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RESEARCH ARTICLE

OPTIMIZATION AND PERFORMANCE EVALUATION OF COTTON SEED DELINTING MACHINE

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ABSTRACT

An electrically operated cotton seed delinting machine was optimized and its performance was evaluated. The machine was modified by introducing three pulleys with diameters as 250mm, 200mm and 120mm, which produced rotor speeds of 550rpm, 600rpm and 650rpm respectively. The rotor speeds were then used to test the designed machine and its efficiency were evaluated. The belt and pulley were used to transmit power from the electric motor to the shaft of the cotton seed delinting machine unit. The designed machine was operated by a 2hp electric motor. The performance test was carried out using three different feed rates at three different speeds which include 550rpm, 600rpm and 650rpm, using 5g, 6g and 7g weight of feed rates of the cotton wool with their seeds. Each one was replicated five times. The results showed that the efficiency of the machine was high at 7g feed rate, which was 79.93% and the speed does not influence the efficiency of the machine. The statistical analysis [ANOVA] for the effect of speed of the rotor and feed rate on the capacity and performance of the evaluated machine at 5% probability level was computed. The result of the analysis confirms that feed rate was significant processing parameter that affects machine efficiency.

INTRODUCTION

Cotton plant has a taproot system that grows quickly and it can reach a depth of 20-25cm before the seedling has even emerged above ground. Cotton plant consists of an erect main stem and a number of lateral branches, also, Leaves of cotton are generally hairy and some varieties have glabrous leaves. Lateral branches arise from the axils of the leaves of main stem and consist of two types viz., vegetative and fruiting. Cotton bolls are made up of 4 to 5 locks. Each lock contains approximately 7 seeds to which the lint is tightly attached. When fully mature these bolls dry out and fluff open to give the characteristic look of a field of white cotton ready to pick (Chikwendu, 2003). Producers can harvest cotton when the quality is at its peak and then store it in modules, rather than leaving the crop exposed to weather in the field. Modules allow gins to handle seed-cotton more efficiently, to help extend the ginning season and to operate more hours each year without expensive down time. Properly built modules will withstand adverse weather and losses during storage, loading and hauling. However, to avoid damage to lint and seed quality, modules must be carefully managed. Harvested seed-cotton (lint, seed and trash combined) that is twelve percent moisture content or lower, may be stored without deterioration of lint or seed if modules are carefully built, covered and stored on a well drained site (Barnett and Ossowski, 2002). Cotton is a major fibre crop of global importance and has high commercial value. It is grown commercially in the temperate and tropical regions of more than 70 countries. Specific areas of production include countries such as China, USA, India, Pakistan, Uzbekistan, Turkey, Australia, Greece, Brazil, Egypt, Nigeria, etc., where climatic conditions suit the natural growth requirements. Cotton is harvested as 'seed cotton' which is then 'ginned' to separate the seed and lint. The long 'lint' fibres are further processed by spinning to produce yarn which is knitted or woven into fabrics. China is the world's leading cotton producer. It has been estimated that cotton contributes to approximately 30% of the Indian (second largest cotton producer) agricultural gross domestic product and considerable export earnings (Matlock *et al.,* 2008).

There are three main types of cotton seed delinting machines which include roller delinters, rotobar delinters and saw delinters. The roller delinters are classified as oscillatory knife gin and rotary knife gin depending upon the type of motion of moving knife. Oscillatory type gins are further classified as single roller (SR) and Double roller (DR) depending on the number of rollers used per machine (Ismail *et al.,* 2011).

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Delinting or Ginning is the mechanical process for separating cotton into its constituents namely lint (Cotton Fibre) and Cotton Seed. The Seed Cotton that comes from the field has to be subjected to various treatments in the ginning factories depending upon its inherent characteristics such as trash contents, moisture contents, length of the fibre, variety of seed i.e. fuzzy or black, method of seed cotton transportation, storage practices, handling practices inside the ginning factories and finally subjected to ginning process for separation of fibre and seed before packing into bales etc (Mohsenin, 2006).

