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Eco-Friendly Rubberized Cotton Fabric Roller For Ginning Machines

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Abstract: - This paper discusses the pollution caused by Chrome Composite Leather-Clad (CCLC) rollers commonly used in cotton roller ginning industries and suggests an alternative roller material. The CCLC rollers contain about 18000 to 36000 mg/kg (ppm) total chromium of trivalent and hexavalent forms which are toxic and carcinogenic to human health. When the seed-cotton is processed in Double Roller (DR) ginning machines, the lint is contaminated with chromium of about 140 to 1990 ppm as against the safety limits of 0.1 ppm. During the ginning process due to persistent rubbing of leather over stationary knife, chromium particles are carried into the lint 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. To offset this problem, pollution-free Rubberized Cotton Fabric (RCF) rollers have been fabricated, used and experimented in roller gins. RCF 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 ginning 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 reference to techno-commercial and eco-friendliness in ginneries.

Key-Words: - carcinogenic, cotton, chromium, eco-friendly, ginning, roller, rubberized roller

1 Introduction

The roller ginning process for cotton was invented by McCarthy. This process is the mechanical separation of cotton fibres from seeds by means of one or more rollers to which fibres adhere while the seeds are struck off or pulled loose (9). Figure 1 shows the working principle of the roller ginning process. 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 semi-finished chrome leather washers which contain 3 to 4% chromium are being used by roller ginning industries in India, Africa, Tanzania, China and Egypt, attention has been drawn to the contaminating and polluting aspects of the process. The ginned lint 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 use of CCLC rollers in the ginning process cause air pollution in the mill environment. The air pollution due to Chrome Specific Dust (CSD) and cotton dust is responsible for synergistic (augmentative) health complications of chromium-based diseases and byssinosis among gin and mill workers (3). Chromium adsorbed into lint causes toxic effects in humans such as allergic symptoms, cancer incidence, brain damage, chronic ulceration and perforation of nasal septum 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 (8). An alternative roller material which is eco-friendly, non-polluting and chrome-free has been made of RCF to replace conventional CCLC rollers (2).

2 Problem Formulation

2.1 Objectives and Present Research Status

The research has been carried out with the following objectives:

1. To identify and study the environmental problems existing with the present chrome rollers employed in cotton roller ginning industries.
2. To design and develop an eco-friendly chrome-free roller and evaluate its performance with particular reference to environmental and techno-commercial aspects in 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. RCF roller has been used successfully by United States gin machinery manufacturers for more than 30 years. But current roller gins manufactured by Indian and foreign companies incorporate the CCLC materials commonly.

Hence, extensive literature survey was carried out to meet the objectives of design and development of eco-friendly alternatives. Various eco-friendly alternative roller covering materials namely, vegetable tanned leather, eco-friendly tanned leather, including rubber and rubber-processing technology and modifying the present CCLC roller ginning system has also been studied (2).

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.

3 Problem Solution

3.1 Description and Performance of Rollers of Double Roller Gins

The roller is the main component of DR gins. The roller length varies from 1025 to 1148 mm with a diameter ranging from 178 to 180 mm suitable for operation (7). The roller consists of 78 to 80 washer disks. Each disk of diameter 180 mm and thickness 10 mm is made of 18 CCLC flaps stitched and bonded together. (See Figure 2). Basic Chromium Sulphate (BCS) $Cr\ (OH)\ SO_4\ nH_2O$ and impure chromate having 45-50 % basicity are used during *chrome leather tanning process* for making such CCLC flaps. The discs are mounted on a steel shaft having a square cross section (50 mm X 50 mm) to form a roller. The filled discs 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. The pressed roller is turned and finished to a diameter of 180 mm on a lathe machine. Spiral grooves are made on the surface of the finished rollers by using a band saw or circular saw cutting machine.

To offset the problem of pollution caused by the use of chrome leather rollers , pollution-free rubberized cotton fabric (RCF) washers both for laboratory and commercial studies have been fabricated and used in rollers of ginning machines. These eco-friendly chrome-less rollers were evaluated for their performances; with particular reference to techno-commercial and environmental aspects. In this the roller covering was 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 reference to techno-commercial and eco-friendliness in ginneries. Figure 3 shows assembly drawing of rubberized cotton fabric (RCF) washers for making RCF rollers for double roller gins. These newly developed RCF rollers were successful in their operation and were found more effective in functioning than CCLC roller ginneries.

3.2 Materials and Methods

For the present study, a roller wear and compaction rate studies were conducted in Roller ginning factories at Belgaum for the cotton seasons 1996-1997 , 1998-2000, 2001-2002, 2002-2003, 2003-2004,2004-2005 and 2005-2006. The roller gins were adjusted using spacers as per the standards. Grooving was done regularly at the start of each shift as per requirements of cotton varieties (11,12). An atomic absorption spectrophotometer was used while following the standard American Public Health Association (APHA) method for the chromium analysis in samples of lint, seed , seed-cotton , CCLC roller, soil , plant roots , fibre, yarn, fabric , textile effluent. Respirable (RSPM) and suspended particulate matter (SPM) quantity in gin house air was monitored using a High Volume Air Sampler (HVAS) with a cascade impactor with appropriate glass fibre filters. Pollutants was collected by the HVAS over 8 hours and analyzed for chromium (4). The worker dose and exposure time were found using the personal sampler (5).

