

Eco-Friendly Rubberized Cotton Fabric Roller Development For Cotton Roller Gins

Gurumurthy Vijayan Iyer,
MNM Jain Engineering College,
36, Venkatesh Nagar Main Road,
Virugambakkam, Chennai-600 092,
INDIA

Nikos E. Mastorakis
WSEAS European Office
Agiou Ioannou Theologou 17-13,
15773, Zografou, Athens,
GREECE

Abstract: This paper realizes the hazards of chromium contamination and pollution caused by the use of Chrome Composite Leather-Clad (CCLC) rollers commonly used in cotton roller ginning industries and attempts to eliminate the chromium contamination and pollution during the complete process. Most of the cotton ginning operations are performed by using double roller (DR) ginning machines which serve an important role in the cotton ginning industries. The rollers used in these industries are made of Chrome Composite Leather-Cladding (CCLC) covering fixed to a shaft. The CCLC coverings contain about 18 000 to 36 000 mg/kg (ppm) as total chromium of trivalent and hexavalent forms which are toxic and carcinogenic to human health. When the seed-cotton is processed in DR ginning machines, the lint cotton is contaminated with chromium of about 140 to 1990 ppm as against the safety limits of 0.1 ppm. During the cotton ginning process due to persistent rubbing of leather over stationary knife the chromium particles are carried into lint cotton such that the spun yarns and cotton by-products contain about 100 to 200 ppm, which according to world environmental standards should not be more than 0.1 ppm. Gin and mill workers are directly exposed to this carcinogenic substance and are vulnerable to health hazards. To offset this problem, pollution-free rubberized cotton fabric (RCF) rollers both for laboratory and commercial studies have been fabricated, experimented and used in roller gins. In this the roller covering is made of multiple layers of fabrics bonded together using white rubber compounding which has a surface finish conducive to high ginning efficiency. This nullifies chromium contamination and pollution during the cotton ginning process process. On the basis of the design and development of various rollers with subsequent performance evaluation studies, pollution-free RCF washers/ rollers have been demonstrated with a reference to techno-commercial and eco-friendliness in ginneries. Cotton technological parameters are well proven for commercial acceptance. This cleaner technology is a source-at-control preventive measure such that the cotton ginning and textile industries meet the requirements of environmental standards being enforced by many countries and high quality yarns and fabrics meeting international standards are produced. This found better in all aspects with reference to cotton technological properties, dye-catch properties, physical and chemical properties. Eco-friendly rubberized cotton fabric rollers can be used commercially as an alternative to the present CCLC rollers in the cotton roller ginning industries for the benefit of environment, society, gin and textile mill owners, traders, workers, employees and the government.

Keywords : Cotton, chromium, roller, ginning, gins, eco-friendly, rubberized roller

1. Objectives and Need of the Present Research

The objectives of this research are:

- To identify and study the environmental problems existing with the present chrome rollers employed in cotton roller ginning industries.
- To design and develop an eco-friendly non-chrome rubberized cotton fabric rollers and evaluate its performance with particular reference to environmental and techno-commercial aspects in cotton ginning industries.

With the author's research background and practical experience in ginning and textile industries, present study is attempted to eliminate this problem to the great extent at the source itself, through a suitable design and development of an eco-friendly, pollution-free chrome less roller for cotton roller gins. An eco-friendly roller ginning process has been developed for replacing conventional CCLC roller ginning process to eliminate the chromium contamination and pollution from cotton roller ginning industries so as to meet the requirements of environmental standards while maintaining high quality spun yarns and woven fabrics meeting the international standards.

2. Introduction

The principle of the cotton roller ginning process was invented McCarthy. This process is the mechanical separation of cotton fibres from their seeds by means of one or more rollers to which fibres adhere while the seeds are impeded and struck off or pulled loose. In this conventional ginning process CCLC rollers emit chromium into the environment due to the constant dust-producing grinding action, which contaminates the cotton and its products beyond the safe limit of world environmental standards. Since the semi-finished chrome leather washers contain 3

