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Development and Performance Evaluation of Self-Grooving Rubber Roller for Use in Roller Ginning Machine

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Abstract. Self-grooving rubber roller as substitute to chrome composite leather roller for use in ginning machine was developed. Self-grooving rubber roller was made out of rubber discs of hard and soft rubber compound prepared in a specially designed die by moulding technique. Roller was made with nitrile rubber having radial layers of softer rubber compound to form grooves. Compounding ingredients in appropriate proportion were added to provide sufficient hardness, temperature resistance, and to ensure effective ginning. Self-grooving rubber roller was tested on commercial double roller (DR) gin. Roller speed of 40 rpm was found to be optimum to achieve efficient ginning without any adverse effect on fibre and seed quality as against 100 rpm for leather roller. Gear box of the conventional DR gin was suitably modified to run at 40 rpm. Ginning performance of self-grooving rubber roller in terms of capacity, energy consumption, effect on fibre quality and cost economics was studied and compared with the leather roller. Use of the self-grooving rubber rollers was found to increase the productivity of the DR gin by 25 to 30%. Periodical grooving and drudgery involved in grooving operation in leather roller was eliminated in rubber roller which consequently resulted in reduction in machine downtime up to 2 hours/day. Energy consumption was found to be 15 to 18% lower and working like of the rubber roller was estimated to be 5000 hours as against 1000 hours in leather roller. Rubber roller is eco-friendly roller and there is no environmental pollution and health hazard to workers as there is no chromium contamination while ginning. It was observed that one time investment on the modification in DR gin can be paid back within a period of 76 working days of 20 hrs.

Keywords: Ginning, Rubber, Roller, Self-grooving

1. Introduction

Ginning machines are devices to separate the cotton fibres from seed cotton. There are normally three types of roller gins, namely Single Roller (SR) gin, Double Roller (DR) gin, and Rotary knife gin. The roller gins are commonly used in countries like India, Turkey, Uganda, Kenya, Myanmar, Tanzania, Thailand etc. The double roller gins work on the principle of Ma-carthy's gin. In India about 80% of cotton produced is processed using double roller gins. DR gin is the most important machine in ginning Industry.

The roller is the main component of a roller gin machine. Ginneries across the world primarily use materials for rollers viz., chrome composite leather, newspapers, walrus leather, rubber-canvas composite material, cotton woven fabrics, etc.[1]. Among these materials the chrome composite leather is the most widely used roller material. Annually about 2 lakh rollers of 1.2 to 1.5 m length are required in Indian roller gins. Though leather rollers are cheap but some problems are associated with them [2].

2. Problems with Chrome Composite Leather Roller

2.1. Roller Wear

The surface of the leather roller gets polished very fast while running. Therefore ginning output drops continuously. The decrease in output is observed to be up to 40-50% and monetary loss of about rupees twenty thousand per machine per season is seen. Maximum service life of the roller is about 1500 h.

2.2. Roller Grooving

Periodical grooving of leather roller is required to make the grooves of optimum size and make surface rough in order to catch the fibres. This process is labour intensive and lot of human drudgery is involved. Grooving is to be carried out manually and daily. It results in high downtime of gin machine, upto 1 hour per roller. Hence grooving operation is many a times uncared and neglected. It directly affects the production and deteriorates fibre and seed quality.

2.3. Water Absorption

The leather roller tends to absorb water and gets swelled whenever environment humidity becomes very high. It creates difficulties in ginning due to chocking of cotton between the roller and fixed knife. It leads to loss of output and damage to the fibre quality.

2.4. Chromium Contamination and Health Hazards

Leather washers contain 3 to 4 % chromium. During ginning process chromium gets mixed up into the lint, seed and air. Subsequently it contaminates the products made out of the lint and seed. Chromium emitted during ginning process pollutes ginning factory and premises. Since it is carcinogenic material, the gin and mill workers are exposed to the threat of respiratory diseases, allergic symptoms, brain damage, chronic ulceration, byssinossis disease, and continuous exposure can even lead to lung cancer [3].

2.5. Eco-standards

As per the eco-standards, chromium content in cotton and its products should not be more than 0.1 ppm but SPM and RSPM chromium concentration are found in the range of 50 to 190 ppm. There is a near possibility of the major developed countries introducing a specification limit for the extent of chromium level on finished cotton. Cotton processed in the chrome leather ginning machines will disqualify this criterion [4].

In view of the above problems the replacement or alternative to the chrome composite leather as roller material was very much desired for last several decades by ginning industries. Therefore efforts were made to develop a self-grooving rubber roller to overcome the problems encountered in chrome composite leather roller and to provide an alternate material for ginning roller.

3. Materials and Methods

The development of self-grooving rubber discs, preparation of ginning roller out of rubber discs, optimization of double roller (DR) gin machine parameters for efficient ginning with rubber roller, modifications in gear box of DR gin to adapt the rubber roller and performance evaluation of DR gin with self-grooving rubber roller in a commercial ginnery were carried out.

