kotak alat MATLAB iaitu Kalibrasi Berasaskan Model (MBC) untuk menghasilkan nilai saranan penyuntik yang optimal. Akhir sekali, kajian ini mengesahkan nilai optimal penyuntik yang telah diperolehi melalui eksperimentasi dan juga simulasi penyuntik. Berdasarkan keputusan yang terhasil, eksperimentasi menunjukkan tren kadar aliran jisim penyuntik yang menyerupai pengiraan teori kecuali pada titik turun naik kadar aliran jisim gas. Parameter penyuntik yang paling berpengaruh adalah diameter muncung penyuntik dengan nilai kepekaan 1489.71 g/s/m sementara parameter penyuntik paling tidak mempengaruhi adalah pemalar pegas dengan nilai kepekaan 0.000083 g/s/N/m. Pemodelan berdasarkan data telah menghasilkan nilai RMSE 0 serta pengesahan RMSE 0.0249. Hasil simulasi menunjukkan kadar kenaikan aliran jisim sebanyak 15.64% antara pengoptimuman dan garis dasar tatkala hasil eksperimen menunjukkan peningkatan sebanyak 35.79% antara pengoptimuman dan garis dasar. Hasil yang diperoleh dari kajian ini penting untuk meningkatkan keberkesanan strategi kawalan pemacu dan pengawal penyuntik yang didedikasikan khusus untuk penyuntik langsung secara gas.

ABSTRACT

This study focuses on the Direct Injection (DI) system utilizing Compressed Natural Gas (CNG) as the fuel. A conventional Gasoline Direct Injector (GDI) was converted into a gaseous fuel application. One of the issues that arises is the fluctuation in injector mass flow rate. The crucial factor leading to the occurring problem is a non-optimal injector driver and controller. Thus, the purpose of this study is to identify the most influential parameters of the injector, construct an analytical and data-driven model of the injector, conduct the model-based optimization of the injector and verify the optimal injector setup via simulation and experiment. A standalone injector test rig was used as the experimental setup. A parametric study was conducted using a one-dimensional (1D), first principle injector model builds in MATLAB Simulink. Data-driven modelling using a one-stage plan and an Interpolating Radial Basis Function (RBF) model was generated based on data collected from the injector simulation. An optimization study was conducted using Normal Boundary Intersection (NBI) algorithm in MATLAB Model-Based Calibration (MBC) Toolbox to produce an optimal injector setup. Finally, a verification study was performed using the attained optimal injector setup in both experiment and simulation of the injector. Based on the results, the experimental result shows a similar injector mass flow rate trend compared to the theoretical calculation except for the mass flow rate fluctuation point. The most influential injector parameter is the nozzle diameter with a sensitivity value of 1489.71 g/s/m, while the least significant injector parameter is the spring constant with a sensitivity value of 0.000083 g/s/N/m. Data-driven modelling produced an RMSE of 0 and a validation RMSE of 0.0249. The simulation result of the mass flow rate for baseline versus optimization shows an increment of 15.64% compared to the experimental result for baseline versus optimization, which shows an increase of 35.79%. The results obtained from the study are important to increase the effectiveness of control strategies embedded in the development of a dedicated driver and controller for the gaseous fuel direct injector.

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Abe, M., Maekawa, N., Yasukawa, Y., Ishikawa, T., Namaizawa, Y., & Ehara, H. (2012). Quick Response Fuel Injector for Direct-Injection Gasoline Engines. *Journal of Engineering for Gas Turbines and Power*. https://doi.org/10.1115/1.4005995

Alias, M. H. R., Rahim, M. F. A., & Bakar, R. A. (2020). Single hole direct injector simulation validation and parametric sensitivity study. *IOP Conference Series: Materials Science and Engineering*. https://doi.org/10.1088/1757-899X/788/1/012063

Alias, M. H. R., Rahim, M. F. A., & Bakar, R. A. (2022). Optimization of CNG Direct Injector Parameters Using Model-Based Calibrtion Framework. *Recent Trends in Mechatronics Towards Industry 4.0. Lecture Notes in Electrical Engineering, 730*. https://doi.org/https://doi.org/10.1007/978-981-33-4597-3_83

Alias, M. H. R., Rahim, M. F. A., Rodzi, M. H. M. I., & Bakar, R. A. (2018). Effect of Injection Pressure, Injection Duration, and Injection Frequency on Direct Injector's Mass Flow Rate for Compressed Natural Gas Fuel. *MATEC Web of Conferences*, *225*(02008). Retrieved from https://doi.org/10.1051/matecconf/201822502008

Ambrosio, S., & Ferrari, A. (2018). Diesel engines equipped with piezoelectric and solenoid injectors : hydraulic performance of the injectors and comparison of the emissions , noise and fuel consumption. *Applied Energy*, *211*(October 2017), 1324–1342. https://doi.org/10.1016/j.apenergy.2017.11.065

Andsaler, A. R., Khalid, A., Abdullah, N. S. A., Sapit, A., & Jaat, N. (2017). The effect of nozzle diameter , injection pressure and ambient temperature on spray characteristics in diesel engine. *Fifteenth Asian Congress of Fluid Mechanics*, 2–9. https://doi.org/10.1088/1742-6596/755/1/011001

Angadi, S. V., Jackson, R. L., Choe, S.-Y., Flowers, G. T., Suhling, J. C., Chang, Y., & Ham, J. (2009). Reliability and life study of hydraulic solenoid valve . Part 1 : A multi-physics finite element model. *Engineering Failure Analysis*, *16*(3), 874–887. https://doi.org/10.1016/j.engfailanal.2008.08.011

Antunes, J. M. G. (2010). *The Use Of Hydrogen As A Fuel For Compression Ignition Engines*. Newcastle University.

Atkinson, C., Allain, M., & Savonen, C. (2005). Model-Based Transient Calibration Optimization for Next Generation Diesel Engines. In *11th Annual Diesel Engine Emisssions Reduction (DEER) Conference*.