A health study was conducted by the author at Guntur, Bailhongal, Sendhwa and Surendranagar, India as also in Tanzania and other countries 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 the literature survey made, it was decided to develop environmentally safe 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 to be tested in ginning factories at Bailhongal and Sendhwa. Environmental analysis was done at the Centre of Mining Environment, Indian School of Mines, Dhanbad, and Eco-Textile laboratory of Textiles Committee Ministry of Textiles, Mumbai. Mechanical properties were analyzed in various mechanical engineering laboratories. The pilot model *'System after Modification'* was demonstrated in a roller ginning factory at Bailhongal, Belgham.

3.3 Results and Discussions

An experiment was 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 the season the diameter of the rollers was 180 mm. At the end of the season the roller dimensions were noted at left, middle and right positions for all of the 18 roller gins in the factory. The results are presented in Table-1 . Apart from the wear and tear rate, the table expresses the quantity of pollutants generated during the operation, viz. chromium, leather powder, cotton dust and chrome specific dust. It has been found that the wearing rate was 0.033mm / hour and the percentage material removed per roller was 43.8%. The final diameter at the end of study was nearing to 140 mm. The compaction rate was 0.050 mm/hour. Figure 4 shows a graph showing wearing rate of dust-producing grinding of CCLC roller and RCF roller. Chromium analysis report of cotton lint samples, seed and seed linter, seed-cotton samples, fibre, yarn and fabric samples is projected in tables 2 and 3 . 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 to the extent of 143 mg/Kg (ppm) to 1994 mg/Kg (ppm) because cotton dust is a good of adsorbant of chromium powder (1*).* The CCLC roller was grooved at the start of each shift and filing or turning of the roller for leveling was done to get a uniform diameter at the start of each season. At that time, the beginning of the season of roller wear was more and chromium levels reached 1994 mg/Kg (ppm) in the lint. The total weight of chromium removed during a cotton season of 16 hours per day was 450 to 600 grams per gin roller . The chrome specific dust from one ginning machine enters into the environment and was adsorbed in lint to a 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) , Table-6.Cotton technological parameters, fibre, yarn properties, chemical and dye catch parameters have also been provided in table-4 for comparative performances.

Table 1- Results Of Roller Wear-Out Data

M/c No.	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

Table 1 Footnote: Initial diameter of the rollers = 180 mm . Chromium roller compactness rate was 0.010 to 0.050 mm, i.e. 10 to 50 μm per hour. Wearing rate was 0.033 mm / hour and the percentage material removed per roller was 43.8%.

Table-2 ; Measured Chromium Contamination Levels In Cotton And Its Products

Source: Chrome composite leather-clad(CCLC) roller = 18,077 to 30,783 mg/kg			
Sl.No.	Cotton and its Products	Total Chromium	Environmental Standards # Allowable Levels
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	0- -
5.	Edible oil	259 ppm	0- -
6.	Oil cake	190 ppm	0- -
7	Linter	159 ppm	-

Table-2 Footnote:
Bio-availability for chromium uptake on cotton = 3 ppm

Table -3 - Chromium Level in Dust Samples

Sl.No.	Source of Dust	Total Cr	Environmental Standards (NIOSHS,1992)*
1.	Ginning point	51-173 ppm	50 ppm
2.	CCLC grooving point	17-1994 ppm	50 ppm * LD_{50}

Table – 4; Data of Engineering Analysis of Eco-Friendly Cotton Lint and Chromium Contaminated Cotton Lint

Sl. No.	Particulars	Eco-friendly gin Roller/ginned Lint	Chrome gin Roller / Ginned Lint
1.	Seed Index	7.07	7.34
2.	Knife blunting	Every four days	daily
3.	Grooving of gin roller Frequency period	Every five days	daily
4.	Power at No load, 400 V	1.28 KW	1.6 KW
5.	Power at Full load, 400V	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 %	5.0 %
9.	Diameter reduction per machine-hour	37.89 μm	64 μm
10.	Production per machine-hour	38.26 kg	36 kg
11.	Expected useful life of washer (wearing up to 30 000 μm)	844 Machine-hour	437.5 Machine-hour
12.	Friction of roller to lint cotton	0.768	0.123

