Development of Prototype Double Roller Gin with Improved Power Transmission and its Performance Evaluation

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ABSTRACT
Double roller gins are commonly used in India for ginning seed cotton. International Textile Manufacturers Federation's survey 2005 reported that degree of grease and oil contamination in cotton lint is serious in India[1]. Study revealed that the source of this contamination is the gearbox (power transmission system) of double roller gin as it is filled with grease/oil measuring about 20 kg. Prototype double roller gin has been designed and developed with new power transmission system which minimizes the use of oil and grease to a great extent. High Volume Instrument's results on fiber parameters indicated that quality of lint is at par with existing double roller gin with no prospect of oil and grease contamination. Developed machine is useful for cotton breeders, ginners, farmers to ascertain the ginning percentage and purity of seeds could be maintained. This prototype double roller gin could be the basis for design of modified double roller gin of a commercial size.

INTRODUCTION
India ranks first in area under cotton cultivation (9.0 million hectares) and is the second largest producer of cotton fiber in the world producing 4.59 million tonnes during 2006-07 [2]. Ginning is the process by which seed cotton is separated into lint (fibers) and seed and machine used for its separation is called as gin. Thus ginning is the first engineering activity that cotton undergoes on its way from cotton field to textile mills [3]. There are mainly two types of gin viz; (i) roller (rotary knife and double roller) gin (ii) saw gin. In India, mostly roller gins are used for commercial ginning. About 50,000 double roller (DR) gins are operating in India for ginning and producing 5.1 million tonnes of fibers (90 % of total cotton lint production) on DR gin in year 2006-2007.

Further only 10 % of seed cotton is ginned on saw gins particularly in northern part of India and since last five years the saw gins are being replaced by the roller gins.

In design of existing DR gin, planetary gear train as shown in *Figure 1* is used for the power transmission which requires greasing frequently. The gear box is to be filled up to 20 % of its capacity by grease weighing about 20 kg as shown in *Figure 2* and 500 grams of grease is to be added weekly in the gearbox to maintain the level of grease in the gearbox[4]. Yearly oil and grease consumption by DR gin in India is estimated to be 1500 tonnes costing about Indian Rs. 120 to 150 million (US $ 2.6 to 3.2 millon). During the running of DR gin, there is a leakage of the grease from the gearbox, which subsequently falls on the floor surface of the gin house and damages the cotton lint quality.

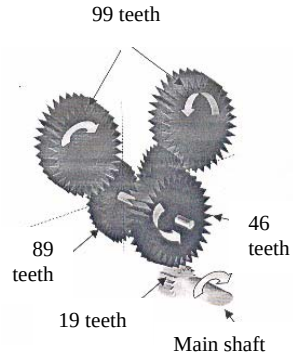


FIGURE1 Gear train in existing DR gin

FIGURE2 Grease application in existing DR gin

Therefore the power transmission system consisting of V-belt and chain sprocket which requires very

minimal lubrication is to be designed. Before incorporating this design in commercial DR gin, it is felt necessary to develop prototype model of DR gin to study the performance of new power transmission system. Also the performance evaluation of newly developed prototype machine for ginning cotton has to be studied. Advantages of developing prototype model of DR gin are such as cost required for fabrication of prototype model, the expenses and time required for carrying out experimental work will be less and some minor design modifications required can be incorporated quickly and economically.

The ginning rate and energy consumption are dependent on the roller speed, beater oscillations, moisture content and staple length of cotton. Similar studies were conducted by Leonard C. G. and Gillum M.N. [5] who studied the effect of fiber moisture on roller ginning i. e. rotary knife roller gin having 1016 mm (40 inch) wide and 381 mm (15 inch) diameter of roller. It was observed that the optimum range of fiber moisture content for roller ginning and lint cleaning was found to be from 5 to 6 percent. The maximum ginning rates were obtained in the 5 to 5.4 percent range of fiber moisture content. The maximum average energy consumption by the gin stand was associated with low fiber moisture contents. Energy consumption increased substantially with fiber moisture content above 7 percent. Johnson, Townsend and Walton[6] studied the ginning performance by varying the crank and roller speeds on Pima and SXP varieties of cotton on 1016 mm (40 inch) roller gin. Study revealed that by increasing the speed of crank from 650 to 840 (29 %) revolutions per minute (RPM), the amount of lint ginned per hour increased from 18.2 to 22 kg (i.e. 40 to 48.3 pounds) (21 %). It was further observed that by increasing the speed of the roller from 110 to 150 (36 %) revolutions per minute, the amount of lint ginned per hour was stepped up from 18.8 to 22.5 kg (i.e. 41.5 to 49.5 pounds) (19%). The staple length of cotton was not affected by increasing the roller speed and the indicated differences in grade steps were insignificant. Patil, Padole, Agrawal and Dahake[7] studied the effect of roller speed and moisture content on ginning rate, lint quality and electric energy consumption in double roller gins. This study revealed that highest roller speed of 120 RPM coupled with 7 % moisture content of seed cotton showed highest ginning rate with maximum saving in electric energy. Further, highest ginning rate and maximum energy saving were observed for higher staple length of fiber as compared to lower staple length of fibers. Fiber properties of lint obtained from different treatments were measured using HVI and AFIS system and results showed that the important fiber parameters remain unaffected.

