

# DESIGN AND PRODUCTION OF AN ECO-FRIENDLY GINNING TECHNOLOGY FOR THE PROCESSING OF COTTON FIBRES

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*This article discusses the pollution caused by chrome composite leather-clad (CCLC) rollers commonly used in cotton roller ginning mills and suggests an alternative roller material. CCLC rollers contain about 18,000 to 36,000 mg/kg (ppm) total chromium in trivalent and hexavalent forms, which are toxic to human health and carcinogenic. When seed-cotton is processed in double roller (DR) ginning machines, the lint is contaminated with chromium, and chromium particles are carried into the spun yarns and cotton by-products. Specifically, due to persistent rubbing of the leather-clad roller over the stationary knife during the ginning process, the lint is contaminated with about 140 to 1,990 ppm of chromium, and the spun yarns and cotton by-products contain about 100 to 200 ppm, far in excess of the standard limit of 0.1 ppm. Gin and mill workers are directly exposed to this carcinogenic substance. To offset this problem, pollution-free rubberized cotton fabric (RCF) rollers have been fabricated and tested in roller gins. The RCF roller covering is made of multiple layers of fabric bonded together using a white rubber compound, which has a surface finish conducive to high ginning efficiency. This eliminates chromium contamination and pollution during the ginning process. On the basis of the design and development of various test rollers and subsequent evaluation studies, the performance of pollution-free RCF rollers has been demonstrated with reference to their commercial benefit and eco-friendliness in cotton ginning mills.*

**Key words:** Carcinogenic problems, Chromium, Cotton, Eco-friendly, Ginning, Roller, Rubberized roller.

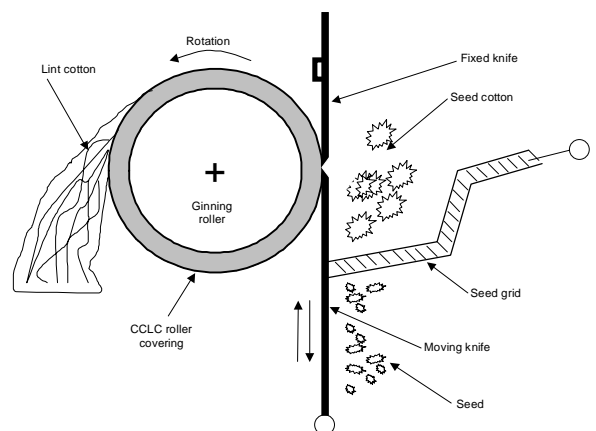
## INTRODUCTION

The roller ginning process for cotton was invented by Fones McCarthy in 1840<sup>1,2</sup>. This process mechanically separates cotton fibers from seeds by means of one or more rollers to which fibers adhere while the seeds are struck off or pulled loose. Figure 1 shows the working principle of the roller ginning process. In the conventional ginning process, the chrome composite leather-clad (CCLC) rollers emit chromium into the environment due to the constant dust-producing grinding action<sup>2</sup>. This contaminates the cotton and its products beyond the safe limit prescribed by world environmental standards. The

ginned lint becomes contaminated with 140 to 1,994 mg/kg (ppm) of chromium and the spun yarns with 17 to 500 ppm, far above the safe limit of 0.1 ppm<sup>3</sup>. Since semi-finished chrome leather washers, which contain 3% to 4% chromium, are being used by roller ginning mills in India, Africa, Tanzania, China, and Egypt, attention has been drawn to the contaminating and polluting aspects of the process<sup>4</sup>.

The use of CCLC rollers in the ginning process also causes air pollution

in the mill environment. It has been argued that the air pollution due to chrome-specific dust (CSD) and cotton dust is responsible for



**Fig. 1. Working principle of the cotton roller ginning process.**

synergistic health complications (chromium-based diseases and byssinosis) among gin and mill workers<sup>5</sup>. Chromium adsorbed into the lint causes toxic effects such as allergic symptoms, cancer, brain damage, chronic ulceration, and perforation of nasal septa in cotton processing workers<sup>6</sup>. Toxic effects are produced by prolonged contact with airborne, solid, or liquid chromium contamination and pollution, even in small quantities<sup>7</sup>. An alternative roller material, rubberized cotton fabric (RCF), that is eco-friendly, non-polluting, and chromium-free, has been developed to replace conventional CCLC rollers<sup>2,8</sup>.