Atkinson, C., Allain, M., & Zhang, H. (2008). Using Model-Based Rapid Transient Calibration to Reduce Fuel Consumption and Emissions in Diesel Engines. *SAE Technical Paper Series*, *01*(1365). https://doi.org/10.4271/2008-01-1365

Auzmendi, J. A., & Moffatt, L. (2010). Increasing the reliability of solution exchanges by monitoring solenoid valve actuation. *Journal of Neuroscience Methods*, *185*, 280–283. https://doi.org/10.1016/j.jneumeth.2009.10.002

Badawy, T., Attar, M. A., Hutchins, P., Xu, H., Venus, J. K., & Cracknell, R. (2018). Investigation of injector coking effects on spray characteristic and engine performance in gasoline direct injection engines. *Applied Energy*, *220*, 375–394. https://doi.org/10.1016/j.apenergy.2018.03.133

Badawy, T., Attar, M. A., Xu, H., & Ghafourian, A. (2018). Assessment of gasoline direct injector fouling e ff ects on fuel injection , engine performance and emissions. *Applied Energy*, *220*, 351–374. https://doi.org/10.1016/j.apenergy.2018.03.032

Baratta, M., Kheshtinejad, H., Laurenzano, D., Misul, D., & Brunetti, S. (2015). Modelling aspects of a CNG injection system to predict its behavior under steady state conditions and throughout driving cycle simulations. *Journal of Natural Gas Science and Engineering*, *24*, 52–63. https://doi.org/10.1016/j.jngse.2015.03.010

Baratta, M., Misul, D., Xu, J., Peletto, C., Preuhs, J., & Salemi, P. (2017). Development of a High Performance Natural Gas Engine with Direct Gas Injection and Variable Valve Actuation. *SAE International*. https://doi.org/10.4271/2017-24-0152

Baratta, M., & Rapetto, N. (2014). Fluid-dynamic and numerical aspects in the simulation of direct CNG injection in spark-ignition engines. *Computers & Fluids*, *103*, 215–233. https://doi.org/https://doi.org/10.1016/j.compfluid.2014.07.028

Baratta, M., & Rapetto, N. (2015). Mixture formation analysis in a direct-injection NG SI engine under different injection timings. *Fuel*, *159*, 675–688. https://doi.org/https://doi.org/10.1016/j.fuel.2015.07.027

Baratta, M., Rapetto, N., Spessa, E., Fuerhapter, A., & Philipp, H. (2012). Numerical and Experimental Analysis of Mixture Formation and Performance in a Direct Injection CNG Engine. *SAE International*. https://doi.org/10.4271/2012-01-0401

Barroso, P. M., Dominguez, J., Sr, M. P., & Ribas, X. (2014). Performance and Emissions of a HD Diesel Engine Converted for Alternative Fuel Use. *SAE Technical Papers*, *01*(2685). https://doi.org/10.4271/2014-01-2685.Copyright

Beccari, S., Pipitone, E., Cammalleri, M., & Genchi, G. (2014). Model-based optimization of injection strategies for SI engine gas injectors. *Journal of Mechanical Science and Technology*, *28*(8), 3311–3323. https://doi.org/10.1007/s12206-014-0742-x

Bertram, C., Rezaei, R., Tilch, B., & Horrick, P. Van. (2014). Development of An Euro VI Engine Using Model-Based Calibration. *MTZ Worldwide*, *75*(10), 4–9.

Boja, D., Becker, M., Flaemig-vetter, T., & Kraemer, S. (2006). *Tool Based Automated ECU Controller Optimization*. *IFAC Proceedings Volumes* (Vol. 39). IFAC. https://doi.org/10.3182/20060912-3-DE-2911.00135

Boretti, A. A., & Watson, H. C. (2009a). Development of a Direct Injection high flexibility Cng/Lpg Spark Ignition engine. *SAE Technical Papers*, *4970*. https://doi.org/10.4271/2009-01-1969

Boretti, A. A., & Watson, H. C. (2009b). Development of a Direct Injection High Flexibility Cng / Lpg Spark Ignition Engine. *SAE International*.

Brahma, I., & Chi, J. N. (2012a). Development of a model-based transient calibration process for diesel engine electronic control module tables-Part 1: Data requirements, processing, and analysis. *International Journal of Engine Research*, *13*(1), 77–96. https://doi.org/10.1177/1468087411424376

Brahma, I., & Chi, J. N. (2012b). Development of a model-based transient calibration process for diesel engine electronic control module tables - Part 2: Modelling and optimization. *International Journal of Engine Research*, *13*(2), 147–168. https://doi.org/10.1177/1468087411424377

Cameretti, M. C., Landolfi, E., Tesone, T., & Caraceni, A. (2019). Virtual Calibration Method for Diesel Engine by Software in The Loop Techniques. *International Journal of Automotive and Mechanical Engineering*, *16*(3), 6940–6957.

Cammalleri, M., Pipitone, E., Beccari, S., & Genchi, G. (2013). A mathematical model for the prediction of the injected mass diagram of a S.I. engine gas injector. *Journal of Mechanical Science and Technology*, *27*(11), 3253–3265. https://doi.org/10.1007/s12206-013-0848-6

Cathcart, G., Houston, R., & Ahern, S. (2004). The Potential of Gasoline Direct Injection for Small Displacement 4-Stroke Motorcycle Applications. *SAE International*, *32*(98).

Chala, G T, Aziz, A. R. A., & Hagos, F. Y. (2017). Combined Effect of Boost Pressure and Injection Timing on The Performance and Combustion of CNG in a DI Spark Ignition Engine. *International Journal of Automotive Technology*, *18*(1), 85–96. https://doi.org/10.1007/s12239

Chala, Girma T, Aziz, A. R. A., & Hagos, F. Y. (2018). Natural Gas Engine Technologies: Challenges and Energy Sustainability Issue. *Energies*, *11*(2934). https://doi.org/10.3390/en11112934

Channappagoudra, M., Ramesh, K., & Manavendra, G. (2020). Effect of injection timing on modi fi ed direct injection diesel engine performance operated with dairy scum biodiesel and Bio-CNG. *Renewable Energy*, *147*, 1019–1032. https://doi.org/10.1016/j.renene.2019.09.070

Chen, H., He, J., & Zhong, X. (2018). Engine combustion and emission fuelled with natural gas : A review. *Journal of the Energy Institute*, 1–14. https://doi.org/10.1016/j.joei.2018.06.005

Chen, W., Pan, J., Fan, B., Liu, Y., & Peter, O. (2017). Effect of injection strategy on fuel-air mixing and combustion process in a direct injection diesel rotary engine (DI-DRE). *Energy Conversion and Management*, *154*(October), 68–80. https://doi.org/10.1016/j.enconman.2017.10.048

Cheng, Q., Zhang, Z., & Xie, N. (2015a). Power losses analysis of the gasoline direct injector within different driven strategies. *Applied Thermal Engineering*. https://doi.org/10.1016/j.applthermaleng.2015.08.053

Cheng, Q., Zhang, Z., & Xie, N. (2015b). Power losses and dynamic response analysis of ultra-high speed solenoid injector within different driven strategies. *Applied Thermal Engineering*, *91*, 611–621. https://doi.org/10.1016/j.applthermaleng.2015.08.053

Chincholkar, S. P., & Suryawanshi, J. G. (2016). Gasoline Direct Injection : An Efficient Technology. *Energy Procedia*, *90*(December 2015), 666–672. https://doi.org/10.1016/j.egypro.2016.11.235

Chitsaz, I., Hassan, M., Asghar, A., & Hajialimohammadi, A. (2013). Experimental and numerical investigation on the jet characteristics of spark ignition direct injection gaseous injector. *Applied Energy*, *105*, 8–16. https://doi.org/10.1016/j.apenergy.2012.11.023

Chiu, A. S. K. (2010). *The Development Of A Piezoelectric Fuel Injector For Diesel Engine*. Ryerson University.

