SINGLE HOLE DIRECT INJECTOR SIMULATION VALIDATION AND PARAMETRIC SENSITIVITY STUDY

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ABSTRACT

This paper presents a parametric study conducted on electronically controlled solenoid direct fuel injector running on compressed natural gas. The purpose of the study is to identify the influential injector parameters on the output mass flowrate. These injector parameters are to be optimized in the next stage of the study. The parametric study is conducted using zero-dimensional, first principle injector model, which consist of electromagnetic, mechanical and flow sub-models. In the current study, seven (six input and one output) parameters have been analysed which are the injection pressure, injection duration, nozzle diameter, armature mass, the input voltage, spring constant and the output mass flow rate. Each input parameters are varied in the prescribed range based on the literature. Based on the study, the most influential parameters (in rank) are the nozzle diameter, the armature mass and the injection duration. The input voltage, the injection pressure and the spring constant were found to have no impact on the injector mass flow rate based on the values of the parameter's sensitivities. Based on the results, the potential parameters to be optimized are identified.

Keywords

Compressed Natural Gas, Direct injection, Modelling, Parametric study

1. INTRODUCTION

For many years, researchers and manufacturers have been working hard to comply with the ever demanding stringent emissions regulations set by every country around the world. Compress natural gas (CNG) has already regarded as one of the most recognise fuel for Gasoline and Diesel replacement. Compared to conventional fuel, the fuel cost of CNG is 20 to 40% lower, which is the major advantage.[1] CNG also most sought after for the sake of its massive reserves and its distinctive cleaner combustion.[2]

Set against the conventional fuels, CNG has higher thermal efficiency and higher knock resistance [3], [4] as a result of its high octane number (RON = 110–130).[5], [6] Furthermore, thanks to its peculiar ratio between carbon and hydrogen CNG fuel can produce a much higher compression rate while emits a far less CO2 compare conventional fuels.[5], [6] Basically, natural gas engines can be operated at lean burn and stoichiometric conditions hence will promote a diversity of combustion and emission qualities.[7]

Port-injected CNG technology has been put into trials phase; sadly the market still prefer the conventional fuelled vehicles better. The reason behind it was refuelling stations insufficiency, and when compared to gasoline, the power and torque produced were relatively lower.[4] Port-injected engines generally known to work in a stoichiometric mixture of air-fuel ratio (AFR) complementary to its mode combustion of homogeneous-charge.[8]

Meanwhile, in the rotary engine, the most prominent problem when using CNG as the fuel is the inadequate fuel combustion process, in which it can surpass the typical utilization of fuel as well as give out much higher emissions than before. Installing the turbocharger is one of the many ways to better refining the commercial grade and emission waste of rotary engine.[9] The diesel engine is a more utilized platform for CNG engine conversion.[10] A comparison study between direct injected gasoline, port injected gasoline and carburetted gasoline have been conducted.[11] Crucial information obtained from the results where it was found that the maximum power of CNG-DI is only 5% lower than gasoline port injection.

The scientific and technical knowledge behind the technology of Direct Injection (DI) system can be the solution to resolve the spark-ignition engine's performance when using natural gas as fuel. DI system gives the engine a boost in its volumetric capability [2], [8] which allows an increase in total power hence give the engine what it takes to drive at more advance velocity pace. Along with that, DI will reduce the needed for throttling control[6], to such a degree, the pumping revolution deficiency and heat transfer losses can be cut down, which promote low fuel consumption.[7]

It is concluded that CNG-DI engine has the best capability to revamp fuel flow and ignition process that stimulates a more comprehensive engine performance and lessen the fuel usage [11] as well as emissions.[5], [8] As the DI system enhancing the injection strategy and carry out the stratified allocation of fuel, it can accurately manage the framework of fuel injection, such as injection timing and the angle of injection.[9] The latest Gasoline direct injection (GDI) system can be operated at 80 to 200 bar of pressure based upon its operating setting.[8] GDI engines can run on homogeneous stoichiometric combustion mode as well as the advanced combustion mode of stratified-charge.[8]

Per contra, the technology of DI system as it may be constructive features it also has the destructive consequences upon the engine. In the homogeneous-charge combustion mode, the spray-induced flow might increase the instability in the cylinder chamber. The uniformities of fuel blend can be deteriorated because of the reduction inthe the period and gap area of air-fuel mixture. In the stratified-charge combustion

Armature Mass, Injection Duration, Input Voltage, Injection Pressure and Spring Constant as the least sensitive parameter with only 0.0000834 g/s increasing of mass flow rate for every 1 N/m of Spring Constant increments. The results of the injection experiment and simulation are useful to understand the characteristics of the injector. Detail study of the inconsistency of injector mass flow rate is very crucial to help to understand the injection characteristics of the injector better. Further study on how to eliminate or reduce the fluctuating effect need to be done to ensure optimum injector performance.

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