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Title of the Thesis : **Exergy Analysis and Utilization of Wet Ethanol in HCCI Engines for Cogeneration and Trigeneration Applications**

ABSTRACT

This research was undertaken to perform exergy analysis of wet ethanol operated Homogeneous charge compression ignition (HCCI) engine for cogeneration and trigeneration applications. The HCCI engine is an advance combustion engine which combines the advantages of both SI and CI engines. In HCCI engine, air fuel charge is premixed like SI engine and compressed to the point of auto ignition like diesel engine. Hence, HCCI engine seems to have the potential to match or exceed efficiency of CI engines without major challenge of emission like NO_X and particulate matters (PM).

The methodology and approach followed in the literature survey provided a comprehensive overview of biofuels particularly wet ethanol as a fuel. It is difficult to run conventional prime movers (SI and CI engine) on wet ethanol. Fortunately, effective and promising engine technology available for efficient utilization of wet ethanol is HCCI engine. A comprehensive literature review on fundamentals of HCCI engine, its history, challenges and proposed solution have been carried out. In addition to it, review of the works on the organic Rankine cycle, cogeneration, trigeneration and second law analysis on IC engines was also reported.

Exergy analysis of wet ethanol operated HCCI engines was performed and its different configurations were presented. The result of thermodynamic analysis demonstrated that the first law efficiency of HCCI engine was 38.99% at mean operating conditions and it has been validated from the results available in the International Journals. Further, the first law efficiency of wet ethanol operated HCCI engine combined cycle, cogeneration system and trigeneration system were evaluated as 41.09%, 46.47% and 48.89% respectively. Second law efficiencies for wet ethanol operated HCCI engine, HCCI combined cycle, cogeneration system and trigeneration system were evaluated as

36.51%, 37.34%, 38.5% and 38.66% respectively at mean operating conditions. It was observed that second law efficiency increases similar to the first law efficiency of the HCCI engine configurations. It has been found that the HCCI engine has very high efficiency as compared to conventional SI and CI engines with more potential to reduce NO_X and PM emission to meet the requirement of future emission norms. The increase in the efficiency was due to efficient HCCI combustion and further due to incorporation of cogeneration and trigeneration concept based on the principle of thermal cascading, it leads to much higher gain in useful energy yield from trigeneration arrangement as compared to single generation. It also became possible with making full use of waste heat leading to higher efficiency. The research highlighted the importance of integrating various systems for efficiency improvement through minimization of exergy loss to environment. The reduction in temperature of exhaust gases was also helpful in reducing the thermal pollution of the environment. The present methodology is a powerful tool in assessment of cogeneration and trigeneration system.

The parametric study of various HCCI engine configurations was carried out. The first and second law efficiency of wet ethanol operated HCCI engine trigeneration system increased with increase in turbocharger pressure ratio. It was further observed that these efficiencies increased marginally with increase in turbocharger efficiency while decreased with ambient temperature and effectiveness of regenerator. The effect of the turbocharger pressure ratio was found to be very significant on the efficiencies of various HCCI engine configurations. The exergy analysis indicated that the maximum exergy losses occur in HCCI engine followed by the exergy loss in catalytic converter. This was due to significant entropy generation in chemical processes within these systems. This research should be viewed in the context of current and future engine development to achieve higher efficiency together with much better understanding with respect to the effects of engine operating parameters. These results will also further help in research and development of HCCI engine for the adoption of this efficient and clean technology in automotive sector and other industrial applications.

Keywords: Cogeneration, Exergy analysis, Exergy destruction, Effectiveness of regenerator, First law efficiency, HCCI engine, Organic Rankine cycle, Pinch point, Turbocharger pressure ratio, Turbocharger compressor efficiency, Second law efficiency, Trigeneration, Wet ethanol.