The importance of the cotton crop to the Nigerian economy cannot be over-emphasized (Adeniji *et al.,* 2007). The lint removed from the seed is used as raw material for the textile industry. Cottonseed is an excellent feeds. It is high in protein, energy and fiber, and is a good source of phosphorus and vitamin E. Cottonseed meal is high in protein, and is a good source of fiber and phosphorus. Cotton-seed provide edible vegetable oil for human consumption (Kordylas, 2002). The cotton-seed cake is used as an important raw material for livestock feeds (Ismail *et al.,* 2011). Cotton was thus an important source of food for man, feed for animals, raw material for the textile industry, direct employment to cotton farmers as well as an indirect source of employment to workers employed by agro-based industries that relied on cotton as raw material i.e., textiles, edible oil and animal feed manufacturers. The main objective of this work is to optimize and fabricate cotton seed delinting machine that can separate cotton seed from cotton wool and its performance was evaluated.

MATERIALS AND METHODS

The parameters considered in design and construction of cotton seed delinting machine include the physical, mechanical, electrical, aerodynamics properties, ease of maintenance and height of the machine. A motorized vertical cotton seed delinting machine that is efficient and economically viable was optimized and fabricated with readily available and cheap materials (suitable engineering materials that could give optimum performance in service). Materials for fabricating the machine were chosen on the basis of their availability, suitability, economic consideration, viability in service etc. The components parts of the machine were optimized, fabricated and evaluated. The parts and their quantity are given in the part list below.

Methods and Optimization of Cotton Seed Delinting Machine

Shafts design consideration

The shaft is a cylindrical solid rod for transmitting motion through a set of load carried on it. The shaft uses for the delinting was enclosed by a delinter drum. Therefore, there would be a combined bending and torsional stresses acting on the solid shaft during operation. To determine the shaft diameter, we adopt the formula (Shigley and Charles, 2001)

$$d^3 = \frac{16}{\pi\delta_{sy}}[(K_b M_b)^2 + (K_t M_t)^2]^{\frac{1}{2}} \quad \text{.....1}$$

Where;

d = diameter of shaft (mm)
K_b= combined shock and fatigue factor for bending moment.
K_t = combined shock and fatigue factor for torsional moment.
M_b = Resultant bending moment (Nm)
M_t = Resultant torsional moment (Nm)
δ_{sy} = Allowable shear stress (MN/m^2)
π = constant, 3.142

Testing the Machine

The machine was first run under no-load using an electric motor of 2 hp to ascertain the smoothness of operation for the machines rotating parts. The actual test was conducted using three different feeds rates and speed. Three different speeds were gotten by changing the diameter of the driven pulley. Testing the machine was targeted at evaluating its delinting efficiency and through put capacity. The results obtained were analyzed using analysis of variance (ANOVA).