High Volume Instrument (HVI) Test Results of Lint Cotton

Sl. No.	Particulars	Eco-friendly gin Roller/ginned Lint	Chrome gin Roller / Ginned Lint
13.	2.5% Span length	27.7	28.6
14.	Tenacity, g/tex	21.3 g/tex	22.2 g/tex
15.	Uniformity Ratio, UR%	46	45
16.	Short Fibres,%	3.5%	4.0%
17.	Color/grade/appearances	Yellowish and Very good	White shining, poor
	Scanning Electron Microscope Test Results		
18.	Wax content proportions	0.3% and better dye Catching properties	Nil Poor dye Catch properties
19.	Dye up-take	Very good	Poor
20.	Scanning physical and chemical properties	Very good	Poor
21.	2.5% span length, mm	35.6	35.4
22.	Uniformity, %	46.0	44.0
23.	Baer sorter, Mean length, mm	32.3	32.8
24.	Elongation	40.0	42.0
25.	Short fibre, %	14.6	16.4
26.	Tenacity, g/tex	28.6	27.8
27.	Micronnaire	3.0	2.8
28.	2.5% Span length, mm	28.5	28.2
29.	Uniformity Ratio, %	47.0	47.2

Sl. No.	Particulars	Eco-friendly gin Roller/ginned Lint	Chrome gin Roller / Ginned Lint
30.	Short fibre, %	6.2	5.2
31.	Tenacity, g/tex (1/8 “stello gauge)	21.8	21.4
32.	Elongation	6.0	5.7
33.	Micronnaire	3.4	3.3
34.	Leaf	3.0	4.0
35.	Area ,%	0.60	0.7
36.	Trash Count	28	28
37.	Rd	67.7	67.8
38.	+b	14.5	14.5
39.	Colour Grade	24.4	24.4
40	SCI	128.0	129.0

3.4 Comparative Economics

Comparative economics have been worked out for the chrome less RCF roller ginneries and CCLC rollers ginneries ; that is for both the 'System before and after modifications' and for commercialization to the ginning industries (Table-5).

Table-5 ; Comparative Economics

Sl N	CCLC rollers for DR gins (System Before Modification)	Eco-friendly, chrome-free RCF roller for DR gins (System After Modification)	Saving with RCF roller
1.	Initial cost Rs.7/- to 20/- per washer/ disk. The washers can be used for 2 to 3 months in a cotton season. About two times, new washers are to be replaced in an year. Maintenance cost is ten times more than RCF roller gins, because of roller grooving, gin-settings and pressure adjustments are to be done at frequent intervals. Lower productivity. Cr contamination and pollution problems are there in major cotton growing areas in India, Tanzania, Africa and Egypt.	Initial cost is Rs. 88/- per washer. 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 up to seven years. There is zero maintenance. Considering the maintenance and washer replacement cost, the washer cost worked out to be Rs.18/- per washer. No grooving is required except in initial maintenance. High productivity. Cleaner production. No waste in product. Chromium contamination and pollution problems are not there.	Though the initial cost is more, washer replacement and maintenance cost is 8 times less than the CCLC washer.
2.	Initial total cost is Rs.1,500/-per roller	Initial total cost is Rs. 1350/- per roller	Rs. 150/-
3.	Washer replacement cost for a ginning industry having 12 DR gins is Rs. 72,000/- per cotton season.	Washer replacement of a ginning industry having 12 DR gins is Rs. 62,800/- per cotton season	Rs. 9,200/-
4.	Medical charges for treating the workers is abnormal	Charges for treating the workers is very less in respect of chromium pollution problem and benefits increase manifold	Safe environment
5.	Labour output per hour is 1.2 standard performances rating	Labour output per hour is 2.4 standard performances rating which is twice than CCLC ginning industries because of cleaner environment	Safe environment

6.	Gin output is 1.25 times less than the RCF ginning industries.	Gin output is of about 1.25 times more than the CCLC rollers because of the developed roller made up of RCF and has got a surface finish conducive to high ginning efficiency.	1.25 times
7.	Cumulative power consumption is three times more as compared to RCF gins.	Cumulative power consumption is three times less as compared to CCLC gins.	Three times
8.	Washer is consumable.	Washer is not consumable.	7 years life
9.	Unsafe chromium contamination and pollution.	Safe environment. No chromium pollution in the environment.	Eco-friendly technology

Table 6 ; Consolidated Report And Relevant Eco-Standards (Number Of Times Increase Than Eco-Standards)