Hence the proposed study is undertaken with the following objectives

(1) To design and development of prototype double roller gin with improved power transmission system which requires minimal grease for lubrication.
(2) To study the performance evaluation of prototype double roller gin.

MATERIALS AND METHODS

Principle of operation of prototype double roller gin

Prototype double roller gin is so designed that it will work on the principle of Mc-Carthy's gin. The principle of operation of prototype DR gin is shown in *Figure 3*. The chrome leather rollers, fixed knives and oscillating knives are the main components of the gin. Spirally grooved rollers are pressed against fixed

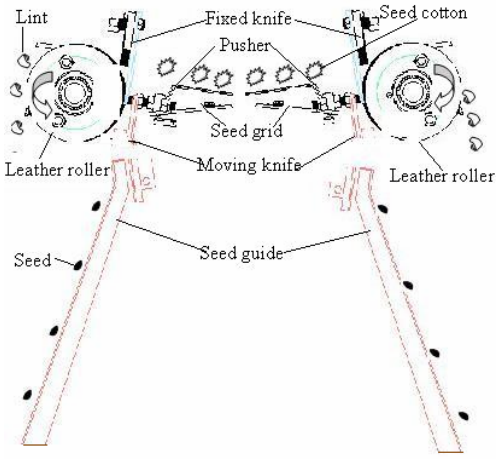


FIGURE 3 Principle of operation of prototype DR gin

knives and are made to rotate at a definite speed. Each moving knife reciprocates by means of a crank or eccentric shaft close to the leather roller. When seed cotton is fed to the machine in action, fibers adhere to the rough surface of the roller. Fibers are carried in between the fixed knife and the roller such that the fibers are partially gripped between them. The moving knife beats the seeds and separates the fibers, which are gripped from the seed end. This process is repeated number of times and due to the 'push and pull' action, the fibers are separated from the seeds. The separated fibers are carried forward on the roller and passing upwardly and dropped out of

the machine. The ginned seeds drop down through the grid slots provided.

Design of prototype double roller gin

Total electric power = 2 hp
Speed of the motor = N1 = 1440 RPM
Diameter of motor pulley = D1 = 25 mm
Diameter of crank shaft pulley = D2 = 125 mm
Speed of crankshaft = N2
N1/N2 = D1/D2 :1440/N2 = 125/25
So, N2 = 288 RPM

In the first stage, speed reduction ratio is 1:5 which is achieved with the help of v-belt drive. In second stage the reduction of speed is carried out in 1:2 ratio and achieved with the help of chain drive. Both the drive requires minimal grease.
No. of teeth on crankshaft sprocket = T2 = 15
No. of teeth on roller sprocket = T3 = 30
Speed of crankshaft = N2 = 288 RPM
Speed of roller = N3
N2/N3 = T3/ T2: 288/N3 = 30/15
So, N3 = 144 RPM

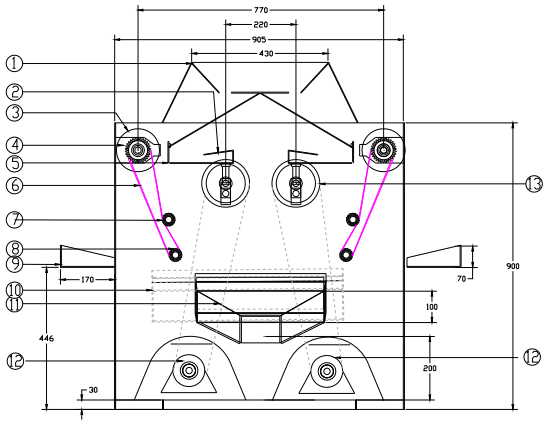
The length and diameter of roller are 254 mm and 125 mm respectively. The roller rotates at the speed of 144 RPM having surface speed of about 95 cm/s. It may be mentioned here that in existing DR gin, surface speed of roller is found to be 95 to 105 cm/s.