to 4% chromium and are being used by roller ginning industries in India, Africa, Tanzania and Egypt, attention has been drawn to view the contaminating and polluting aspects during the complete process. The ginned lint cotton gets contaminated to an extent of 140 to 1994 mg/kg (ppm) of chromium and the spun yarns of 17 to 500 ppm of chromium against the safe limit of 0.1 ppm. The CCLC rollers in the ginning process cause air pollution in the mill environment. The air pollution due to CSD and cotton dust is responsible for synergistic (augmentative) health complications of chromium based diseases and byssinosis diseases among gin and textile mill workers. Chromium adsorbed into lint causes allergic symptoms, cancer incidence, brain damage, chronic ulceration and perforation of nasal septums to cotton processing workers. Toxic effects are produced by prolonged contact with airborne or solid or liquid chromium contamination and pollution even in small quantities. Suitable eco-friendly roller ginning process can eliminate this unsafe chromium contamination and pollution in the environment. Therefore, an exhaustive study was undertaken for the design, fabrication and development of eco-friendly, pollution-free, chrome less, rubberized fabric (RCF) rollers for modifying the existing conventional CCLC rollers.

3. Description and Performance of Rollers of Cotton Double Roller Gins

The roller is the major component of DR gins. The gin roller length varies from 1025 to 1148 mm with a diameter varying from 178 to 180 mm suitable for operation. The roller consists of 78 to 80 numbers washer disks. Each washer disk is made of dimensions having the diameter 180 mm and thick 10 mm comprising of 18 numbers

CCLC flaps stitched and bonded together. Basic Chromium Sulphate (BCS) $Cr(OH)SO_4 \cdot nH_2O$ and impure chromate having 45-50 % basicity are used during *chrome leather tanning process* for making such CCLC flaps. The various unit operations involved in making washers to final shape of the roller are (i) The washers are mounted on a steel shaft having square cross section of 50 mm² or hexagonal section of 50 mm E/E to form a roller, (ii) The filled washers are compressed to a pressure of 140 kPa by using a conventional pressing machine. The roller is to be pressed on both sides by adding the required number of washers on each side, (iii) The pressed roller is turned and finished to a diameter of 180 mm in a center lathe, (iv) Spiral grooves are made on the surface of the finished rollers; The finished roller is ready for the grooving operation by using a band saw; initially by marking 'U'-shaped spiral grooves, fixing in the grooving machine and lastly spiral grooves are made on the roller surface by a band saw or circular saw cutting machine. The ginning efficiency primarily depends upon the surface speed of the roller and the number of working strokes on the moving knife (Shete *et al.*, 1993). When the rollers are used in the ginning machines, the rate of ginning decreases as the roller diameter decreases. At the end of a cotton season having three months duration, the roller diameter was reduced to 114 mm, the washers are removed from the shaft. Again the new washers are recovered and cladded. To offset this problem, pollution-free rubberized cotton fabric (RCF) washers/rollers both for laboratory and commercial studies have been fabricated and experimented. These eco-friendly chrome-less rollers were evaluated for their performances; with a particular reference to techno-commercial and environmental aspects. In this the roller covering is made of multiple layers of fabrics bonded together using white rubber compounding which has a surface finish conducive to high ginning efficiency. On the basis of the design and

development of various rollers with subsequent performance evaluation studies, pollution-free RCF washers/ rollers have been demonstrated with a reference to techno-commercial and eco-friendliness in ginneries. These newly developed RCF rollers were successful in their operation. These were found more effective in functioning than CCLC roller ginneries.

4. Literature survey

In conventional ginning process, CCLC rollers emit tremendous chromium in ginning environment due to constant dust-producing, grinding action which contaminates the cotton and its products. This also causes air pollution in the mill environment. An exhaustive study is needed for the development of eco-friendly chrome less roller, which can be an alternative to the existing CCLC rollers. An exhaustive material studies were done for the suitable material's selection of the gin rollers which are made of Walrus animal skin, Spider tuck packing, coir-board, rubber packing, metal cylinder, rubber roll, fabric and rubber packing, leather, cotton, rubber and cork, plastics and fluorinated ethylene propylene. The peculiar gripping action or adherence of the cotton fibres to the roller surface was considered while designing the rollers. The leather surfaces possess *interfibrillary* action, which enables to adhere the fibre on the surface. This particular property is studied extensively for the different materials and combination of different materials so as to design and fabricate laboratory gin chrome less rollers for gin roller experimentation device (GRED) and prototype eco-friendly chrome less rollers for existing DR gins. One of the associated objectives of laboratory studies were to define the physical properties of a roller covering material which contributes to its energy consumption, ginning rate potential, eco-friendly parameters, cotton technological parameters, mechanical engineering analysis, wear resistance properties, heat proof capacity and to search better roller covering materials.