Cho, H. M., & He, B.-Q. (2007). Spark ignition natural gas engines — A review. *Energy Conversion and Management*, *48*, 608–618. https://doi.org/10.1016/j.enconman.2006.05.023

Choi, M., Lee, S., & Park, S. (2015). Numerical and experimental study of gaseous fuel injection for CNG direct injection. *Fuel*, *140*, 693–700. https://doi.org/https://doi.org/10.1016/j.fuel.2014.10.018

Choi, M., Song, J., & Park, S. (2016). Modeling of the fuel injection and combustion process in a CNG direct injection engine. *Fuel*, *179*, 168–178. https://doi.org/https://doi.org/10.1016/j.fuel.2016.03.099

Chung, M., Kim, J., Kim, S., Sung, G., & Lee, J. (2015). Effects of hydraulic flow and spray characteristics on diesel combustion in CR direct-injection engine with indirect acting Piezo injector. *Journal of Mechanical Science and Technology*, *29*(6), 2517–2528. https://doi.org/10.1007/s12206-015-0547-6

Chunming, H. U., Shengzhi, H. O. U., Zhangsong, Z., Bin, L. I. U., Na, L. I. U., Yong, Y. U., & Xijuan, S. (2011). Mixture Preparation and Combustion of CNG Low-Pressure Compound Direct Injection Spark-Ignited Engines. *Transactions of Tianjin University*, *17*(6), 411–417. https://doi.org/10.1007/s12209

Corti, E., Cavina, N., Cerofolini, A., Forte, C., Mancini, G., Moro, D., … Ravaglioli, V. (2014). Transient Spark Advance calibration approach. *Energy Procedia*, *45*, 967–976. https://doi.org/10.1016/j.egypro.2014.01.102

Cvetkovic, D., Cosic, I., & Subic, A. (2008). Improved performance of the electromagnetic fuel injector solenoid actuator using a modelling approach. *International Journal of Applied Electromagnetics and Mechanics*, *27*, 251–273.

Deshmukh, A. Y., Falkenstein, T., Pitsh, H., Khosravi, M., Bebber, D. Van, & Klaas, M. (2018). Numerical Investigation of Direct Gas Injection in an Optical Internal Combustion Engine, 1–27. https://doi.org/10.4271/2018-01-0171.Abstract

Douailler, B., Ravet, F., Delpech, V., Soleri, D., Reveille, B., & Kumar, R. (2011). Direct injection of CNG on high compression ratio spark ignition engine: Numerical and experimental investigation. *SAE 2011 World Congress and Exhibition*, *2011-01–09*. https://doi.org/10.4271/2011-01-0923

Duronio, F., Vita, A. De, Allocca, L., & Anatone, M. (2020). Gasoline direct injection engines – A review of latest technologies and trends . Part 1 : Spray breakup process. *Fuel*, *265*(December 2019), 116948. https://doi.org/10.1016/j.fuel.2019.116948

Duronio, F., Vita, A. De, Montanaro, A., & Villante, C. (2020). Gasoline direct injection engines – A review of latest technologies and trends . Part 2. *Fuel, 265*(July 2019), 116947. https://doi.org/10.1016/j.fuel.2019.116947

Erfan, I., Chitsaz, I., Ziabasharhagh, M., Hajialimohammadi, A., & Fleck, B. (2015). Injection characteristics of gaseous jet injected by a single-hole nozzle direct injector. *Fuel*, *160*, 24–34. https://doi.org/https://doi.org/10.1016/j.fuel.2015.07.037

Erfan, I., Hajialimohammadi, A., Chitsaz, I., Ziabasharhagh, M., & Martinuzzi, R. J. (2017). Influence of chamber pressure on CNG jet characteristics of a multi-hole high pressure injector. *Fuel*, *197*, 186–193. https://doi.org/10.1016/j.fuel.2017.02.018

Everett, R. V. (2011). *An Improved Model-Based Methodology for Calibration of an Alternative Fueled Engine*. The Ohio State University.

Fan, B., Pan, J., Yang, W., Pan, Z., Bani, S., Chen, W., & He, R. (2017). Combined effect of injection timing and injection angle on mixture formation and combustion process in a direct injection (DI) natural gas rotary engine. *Energy*, *128*, 519–530. https://doi.org/10.1016/j.energy.2017.04.052

Farzaneh-Gord, M., Rahbari, H. R., & Deymi-Dashtebayaz, M. (2014). Effects of Natural Gas Compositions on CNG Fast Filling Process for Buffer Storage System, *69*(2), 319–330. https://doi.org/10.2516/ogst/2012010

Ferrari, A., Paolicelli, F., & Pizzo, P. (2015). The new-generation of solenoid injectors equipped with pressure-balanced pilot valves for energy saving and dynamic response improvement. *Applied Energy*, *151*, 367–376. https://doi.org/10.1016/j.apenergy.2015.03.074

Firmansyah, & Aziz, A. R. A. (2011). Thermodynamic Analysis of CNG DI Engine Operating with Different Spray Angle. *IEEE*, 375–380.

Ge, H., Shi, Y., Reitz, R. D., Wickman, D. D., & Willems, W. (2009). Optimization of a HSDI Diesel Engine for Passenger Cars Using a Multi-Objective Genetic Algorithm and Multi-Dimensional Modeling, *2*(1), 691–713.

Gogolev, I. M., & Wallace, J. S. (2017). Study of Assisted Compression Ignition in a Direct Injected Natural Gas Engine. *Journal of Engineering for Gas Turbines and Power*, *139*(122802), 1–12. https://doi.org/10.1115/1.4036968

Gogolev, I. M., & Wallace, J. S. (2018). Performance and emissions of a compression-ignition direct-injected natural gas engine with shielded glow plug ignition assist. *Energy Conversion and Management*, *164*, 70–82. https://doi.org/10.1016/j.enconman.2018.02.071

Golzari, R. (2018). *Experimental Study of The Impact of Port and Direct Fuel Injection Strategies on The Efficiency, Performance and Emissions of a Downsized GDI Engine*. Brunel University.

Grahn, M. (2013). *Model-Based Diesel Engine Management System Optimization A Strategy for Transient Engine Operation*. Chalmers University of Technology.

Guerrier, M., & Cawsey, P. (2004). The Development of Model Based Methodologies for Gasoline IC Engine. *SAE Technical Paper Series*, *01*(1466).