Constructional Features of Prototype Double Roller Gin

The essential machine parts of prototype double roller gin are

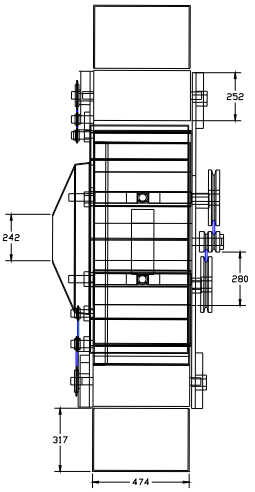
1. Main frame of machine
2. A pair of chrome leather roller
3. A pair of fixed knives
4. Power transmission system
5. A pair of reciprocating (moving) knives
6. Eccentric shaft

Side and top views of prototype DR gin are shown in *Figure 4* and *5* respectively. The main frame of the machine is fabricated out of cold rolled sheet metal. Both the moving and fixed knives are made up of EN-8 alloyed steel. The roller is made of chrome composite leather washers. Two single-phase, 1 hp motors are used to drive the rollers and moving knives independently. The eccentric shaft is fixed in between the two metal sheets, which is driven by belt and pulley mechanism from the motor. The power to drive the rollers is supplied by chain and sprocket mechanism driven by eccentric shaft. The eccentric shaft drives the moving knife and the pusher for both the sides, which helps to feed the seed cotton at the ginning point.



Part No.	Name of part	Part No.	Name of part
1	Feed hopper	8	Sprocket
2	Moving knife	9	Lint collection tray
3	Leather roller	10	Seed tray
4	Roller sprocket	11	Seed outlet
5	Fixed knife	12	Motor
6	Chain	13	Pulley
7	Idler sprocket	All dimensions are in mm	

FIGURE 4 Side view of prototype double roller gin



All dimensions are in mm

FIGURE 5 Top View of prototype double roller gin

The two screws are provided to adjust height of fixed knife in order to adjust the overlap between the fixed knife and moving knife. Slots are provided on bearing housings of roller to adjust the pressure between the fixed knife and roller. The suitable mechanism is provided to adjust the gap between the fixed and moving knife.

The moving knife reciprocates at a speed of 288 strokes per minute. The grooves are made on the surface of the roller which are 25 mm apart. The width and depth of groove are 2 mm. The wooden flat is placed on the front side of the roller to avoid the backlash. The lint collection tray is provided just below the roller and the seed collection tray is beneath the seed grid. A small rectangular hopper is used to feed the cotton. The belt pulley and chain sprocket have safety guards and handles are provided on both the sides of the machine for ease in handling. The photographs showing the top and side views of the gin are shown in *Figure 6* and *7.*

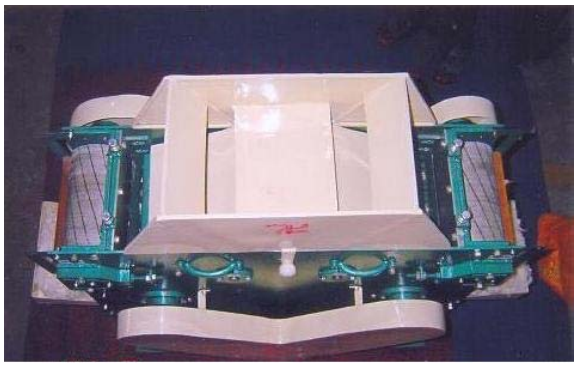


FIGURE 6 Top view of the machine showing both the leather rollers, fixed knife, feed hopper and power transmission system of prototype DR Gin

