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Design and development of boll opener machine for processing of kawdi Cotton in Indian ginneries

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Abstract : Cotton boll opener machine has been designed and developed for processing of the immature and unopened cotton bolls popularly called as *kawdi* cotton. The machine works on the principle of opening up of *kawdi* fibres by air turbulence and beating and rubbing action inside the horizontal cylindrical structure. The new design of boll opener has centrally mounted paddle type beater assembly, motor drive, feed hopper and concave screen sections of sizes 12, 16 and 20 mm for separating dust and impurities. The paddle type boll opener has the capacity of processing 6-8 q/h of *kawdi* cotton with an efficiency of about 80 per cent, thus yielding 5-6 q/h of opened and cleaned *kawdi* cotton that can be ginned on double roller gin to extract lint and cottonseed yielding additional economic benefits to ginners.

Keywords : Boll, cotton, ginning, *Kawdi*, opener, lint

India is the leading cotton producing country in the world with 13 million hectare area and 18 million tonnes of seed cotton production every year. The harvested seed cotton, along with dust particles and leafy trash, may also contain immature and unopened cotton bolls, called "*kawdi*" (Fig. 1), which are removed in pre-cleaning sections in ginneries. Kawdi is also removed during further processing through auto- feeder and gin hopper grid. In India, about 3-5 lakh tonnes *i.e.*, 2 per cent of seed cotton arriving in Indian ginneries is separated as *kawdi* cotton every year, incurring huge losses to ginners. However, if *kawdi* cotton is properly processed using boll opener machines, good quality lint could be recovered from cleaned and opened *kawdi* (Fig. 2) yielding additional economic benefits to ginners (Ghadge *et al.* 2018). Without proper opening and cleaning, *kawdi* is not ginnable on a double roller gin because its fibres, not fluffy enough and snuggly held to the seed, pose problems in ginning and are not easily picked up by gin rollers.

Only few machines are available in the Indian market for processing of *kawdi* cotton by beating and rubbing action for opening up of fibres and cleaning. However, these machines are custom made for small traders, there is a lack of standardisation in design principles and seem to be inefficient. The ginning industry is looking for a better and efficient solution to effectively clean and open *kawdi* cotton as well as to maximize the machine output so that economic profits could be increased. The ginning industries which are using boll opener are manufactured by M/s Bajaj Steel Industries Ltd. (BSIL), Nagpur. Hence, In the present study, the boll opener machine manufactured and marketed by M/s Bajaj Steel Industries Ltd. (BSIL), Nagpur was selected for performance evaluation and carrying out design modifications for improvement.

The existing design of Bajaj Boll Opener (Fig. 3) consists of a rotating helical beater assembly mounted on a frame with a set of 12-, 20- and 25-mm perforated screens arranged underneath for trash separation. The length, width and height of the machine are 3.2, 1.0 and 1.3 m, respectively. Beater diameter is 800 mm and its rotational speed is 250 RPM. The width of each perforated screen section is 812 mm. A 1440-rpm, 5-hp electric motor is used as prime

Fig. 1. Raw *kawdi* cotton showing closely held fibres unavailable for ginning

Fig. 2. *Kawdi* cotton with opened up fibres on passing through boll opener machine

mover to drive the beater assembly using V-belt transmission system. The test trials of 'Bajaj Boll Opener' revealed that only about 40 per cent of *kawdi* cotton could be recovered for ginning, the rest 60 per cent going out as losses through different screens and as feeder splash out.

Based on the observations during the test trials, many design changes were incorporated and a new paddle type design was developed, the test prototypes were fabricated, trials conducted and design refined into an efficient system for processing of *kawdi* cotton in Indian ginneries. Hence, A new efficient system has been designed and developed as per the industry demand for a better and efficient solution to process *kawdi* cotton for opening the unopened *kawdi* cotton buds to extract useful cotton fibres and cotton seeds from it so as to minimise economic losses to ginners.

The methodology adopted for development of cotton boll opener as an efficient system for processing of *kawdi* cotton in Indian ginneries was based on the performance evaluation of the existing design of boll openers available in the market.