## OBJECTIVES AND PRESENT RESEARCH STATUS

The objectives for this research were to:

- Identify and study the environmental problems associated with the chrome rollers currently employed in cotton roller ginning mills.
- Design and develop an eco-friendly, chrome-free roller and evaluate its performance with particular reference to the environmental, technical, and commercial aspects of ginning mills.

This research is an attempt to eliminate the contamination of cotton and its products, air pollution in cotton ginning mills, and other ginning problems at the source through the design and development of an eco-friendly, pollution-free chromeless roller<sup>2</sup>. RCF rollers have been used successfully by U.S. gin machinery manufacturers for more than 30 years<sup>2</sup>. Nevertheless, current roller gins manufactured by Indian and foreign companies commonly incorporate CCLC materials<sup>2,9</sup>.

A literature survey was carried out to help meet the objective of designing and developing eco-friendly alternatives<sup>22</sup>. Various eco-

friendly alternative roller covering materials and methods have been studied, such as vegetable tanned leather, eco-friendly tanned leather, alternative rubber and rubber-processing technologies, and modification of the present CCLC roller ginning system<sup>2,8</sup>. As a result, an eco-friendly roller ginning process has been developed for replacing the conventional CCLC roller ginning process to eliminate the chromium contamination and pollution from cotton roller ginning mills. This process meets the requirements of environmental standards while maintaining high-quality spun yarns and woven fabrics to meet international standards<sup>2</sup>.

## DESCRIPTION AND PERFORMANCE OF ROLLERS

The roller is the main component of double roller (DR) gins. The roller length varies from 1025 to 1148 mm with a diameter ranging from 178 to 180 mm<sup>10</sup>. The roller consists of 78 to 80 washer disks. Each disk is 180 mm diameter and 18 mm thick and is made of 18 CCLC flaps stitched and bonded together (Fig. 2). Basic chromium sulfate (BCS),  $\text{Cr}(\text{OH})\text{SO}_4 \cdot n\text{H}_2\text{O}$ , and impure chromate having 45% to 50% basicity are used during the chrome leather tanning process for

making each of the CCLC flaps<sup>11</sup>. The disks are mounted on a steel shaft with a 50 x 50 mm square cross-section to form a roller. The roller is pressed on both ends by adding the required number of disks on each end<sup>2</sup>. The disks are compressed to a pressure of 140 kPa using a conventional pressing machine<sup>12</sup>. The pressed roller is then turned and finished to a diameter of 180 mm on a lathe. Spiral grooves are made on the surface of the finished roller using a band saw or circular saw cutting machine<sup>13</sup>.

To offset the problem of pollution caused by the use of chrome leather rollers, pollution-free rubberized cotton fabric (RCF) washers were fabricated for laboratory and commercial studies and were used in the rollers of ginning machines<sup>2</sup>. The performance of these eco-friendly chromeless rollers was evaluated with particular reference to the technical, commercial, and environmental aspects of the ginning process. For these tests, the roller covering was made of multiple layers of fabric bonded with a white rubber compound, which has a surface finish conducive to high ginning efficiency. Fig. 3 shows an assembly drawing of the

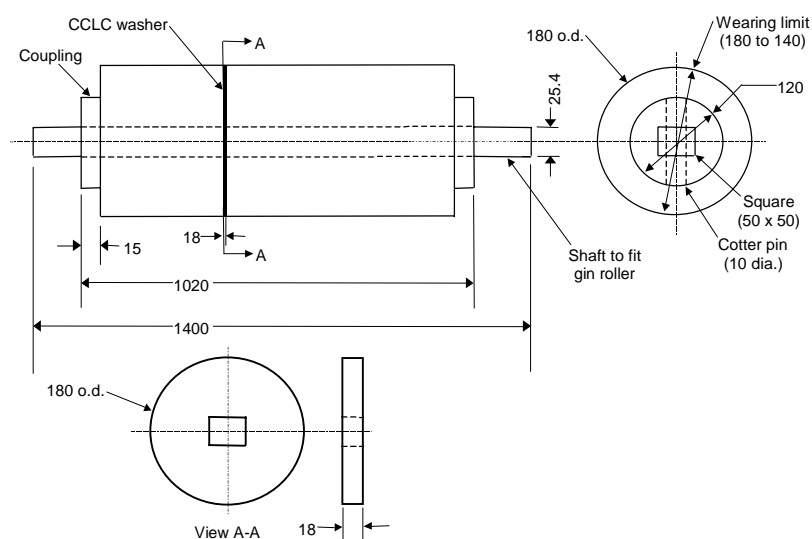


Figure 2. Drawing of the chrome composite leather-clad (CCLC) washers that comprise the roller of a double roller ginning machine (all dimensions in mm).