Gutjahr, T., Kruse, T., & Huber, T. (2017). Advanced Modeling and Optimization For Virtual Calibration of Internal Combustion Engines. In *2017 Ground VehicleSystems Engineering and Technology Symposium (GVSETS)*.

Ha, J. Y., Park, J. S., & Kang, J. H. (2010). Effects of The Throttle Opening Ratio and The Injection Timing of CNG on The Combustion Characteristics of a DI Engine. *International Journal of Automotive Technology*, *11*(1), 11–17. https://doi.org/10.1007/s12239

Hajialimohammadi, A., Edgington-mitchell, D., Honnery, D., Montazerin, N., Abdullah, A., & Agha, M. (2016). Ultra high speed investigation of gaseous jet injected by a single-hole injector and proposing of an analytical method for pressure loss prediction during transient injection. *Fuel*, *184*, 100–109. https://doi.org/10.1016/j.fuel.2016.06.112

Hajialimohammadi, A., Honnery, D., Abdullah, A., & Agha, M. (2013). Time resolved characteristics of gaseous jet injected by a group-hole nozzle. *Fuel*, *113*, 497–505. https://doi.org/10.1016/j.fuel.2013.05.050

Hamzehloo, A., & Aleiferis, P. (2013). Computational Study of Hydrogen Direct Injection for Internal Combustion Engines. *SAE International*, *1*(2524). https://doi.org/10.4271/2013-01-2524

Hao, H., Liu, Z., Zhao, F., & Li, W. (2016). Natural gas as vehicle fuel in China: A review. *Renewable and Sustainable Energy Reviews*, *62*, 521–533.

Hardie, C., Tait, H., Craig, S., Chase, J. G., Smith, B. W., & Harris, G. (2002). Automated tuning of an engine management unit for an automotive engine. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, *216*(10), 841–849. https://doi.org/10.1177/095440700221600107

Hessel, R. P., & Reitz, R. D. (2002). Diesel Engine Injection Rate-Shape Optimization Using Genetic Algorithms and Multi- Dimensional Modeling for a Range of Operating Modes, 1–5.

Ho, T., & Karri, V. (2011a). Hydrogen powered car : Two-stage modelling system. *International Journal of Hydrogen Energy*, *36*(16), 10065–10079. https://doi.org/10.1016/j.ijhydene.2011.05.020

Ho, T., & Karri, V. (2011b). Optimising multi-objective control methodology of a hydrogen powered car. *International Journal of Hydrogen Energy*, *36*(10), 6269–6280. https://doi.org/10.1016/j.ijhydene.2011.02.041

Horesh, L., Kessel, T. van, Conn, A., Kormaksson, M., & Saliu, O. (2016). Towards a First-Principles Data-Driven Symbiosis. *Optimization and Uncertainty Quantification in Energy and Industrial Applications*.

Huang, D., Ding, H., Wang, Z., & Huang, R. (2011). Design of Drive Circuit for GDI Injector. *IEEE*, 6–9.

Huang, Y., Hong, G., & Huang, R. (2016). Effect of injection timing on mixture formation and combustion in an ethanol direct injection plus gasoline port injection (EDI þ GPI) engine. *Energy*, *111*, 92–103. https://doi.org/10.1016/j.energy.2016.05.109

Huang, Z., Shiga, S., Ueda, T., Nakamura, H., Ishima, T., Obokata, T., … Kono, M. (2003). Correlation of ignitability with injection timing for direct injection combustion fuelled with compressed natural gas and gasoline, *217*, 499–506.

Hung, N. B., & Lim, O. T. (2019). A simulation and experimental study on the operating characteristics of a solenoid gas injector, *11*(1), 1–14. https://doi.org/10.1177/1687814018817421

Husted, H. L., Karl, G., Schilling, S., & Weber, C. (2014). Direct Injection of CNG for Driving Performance with Low CO2. *23rd Aachen Colloquium Automobile and Engine Technology*, (2), 829–850.

Isermann, R., & Sequenz, H. (2016). Model-based development of combustion-engine control and optimal calibration for driving cycles : general procedure and application. *IFAC-PapersOnLine*, *49*(11), 633–640. https://doi.org/10.1016/j.ifacol.2016.08.092

Jankowski, A., Sandel, A., Seczyk, J., & Sieminska-Jankowska, B. (2002). Some Problems of Improvement of Fuel Efficiency and Emissions in Internal Combustion Engines. *Journal of KONES Internal Combustion Engines*, (1), 333–356.

Jiang, C., Parker, M. C., Helie, J., Spencer, A., Garner, C. P., & Wigley, G. (2019). Impact of gasoline direct injection fuel injector hole geometry on spray characteristics under fl ash boiling and ambient conditions. *Fuel*, *241*, 71–82. https://doi.org/10.1016/j.fuel.2018.11.143

Jiang, S., Nutter, D., & Gullitti, A. (2012). Implementation of Model-Based Calibration for a Gasoline Engine. *SAE International*, *01*(0722). https://doi.org/10.4271/2012-01-0722

Jorach, R. W., Bercher, P., Meissonnier, G., & Milovanovic, N. (2011). Common Rail System from Delphi with Solenoid Valves and Single Plunger Pump, 38–43. https://doi.org/10.1365/s40112-012-0020-1

Kalam, M. A., & Masjuki, H. H. (2011). An experimental investigation of high performance natural gas engine with direct injection. *Energy*, *36*(5), 3563–3571. https://doi.org/https://doi.org/10.1016/j.energy.2011.03.066

Kar, T., & Agarwal, A. K. (2015). Development of a single cylinder CNG direct injection engine and its performance, emissions and combustion characteristics. *International Journal of Oil, Gas and Coal Technology*, *10*(2), 204–220. https://doi.org/10.1504/IJOGCT.2015.070839

Keskinen, K., Kaario, O., Nuutinen, M., Vuorinen, V., Künsch, Z., Ola, L., & Larmi, M. (2016). Mixture formation in a direct injection gas engine : Numerical study on nozzle type , injection pressure and injection timing effects. *Energy*, *94*, 542–556. https://doi.org/10.1016/j.energy.2015.09.121

Khan, muhammad I., Yasmin, T., & Shakoor, A. (2015). Technical overview of compressed natural gas (CNG) as a transportation fuel. *Renewable and Sustainable Energy Reviews*, *51*, 785–797. https://doi.org/10.1016/j.rser.2015.06.053

Kim, J. G., & Lee, C. H. (2016). An experimental study of the driving of a solenoid type diesel common rail injector using microprocessors, *8*(5), 2346–2354. https://doi.org/10.21817/ijet/2016/v8i5/160805046

Kumar, A., Kumar, A., Banerjee, N., Mohan, N., & B., A. (2016). Study of the Injector Drive Circuit for a high pressure GDI Injector. *2016 International Conference on Recent Advances and Innovations in Engineering (ICRAIE)*, 1–6. https://doi.org/10.1109/ICRAIE.2016.7939562

Kumar, S., Pai, P. S., & Rao, B. R. S. (2012). Radial-Basis-Function-Network-Based Prediction of Performance and Emission Characteristics in a Bio Diesel Engine Run on WCO Ester, *2012*. https://doi.org/10.1155/2012/610487

Kurniawan, Wendy H, Abdullah, S., Nopiah, Z. M., & Sopian, K. (2007). The Application of Artificial Neural Network in Predicting and Optimizing Power and Emissions in a Compressed Natural Gas Direct Injection Engine, (724), 776–790.

