Micro Combined Heat and Power to provide heat and electrical power using biomass and Gamma-type Stirling engine

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ABSTRACT

With consideration of the biomass energy potential, a Gamma type Stirling engine with 220 cc swept volume and 580 cc total volume was designed, optimized and manufactured. The engine was tested with helium. Working characteristics of the engine were obtained within the range of heat source temperature of 370–410 °C and charge pressure of 10 bar for biomass resources. The heat source temperature of 540–560 °C and range of charge pressure 1–12 bar with 1 bar increments at each stage for gases were also looked into. By using of thermodynamic and heat transfer design methods, the key parameters of the designed Stirling engine like required surfaces for heat transfer were calculated (hot side 307 and the cold side 243 squares of centimeters). For the purpose of the analysis of fluid flow, a two-dimensional flow analysis method was performed with the CFD software methods. The principles of thermodynamics as well as the Schmidt theory were adapted to use for modeling the engine and then pressure – volume diagrams of the thermodynamic and Schmidt analysis were compared. During the test, the temperature was monitored by thermocouples and the pressure of the working fluid helium was monitored by pressure sensors. Indicated power, friction power and brake power were measured and the maximum brake power output was obtained with helium at 550 °C heat source temperature and 10-bar charge pressure at 700 rpm as 96.7 W. The electrical energy was produced from burning of biomass and flammable agricultural wastes (biomass sources). Sugarcane bagasse, wood resulting from pruning orchards, wheat straw, poplar wood and sawdust as fuel system were also selected. Most power was obtained from the sawdust (46 W) and pruning of trees for wood for low power (21 W), respectively. Meanwhile, minimum ignition time of the Sawdust (4 min) and the most time flammable wood from pruned trees (10 min) were measured. At the maximum power, the internal thermal efficiency of the engine was measured as 16%. The test results confirmed the fact that Stirling engines driven by temperature of biomass gases are able to achieve a valuable output power. Results of the present work encouraged initiating design of a single cylinder, Gamma type Stirling engine of 1 kWe capacity for rural electrification.

KEYWORDS: CHP system; Stirling engine; Biomass; Schmidt analysis; Flow analysis; Electricity production

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