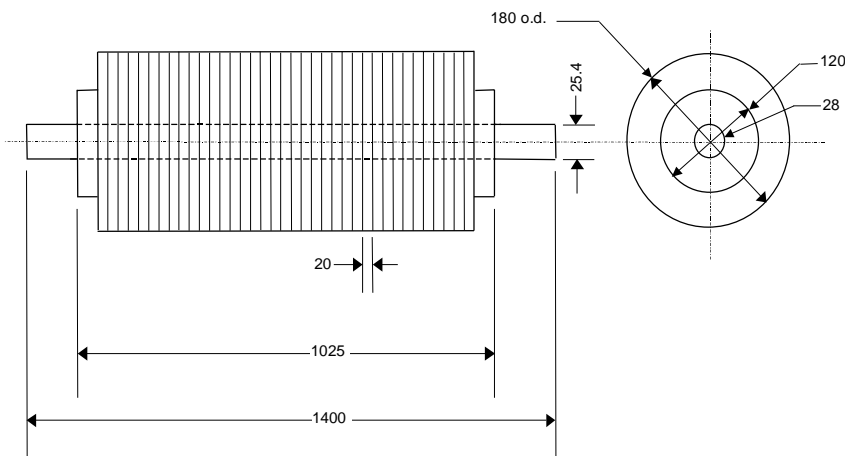


Fig. 3. Drawing of rubberized cotton fabric (RCF) washers for making RCF rollers of double roller gins (all dimensions in mm).

rubberized cotton fabric (RCF) washers used for making RCF rollers for double roller gins.

### MATERIALS AND METHODS

For the present study, roller wear and compaction rate studies were conducted in roller ginning mills in Belgaum, India, for the 1996-1997, 1998-2000, and 2001-2006 cotton seasons<sup>2</sup>. The roller gins were adjusted using spacers as per the standards. Grooving was done regularly at the start of each shift as per the requirements of the cotton varieties<sup>14</sup>. An atomic absorption spectrophotometer was used following the standard American Public Health Association (APHA) method for chromium analysis of samples of lint, seed, seed-cotton, CCLC rollers, soil, plant roots, fiber, yarn, fabric, and textile effluent<sup>15</sup>. Respirable suspended particulate matter (RSPM) and suspended particulate matter (SPM) levels in the ginning mill environment were monitored using a high-volume air sampler (HVAS)<sup>17</sup> with a cascade impactor and appropriate glass fiber filters. Pollutants were collected by the HVAS over 8 h and analyzed for chromium<sup>16</sup>. Worker dose and exposure times were determined using personal samplers<sup>17</sup>.

A health study was conducted by the author at ginning mills in Guntur, Bailhongal, Sendhwa, and Surendranagar in India. Studies

were also conducted in Tanzania and other countries to survey health effects and occupational health hazards<sup>4</sup>.

The ginning investigations were carried out at the Central Institute for Research on Cotton Technology (CIRCOT), Mumbai, India. The laboratory rollers for the GRED (gin roller experimentation device) were designed and fabricated in Kolkata, India, at a local manufacturing firm. After the initial tests, pilot model rollers were designed and fabricated to be tested in ginning

mills in Bailhongal and Sendhwa. Environmental analysis was done at the Centre of Mining Environment, Indian School of Mines, Dhanbad, and at the Eco-Textile Laboratory of the Textiles Committee, Ministry of Textiles, Mumbai. Mechanical properties were analyzed in various mechanical engineering laboratories. The pilot model was demonstrated in a roller ginning mill in Bailhongal<sup>2</sup>.