Kawdi cotton

Kawdi cotton for conducting the research work was collected from ginneries nearby GTC

Fig. 3. Inside view of Bajaj Boll Opener showing helical beater type assembly

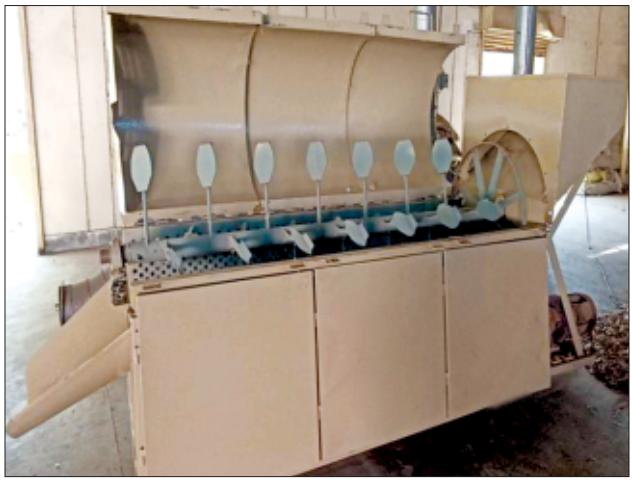

Fig. 4. Inside view of new paddle type boll opener showing beater assembly, motor drive, side mounted feed hopper, concave screen sections (12, 16 and 20 mm) and outlet chute

Nagpur. It was a mix of *kawdi* waste collected from the different stages in ginning process namely, hot box dispenser, pre-cleaner chamber, auto feeder and DR gin hopper grid.

New paddle type cotton boll opener

The new paddle type cotton boll opener (Fig.4) works on the same principle of operation as in case of the existing machine by opening up of fibres by air turbulence and beating and rubbing action of rotating beater assembly mounted centrally on a horizontal cylindrical structure having perforated concave screens for separating dust and seeds from the cleaned and

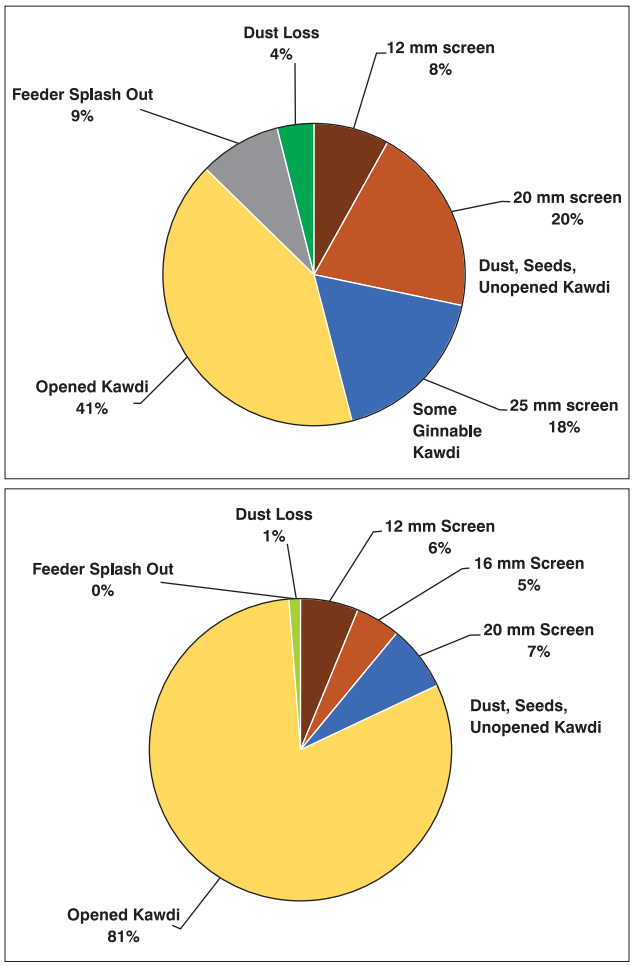

Fig. 5. (a) Performance of Helical Beater type Bajaj Boll Opener, and (b) Performance of new paddle type Boll Opener

opened *kawdi* cotton which is collected at the output end of the machine.