Sl. No.	**Cotton Textile Processing**	**Substance**	**Permitted value , ppm**	**Present Analysis**	**#no.times**
1	GINNING	CCLC ROLLER RSPM,SPM LINT COTTON SEED,SEED LINTER	2 ppm for Cr 0.1 ppm Cr(III) Nil for Cr(VI), 20 $\mu g/m^3$ US OSHA- 500$\mu g/m^3$ ACGIV TLU for Cr(VI)- 52 $\mu g/m^3$	32012 ppm Cr(VI)-12000 ppm 4232 $\mu g/m^3$ 180 ppm	15,392 212 35 71 63
2	BLOW ROOM	LINT COTTON	2 ppm for Cr 0.1 ppm for Cr (III) Nil for Cr(VI)	50-100 ppm Cr(VI)-25 ppm	22
3	CARDING	LINT COTTON	2 ppm for Cr 0.1 ppm for Cr (III) Nil for Cr(VI)	50-435 ppm Cr(VI)-45 ppm	22
4	SPINNING	SPUN YARN	2 ppm for Cr ppm for Cr(III) Nil for Cr(VI)	25-50 ppm Cr(III) Cr(VI) Cr(VI)	13
5	GREY CLOTH	WOVEN FABRICS	ppm for Cr ppm for Cr (III) Nil for Cr(VI)	17 ppm Cr(VI) 34 ppm Cr(III)	170
6	FINISHING	WOVEN FABRICS	ppm for Cr(III) Nil for Cr(VI)	17 ppm Cr(III) 50 ppm Cr(VI)	170
7	FINISHING	TEXTILE EFFLUENT	2mg/1 for Cr for Cr(III) Nil for Cr(VI)	550 mg/1	225
8	GINNING AND TEXTILE ENVIRONMENT	GIN HOUSE AIR SPM,RSPM CONCENTRATION SPM CONCENTRATION	200 $\mu g/m^3$ Hex-0.05 mg/m^3 TA-Luft 0.1 mg/m^3 SPM Particle size cut off 45 μm RSPM Particle size below 10 μm	7240 $\mu g/m^3$ 2723 $\mu g/m^3$ 390 $\mu g/m^3$ 185 ppm	362 135, 1000

		RSPM in air Cr in air	200 μg/m^3 National Ambient Air Quality Standards for RSPM not to be more than 100 μg/m^3 and chromium in Ambient air safe limit is 1.5 μg/m^3	350 μg/m^3 250 μg/m^3 239 ppm	125, 95

Foot Note: #Number of times increase than eco-standards)

4 Conclusion

The CCLC rollers used in ginning industries get powdered during ginning operation and enter the environment as Chrome specific dust (CSD). It was observed that CSD contaminates cotton and its products. The chromium contamination levels for cotton and its products were well above allowable limits for all samples except the cotton samples ginned by RCF roller gin rollers. 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. Economic analysis reveals that eco-friendly RCF roller ginnery performs better with reference to environmental, cotton technological and techno-commercial aspects. This improved technology is suitable for commercialization. Though the initial cost of the RCF roller is 11 times more than the CCLC roller, the high price is compensated. The RCF roller is durable with an estimated life of seven years (compared to a few months for CCLC rollers) Besides, it ensures the following advantages:

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

(2) High ginning efficiency and output of about 1.25 times more than the CCLC rollers because the 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 reduce 25% electrical energy consumption compared to CCLC roller ginneries.

(4) It is observed that the noise level in eco-friendly ginneries is reduced to 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 that for CCLC ginneries.

(7) Medical expenses for treating affected workers decrease considerably.

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. Fibre bristles protrude 0.76 mm 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 (Figure-5). Eco-friendly RCF rollers have environmental, technical and economical advantages over CCLC rollers. Eco-friendly rollers allow source pollution control, so the ginning can comply with environmental standards being enforced by many countries, and high quality yarns and fabrics meeting international standards can be produced. The industries will be free from chrome-related contamination and pollution problems, occupational and non-occupational health hazards. The products have been tested commercially and found better in all aspects with reference to cotton technological parameters, dye-catching properties, physical and chemical properties. Eco-friendly

rollers could be successfully used commercially as an improved alternative in ginning industries for the cleaner environment with benefits to society, industry owners, traders, workers, employees .

Recommendations

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 is taken to do away with these rollers and get them replaced with eco-friendly rollers.

The Government and Regulatory authorities like Central Pollution Control Board should come forward to subsidize this venture in view of its demonstrated and proven techno-commercial feasibility in connection with eco-friendliness.