### RESULTS AND DISCUSSIONS

An experiment was conducted to determine the wear rate and compactness rate (compactness is defined as the mechanical binding effect of chrome composite leather cladding due to the constant dust-producing grinding action of the rollers) of the CCLC rollers used by roller ginning mills for a season lasting three months. At the start of the season, the diameter of the rollers was 180 mm. At the end of the season, the roller dimensions were noted at the left, middle, and right positions for all 18 roller gins in the mill<sup>2</sup>.

The results are presented in Table 1. In addition to the wear

Machine Number	Diameter of the Rollers after One Season*					
	Roller Side A			Roller Side B		
	Left	Middle	Right	Left	Middle	Right
1	140	140	140	141	143	142
2	140	140	140	140	142	142
3	145	146	150	150	145	140
4	153	153	153	148	148	148
5	148	147	148	148	148	148
6	146	147	148	146	146	146
7	135	135	135	145	142	140
8	140	140	140	145	142	140
9	150	150	150	148	148	148
10	138	136	136	136	136	136
11	145	145	146	145	145	145
12	136	136	136	136	136	136
13	158	158	158	158	157	157
14	160	160	160	161	160	160
15	154	154	154	155	156	156
16	155	155	156	155	154	154
17	160	160	159	160	160	160
18	160	160	161	160	161	166

\* Initial diameter of the rollers was 180 mm, roller compactness rate was 0.010 to 0.050 mm (i.e., 10 to 50 mm/h), wear rate was 0.033 mm/h, and average percent material removed per roller was 43.8%.

rate, the table indicates the quantity of pollutants generated during the operation, e.g., chromium, leather powder, cotton dust, and chrome-specific dust. The overall wear rate was 0.033 mm/h, and the percentage material removed per roller was 43.8%. The final roller diameter at the end of the study was nearing 140 mm. The compaction rate was 0.050 mm/h.

Figure 4 shows a graph of the wear rates during dust-producing grinding of the CCLC roller and the RCF roller. The results of the chromium content analysis of cotton lint samples, seed and seed linters, seed-cotton samples, and fiber, yarn, and fabric samples are shown in Tables 2 and 3. The CCLC roller contains 18,077 mg/kg (ppm) to 30,780 mg/kg (ppm) of total chromium (3% to 4% total chromium). These levels include trivalent and hexavalent chromium. During the ginning operation, lint adsorbs chromium particles in the range of 143 mg/kg (ppm) to 1,994 mg/kg (ppm) because cotton dust is a good adsorbent of chromium powder<sup>18</sup>. At the beginning of the season, roller wear was greater, and chromium levels reached 1,994 mg/kg (ppm) in the lint, as listed in Table 3. The total weight of chromium removed during a cotton season of 16 h per day for three months was 450 to 600 g per gin roller. The environmental standards for trivalent chromium, Cr(III), in baby clothing such as fabrics, spun yarns, etc., is 0.1 ppm (mg/kg), and 0 ppm (mg/kg) for hexavalent chromium, Cr(VI)<sup>3</sup>. Engineering parameters, cotton technological parameters, fiber properties, yarn properties, and chemical and dye catch parameters from a total of 41 tests are listed in Tables 4, 5, and 6 for comparative purposes<sup>2</sup>.