Design calculations for the new paddle type boll opener

The fixed parameters in the new paddle-type boll opener were 0.692m diameter of worm pipe assembly (D), 0.356m radius of worm pipe assembly (r), 250RPM speed of assembly (N), 60kg mass of worm pipe assembly(m) and factor of safety (FOS) was 3. Table 1 shows the values of various parameters such as Kinetic Energy K.E (rotation), Moment of Inertia (I), Angular Momentum (w) and, for Power(P).

Power required to open up cotton bolls

In the process of power requirement for opening the cotton bolls, the known parameters are Paddle Plate size (159mmx 130mmx 2mm), Density of immature cotton bolls (200 kg/m3), and Surface Area of one Paddle (4.2496 x 10-5 m3). It was assumed that the height of one layer of cotton bolls is 60mm. The calculated parameters have shown in table 2. Hence, total power requirement is 2.1464 kW. As per the standard power rating, 2.2 kW motor was selected for the application.

Fig. 6. Performance evaluation of new paddle type Boll Opener

Conducting test trials of boll opener machine

The test trials of boll opener machine were conducted at the factory premises of M/s BSIL Nagpur and at GTC, ICAR-CIRCOT, Nagpur. The performance of the machine was evaluated in terms of raw *kawdi* cotton handling capacity (Q/h), recovery (%) of ginnable seed cotton obtained from raw *kawdi* cotton and increase in specific volume (%) of kawdi cotton. The extent of fibre opening of *kawdi* cotton on passing through boll opener machine was determined in terms of per cent increase in specific volume of kawdi cotton, which is also the reciprocal of bulk density. The bulk density of *kawdi* cotton was calculated by noting the weight of *kawdi* cotton required to fill the specially designed measuring cylinder of known volume (56150cc). The recovery of ginnable seed cotton was calculated as weight per cent of opened *kawdi* cotton obtained at the outlet to the input weight of raw *kawdi* cotton. Opened *kawdi*

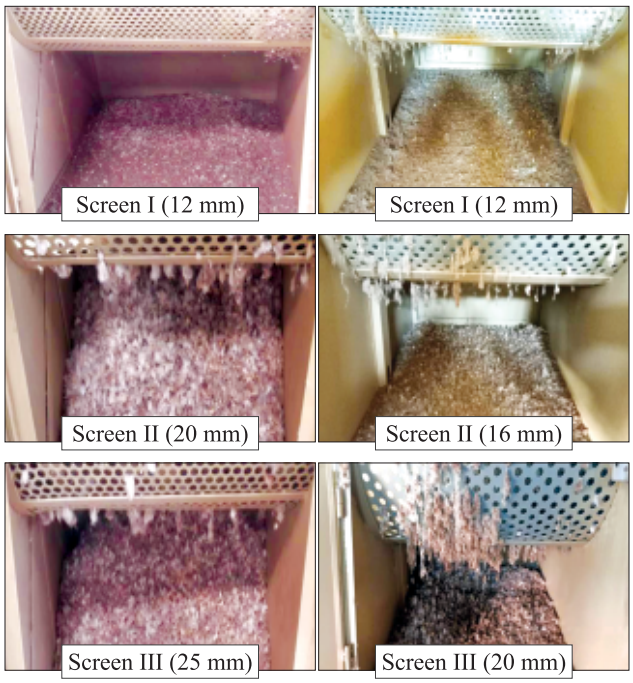

Fig.7. Cleaning Performance of old and new designs of cotton boll openers

cotton, trash, dust and cottonseed removal through different screens were determined as weight percentages based on the weight of input *kawdi* cotton.