Kurniawan, Wendy Hardyono, & Abdullah, S. (2008). Numerical analysis of the combustion process in a four-stroke compressed natural gas engine with direct injection system, *22*, 1937–1944. https://doi.org/10.1007/s12206-008-0737-6

Lather, R. S., & Das, L. M. (2019). Performance and emission assessment of a multi- cylinder S . I engine using CNG & HCNG as fuels. *International Journal of Hydrogen Energy*, *44*(38), 21181–21192. https://doi.org/10.1016/j.ijhydene.2019.03.137

Lee, B. (2005). *Methodology for rapid static and dynamic model-based engine calibration and optimization*. The Ohio State University.

Lee, S. H., Howlett, R., & Walters, S. D. (2004). Engine Fuel Injection Control using Fuzzy Logic.

Lee, S., Kim, C., Lee, S., Lee, J., & Kim, J. (2020). Diesel injector nozzle optimization for high CNG substitution in a dual-fuel heavy-duty diesel engine. *Fuel*, *262*(July 2019), 116607. https://doi.org/10.1016/j.fuel.2019.116607

Lee, Y., & Lee, C. H. (2018). Development of Diesel Piezo Injector Driver Using Microcontrollers. *Journal of Engineering and Applied Sciences*, *13*(18), 4860–4865.

Lei, Y., Liu, J., Qiu, T., Li, Y., Wang, Y., Wan, B., & Liu, X. (2019). Gas jet flow characteristic of high-pressure methane pulsed injection of single-hole cylindrical nozzle. *Fuel*, *257*(August), 116081. https://doi.org/10.1016/j.fuel.2019.116081

Li, X., Wang, S., Zhang, Y., & Xiong, Q. (2010). Methodology for Model-Based Calibration on 4jb1 High-Pressure Common-Rail Diesel Engine. https://doi.org/10.1109/ETCS.2010.546

Lino, P., & Maione, G. (2016). Accurate dynamic modeling of an electronically controlled CNG injection system. *IFAC-PapersOnLine*, *49*(11), 490–496. https://doi.org/10.1016/j.ifacol.2016.08.072

Lino, P., Maione, G., Kapetina, M. n., & Rapaic, M. R. (2015). Parameter estimation in non-linear models of pressure dynamics in CNG injection systems. *IEEE Transactions on Industry Applications*, *987*(1), 4799–7800.

Lino, P., Maione, G., & Saponaro, F. (2015). Fractional-Order Modeling of High-Pressure Fluid-Dynamic Flows: An Automotive Application. *IFAC-PapersOnLine*, *48*(1), 382–387. https://doi.org/10.1016/j.ifacol.2015.05.093

Lippert, A. M., Tahry, S. H. El, Huebler, M. S., Parrish, S. E., Inoue, H., Nakama, T., & Abe, T. (2004). Development and Optimization of a Small- Displacement Spark-Ignition Direct-Injection Engine – Stratified Operation, *1*(33).

Liu, E., & Su, W. (2019). Study on Effects of Common Rail Injector Drive Circuitry with Different Freewheeling Circuits on Control Performance and Cycle-by-Cycle Variations. *Energies*, *12*(564). https://doi.org/10.3390/en12030564

Liu, Y., Hwang, S. I., Yeom, J. K., & Chung, S. S. (2014). Experimental Study On The Spray and Combustion Characteristics of SIDI CNG. *International Journal of Automotive Technology*, *15*(3), 353–359. https://doi.org/10.1007/s12239−014−0037−3

Liu, Yu, Yeom, J., & Chung, S. (2013). A study of spray development and combustion propagation processes of spark-ignited direct injection (SIDI) compressed natural gas (CNG). *Mathematical and Computer Modelling*, *57*(1), 228–244. https://doi.org/https://doi.org/10.1016/j.mcm.2011.06.035

Liu, Yu, Yeom, J. K., & Chung, S. S. (2012). An experimental study on the effects of impingement-walls on the spray and combustion characteristics of SIDI CNG. *Journal of Mechanical Science and Technology*, *26*(8), 2239–2246. https://doi.org/10.1007/s12206-012-0604-3

Lu, H., Deng, J., Hu, Z., Wu, Z., & Li, L. (2014). Impact of Control Methods on Dynamic Characteristic of High Speed Solenoid Injectors. *SAE International*, *7*(3). https://doi.org/10.4271/2014-01-1445

Mahato, C. (2010). *Lean Burn and Stratified Combustion Strategies for Small Utility Engines*. The University of Alabama.

Majczak, A., Barański, G., Sochaczewski, R., & Siadkowska, K. (2017). Cng Injector Research for Dual Fuel Engine. *Advances in Science and Technology Research Journal*, *11*(1), 212–219. https://doi.org/10.12913/22998624/68458

Martins, F. P., & Souza, F. J. De. (2018). Mixture Formation Analysis in a Direct Injection Spark Ignition (DISI) Engine.

Matsumoto, S., Date, K., Taguchi, T., & Herrmann, O. E. (2013). The New Denso Common Rail Diesel Solenoid Injector, 24–29.

Mazlan, S. K. (2017). *Study of Direct Injection and Pre-Chamber Application in Light Duty Gaseous Fuel Engines*. RMIT University.

Misul, D. A., Baratta, M., & Kheshtinejad, H. (2014). Fluid-Dynamic Modeling and Advanced Control Strategies for a Gaseous-Fuel Injection System. https://doi.org/10.4271/2014-01-1096.Copyright

Model-Based Calibration Toolbox Model Browser User's Guide. (2004) (Version 2). The MathWorks, Inc.

Mohamad, T. I. (2009). Compressed natural gas direct injection (spark plug fuel injector). *Natural Gas*, 289–308.