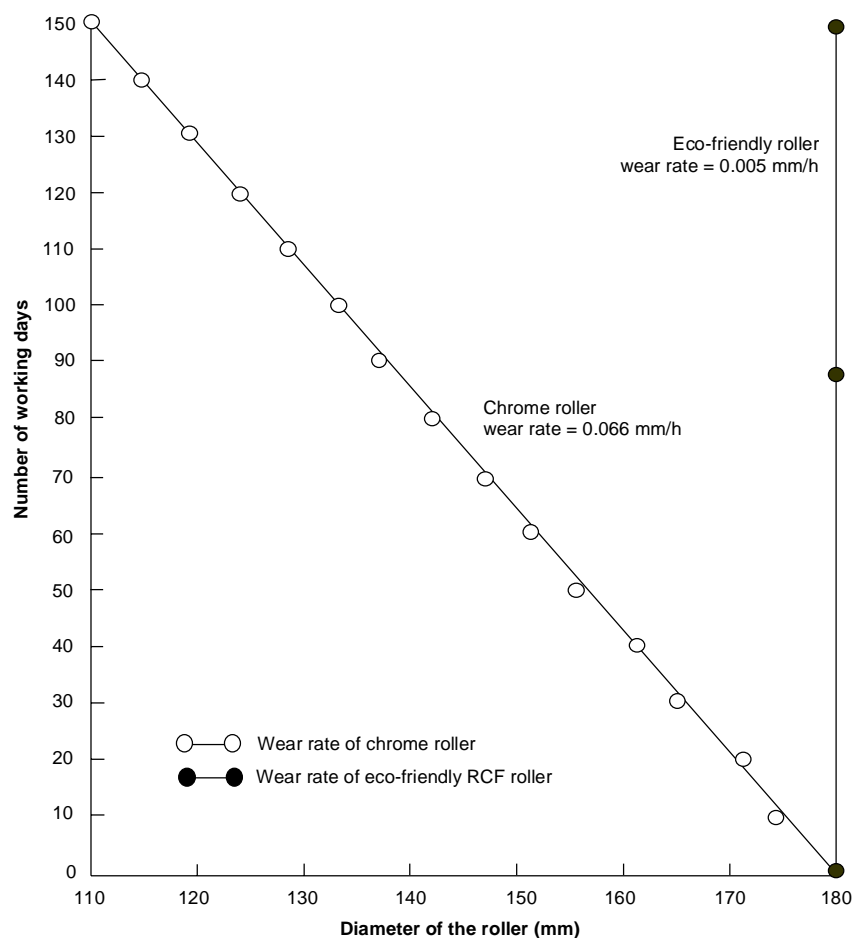


Fig. 4. Wear Rates During Dust-producing Grinding of Chrome Roller And Eco-friendly Roller.

Table 2 : Measured Chromium Contamination Levels In Cotton and Its Products.

Sample	Source Chromium (cotton and its products)	Total Chromium Cr(III) + Cr(VI), ppm (mg/kg)	Environmental Standards for Allowable Levels, ppm (mg/kg)
1	CCLC rollers	18,077 to 30,783	Cr(III) = 0.1; Cr(VI) = 0
2	Lint cotton	143 to 1,990	Cr(III) = 0.1; Cr(VI) = 0
3	Spun yarns	17 to 250	Cr(III) = 0.1; Cr(VI) = 0
4	Woven fabrics	17 to 45	Cr(III) = 0.1; Cr(VI) = 0
5	Cotton seeds	0 to 312	Cr(VI) = 0
6	Edible oil	0 to 259	Cr(VI) = 0
7	Oil cake	0 to 190	Cr(VI) = 0
8	Linters	0 to 159	Cr(VI) = 0
9	Bio-availability	3	Cr(VI) = 0

**Table 3. Chromium level in dust samples.**

Sample	Sources of Dust Samples	Total Chromium, Cr(III) + Cr(VI), ppm (mg/kg)	Environmental Standards (ppm)*
1	Ginning point	51 to 173	50
2	CCLC grooving point	17 to 1,994	50
3	Respirable suspended particulate matter (RSPM)	358	50
4	Suspended particulate matter (SPM)	1,290	50
5	Cotton dust	856	50

\* Lethal oral dose, LD<sub>50</sub> (NIOSH, 1992).

**Table 4. Test Results of Engineering analysis of Eco-friendly Lint Cotton and Chromium-contaminated Lint Cotton.**

Test	Engineering Parameters	Ginned Lint Cotton from:	
		Eco-friendly	CCLC
		Gin Rollers	Rollers
1	Seed index	7.07	7.34
2	Knife blunting	Every 4 days	Daily
3	Frequency of grooving of gin rollers	Every 5 days	Daily
4	Power at no load conditions, 400 V	1.28 kW	1.6 kW
5	Power at full load conditions, 400 V	1.696 kW	1.92 kW
6	No load current	4 A	5 A
7	Full load current	5.3 A	6 A
8	Seed fuzz	6.2%	5%
9	Diameter reduction per machine-hour	37.89 mm or less	64 mm
10	Production per machine hour	38.26 kg	36 kg
11	Expected useful life of clad washers (wearing up to 30,000 mm)	844 or more machine-hours	437.5 machine-hours
12	Friction of roller to lint cotton	0.768	0.123
13	Noise equivalent energy level (Leq) of the gins	97-103 dB(A)	103-106 dB(A)
14	Chromium particulates	0 ppm	143 ppm

**Table 5. Test Results of Technological Analysis of Eco-friendly Lint Cotton and Chromium-contaminated Lint Cotton Using High-volume Fiber Testing Instrument.**