5. Materials and Methods

For the present study, a roller wearing and compaction rate study were conducted in Roller ginning industries at Belgaum, India for the cotton seasons 1996-1997, 1998-2000, 2001-2002 and 2002-2003. The roller gins are adjusted using spacers as per the standards. Grooving is done regularly at the start of each shift as per cotton varieties. To study the heavy metal as total chromium mg/Kg (ppm) in cotton lint samples, seed samples, seed-cotton samples, CCLC roller samples, CCLC roller samples collected during grooving operation, soil samples from the region of investigation is made, root of the plant for bio-availability, fibre, yarn, fabric samples, textile effluent samples, the standard American Public Health Association (APHA) method is followed for chromium (as total and hexavalent) analysis using Atomic Spectrometer (AAS). Respirable and suspended particulate matter quantity in gin house air are monitored using High Volume Air Sampler (HVAS) with cascade impactor with appropriate glass fibre filters. The quantity of pollutants are collected in HVAS as 8 hours basis and analysed for chromium. The worker dose and exposure time are found using the personal sampler. A health study was conducted by the author at Guntur, Bailhongal, Sendwa, Surendranagar, India, Tanzania and other countries, where maximum number of ginning factories are situated to survey the health effects and occupational health hazards. In view of the environmental problems existing with the present CCLC rollers employed in ginning industries and subsequent to literature survey made, it was decided to develop environmentally free alternatives. The details are discussed henceforth.

The ginning investigations were carried out at Central Institute for Research on Cotton Technology (CIRCOT), Mumbai. The laboratory rollers for GRED were designed and fabricated at Calcutta at a local manufacturing firm. Experiments with the

designed rollers were conducted at CIRCOT, Mumbai along with the cotton technological parameters. After the initial tests, pilot model rollers were designed and fabricated which were tested in ginning factories at Bailhongal and Sendhwa. Environmental analysis was done in Centre of Mining Environment, Indian School of Mines, Dhanbad, and Eco-Textile laboratory, Mumbai. Mechanical properties were analyzed in various mechanical engineering laboratories. Pilot model '*System after Modification*' was demonstrated in a ginning industry at Bailhongal.

5. Results and Discussions

An experiment is conducted to find out the wearing and compactness rate of CCLC rollers used by roller ginning industries for a season lasting three months. At the start of season the diameter of rollers are 180mm. At the end of season the roller dimensions are noted at left, middle and right positions for all the roller gins in the factory, that is 18 ginning machines. The results are presented in Table-1. Apart from the wear and tear rate, the table expresses the quantity of pollutants generating during the operation, viz. chromium, leather powder, cotton dust and chrome specific dust. It is found that the wearing rate is 0.033mm / hour and the percentage material removed per roller 43.8%. The final diameter at the end of study is nearing 140mm. The compaction rate is 0.050 mm/hour. The CCLC roller contains 18 077 mg/Kg (ppm) to 30 780 mg/Kg (ppm) as total chromium (3 to 4% as total chromium). This included trivalent and hexavalent chromium. During the ginning operation, lint adsorbs chromium particles which contains 143 mg/Kg (ppm) to 1994 mg/Kg (ppm). The CCLC roller is grooved at the start of each shift and filing or turning of the roller for leveling is done to get uniform diameter at start of each season. At that time, the wearing of roller is more and presence of chromium to the extent of 1994 mg/Kg (ppm) with lint. The total weight of

chromium removed during a cotton season of 16 hours per day is 450 to 600 grams per gin roller gin. The chrome specific dust from one ginning machine enters in to environment and being adsorbed in lint stage having the level of 143 ppm. The environmental standards for chromium in spun yarn is 2 ppm and Cr (III) for baby clothing and fabric is 0.1 ppm and nil for Cr (VI). The traces found contain hexavalent chromium being adsorbed from contaminated lint, yarn to fabrics and

subsequently cannot be removed in fabrics. There is evidence that the toxic effects on humans due to Cr (III) and Cr (VI) of its carcinogenicity and corrosiveness. The analysis show that traces of Cr (VI) are found in even analar grade trivalent chromium compounds and complications do arise due to the reducibility nature of these traces that affect the organic tissues of the body. This regenerating effects occur rapidly and dependent of the worker dose and exposure time.