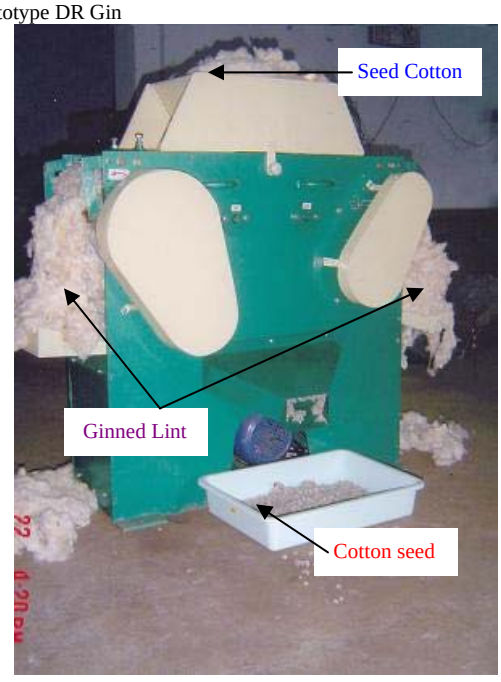


FIGURE 7 Developed prototype double roller gin in operation

Three seed cottons of different staple lengths i.e. short staple, long staple and extra-long staple (Y.1: 23-24 mm, Rasi: 29-30 mm and DCH.32: 33-35 mm) were subjected to seven levels of roller speeds (80, 90,100,110,120,130 & 140 RPM). It however, may be noted that the ratio of roller RPM and beater oscillations per minute (OPM) is remained constant at 1:2. The desired RPM of the roller was achieved by AC drive (Specification: X 4 C 40 100 C 1 P 66, 10 hp, Input volts: 380 - 460 $\pm$ 15 %, Input Ampere: 19.7/16.3, Output volts: 0 - 380/460, 3 phase, Output Ampere: 15.6/14 A). The test were conducted and analyzed as completely randomized design replicated two times. In all, 42 experiments were conducted to ensure an adequate response in ginning rate, power consumption and quality of lint. Seed cotton sample having weight 2 kg and moisture content of 7 % was ginned on developed prototype double roller gin. The crops were raised in selected farmers fields and the seed cotton used in ginning trials were the mixtures from the first and second pickings. The seed cotton was not processed through pre-cleaner, but was carefully hand opened and cleaned before ginning.

The developed prototype double roller gin was tested to evaluate its performance in terms of ginning rate, ginning percentage and fiber quality parameters. The ginning rate and ginning percentage (GP) were calculated for each cotton type. The GP of given sample was calculated by formula:

Ginning Percentage (%) =
(Weight of lint/ Weight of seed cotton) x 100

The ginning rate in grams of lint obtained per second per metre roller length (g $m^{-1}s^{-1}$) and ginning percentage of three cottons, when ginned using prototype double roller gin and existing DR gin (having roller diameter of 170 mm and length of 1360 mm) were measured.

Important fiber properties such as 2.5 % Span Length (SL), micronaire (Mic), fiber tenacity, Uniformity Ratio (UR), Short Fiber Index (SFI) and elongation are determined using High Volume Instrument HVI-900 of Uster Technologies, (USA). All these tests were performed at standard conditions of humidity and temperature (65 ± 2 % RH and 27 ± 2 ^{0}C).

RESULTS AND DISCUSSION

Summery of results of experimental tests is shown in *Table I.* There exists a definite relationship between the roller speed and lint output as shown in *Figure 8.* Study showed that by increasing the speed of roller from 80 to 140 revolutions per minute (75 %), the amount of lint ginned in grams per hour increased

from 1944 to 8371 (330 %), 1658 to 7113 (329 %) and 1374 to 6428 (367 %) for cotton Y.1, Rasi and DCH.32 respectively.

TABLE I Summery of results showing effect of roller RPM on Lint Output, Power requirement and lint quality

Roller speed, RPM	Lint Output, g/h	Power, kW-h/ kg lint	2.5 % SL mm	Mic	Tenacity g/tex	UR %	SFI	Elong-ation
	Cotton : Y.1							
80	1944	0.23	23.2	4.7	19.6	50.4	11.8	5.8
90	2696	0.17	23.4	4.7	19.6	50.0	11.9	5.9
100	3142	0.17	23.9	4.7	21.3	49.9	10.3	5.7
110	3650	0.14	23.2	4.7	18.8	50.0	12.4	5.7
120	4198	0.14	23.9	4.9	18.6	49.8	11.0	5.5
130	4459	0.11	23.4	4.8	19.5	48.3	10.2	5.9
140	8371	0.06	23.3	4.7	20.2	48.6	10.5	5.5
	Cotton: Rasi							
80	1658	0.27	29.9	4.0	24.0	45.8	7.8	4.8
90	2330	0.19	29.9	4.1	24.1	46.1	8.1	4.6
100	2696	0.19	29.8	3.9	23.7	46.1	7.8	4.7
110	3164	0.16	29.4	4.0	23.7	46.7	7.8	4.7
120	3668	0.16	28.4	4.0	21.5	47.0	8.6	4.7
130	4210	0.11	29.9	3.7	23.6	45.5	7.4	4.5
140	7113	0.08	29.6	3.8	24.2	44.6	7.6	4.8
	Cotton: DCH.32							
80	1374	0.32	34.4	3.1	26.0	42.5	8.1	5.6
90	2104	0.21	32.7	3.2	26.1	44.3	8.9	5.5
100	2398	0.22	34.5	3.2	26.5	43.1	7.7	5.6
110	3048	0.17	32.7	3.1	25.3	44.2	8.5	5.5
120	4002	0.15	32.5	2.9	24.5	44.8	9.0	5.9
130	4283	0.11	33.2	3.1	24.9	42.3	7.4	5.9
140	6428	0.08	33.3	3.1	25.3	42.2	7.2	5.9