Test	Cotton Technological Parameters	Ginned Lint Cotton from:	
		Eco-friendly Gin Rollers	CCLC Rollers
15	2.5% span length	27.7	28.6
16	Tenacity (g/tex)	21.3	22.2
17	Uniformity ratio	46	45
18	Short fibers (%)	3.5%	4%
19	Color, grade, and appearance	Yellowish, very good	White shine, poor

**Table 6: Test Results of Technological Analysis of Eco-friendly Lint Cotton and Chromium-contaminated Lint Cotton Using Scanning Electron Microscope**

Test (Variety)*	Cotton Technological Parameters	Ginned Lint Cotton from:	
		Eco-Friendly Gin Rollers	CCLC Rollers
	Wax content	0.3%	Nil
	Dye-catch properties	Very good	Poor
	Dye uptake	Very good	Poor
	Scanning properties (physical and chemical)	Very good	Poor
(DCH 32)	2.5% span length (mm)	35.6	35.4
(DCH 32)	Uniformity (%)	46	44
(DCH 32)	Baer sorter, mean length	32.3	32.8
(DCH 32)	Elongation	40	42
(DCH 32)	Short fibers (%)	14.6	16.4
20 (DCH 32)	Tenacity (g/tex)	28.6	27.8
21 (DCH 32)	Micronaire	3	2.8
22 (V 797)	2.5% span length	28.5	28.2
23 (V 797)	Uniformity ratio (%)	47	47.2
24 (V 797)	Short fibers (%)	6.2	5.2
25 (V 797)	Tenacity, g/tex (1/8 in. Stello gauge)	21.8	21.4
26 (V 797)	Elongation	6	5.7
27 (V 797)	Micronaire	3.4	3.3
28	Area (%)	0.6	0.7
29	Trash count	28	28
30	Leaf	3	4
31	Rd	67.7	67.8
32	Color grade	24.4	24.4
33	Scanning color index (SCI)**	128.0	129

\*Cotton varieties shown in parentheses where applicable.  
 \*\*(Vijayan,2004)

## COMPARATIVE ECONOMICS

Comparative economics have been worked out for ginning mills with conventional CCLC rollers and with chromeless RCF rollers (the "system before modification" and the "system after modification," respectively), as listed in the Table 7.

## CONCLUSIONS

The CCLC rollers used in ginning mills are ground to powder during the ginning operation and enter the environment as chrome-specific dust (CSD). It was observed that CSD contaminated the cotton and its products<sup>2</sup>. The chromium contamination levels for cotton and its products were well above allowable limits for all samples, except for the cotton samples ginned with RCF rollers. On the basis of the design and development of various rollers and subsequent performance evaluations, the chrome-free RCF roller has been demonstrated to be

**Table 7. Comparative economics.**

System before modification	System after modification	Saving or benefit with RCF roller
CCLC rollers for DR gins	Eco-friendly, chrome-free RCF roller for DR gins	
Initial cost is Rs 20/- to 25/- per washer.	Initial cost is Rs.100/- per washer (price variable based on quantity).	
The washers can be used for 2 to 3 months in a cotton season. New washers are replaced about twice a year. Maintenance cost is ten times more than with RCF roller because roller grooving, gin settings, and pressure adjustments must be done frequently. This results in lower productivity. Chromium contamination and pollution problems occur in major cotton growing areas in India, Tanzania, Africa, and Egypt.	Although the initial cost of the RCF roller is four times that of the CCLC roller, it lasts for up to seven years with no maintenance. Considering the maintenance and replacement costs, the cost works out to be Rs. 20 per washer. No grooving is required except in initial maintenance. Additional benefits include: high productivity, cleaner production, no waste in product, ecological production, and no chromium contamination or pollution problems.	Although the initial cost is higher, the replacement and maintenance costs of the RCF roller are eight times less than those of the CCLC roller.
Washer replacement cost for a mill with 12 DR gins is Rs.90,000/- per cotton season.	Washer replacement cost for a mill with 12 DR gins is Rs.50,000/- per cotton season.	Rs.40,000/-
Medical costs for treating the workers are abnormal <sup>11,21</sup> .	Medical costs for treating the workers are much less, as there is no chromium pollution problem <sup>12,20</sup> .	Safe environment
Labor output per hour is 1.2 standard performance rating <sup>11</sup> .	Labor output per hour is 2.4 standard performance rating, which is twice that of CCLC ginning because of the cleaner environment <sup>12</sup> .	Two times higher productivity with RCF roller.
Washers last one season.	Washers last for 14 seasons.	Longer life with RCF roller.
Unsafe chromium contamination and pollution.	No chromium contamination or pollution in the environment.	Eco-friendly technology.