Table 1
Results Of Roller Wear Out Data

M/c	DIAMETER OF THE ROLLERS AFTER ONE SEASON IN mm					
	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 = 180 mm . Chromium roller compactness rate is – 0.010 to –0.050 mm, i.e. –10 to –50 µm per hour. Wearing rate is 0.033mm / hour and the percentage material removed per roller 43.8%.

Table-2

Chromium Contamination Levels in Cotton and Its Products			
Source: Chrome composite leather-clad(CCLC) roller = 18,077 to 30,783 mg/kg			
Bio-availability for chromium uptake on cotton = 3 ppm			
Sl.No.	Cotton and its Products	Total Chromium	Environmental Standards
			*MOEF Notification -157
1.	Lint cotton	143-1990 ppm	0.1 ppm
2.	Spun yarns	17- 250 ppm	0.1 ppm
3.	Woven fabrics	17-45 ppm	0.1 ppm
4.	Cotton seeds	0-312 ppm	-
5.	Edible oil	0-259 ppm	-
6.	Oil cake	0-190 ppm	-
7.	Linters	0-159 ppm	-

● * Ministry of Environment & Forests Notification No.157, Dated 1 st May 1996.

Following are the significant findings of chromium in dust samples with relevant eco-standards:

TABLE-3 Chromium Level in Dust Samples			
Sl.No.	Source of Dust	Total Cr	**Environmental Standards,
1.	Ginning point	51-173 ppm	50 ppm
2.	CCLC grooving point	17-1994 ppm	50 ppm LD ₅₀

**U.S. National Institute of Occupational and Safety Hazard Standards, 1992

6. Conclusions and Suggestions

The CCLC rollers used in ginning industries get powdered during ginning operation and enter the environment as Chrome Specific Dust . It was observed that the chrome specific dust contaminates cotton and its products. The chromium contamination levels for cotton and its products were abnormal for all the samples except that the cotton samples obtained from RCF roller gin rollers *i.e.*, eco-friendly ginning industries. As per the world environmental standards , chromium content in cotton and its products not to be more than 0.1 ppm. The samples, namely, lint cotton, yarn, fabrics, seed, linter, edible oil and oil cake were found contaminated and their levels were in the range of 110 to 1990 ppm obtained from the source of dust-producing grinding CCLC rollers sample which contained 18 077 to 30 783 ppm. The ginned lint cotton gets contaminated to an extent of 143 to 1990 mg/kg (ppm) of chromium and the woven fabrics to the tune of 17 to 45 ppm of chromium against the safe limit of 0.1 ppm. The variations in concentration levels were because of the coating of chromium with fine dust particle and adsorption properties on to the cotton and its products. The chromium was not detected from RCF ginned lint cotton as there is no chromium in the source, which confines the eco-standards. On the basis of the design and development of various rollers with subsequent performance evaluation studies, chrome-free RCF roller has been demonstrated with reference to techno-commercial and eco-friendliness in ginning industries. The newly developed RCF rollers are successful and effective in functioning and in ginning out the seed-cotton . Cost economics study reveals that eco-friendly RCF roller ginners sounds better in all aspects with reference to environmental, cotton technological and

techno-commercial aspects. This improved technology is amenable for commercialization to the industries. Though the initial cost of the RCF roller is 11 times more than the life of CCLC roller, the high price is compensated, as it is durable upto an estimated life of seven years than more of a few months of CCLC rollers. Besides, it ensures the following advantages.

(1) There is negligible wear and tear and also zero maintenance,

(2) High ginning efficiency and output of about 1.25 times more than the CCLC rollers because the developed roller made up of rubberized cotton fabrics has a surface finish conducive to high ginning efficiency,

(3) 50% reduction in the weight of the rollers consume 25% less in energy consumption that is power saving of three times less compared to CCLC roller ginners.

(4) It is observed that the noise level in eco-friendly ginners is reduced to a range of 4 to 7 dB (A) due to inherent properties and cushioning effects,

(5) Eco-friendly cotton and its products can be obtained.

(6) Labour output / hr is 2.4 standard performance rating, that is twice than for CCLC ginners.

(7) Medical charges for treating the affected workers decrease manifold.

