

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

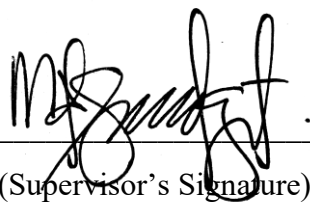
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UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

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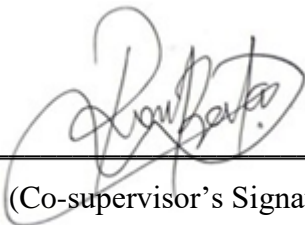


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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti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