Mohammadi, A., Manzie, C., & Nesic, D. (2014). Online optimization of spark advance in alternative fueled engines using extremum seeking control, *29*, 201–211. https://doi.org/10.1016/j.conengprac.2014.02.008

Mohan, B., Yang, W., Yu, W., Tay, K. L., & Chou, S. K. (2015). Numerical investigation on the effects of injection rate shaping on combustion and emission characteristics of biodiesel fueled CI engine q. *Applied Energy*, *160*, 737–745. https://doi.org/10.1016/j.apenergy.2015.08.034

Mohd, M., Ali, M. S., Salim, M. A., Bakar, R. A., Fudhail, A. M., Hassan, M. Z., & S, A. M. M. (2015). Performance analysis of a spark ignition engine using compressed natural gas (CNG) as fuel. *Energy Procedia*, *68*, 355–362. https://doi.org/10.1016/j.egypro.2015.03.266

Moon, S. (2018). Potential of direct-injection for the improvement of homogeneous-charge combustion in spark-ignition natural gas engines. *Applied Thermal Engineering*, *136*(January), 41–48. https://doi.org/10.1016/j.applthermaleng.2018.01.068

Morton, T., Connors, R., Maloney, P., & Sampson, D. (2002). Model-Based Optimal Calibration of a Dual Independent Variable Valve-Timing Engine.

Movahednejad, E., Ommi, F., & Nekofar, K. (2013). Experimental Study of Injection Characteristics of a Multi-hole port injector on various Fuel Injection pressures and Temperatures, *01116*, 1–5.

Mutschler, K., Dwivedi, S., Kartmann, S., Bammesberger, S., Koltay, P., Zengerle, R., & Tanguy, L. (2014). Mechatronics Multi physics network simulation of a solenoid dispensing valve. *Mechatronics*, *24*(3), 209–221. https://doi.org/10.1016/j.mechatronics.2014.02.005

Mutumba, A., Cheeseman, K., Clarke, H., & Wen, D. (2018). Design and development of a direct injection system for cryogenic engines. *Cryogenics*, *91*(January), 77–86. https://doi.org/10.1016/j.cryogenics.2017.12.009

Nguyen, K., Nguyen, V., Hoang-dinh, L., & Nguyen, T. (2019). Performance and emission characteristics of a port fuel injected , spark ignition engine fueled by compressed natural gas. *Sustainable Energy Technologies and Assessments*, *31*(October 2018), 383–389. https://doi.org/10.1016/j.seta.2018.12.018

Nikzadfar, K., & Shamekhi, A. H. (2019). Investigating a new model-based calibration procedure for optimizing the emissions and performance of a turbocharged diesel engine. *Fuel*, *242*(August 2017), 455–469. https://doi.org/10.1016/j.fuel.2019.01.072

Ninish, S., Vaidyanathan, A., & Nandakumar, K. (2018). Spray Characteristics of Liquid-Liquid Pintle. *Experimental Thermal and Fluid Science*. https://doi.org/10.1016/j.expthermflusci.2018.03.033

Park, S., Kim, Y., Woo, S., & Lee, K. (2017). Optimization and calibration strategy using design of experiment for a diesel engine, *123*, 917–928.

Payri, R., Bracho, G., Gimeno, J., & Bautista, A. (2018). Rate of injection modelling for gasoline direct injectors. *Energy Conversion and Management*, *166*(May), 424–432. https://doi.org/10.1016/j.enconman.2018.04.041

Pipitone, E., Beccari, S., Cammalleri, M., & Genchi, G. (2014). Experimental Model-Based Linearization of a S . I . Engine Gas Injector Flow Chart, *60*, 694–708. https://doi.org/10.5545/sv-jme.2013.1321

Pipitone, E., Cagnes, F., & Beccari, A. (2008). Performance Prevision of a Turbocharged Natural Gas Fuelled S.I. Engine. https://doi.org/10.4271/2008-36-0058

Postrioti, L., Cavicchi, A., Paolino, D., Guido, C., Parotto, M., & Di, R. (2016). An experimental and numerical analysis of pressure pulsation effects of a Gasoline Direct Injection system. *FUEL*, *173*, 8–28. https://doi.org/10.1016/j.fuel.2016.01.012

Prucka, R. G. (2008). *An Experimental Characterization of a High Degree of Freedom Spark-Ignition Engine to Achieve Optimized Ignition Timing Control*. The University of Michigan.

Quintana, S. H., Castaño-mesa, E. S., Marín, S., Bedoya, I. D., Zapata, J. F., Quintana, S. H., … Quintana, S. H. (2018). Measurement and control of natural gas mass flow in a dual-fuel engine operating at partial load through sonic nozzles. *Flow Measurement and Instrumentation*. https://doi.org/10.1016/j.flowmeasinst.2018.12.003

Rajagopalan, S. S. V. (2008). *Model Based Control Design and Rapid Calibration For Air To Fuel Ratio Control of Stoichiometric Engines*. The Ohio State University.

Rakshit, S. (2012). *High Speed Flow Simulation in Fuel Injector Nozzles*. University of Massachusetts Amherst.

Roepke, K. (2014). Design of Experiments for Engine Calibration. *Journal of The Society of Instrument and Control Engineers*, *53*(4), 322–327.

Sakawaki, A., Kaji, H., Yamamoto, M., & Sakoda, S. (2009). Real-time Engine Control Parameters Optimization Method for Small Diesel Engine by Multi Objective Genetic Algorithm, *2*(1).

Sankesh, D., Edsell, J., Mazlan, S., & Lappas, P. (2017). Comparative study between early and late injection in a natural-gas fuelled spark-ignited direct-injection engine. *Energy Procedia*, *110*(December 2016), 275–280. https://doi.org/10.1016/j.egypro.2017.03.139

Sankesh, D., & Lappas, P. (2017). Natural-Gas Direct-Injection for Spark-Ignition Engines - A Review on Late-Injection Studies. https://doi.org/10.4271/2017-26-0067.Copyright

Sankesh, D., & Lappas, P. (2019). An experimental and numerical study of natural gas jets for direct injection internal combustion engines. *Fuel*. https://doi.org/10.1016/j.fuel.2019.116745

Sankesh, D., Petersen, P., & Lappas, P. (2018). Flow characteristics of natural-gas from an outward-opening nozzle for direct injection engines. *Fuel*, *218*(December 2017), 188–202. https://doi.org/10.1016/j.fuel.2018.01.009

Satkoski, C. A., Shaver, G. M., More, R., Meckl, P., & Memering, D. (2009). *Dynamic Modeling of a Piezoelectric Actuated Fuel Injector*. *IFAC Proceedings Volumes* (Vol. 42). IFAC. https://doi.org/10.3182/20091130-3-FR-4008.00031

Schimpf, P. H. (2013). A Detailed Explanation of Solenoid Force. *International Journal on Recent Trends in Engineering and Technology*, *8*(2). https://doi.org/01.IJRTET.8.2. 25

Schlosser, A., Kinoo, B., Salber, W., Werner, S., & Ademes, N. (2007). Modern Powertrain Development with Model-Based Methods, *68*.