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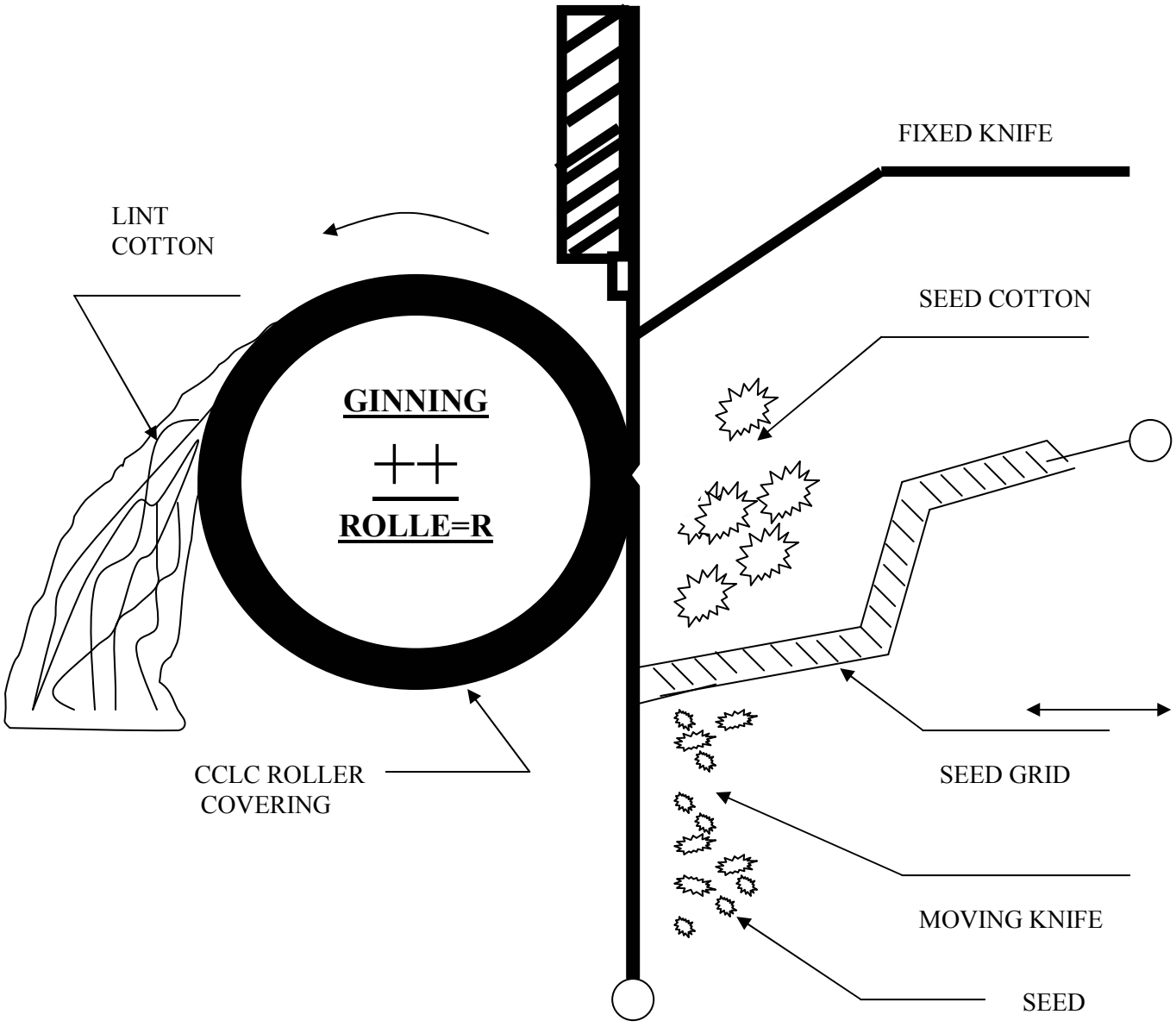


