Abstract

A self-propelled battery operated electric vertical conveyer reaper with a cutting width of 600 mm was designed and developed to overcome the difficulties such as noise and vibration associated with conventional internal combustion engine operated vertical conveyer reaper, rise in the price of fossil fuel and environmental pollution. The cutting width of the electric vertical conveyer reaper was decided following multi-objective optimization using genetic algorithm that minimized the power requirement and maximized the field capacity of the machine. A laboratory setup was developed simulating the cutting process of a vertical conveyer reaper in actual field condition to study power requirement for cutting paddy crop at different combinations of machine and crop parameters. Frictional torque and total maximum cutting torque required for cutting paddy crop at different combination of crop and machine parameters were measured with the developed laboratory setup from which frictional power, absolute maximum cutting power and total power required for cutting paddy stems were obtained. The specific cutting energy for paddy stems (IR 36 variety) at an average moisture content of 71% was found to be varying between 0.025-0.075 J/mm^2. A mathematical model was developed to estimate the total power required for cutting paddy crop with a standard reciprocating cutterbar. This model was validated with both laboratory and field data. A good agreement was found between estimated and measured total power required by the header unit of electric reaper with a R^2 of 0.82 and average absolute variation of 14%. Based on the findings obtained from the multi-objective genetic algorithm carried out for the data obtained from the laboratory experiments, a prototype electric vertical conveyer reaper was developed with an overall dimension of 1970 × 988 × 1050 mm, total weight of 135 kg. Performance of the prototype and comparison with similar conventional vertical conveyer reaper having 1200 mm cutting width, were carried out in test fields having matured paddy crop with an average moisture content of grain and straw as 20-32% and 68-75%, respectively. The developed electric vertical conveyer reaper had average field capacity, cutting efficiency and field efficiency of 0.05 ha/h, 95% and 83.3%, respectively as compared to 0.18 ha/h, 98% and 75% with the conventional reaper. The maximum power required for cutting and conveying by the header unit and for propelling the electric vertical conveyer reaper in the paddy fields was observed to be 550 W and 322 W, respectively. Once the batteries were fully charged, the electric vertical reaper worked effectively for 2 h without any power breakdown. Noise and vibration produced by the electric reaper during harvesting of paddy crops were measured to be 9.9 m/s^2 and 88 dB(A), respectively. The hand vibration produced by the electric vertical conveyer reaper was 2 times lesser than that produced with conventional VCR. The cost of harvesting paddy crop with the developed E-VCR was found to be 1.7 times higher than that with the conventional IC engine operated VCR and 2.3 times lesser than manual harvesting. The developed reaper should harvest at least 3.26 ha of area per year to make the harvesting of paddy crop economical as compared to manual harvesting method.

Keywords: Field efficiency; Genetic algorithm; Mathematical model; Multi-objective optimization; Noise; Standard cutterbar; Vibration.