The opened *kawdi* cotton was ginned using Bajaj 170 mm roller diameter 1370 mm roller length DR gin and Murray 406 mm diameter 90-Saw Gin (SG) stands. Both ginning machines were operated under normal settings. Lint samples of appropriate weights were collected from lint slides and were analysed for quality attributes using High Volume Instrument (HVI). The average values of three replications of the boll opener performance tests and the fibre properties of lint obtained from saw and roller gin were taken for the analysis.

The results of the test trials of old Bajaj Boll Opener and new CIRCOT Boll Opener are shown in Fig.5, 6 & 7 whereas findings on lint recovery and fibre quality parameters are given in Tables 3 & 4, respectively. The extent of opening of fibres in kawdi cotton was assessed by the increase in specific volume of raw kawdi cotton. It was found that specific volume of raw kawdi which was around 7-8 cc/g nearly doubled to 13-14 cc/g on passing through Boll Opener machine, thus indicating loosening of fibres making them ginnable. The maximum capacity of both boll opener machine for processing kawdi cotton was found to be around 800 kg/h, which varied greatly due to uncontrolled manual feeding. The opened kawdi cotton was ginned using DR as well as Saw gins. There was no significant difference observed in the lint outturn in both these methods. The HVI test results of fibre parameters showed no significant differences in both the methods.

The test trials of 'Bajaj Boll Opener' revealed that only about 40% of kawdi cotton could be recovered for ginning, the rest 60 per cent going out as losses through different screens and as feeder splash out. It was sections, especially

Table 1. Results of various parameters

S. No.	Parameters	Formulas used	Results
1	Moment of Inertia (I)	m x r^2 x FOS	22.81 kgm^2
2	Angular Momentum (w)	(2 x π x N) / 60	26.16 rad/sec
3	K.E $_{(rotation)}$	0.5 x I x w^2	7805.81J
4	Power (P)	K.E $_{(rotation)/t}$	1.87639 kW

Table 2. Parameters required to calculate the power to open up cotton bolls

S. No.	Parameters	Formula used	Results
1	Volume (v)	0.042 x 0.06	0.00252 m^3
2	Mass (M)	Density * Volume	0.504 Kg
3	Velocity	r x w	9.05 m/s
4	Impact Force	(0.5 x M x Velocity2) / D	29.825 N
5	Torque (T)	r*F	10.319 Nm
6	Power (P)	2 * π * N * T/60	0.270 kW

Table 3. Lint Recovery (%) from kawdi cotton processed through boll openers

Boll Opener Model	Lint Recovery (%) based on opened kawdi	Lint Recovery (%) based on raw kawdi
Helical Beater TypeBajaj Boll Opener	22.42	9.23
New Paddle TypeCIRCOT Boll Opener	21.85	17.70

Table 4. Fibre Quality parameters of lint obtained from kawdi cotton

Boll Opener Model	UHM Lmm	UI %	Mic	Tenacity 3.2 mm (g/tex)	EL%	Rd	+b	CG
Bajaj Old Model	28.3	82	3.0	25.1	5.7	56.4	14.0	54-3
CIRCOT New Model	29.2	85	3.2	26.3	6.1	62.8	13.3	44-1

Beater Assembly, Feed Hopper and Screen Grids to minimise losses. The existing coil helix design of the beater assembly, though satisfactory in rubbing action against concave screen for cleaning, seemed inefficient in opening up the fibres due to insufficient beating action. Therefore, new paddle type beaters were designed. Feed hopper was repositioned towards one end to minimise splash out losses as well as for better ergonomics. Concave screen set 12, 20, 25 mm was replaced with 12, 16, 20 mm for reducing losses.

Some of the general observations during the test trials include fan blockage, where *kawdi* gets blocked in between the peripheral support flat of the fan and the screen underneath with a possibility of fire hazard due to friction and outlet chute safety there is a risk of operator hand injury in the rotating beater element close to the chute outlet. The location of the feed hopper on top of the machine is observed to be faulty making it inconvenient and difficult for the operator. *Kawdi* has to be manually fed into the hopper using baskets/bags for which two labourers are required, one for filling and delivering the basket to the other standing on the raised platform in order to reach the hopper. In view of this, design modifications in the machine especially for arresting the losses and proper feeding were proposed for increased recovery.