FIGURE 1 : WORKING PRINCIPLE OF THE COTTON ROLLER GINNING PROCESS

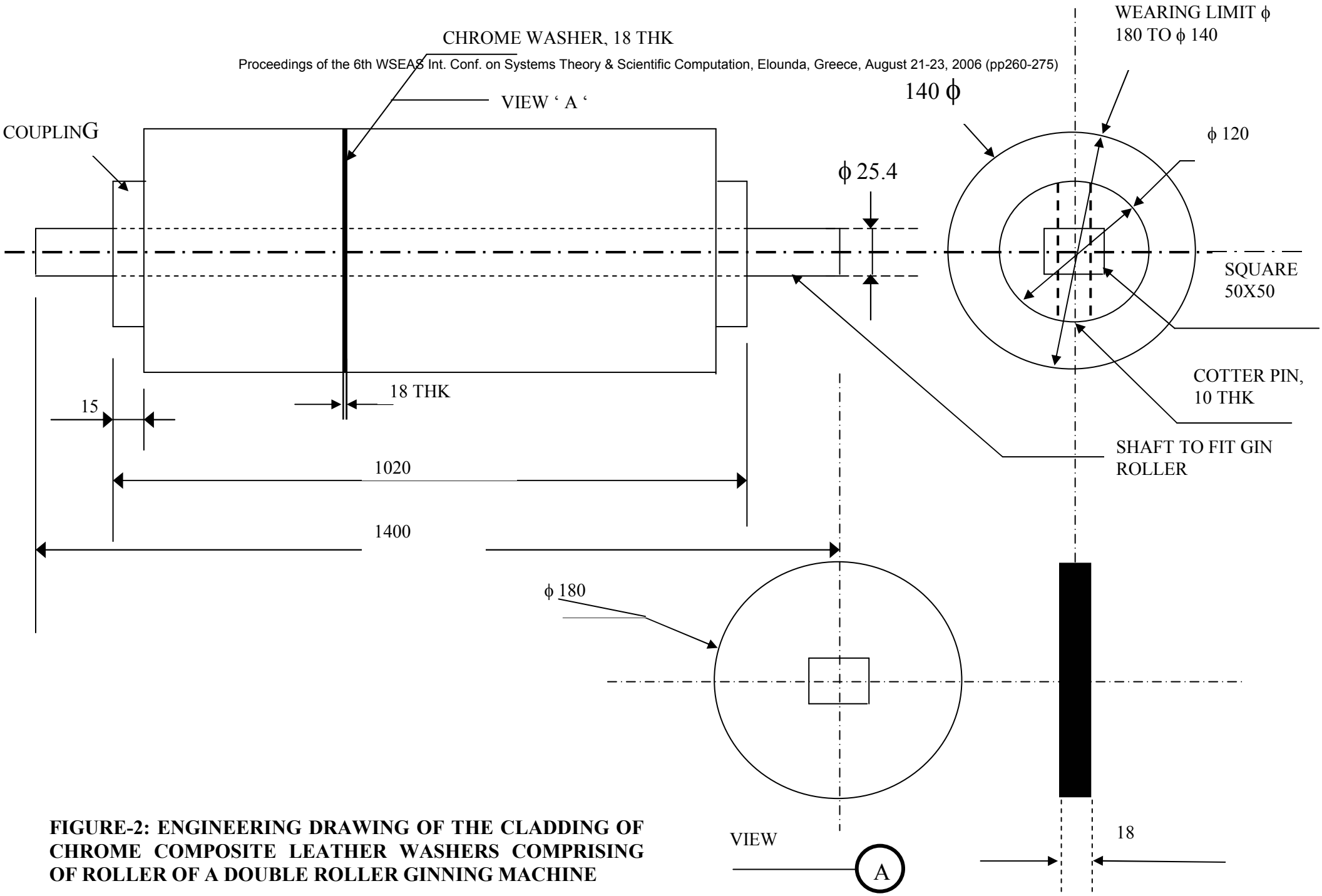
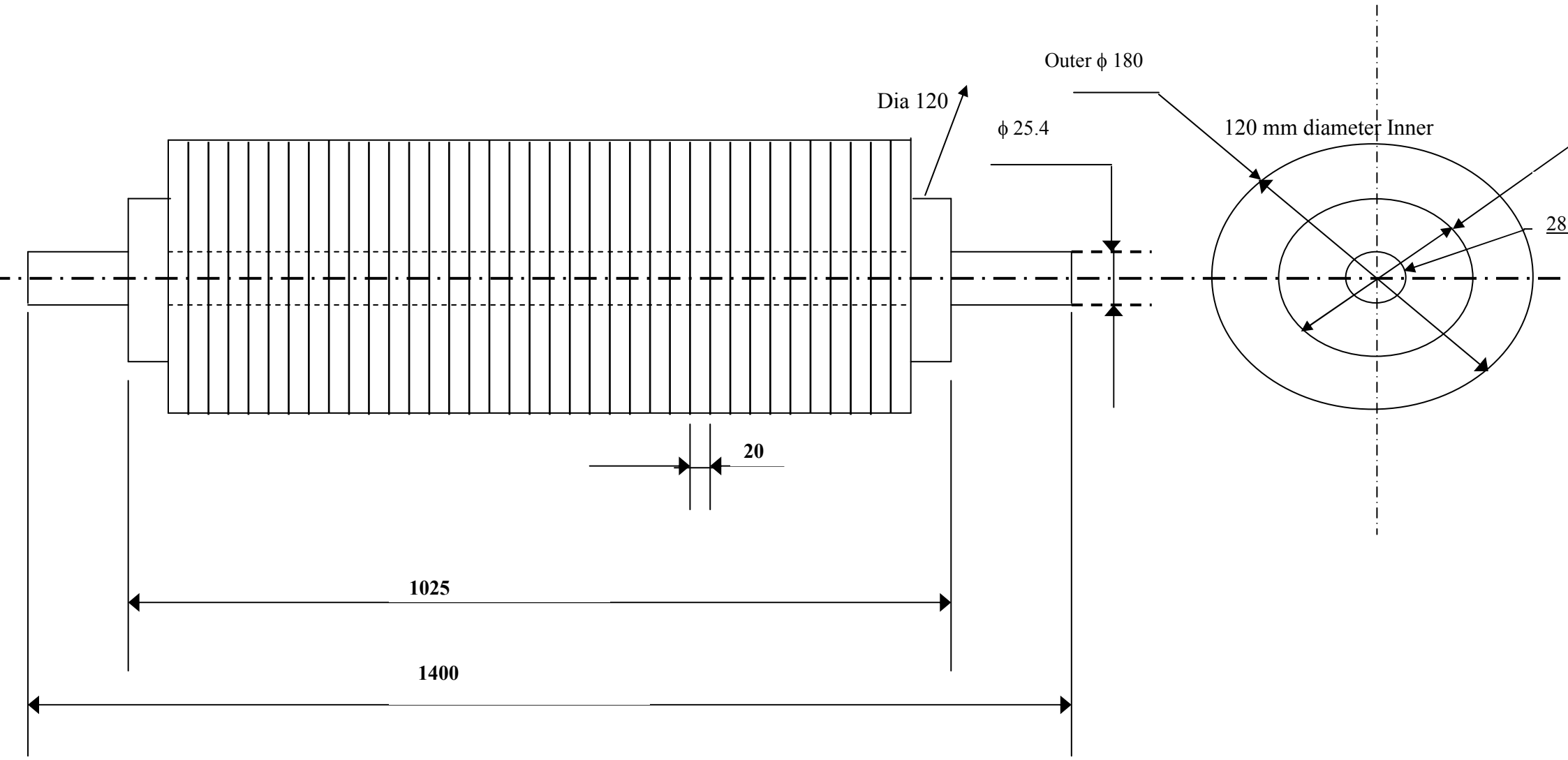