Seboldt, D., Lejsek, D., & Bargende, M. (2016). Injection strategies for low HC raw emissions in SI engines with CNG direct injection. *Automotive and Engine Technology*, *1*(1), 81–91. https://doi.org/10.1007/s41104-016-0002-4

Seboldt, D., Lejsek, D., Wentsch, M., Chiodi, M., & Bargende, M. (2016). Numerical and Experimental Studies on Mixture Formation with an Outward-Opening Nozzle in a SI Engine with CNG-DI. https://doi.org/10.4271/2016-01-0801.Copyright

Semin, & Bakar, R. A. (2008). A Technical Review of Compressed Natural Gas as an Alternative Fuel for Internal Combustion Engines, *1*(4), 302–311.

Semin, Cahyono, B., Amiadji, & Bakar, R. A. (2015). Air-fuel mixing and fuel flow velocity modeling of multi holes injector nozzle on CNG marine engine. *Procedia Earth and Planetary Science*, *14*, 101–109. https://doi.org/10.1016/j.proeps.2015.07.090

Semin, Ismail, A. R., & Bakar, R. A. (2009). Diesel Engine Convert to Port Injection CNG Engine Using Gaseous Injector Nozzle Multi Holes Geometries Improvement : A Review, *2*(2), 268–278.

Sen, A. K., Zheng, J., & Huang, Z. (2011). Dynamics of cycle-to-cycle variations in a natural gas direct-injection spark-ignition engine. *Applied Energy*, *88*(7), 2324–2334. https://doi.org/10.1016/j.apenergy.2011.01.009

Sequenz, H., & Isermann, R. (2011). Emission Model Structures for an Implementation on Engine Control Units. *IFAC Proceedings Volumes*, *44*(1), 11851–11856. https://doi.org/10.3182/20110828-6-IT-1002.03131

Sequenz, H., Mrosek, M., & Isermann, R. (2010). A Global-Local Emissioin-Model For NOx and Soot Emissions of Turbocharged CR-Diesel Engines. In *ASME 2010 Dynamic Systems and Control Conference* (pp. 1–8).

Serras-pereira, J., Aleiferis, P., Richardson, D., & Wallace, S. (2007). Spray Development in a Direct-Injection Spark-Ignition Engine. *SAE Technical Paper Series*, *1*(2712).

Sevik, J. (2017). *Impact of Natural Gas Direct Injection on Thermal Efficiency in a Spark Ignition Engine*. Michigan Technological University.

Shamsudeen, A., Abdullah, S., Ariffin, A. K., Rasani, M. R. M., & Ali, Y. (2014). Design and Simulation of a Cylinder Head Structure For a Compressed Natural Gas Direct Injection Engine. *International Journal of Automotive and Mechanical Engineering*, *9*, 1620–1629. https://doi.org/http://dx.doi.org/10.15282/ijame.9.2013.12.0134

Sharafi, J., Moase, W. H., & Manzie, C. (2018). Multiplexed extremum seeking for calibration of spark timing in a CNG-fuelled engine. *Control Engineering Practice*, *72*(October 2017), 42–52. https://doi.org/10.1016/j.conengprac.2017.11.005

Shinde, T. B. (2012). Experimental investigation on effect of combustion chamber geometry and port fuel injection system for CNG engine, *2*(7), 49–54.

Shrivastava, N., & Khan, Z. M. (2017). Application of Soft Computing in the Field of Internal Combustion Engines : A Review. *Archives of Computational Methods in Engineering*, *0*(0), 0. https://doi.org/10.1007/s11831-017-9212-9

Singh, E., Morganti, K., & Dibble, R. (2019). Dual-fuel operation of gasoline and natural gas in a turbocharged engine. *Fuel*, *237*(May 2018), 694–706. https://doi.org/10.1016/j.fuel.2018.09.158

Sohrabiasl, I., Gorji-bandpy, M., Hajialimohammadi, A., & Mirsalim, M. A. (2017). Effect of open cell metal porous media on evolution of high pressure diesel fuel spray. *Fuel*, *206*, 133–144. https://doi.org/10.1016/j.fuel.2017.06.007

Solomatine, D. P., & Ostfeld, A. (2008). Data-driven modelling : some past experiences and new approaches, 3–22. https://doi.org/10.2166/hydro.2008.015

Song, J., Choi, M., Kim, D., & Park, S. (2017). Combustion Characteristics of Methane Direct Injection Engine Under Various Injection Timings and Injection Pressures. *Journal of Engineering for Gas Turbines and Power*, *139*(8). https://doi.org/10.1115/1.4035817

Song, J., Choi, M., & Park, S. (2017). Comparisons of the volumetric efficiency and combustion characteristics between CNG-DI and CNG-PFI engines. *Applied Thermal Engineering*, *121*, 595–603. https://doi.org/https://doi.org/10.1016/j.applthermaleng.2017.04.110

Storey, J. M., Lewis, S., Szybist, J., Thomas, J., Barone, T., Eibl, M., … Kaul, B. (2014). Novel Characterization of GDI Engine Exhaust for Gasoline and Mid- Level Gasoline-Alcohol Blends. https://doi.org/10.4271/2014-01-1606

Sun, Z., Li, G., Wang, L., Wang, W., Gao, Q., & Wang, J. (2016). Effects of structure parameters on the static electromagnetic characteristics of solenoid valve for an electronic unit pump. *Energy Conversion and Management*, *113*, 119–130. https://doi.org/10.1016/j.enconman.2016.01.031

Taha, Z., Rahim, M. F. A., & Mamat, R. (2017). Injection characteristics study of high-pressure direct injector for Compressed Natural Gas (CNG) using experimental and analytical method. *IOP Conference Series: Materials Science and Engineering*, *257*(1), 12057.

Tay, K. L., Yang, W., Zhao, F., Yu, W., & Mohan, B. (2017). Effects of triangular and ramp injection rate-shapes on the performance and emissions of a kerosene-diesel fueled direct injection compression ignition engine : A numerical study. *Applied Thermal Engineering*, *110*, 1401–1410. https://doi.org/10.1016/j.applthermaleng.2016.09.072

Ticlavilca, A. M., & Torres, A. (2011). Data Driven Models and Machine Learning (ML) Approach in Water Resources Systems.

Tsai, W.-C., & Zhan, T.-S. (2018). An Experimental Characterization for Injection Quantity of a High-pressure Injector in GDI Engines, *8*(36). https://doi.org/10.3390/jlpea8040036

Tsai, W. C., & Yu, P. C. (2011). Design of the Electrical Drive for the High-Pressure GDI Injector in a 500cc Motorbike Engine. *International Journal of Engineering and Industries*, *2*(1), 70–83. https://doi.org/10.4156/ijei.vol2.issue1.9

Tsai, W., Wu, Z., Yu, P., & Chang, S. (2011). Design of Electrical Driving Circuits for a High-pressure Fuel Injector and Control of Fuel Injection Quantities by using the Polynomial Curve Fitting Method, *2*(2), 60–73.