The manufacturing technology, design engineering features and assembly drawings show that the conventional fabric and rubber roller gin covering material can be selected with the following characteristics, namely, Hardness of 90 (type DO durometer) , 9 to 10 layers of fabrics 20 mm length, Thickness of fabrics 1.2 mm, The rubber compounding is resilient and 0.76 mm of fibre bristles protrude beyond the rubber surface is maintained in spite of wear. On the basis

of the design and development of various rollers with subsequent performance evaluation studies, chrome-free RCF roller has been demonstrated with reference to techno-commercial and eco-friendliness in ginning industries. The newly developed RCF rollers are successful and effective in functioning and in ginning out the seed-cotton. Cost economics study reveals that eco-friendly RCF roller ginnery sounds better in all aspects with reference to environmental, cotton technological and techno-commercial aspects. The newly designed and developed eco-friendly ginneries eliminate chromium contamination and pollution from cotton ginning industries. These give rise to control at-source pollution control, such that the industries meet the requirement of environmental standards being enforced by many countries and high quality yarns and fabrics meeting international standards be produced. The industries will be free from chrome-related contamination and pollution problems, occupational and non-occupational health hazards. The ginneries have been tested commercially and found better in all aspects with reference to cotton technological parameters, dye-catching properties, physical and chemical properties. It could be successfully used commercially as an improved alternative in cotton ginning industries for the cleaner environment with benefits to society, industry owners, traders, workers, employees and the Government.

Foot Notes

- Most of the cotton ginning operations are done by using DR gins in India, Africa, Tanzania and Egypt. The lint cotton and cotton seeds processed through these chrome roller ginneries are contaminated. It is imperative that a policy decision can be taken to do away these rollers and get replaced with eco-friendly rollers, and
- Industry, Government and Regulator should come forward to subsidize this

venture in view of its demonstrated and proven techno-commercial feasibility in connection with eco-friendliness.

- Out of the lint obtained from these CCLC roller ginneries in this countries, it is quite important to appreciate the fact that the lint so produces is contaminated with chromium powder produces deleterious effect on the people working in the vicinity. Yarn and seed obtained is also contaminated with chromium. Toxic effects are produced by prolonged contact with airborne or solid or liquid chromium contamination and pollution even in small quantities. Hence, it is imperative that a policy decision be taken to replace the presently used CCLC rollers with eco-friendly rollers or vegetable tanned leather rollers.

ACKNOWLEDGMENTS

The authors of this research paper are thankful to FACULTY DEVELOPMENT BUREAU OF ALL INDIA TECHNICAL EDUCATION , New Delhi for awarding the prestigious faculty-specific AICTE EMERITUS FELLOWSHIP DURING 2005-2008 to the first author.

References

1. Bandyopadhyay, K. and Gangopadhyay, A. and Son, N.N. (2000). "Adsorption Study on Fly Ash as a Waste Resource for the Removal of Chromium."
2. World Congress on Sustainable Development Proceedings, Vol. I, pp. 532-539,
3. Gillum, N., Marvis.A., (1964). "Properties of Roller Covering Materials", United States Department of Agriculture (USDA), Technical Bulletin No.1490, Washington: pp.1-45, 1994.
4. Lippman, M., (1991). "Book on Asbestos and Mineral Fibres." Elsevier Publishers, pp. 34-134, 1991.

5. Rao, C.S. (1995). "Book on Environmental Pollution Control Engineering." Wiley Eastern Ltd., pp. 1-79, *March, 1995*.
6. Rao, M.N. and Rao, H.V.N. (1989). "Book on Air Pollution." Tata McGraw Hill Publishing Co.Ltd., New Delhi, pp.35-56, *1989*.
7. Reference No. 157, MOEF Notification No.157, *dated 4.5.1996*.
8. Shete,D.G. and Sundaram ,V. (1993). "Some Practical Hints for Better Ginning of Cotton with Roller Gins." ICMF Journal, *October, 1983*.
9. Shirley Institute "Research Encyclopedia-II." Manchester, Cotton Dust Hazards, Textile Series Memories, pp. 23-56, *1982*.
10. Sujana, M.G. and Rao, S.B. (1997). "Unsafe Chromium." Science Reporter, pp.27-30, *Sep.1997*.
11. Townsend J.S. Walton T.C. and Martin J. (1940) Roller Gin Construction, Operation and Maintenance, U.S. Department of Agriculture, Washington, USA.
12. National Institute of Occupational and Safety Hazard Standards, 1992
13. Vijayan Iyer G., 1994, Study of Backlash in Double Roller Gins, The Cotton Gin and Oil Mill Press, Texas, USA
14. Vijayan Iyer, G. (1999). "Cotton Ginning and Lint Quality." Indian Textile Industry and Trade Journal, pp 73-80, *1999*.