superior with reference to technical, commercial, and eco-friendliness aspects of the cotton ginning industry. This improved technology is suitable for commercialization<sup>2</sup>. Although the initial cost of the RCF roller is four times that of the CCLC roller, this high price is compensated by benefits. The RCF roller is durable, with an estimated life of seven years (compared to a few months for CCLC rollers), and has the following additional advantages:

8. Negligible wear and tear and very low maintenance requirements.
9. Output is about twice that of CCLC rollers because the RCF roller has a surface finish conducive to high ginning efficiency.
10. Electrical energy consumption is reduced.
11. Noise level is reduced by 4 to 7 dB(A) due to inherent properties and cushioning effects (Table 4).
12. Eco-friendly cotton and cotton by-products are produced.
13. Labor output per hour is 2.4 standard performance rating, which is twice that of CCLC-equipped mills<sup>2</sup>.
14. Medical expenses for treating affected workers are decreased by a factor of 23<sup>12,21</sup>.

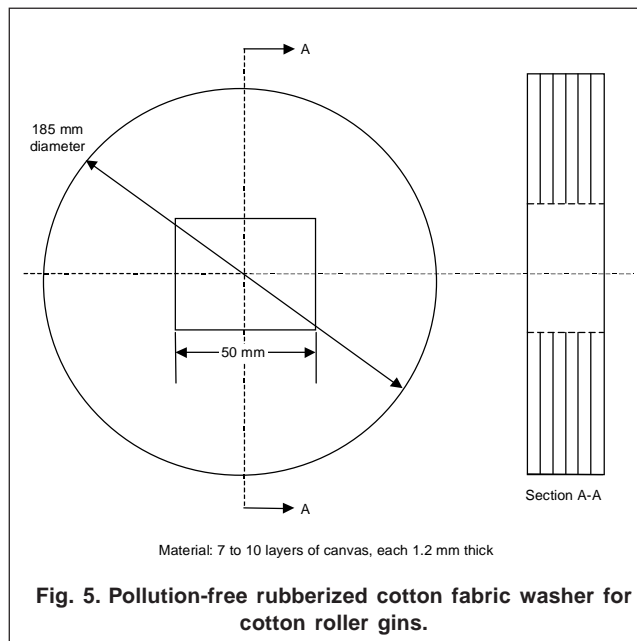
The manufacturing technology, design engineering features, and assembly experience show that the RCF roller covering material can be selected with the following characteristics (Fig. 5): hardness of 90 (type DO durometer), 7 to 10 layers of fabrics 20 mm in length, and fabric thickness of 1.2 mm. The rubber compound is resilient, and fiber bristles protrude 0.76 mm beyond the rubber surface in spite of wear<sup>2</sup>.

## SUMMARY AND RECOMMENDATIONS

The newly developed RCF rollers were successful and effective in ginning seed-cotton<sup>2</sup>. The eco-friendly rollers also allowed source pollution control, so that the ginning process can comply with the environmental standards that are being enforced by many countries, and high-quality

yarns and fabrics that meet international standards can be produced. With RCF rollers, ginning mills will be freed from chrome-related contamination and pollution problems, and from chrome-related health hazards. The products have been tested commercially and found to be better in all aspects with reference to cotton technological parameters, dye-catching properties, and physical and chemical properties.

Eco-friendly rollers could be successfully used commercially as an improved alternative in ginning mills for a cleaner environment, which benefits society, mill owners, clients, workers, and employees. It is imperative that policy is enacted to do away with CCLC rollers and replace them with eco-friendly rollers. Government and regulatory authorities such as the Indian Council of Agricultural Research (ICAR), United States Department of Agriculture (USDA), European Commission (EC) and Central Pollution Control Board (CPCB) should come forward to subsidize this venture in view of its proven technical and commercial feasibility in connection with eco-friendliness<sup>2</sup>.




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