FIGURE-2: ENGINEERING DRAWING OF THE CLADDING OF CHROME COMPOSITE LEATHER WASHERS COMPRISING OF ROLLER OF A DOUBLE ROLLER GINNING MACHINE

ALL DIMENSIONS ARE IN MILLIMETER

FIGURE 3 : ASSEMBLY DRAWING OF RUBBERIZED COTTON FABRIC (RCF) WASHERS FOR MAKING RCF ROLLERS OF DOUBLE ROLLER GINS



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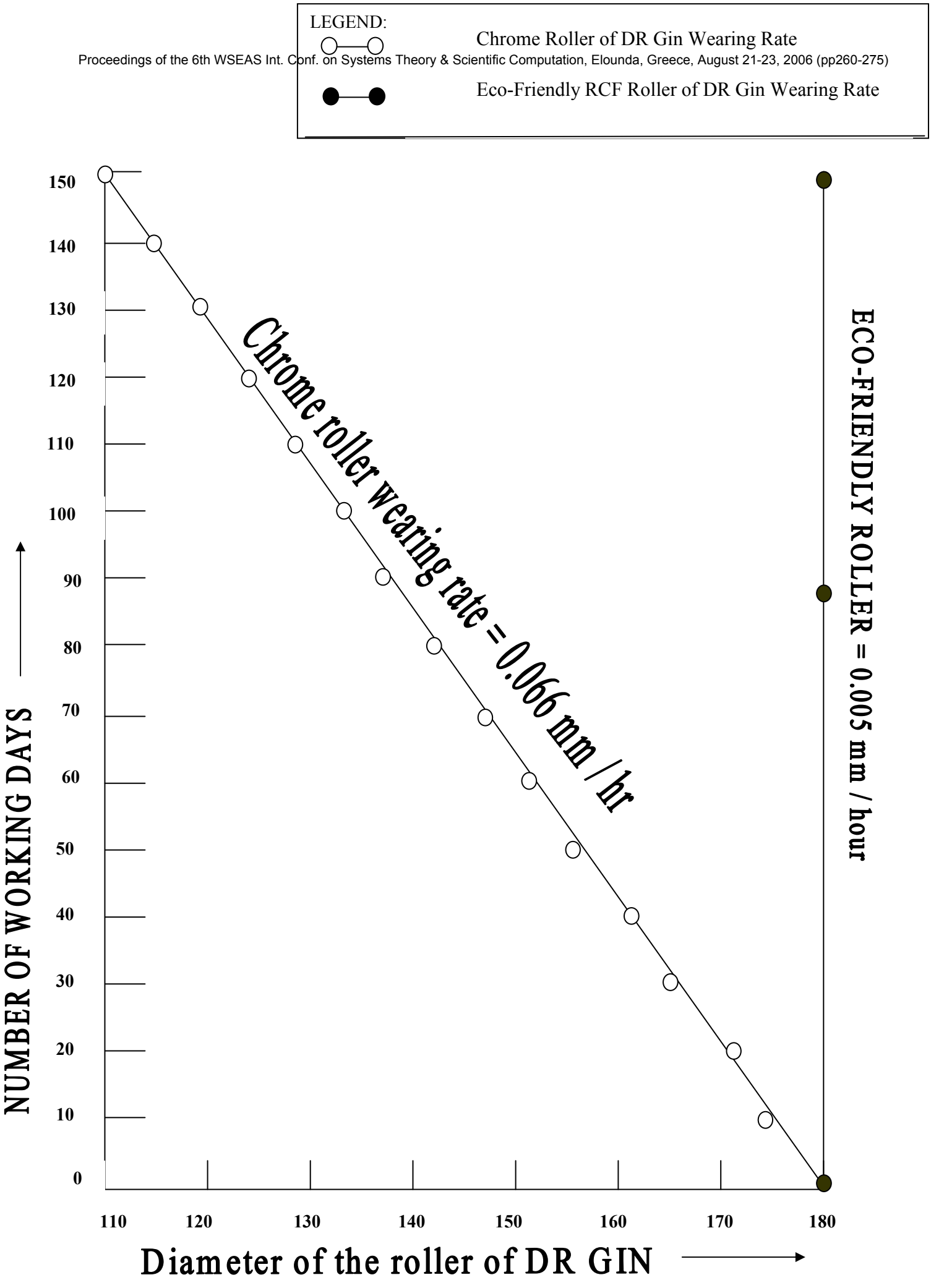