Incorporating these changes, the test prototype of the new paddle type *kawdi* opener was fabricated as per the design specifications. The test prototype was put under repeated trial and modification process for design tweaking and fine tuning. Majority of the problems during test trial were related to beater assembly failures. Paddle plates were found bent due to improper beater elements hitting the concave insides increasing the loading on the paddle plates, which also resulted into poor conveying and reduced capacity. There was a blockage at the inlet portion due to absence of paddle conveyors, which resulted into bent paddles in the inlet section. Necessary changes were incorporated in the design of the paddles shape and thickness to make them sturdier to allow for overloading due to uncontrolled feeding. Length of the beater element was reduced to 1 inch to avoid it hitting the concave wall. Changes were incorporated in the first two paddles so as to provide stirring of the material introduced near to the inlet by providing either L or S type fingers. Paddle plate thickness was increased from 2 to 4 mm to make it sturdier to allow for overloading due to uncontrolled feeding. A lock nut was provided for beater elements fitted on to paddles to avoid any slippage of beater elements. The 'Trial and Error' process was continued until the machine was sturdier and free from any operational break downs due to part failures.

The newly developed 'Cotton Boll Opener' system works on the same principle as in case of the existing machine 'Bajaj Boll Opener' by opening up of fibres by air turbulence and beating and rubbing action of rotating beater assembly mounted centrally on a horizontal cylindrical structure having perforated concave screen underneath for separating dust and seeds from the cleaned and opened *Kawdi* cotton which

is collected at the output end of the machine. However, it does this job more efficiently than the old model due to many improvements incorporated in its design, especially in the design of feed hopper, new paddle type beaters and the new 12, 16, 20 mm set of screens instead of 12, 20, 25 mm set used in the previous design, the changes resulting into arresting of *kawdi* cotton losses through feeder splash out and through 25mm screen in case of old model. In the new model, the grids are made of heavy gauge steel sheets. The main shaft runs on three heavy-duty ball bearing encased in dust proof housing to give trouble free service for number of years, with lower power consumption. Guarding at the feed end as well as at the discharge end has been provided for safety purpose. Suitable base for fitting electric motor has been provided to eliminate slide rails. The covers of the machine are tightened by fly nuts to enable the operator to attend the machine without using spanner. Driving arrangement is totally enclosed.

The handling capacity of the machine remained same at 6-8 q/h of raw *kawdi* cotton, the efficiency doubled to about 80 per cent thus yielding about 5-6 q/h as compared to 3-4 q/h in case of the older model. Lint Recovery based on the weight of opened *Kawdi* was found to be similar to that in case of earlier model at 22-25 per cent whereas the ultimate lint recovery based on the weight of input raw *kawdi* cotton was found to double at about 18 per cent as a result of increased efficiency of the new model. The new machine has overall dimensions of 3.5 x 1.5 x 1 m, 500 kg weight and connected total power of 5 HP.

CONCLUSIONS

Kawdi cotton the immature and unopened cotton bolls rejected in ginneries, if properly processed can yield some ginnable seed cotton earning additional profit to ginners. About 10 lakh tonnes of *kawdi* cotton is discarded every year by Indian ginneries incurring huge losses to ginners. The available systems for processing of *kawdi* cotton seem to be inefficient and there is a need to develop an efficient system to effectively clean and open *kawdi* cotton as well as to maximize the output of the machine so that the economic profits of ginneries can be increased. An improvement in the existing boll opener machine has led to the development of a new system with improved efficiency. The newly developed cotton boll opener machine is useful for cleaning and opening of *kawdi* cotton in Indian ginneries for obtaining useful lint and seed from it. The new paddle type boll opener is an efficient system with the capacity of processing 6-8 q/h of raw *kawdi* cotton with an improved efficiency of 80 per cent thus yielding about 5-6 q/h of opened and cleaned *kawdi* cotton that can be used for further processing to obtain useful lint and seed.

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