Tsai, W., & Yu, P. (2011). Design of the Electrical Drive for the High-Pressure GDI Injector in a 500cc Motorbike Engine, *2*(1). https://doi.org/10.4156/ijei.vol2.issue1.9

Visconti, P., Ventura, V., Carlucci, A. P., & Strafella, L. (2016). Driving electronic board with adjustable piloting signal parameters for characterization of Common Rail diesel injectors with pure Biodiesel. *IEEE*.

Wallner, T., Matthias, N. S., & Scarcelli, R. (2012). Influence of Injection Strategy in a High-Efficiency Hydrogen Direct Injection Engine, *5*(1).

Wang, D. E., & Watson, H. C. (2000). Direct Injection Compressed Natural Gas Combustion and Visualisation, *1*.

Wang, L., Li, G., Xu, C., Xi, X., Wu, X., & Sun, S. (2016). Effect of characteristic parameters on the magnetic properties of solenoid valve for high-pressure common rail diesel engine. *Energy Conversion and Management*, *127*, 656–666. https://doi.org/10.1016/j.enconman.2016.09.057

Wang, Q., Yang, F., Yang, Q., Chen, J., & Guan, H. (2011). Experimental analysis of new high-speed powerful digital solenoid valves. *Energy Conversion and Management*, *52*(5), 2309–2313. https://doi.org/10.1016/j.enconman.2010.12.032

Wang, T., Zhang, X., Zhang, J., & Hou, X. (2017). Numerical analysis of the influence of the fuel injection timing and ignition position in a direct-injection natural gas engine. *Energy Conversion and Management*, *149*, 748–759. https://doi.org/10.1016/j.enconman.2017.03.004

Wang, Yan-jun, Wang, J., Shuai, S., Lei, X., & An, X. (2005). Study of Injection Strategies of Two-stage Gasoline Direct Injection (TSGDI) Combustion System, *1*(107).

Wang, Yue-yun. (2015). Model Based Calibration: A Case Study for Calibrating Control Systems for Downsized Boosted Engines. *Focus on Dynamic Systems & Control*, 19–21.

Whitaker, P., Shen, Y., Agarwal, A., Byrd, K., & Co, F. M. (2010). Development of the Combustion System for a Flexible Fuel Turbocharged Direct Injection Engine, *3*(1), 326–354.

White, T. R., & Milton, B. E. (2008). Shock wave calibration of under-expanded natural gas fuel jets, 353–364. https://doi.org/10.1007/s00193-008-0158-6

Xiong, X., & Lee, K. J. (2020). Data-driven modeling to optimize the injection well placement for waterflooding in heterogeneous reservoirs applying artificial neural networks and reducing, (May). https://doi.org/10.1177/0144598720927470

Xu, H., Wang, C., Ma, X., Sarangi, A. K., Weall, A., & Krueger-venus, J. (2015). Fuel injector deposits in direct-injection spark-ignition engines. *Progress in Energy and Combustion Science*, *50*, 63–80. https://doi.org/10.1016/j.pecs.2015.02.002

Xue, G., Zhang, P., Li, X., He, Z., Wang, H., Li, Y., … Li, B. (2018). A review of giant magnetostrictive injector (GMI). *Sensors & Actuators: A. Physical*, *2*(1). https://doi.org/https://doi.org/10.1016/j.sna.2018.02.001

Yadollahi, B., & Boroomand, M. (2013). The effect of combustion chamber geometry on injection and mixture preparation in a CNG direct injection SI engine. *Fuel*, *107*, 52–62. https://doi.org/10.1016/j.fuel.2013.01.004

Yao, X., Zhang, Z., Kong, X., & Yin, C. (2018). Dynamic Response Analysis and Structure Optimization of GDI Injector based on Mathematical Model. *International Journal of Reliability, Quality and Safety Engineering*, *25*(2), 1–19. https://doi.org/10.1142/S0218539318500080

Yu, J., Vuorinen, V., Hillamo, H., Sarjovaara, T., Kaario, O., & Larmi, M. (2012). An

Experimental Study on High Pressure Pulsed Jets for DI Gas Engine Using Planar Laser-Induced Fluorescence. https://doi.org/10.4271/2012-01-1655

Yu, X., Liu, Z., Wang, Z., & Dou, H. (2013). Optimize Combustion of Compressed Natural Gas Engine by Improving In-Cylinder Flows. *International Journal of Automotive Technology, 14*(4), 539–549. https://doi.org/10.1007/s12239−013−0058−3

Zeng, K., Huang, Z., Liu, B., Liu, L., Jiang, D., Ren, Y., & Wang, J. (2006). Combustion characteristics of a direct-injection natural gas engine under various fuel injection timings, *26*(x), 806–813. https://doi.org/10.1016/j.applthermaleng.2005.10.011

Zeng, K., Lv, S., Liu, B., Ma, F., & Huang, Z. (2006). Development and Calibration on an Electronic Control System of CNG Engine, (January). https://doi.org/10.1109/ICVES.2006.371583

Zeng, Q., Liu, B., Shi, X., Zhang, C., & Hu, J. (2018). Model Based Calibration for Improving Fuel Economy. *THERMAL SCIENCE*, *22*(3), 1259–1270.

Zhang, X., Palazzolo, A., Kweon, C., Thomas, E., Tucker, R., & Kascak, A. (2014a). Direct Fuel Injector Power Drive System Optimization, (Cidi). https://doi.org/10.4271/2014-01-1442

Zhang, X., Palazzolo, A., Kweon, C., Thomas, E., Tucker, R., & Kascak, A. (2014b). Direct Fuel Injector Temporal Measurements, (October). https://doi.org/10.4271/2014-01-1444.

Zhao, J., Wang, M., Wang, Z., Grekhov, L., Qiu, T., & Ma, X. (2017). Different boost voltage effects on the dynamic response and energy losses of high-speed solenoid valves. *Applied Thermal Engineering*, *123*, 1494–1503. https://doi.org/10.1016/j.applthermaleng.2017.05.117

Zhao, J., Yue, P., Grekhov, L., & Ma, X. (2018). Hold current effects on the power losses of high-speed solenoid valve for common-rail injector. *Applied Thermal Engineering*, *128*, 1579–1587. https://doi.org/10.1016/j.applthermaleng.2017.09.123

Zhou, D., Lin, K., Tu, Y., Li, J., Yang, W., & Zhao, D. (2018). A numerical investigation on the injection timing of boot injection rate- shapes in a kerosene-diesel engine with a clustered dynamic adaptive chemistry method ☆. *Applied Energy*, *220*(December 2017), 117–126. https://doi.org/10.1016/j.apenergy.2018.03.055