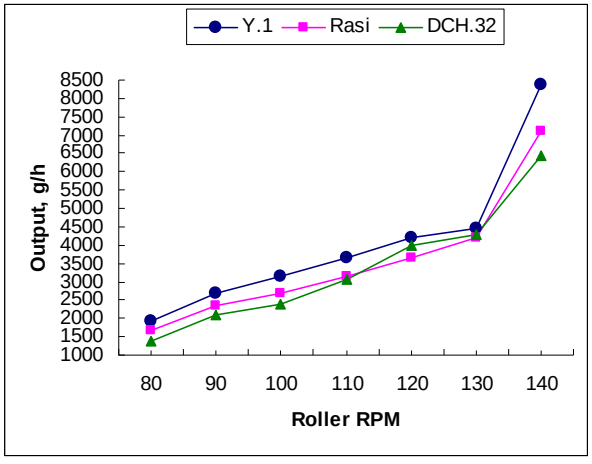


FIGURE 8 Roller speed Vs Lint output

From *Figure 9* it is also revealed that electrical units consumed to gin 1 kg lint decreases with the increase in the RPM of roller. Further study showed that by increasing the speed of roller from 80 to 140 revolutions per minute (75 %) there is saving in electricity of 73, 70 and 75 % for cotton Y.1, Rasi and DCH.32 respectively.

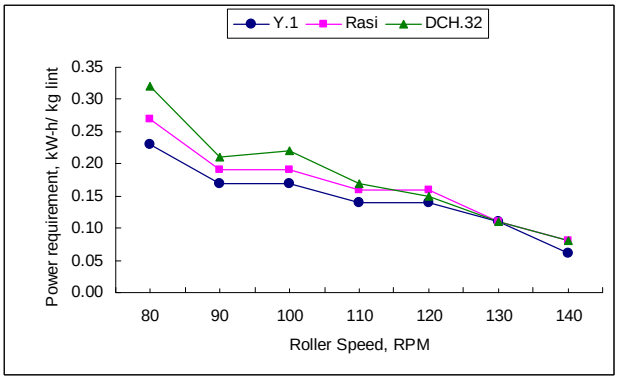


FIGURE 9 Roller speed Vs. Electrical units

Fiber property measurements showed that there is no significant variation of the 2.5 % span length, UR %, Mic, Tenacity, SFI, elongation with different roller speeds of 80 to 140 RPM. Thus it is clear that output per hour can be increased significantly by increasing the speed of the roller at the same time preserving the quality of lint.

Table II shows that there is no significant variation of ginning percentage of three cottons, when ginned using Prototype double roller gin and existing DR gin. The ginning rate in grams of lint obtained per second per metre roller length (g $m^{-1}s^{-1}$) is also given in *Table II*.

TABLE II Ginning percentage and ginning rate of prototype double roller gin and existing DR gin

Particulars of DR Gin	Ginning Percentage, %			Ginning rate, g $m^{-1}s^{-1}$		
	Y.1	Rasi	DCH.32	Y.1	Rasi	DCH.32
Prototype Gin	38.6	35.8	31.0	4.6	3.9	3.5
Existing Gin	38.4	35.9	31.1	5.1	5.2	5.1

The cost of the prototype double roller gin is about US $ 1000 (about Indian Rupees 40,000). Prototype double roller gin will have application in various cotton research institutes, agricultural universities, cotton markets, ginneries and seed industries for ginning the medium size cotton samples

CONCLUSIONS

The prototype double roller gin was designed and developed. Quantity of grease and oil requirement for newly designed machine is minimal. Gear train is totally replaced by v-belt and chain sprocket combination. The machine is simple and robust in construction. Quality evaluation studies indicate that quality of lint is not affected. Prototype DR gin will

have application in various cotton research institutes, agricultural universities, cotton markets, ginneries and seed industries for ginning and to ascertain ginning percentage. The design improvements incorporated in prototype DR gin are encouraging therefore scale-up model having roller length equivalent to one with commercial DR gin (i.e. 1360 mm) can be designed and developed. Further its' performance need to be evaluated by carrying out the extensive experimentation.

ACKNOWLEDGEMENT

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