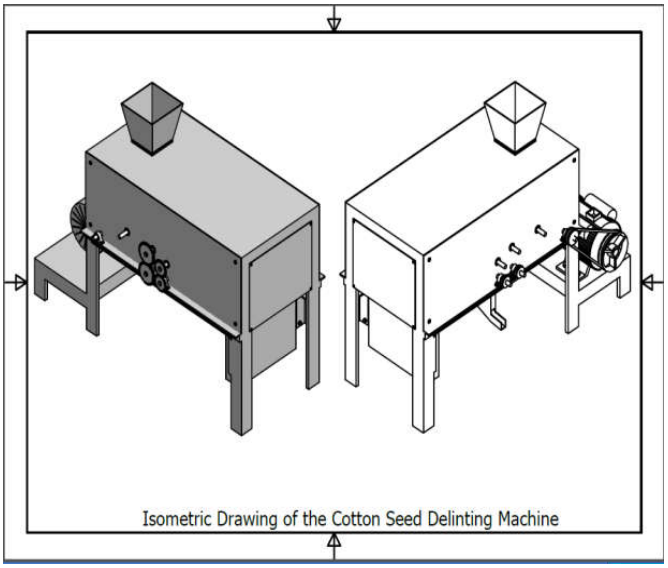

Figure 1. Isomeric view of the cotton seed delinting machine

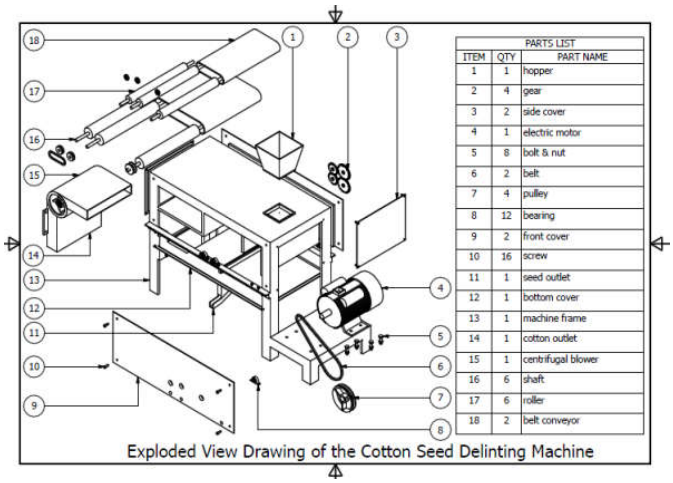

Figure 2. Exploded view and Part name of the cotton seed delinting machine

Table 1. The efficiency of the machine at 5g feed rate of cotton wool and seed

Speed(rpm)	Initial weight of cotton with seed (g)	Weight after delinting(g)	Weight of seed delinted (g)	Weight of seed not delinted(g)	Performance of the machine (%)
	5	3.5	1.2	0.3	70
	5	4.0	0.8	0.2	80
550	5	3.8	0.8	0.4	76
	5	3.7	0.8	0.5	74
	5	4.1	0.6	0.3	82
	Average	3.82	0.84	0.34	76.4
	5	3.5	0.9	0.6	70
	5	3.6	0.9	0.5	72
600	5	4.0	0.8	0.2	80
	5	3.8	0.9	0.3	76
	5	4.1	0.8	0.1	82
	Average	3.8	0.86	0.34	76
	5	4.4	0.5	0.1	88
	5	4.3	0.6	0.1	86
650	5	3.9	0.8	0.3	78
	5	3.8	0.8	0.4	76
	5	4.6	0.3	0.1	92
	Average	4.2	0.6	0.2	84

Table 2. The efficiency of the machine at 6g feed rate of cotton wool and seed

Speed(rpm)	Initial weight of cotton with seed (g)	Weight after delinting(g)	Weight of seed delinted (g)	Weight of seed not delinted(g)	Performance of the machine (%)
	6	5.0	0.6	0.4	83
	6	4.9	0.8	0.3	82
550	6	5.2	0.7	0.1	87
	6	5.1	0.6	0.3	85
	6	4.8	0.8	0.4	75
	Average	5.0	0.7	0.3	82.4
	6	3.6	1.9	0.5	60
	6	3.9	1.5	0.6	65
600	6	4.3	1.3	0.4	72
	6	4.7	0.9	0.4	78
	6	5.1	0.7	0.2	85
	Average	4.32	1.26	0.42	72
	6	4.9	0.8	0.3	82
	6	5.0	0.8	0.2	83
650	6	4.8	0.9	0.3	75
	6	5.2	0.6	0.2	87
	6	5.1	0.7	0.2	85
	Average	5.0	0.76	0.24	84.4