4. Development of Rubber Disc

Self-grooving rubber roller (Fig. 2) was made out of rubber discs (Fig. 1) of hard and soft rubber compound prepared in a specially designed die by moulding technique. Roller was made with nitrile rubber having radial layers of softer rubber compound to form grooves. Compounding ingredients in appropriate proportion were added to provide sufficient hardness, temperature resistance, and to ensure effective ginning. The hardness and the abrasion resistance of two rubber parts are adjusted in such a way that the soft rubber area abrade faster and form a groove. This special design of hard and soft rubber compound eliminates periodical grooving operation. Self-grooving rubber disc comprises of three parts i.e. inner hard core, outer ginning body and soft groove area.

4.1. Inner hard Core

It is a composite of rice husk, nitrile rubber and phenol formaldehyde resin. The inner core is hard enough to give stability to the roller and it prevents the roller from thermal expansion during ginning. The diameter of inner core of the disc was kept as 130 mm.

4.2. Outer ginning Body

Outer body is made with nitrile rubber. It can withstand high service temperature and is oil resistant. Ginning body catches fibre and performs the actual process of ginning. The depth of the outer body was kept as 35 mm.

Fig.1: Rubber roller disc

Fig.2: Self-grooving rubber roller

4.3. Soft groove Area

Soft grove is more abrading compared to the ginning body and forms the groove which in turn washes out the trash, cut seed etc. along with the ginned lint. The peripheral gap between two soft can be adjusted at the moulding stage. The number of layers of soft rubber compound could be varied depending on the staple length of the cotton to be ginned. The width depth of the soft rubber area is 2 mm and 35 mm deep.

4.4. Process of Roller Preparation

The ginning roller of desired length could be made by inserting required number of rubber discs on the square steel shaft of 50 mm in size. The discs were pressed from both the ends to bring all the rubber discs together and were secured in that position by putting flanges on either side. The roller was resized as per the requirement of roller gins on a lathe machine. The straight, staggered and spiral peripheral grooves can be formed as per the requirement.

Fig.3: View of self-grooving rubber roller showing the groove pattern

Fig.4: Modified double roller gin with rubber roller

4.5. Modifications in Double Roller Gin with Rubber Roller

An extra-long conventional DR gin (1150 mm roller length) was suitably modified by replacing its gear transmission system for fitting the rubber rollers in place of existing leather rollers. The modified gin operates at 40 rpm of roller speed. The conventional DR gins operate at roller of 100 rpm.

4.6. Performance Evaluation

Self-grooving rubber roller was tested on commercial conventional DR gin at Ginning Training Centre of Central Institute for Research on Cotton Technology (CIRCOT), Nagpur. Roller speed was optimized to achieve the efficient ginning without any adverse effect on the fibre and seed quality. The roller and the

modified machine (Fig.4) was tested in a commercial cotton ginnery Ginning performance in terms of capacity, energy consumption, effect on fibre quality, ease of operation and cost economics was studied. The comparative analysis of ginning of cotton by using chrome composite leather roller and self-grooving rubber roller was also carried out

5. Results and Discussion

5.1. Performance Evaluation of Self Grooving Rubber Roller on Conventional DR Gin

Self-grooving rubber roller was tested on conventional DR gin with roller length of 1150 mm. Effective ginning was achieved and self-grooving principle was found to work satisfactorily. Rubber roller has very high abrasion resistance and temperature rise during ginning was found within the acceptable range. The fibre holding capability between knife and rubber roller was found to be better than between knife and leather roller. The slippage of cotton was observed to be less in rubber roller. The pull exerted by the rubber roller was noticed to be higher at speeds more than 40 rpm. Cotton pulled by the roller was much higher at roller speed of 100 rpm resulting in higher ginning rate. It was observed that rubber has great potential for providing higher ginning capacity in roller gins without affecting the fibre quality. Conventional DR gin has certain limitations of metering higher seed rate through the grids. It resulted in chocking of lint and seed cuts. Therefore the roller speed was optimized to achieve the efficient ginning. The roller speed of 40 rpm was observed to be optimum for ensuring effective ginning. Lint output of DR gin with rubber roller at a speed of 40 rpm was found to be 25-30% higher than conventional DR gin running at 100 rpm.

