Abstract

Energy and environmental conservation are today's major national requirements. Therefore, alternative fuels are gaining importance due to potential of diminishing fossil fuel resources and associated environmental issues. Globally, 860 million people lack electricity access, with coal-fired generation dominating 38% of primary energy. Renewable resources like residual forest activities and agricultural waste biomass can support small industries in rural areas. Efficient waste-to-energy conversion can reduce pollution and reliance on traditional fuel. Worldwide, biomass is available in abundant quantities. India generates around 500 million tonnes of agro-crop residues annually, and out of it, only 12.2% is used for energy production, and the remaining is unexploited. Thus, this unexploited agriculture waste biomass could be bio-transformed to fuels. The primary technologies for the biomass conversion process are direct combustion, thermochemical, biochemical, and agrochemical. Among these, thermochemical gasification-derived producer gas fuel is a promising technology, but challenges like seasonal biomass availability hinder year-round energy production. Therefore, co-gasification, combining two or more biomass or carbonaceous residues, offers economic and environmental benefits. However, research in biomass gasification has focused on limited conditions, where the challenges in feedstock availability affecting the power generation stability. Moreover, literature shows that that there is research gap exists in exploring the economic viability of small-scale briquette production for waste-to-fuel conversion. Thus, research into novel energy-efficient technologies, alternative biomass usage, and blending must be conducted in order to improve the feasibility and sustainability of co-gasification. Also, the comparative study is further needed to recommend suitable feedstocks blend for economic viability, and power generation through

engine integration. So far previous research is concerned, lack of research has been found on the performance and emission characteristics of gasifier-dual fuelled engines for the gasification of feedstocks like Mahua wood waste, coconut shell, briquette and their blends with low-grade coal. Further, to the best of our knowledge, there is no comprehensive study has been conducted to assess the cumulative effect of gasifier operating variables and engine input variables to optimize between maximum engine power, minimum exhaust emissions, and fuel consumption. Concerning above mentioned requirement and relative research gap and, the present study has attempted to resolve this obvious gap.

In respect to the literature review, existing perspectives, and research gap, the present thesis work comprises with two main parts: (1) Conducting experiments and respective analysis, and (2) Optimizing of operating variable setting for the best response of power deliverance and exhaust emission of an engine. In respect to the novelty, the first part includes an experimental investigation on individual feedstock (coal, mahua tree, coconut shell, and briquette) gasification to make producer gas (PG) and utilized as secondary fuel with diesel/biodiesel in the compression ignition (CI) engine. Thereafter, co-gasification of these feed materials was conducted with a 50:50 ratio of biomass and coal, and generated PG was utilized in a dual mode CI engine. In both conditions, gasifier-engine performance (power and emission) was experimentally investigated with varying operating settings as gasification equivalence ratio, engine load, and compression ratio. Thus, the novelty is to optimize the trade-off between power and emission in relation to operating variables, a Response surface methodology (RSM) optimizer and ANOVA sensitivity test was conducted to achieve control strategies for the best gasifier engine performance response. ANOVA analysis revealed that gasification equivalence ratio (GER), compression ratio (CR), engine load were the important parameters for describing the output responses. And, the RSM results showed that optimum input setting of gasification-CI engine was GER 0.1-0.4, CR 16-17, and engine load 80-100%. Also, the works on the economic feasibility of waste biomass through briquette production plant and gasification-engine system was analysed. In conjunction with the experimental investigation as first part, the second part of the thesis comprise of a numerical simulation study of a spark ignition (SI) engine performance and emission through a comprehensive quasi-dimensional thermodynamic model. Thereafter, parametric optimization has been performed to improve the performance of SI engines fueled with peach-based producer gas and propane blend. In this regard RSM optimization and ANOVA based simulation has been conducted. In this work, the novelty is to determine the optimum operating variables (blend percentage, equivalence ratio, and spark timing) for the best response of performance of dual-fuelled SI.

In light of the aforementioned contemplations, the current thesis is divided into five chapters, which includes the motivation to emphasize and resolve various issues related to the possibilities and problems. The results of experimental and economic study shows that Gasifier-Engine integration system is successful for further utilization. Further, this thesis provides the data for the prospects of utilizing gasification technique in better way, so that the renewable energy can be promoted and subsequently problems of fuel oil scarcity and environment degradation could be squarely met.