Heat transfer and knock analysis of hydrogen enriched compressed natural gas engine on different exhaust gas recirculation rates by different convective heat transfer models

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Abstract

This study aims to conduct comprehensive in-cylinder heat transfer rate and knock analysis of hydrogen enriched compressed natural gas fueled engine operating at 900 rpm and 30% load under stoichiometric conditions. A prime objective is to investigate the influence of varying exhaust gas recirculation (EGR) rates, ranging from 2.4% to 11.2%, on heat transfer and knock propensity. To achieve this objective, eight different convective heat transfer models were applied to calculate in-cylinder heat transfer rate. Eight convective heat transfer models (Woschni, Chang, Nusselt, Han, Eichelberg, Assanis, Hohenberg and Sitkei) have been incorporated in quasi dimensional combustion model (QDCM) to calculate in-cylinder pressure and heat transfer rate of hydrogen enriched compressed natural gas (HCNG) engine. In-cylinder pressure calculated by incorporating aforementioned convective heat transfer models in QDCM; and minimum difference b/w peak experimental and theoretical in-cylinder pressure is for Chang model for 2.4% EGR rate. The overall decrement observed in experimental in-cylinder pressure and indicated mean effective pressure by increasing EGR (2.4% to 11.2%) under similar operating condition is 17.8% & 4.5% respectively. Maximum pressure crank angle shifts from 377^{o} CA to 384^{o} CA by increasing EGR from (2.4% to 11.2%). By increasing EGR (2.4% to 11.2%) decrement in heat transfer observed is 24.97% by Woschni model and 9.6% by Assanis model respectively operating on HCNG10% at 900 rpm and 30% load. Respective simulated model for maximum and minimum difference b/w simulated results are Woschni and Assanis models respectively. By increasing EGR; knock intensity (KI) reduces and overall decrement observed in experimental KI is 20.7% by increasing EGR (2.4% to 11.2%) under similar operating conditions. The maximum and minimum error b/w experimental and simulated KI is 20.7% at 2.4% EGR and 3.8% at 11.2% EGR respectively. Respective simulated model for maximum and minimum difference b/w experimental and simulated results are Woschni and Han models respectively. Exhaust gas recirculation significantly decreases the in-cylinder heat transfer and knock intensity. By optimizing EGR rates and selecting a suitable heat transfer model, engine performance can be improved while minimizing knock-related limitations. Assanis model is best model for heat transfer calculations under given operating conditions and Han model is best to calculate knock intensity efficiently. The findings of this study can be utilized in the development of HCNG engine.