5.2. Performance Evaluation of Modified Double Roller gin with Self Grooving Rubber Roller

The modified DR gin with rubber roller was installed at M/s. Narendra Sahakari Ginning Pressing Factory, Parsioni, Maharashtra for its extensive field trials. The performance of the gin was compared with the conventional extra-long DR gin fitted with chrome leather roller. The modified gin was run for around 700 hours. The comparative performance of the modified DR gin and conventional DR gin leather roller gin is shown in Table 1. The productivity of the modified gin was found to be 25 to 30% higher compared to the leather roller gin. The difference in the productivity widens with the running time. It is probably due to higher rate of leather roller wear compared to the rubber roller. Moreover, the specific energy consumption for the modified gin was found to be 15 to 18% lower than that of the leather roller gin. The energy saving in the modified gin was seen due to the lower roller speed and higher friction coefficient of the rubber material compared to the leather roller. It was further observed that the leather roller got polished during the ginning operation leading to the reduction in the ginning outturn. Fibre parameters presented in Table 2 shows that the leather roller and rubber roller do not have any significant effect on the fibre parameters.

There was significant reduction in the vibration for the modified gin compared to the leather roller gin. It was mainly due to working of the modified gin at 40 rpm while the DR gin was operated at 100 rpm. The lower sped of the rubber roller results in insignificant wear of fixed knife for around 350 hours of ginning while 1 mm fixed knife wear was observed for the same period of operation in case of leather roller gin. The downtime required towards grooving operation was completely eliminated by use of self-grooving rubber roller.

Table 1: Comparison of DR gin with leather roller and modified DR gin with rubber roller

Particulars	Leather Roller	Rubber Roller
Roller RPM	**100**	**40**
Current, amp	**5.91 – 6.23**	**5.29 – 5.67**
Voltage, V	**389**	**395**
Power requirement, kW	**3.29 – 3.48**	**3.47 – 3.70**
Power Factor	**0.816**	**0.975**
Energy Consumption, kWh	**3.36**	**3.52**

Productivity, kg lint/h	**54.1**	**68.9**
% increase in productivity	**-**	**27.4**
Specific energy consumption, kWh/kg lint	**0.062**	**0.051**
% decrease in energy consumption	**-**	**17.4**
Wearing of Knife	**-**	**-**
Maximum Roller Temp., ^{0}C	**92**	**87**
Diameter of Rollers, mm	**161**	**163**
Working Hours	**-**	**-**

Table 2: Fibre Properties of the lint obtained using leather and rubber roller DR Gins

Particulars	2.5% SL (mm)	2.5% SL (mm)	MIC (g/inch)	Strength (g/tex)	UR (%)
Leather Roller	**28.9**	**26.9**	**3.4**	**21.8**	**48**
Rubber Roller	**29.1**	**26.7**	**3.5**	**21.5**	**48**

Table 3: Economics of return on investment for rubber roller DR Gin

Particulars	Value
Cost of one pair leather roller (Rs.)	**4000**
Cost of one pair rubber roller (Rs.)	**50000**
Additional investment required (Rs.)	**46000**
Lint productivity of leather roller gin (kg/h)	**70**
Lint productivity of leather roller gin (kg/h)	**84**
Increase in productivity by using rubber rollers (kg/h)	**14**
Extra productivity of lint due to saving in down time of 1 h per day (kg)	**84**
Increase in productivity for one day of 20 h run (kg)	**364**
Profits due to increased productivity per day (Rs. 120/100 kg ginning charges (Rs.)	**437**
Energy saving (kWh) for running of Rubber roller DR gin for one day of 20 h	**16.8**
Cost of energy saving @ Rs. 10 per unit (Rs.)	**168**
Total economic benefits for using roller roller for one day (Rs.)	**605**
Number of days required for return on investment (days)	**76**

The cost economics is depicted in Table 3. Results indicates that rubber roller can be used as a substitute to leather roller for use in roller gins after making recommended modifications in the gear box of the conventional DR gin to run the roller at 40 rpm. Use of the self-grooving rubber roller increases the productivity of the machines by 25 to 30%. This is on account of the fact that rubber roller surface maintains the required roughness that helps cotton pickup compared to the polished surface of the chrome composite leather. The properties of the ginning surface of the roller remain unchanged throughout the service. So there is no decrease in output with running time. Working like of the rubber roller is estimated to be 5000 hours as against 1000 hours in leather roller. Periodical grooving and drudgery involved in grooving operation is eliminated in rubber roller. Rubber roller is eco-friendly roller and there is no environmental pollution and health hazard to workers as there is no chromium contamination while ginning. Since chromium is not used in rubber rollers, gin and mill workers are not exposed to the threat of respiratory diseases.

6. Conclusions

Self-grooving rubber roller was developed as substitute to chrome composite leather roller. Use of the rubber roller increased the productivity of the DR gin by 25 to 30%. Periodical grooving and drudgery involved in grooving operation was eliminated. It resulted in reduction in downtime up to 2 hours/day.

Energy consumption reduced by 15 to 18% and working like of the rubber roller was estimated to five times that of leather roller. Rubber roller is eco-friendly and there is no environmental pollution and health hazard to workers as there is no chromium contamination while ginning. It was observed that one time investment on the modification in DR gin can be paid back within a period of 76 working days of 20 hrs.

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