Table 3. The efficiency of the machine at 7g feed rate of cotton wool and seed

Speed(rpm)	Initial weight of cotton with seed (g)	Weight after delinting(g)	Weight of seed delinted (g)	Weight of seed not delinted(g)	Performance of the machine (%)
	7	4.8	2.0	0.2	69
	7	5.6	1.0	0.4	80
550	7	5.8	0.9	0.3	83
	7	5.3	1.2	0.5	76
	7	6.0	0.7	0.3	86
	Average	5.5	1.16	0.34	78.8
	7	4.8	1.6	0.6	69
	7	5.7	0.9	0.4	81
600	7	6.0	0.8	0.2	86
	7	5.9	0.9	0.2	84
	7	4.8	1.6	0.6	69
	Average	5.44	1.16	0.4	77.8
	7	6.0	0.8	0.2	86
	7	6.1	0.8	0.1	87
650	7	5.8	1.0	0.2	83
	7	5.6	0.9	0.5	80
	7	5.6	1.0	0.4	80
	Average	5.82	0.9	0.28	83.2

Table 4. ANOVA for the effect of Speed and Feed rate on the machine performance

Source of variation	Sum of square	Degree of Freedom	Mean Square	Computed F
Speed (A)	94.4089	2	47.2045	5.4189
Feed Rate (B)	2.3023	2	1.1512	0.1322*
Error	34.8444	4	8.7111	
Total	131.5556	8		

Significant at 5% probability level

Principle of Operation of the Machine

The machine works by picking the cotton with seed and then moving the cotton fibres between the roller and fixed knife preventing the seeds to pass through. The cotton seed, when thrown into the hopper, passes through the machine. While the machine is working, at each elevation of the moving knife the grids lift the cotton to the level of the stationary knife-edge and of the exposed surface of the rollers. The free ends of the fibres are gripped, in the grooves of the rotating roller, and dragged forward till the seeds reach the edge of stationary knife. The edge where the fibre is caught is the ginning point. By the downward motion of the moving knife, the seeds are detached from the cotton at the ginning point and are thrown out through the slots of the grid. The grooves of the rollers were kept well open and when the leather roller becomes smooth, rough file should be applied occasionally to the surface to keep the same grip and pull on the fibre. The seeds are then hammered by means of the rapidly moving knife whereby some fibres are separated. In subsequent cycles, the remaining fibres also get separated. This process is continued till all the fibres from the seed get removed.

RESULTS AND DISCUSSION

The performance evaluation of the optimized cotton seed delinting machine was determined using three different speeds and three different feed rates of cotton. The efficiency of the machine was obtained by delinting the seed from the cotton using three different machine feed rates at three varying speeds of 550 rpm, 600 rpm and 650 rpm. It was observed in Table 1 that the maximum efficiency of the machine was 84% at 650 rpm speed and the minimum was 76% at 550 rpm speed using 5g feed rate. This means that the efficiency of the machine can be reduced, if the speed is lower. The results obtained from the machine using 6g of cotton as feed rate was shown in Table 2. The results shown that the feed rate hindered the efficiency of the machine. At 550 and 650 rpm, the average machine performance was highest (82.4%) and had the lowest performance at the speed of 600 rpm (72%).

The results obtained using 7g of cotton as feed rate was shown in Table 3. The results showed that the average machine performance was highest at the speed of 650 rpm (83.2%) and lowest at 6000 rpm (77.8%). The efficiency of the machine can be hindered, if the speed goes higher than 650 rpm or lower than 550 rpm. The cotton seed delinting duration of the machine depend on the operator. Table 4 showed the analysis of variance (ANOVA) of the results obtained at 5% percent probability, which signified that the feed rate of the machine was an important parameter that affects the performance of the machine. Speed does not affect the performance of the machine significantly according to the analysis of variance results.

Conclusion and Recommendation

The cotton seed delinting machine was optimized, constructed and evaluated. The result obtained showed that the machine performance was 79.93 % at 7g feed rate. The speeds used on the machine do not show any significant variation on the machine efficiency. The optimized machine, according to the evaluation reduced the labour cost and time involved in delinting the seed from the cotton manually. From the results, it has shown that the efficiency of the machine was high and the speed does not influence the efficiency of the machine negatively. The manual method of removing the seed from the cotton can be improved and modified. The machine is recommended to the farmers and other processors of cotton wool because of its time limitation, ease of operation and good quality of cotton produced.

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