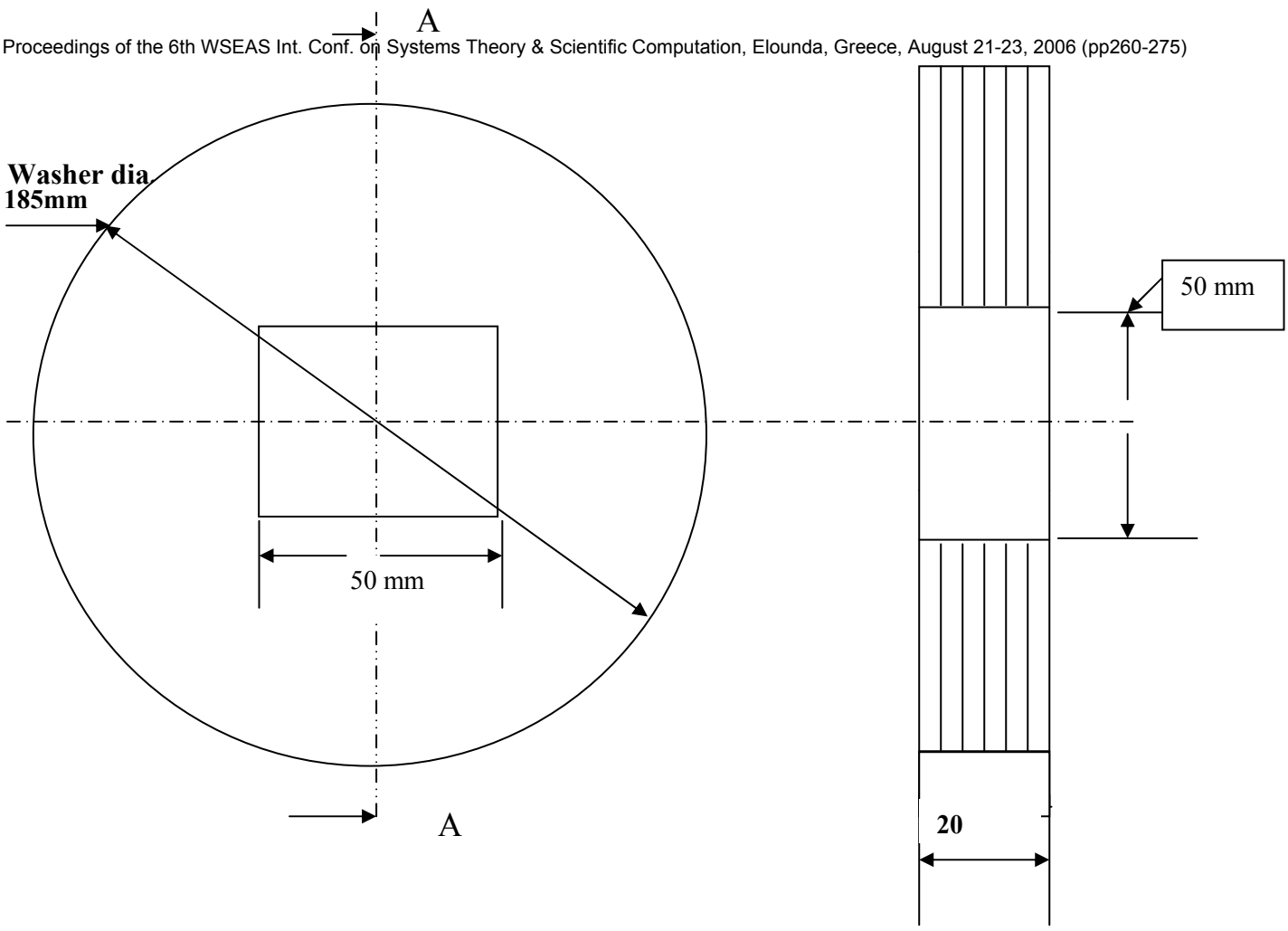


FIGURE 4 : A GRAPH OF WEARING RATE OF DUST – PRODUCING GRINDING OF CHROME ROLLER AND ECO – FRIENDLY ROLLER



SECTION 'AA'

ALL DIMENSIONS ARE IN mm

MATERIALS:

7 TO 10 PLIES CANVAS 1.2 MM THICK

FIGURE- 5: POLLUTION-FREE RUBBERIZED COTTON FABRIC WASHER FOR ROLLER OF COTTON ROLLING GINS