PREPARATION OF SHOE SOLING MATERIAL FROM LEATHER AND TEXTILE WASTE

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Abstract

The aim of this research is recycling of the leather and textile industry solid waste such as chrome shaving and weaving mills hard waste into composite material, such as shoe soling. Chrome shaving and weaving waste from the leather and textile industry were used for making composites by mixing with rubber. Isoprene and Ethylene propylene monomer (EPDM) rubbers were used for this purpose. Various combinations of rubber, chrome shaving waste and weaving hard waste were studied to get the desired characteristics of shoe soling material. The prepared composite materials were characterized for physico-mechanical behaviours like hardness, density, abrasion resistance and tensile strength, and compared with those of the rubber-based soling material available commercially. The composite prepared using a combination of the isoprene and EPDM (70 Phr :30 Phr) rubber along with chrome shaving and weaving hard waste showed physico-mechanical characteristics very close to the commercial available material with higher abrasion resistance. Hence, an efficient use of the fibrous chrome shaving and weaving wastes from leather and textile industry in such composite making would avoid the environmental problem, and could be a source of sustainable value-creation.

Figure 1 –Flow diagram of this research work

1 Introduction

One of the hardest questions of today comes to mind at this point: How will we manage the resultant waste of the products we created? Should we dump the waste to proper waste yards and reuse or recycle them? The answers to these questions are crucial. Scientists, governments, and local authorities work for finding answers to these questions. Wastes can be a problem for local authorities because of their environmental effects.

The waste generated from the leather industry is unavoidable. Liquid and solid wastes are generated during the processing of Hides and Skins. There are noticeable progress are present to treat liquid waste. An easy way to dispose solid wastes like chrome shavings and trimmings is land filling, which is subjected to strict environmental protocols due to the presence of chromium in these solid wastes. In India, more than 24million pieces of cattle hides, 22million of buffalo hides, 106million of goat skins and 37million of sheep skins are processed in about 1600 tanneries of leather industry. This generates around 2 million tons of solid wastes annually (CLRI, 2015). Chrome shavings are considered as a hazardous waste owing to the chrome present in it, also there is a certain risk that chromium may be washed off and it may contaminate the ground water if dumped carelessly. Hence, the safe disposal/application of chrome shavings should be addressed. Presently, chrome shavings are utilized as several low value applications such as –

- Preparation of regenerated leather using natural and synthetic blend polymer (US Patent)(Parrini et.al. 1979)
- Composites made from chrome shavings and natural fibres using rubber solution (US Patent)(Parrini et. al. 1979)
- A composite of natural and synthetic fibres as a leather substitute (US Patent) (Parrini et. al. 1979)
- Production of parchment like materials (Indian Patent No.300DEL 1999)
- Value added composite from leather and no-leather fibres (US Patent) (Parrini et. al. 1979)
- Sustainable Landfill (Indian Patent No.125DEL 2006).

However, most of these applications have not been commercialized. Conventional leather boards have also been made that are used as in Composites and packing materials etc.The products in cotton textiles, from registered manufacturing sector in India, have yielded an output value of Rs. 9,714 crore in 1981-82. This has risen to Rs. 29,746 crores in 1990-91, which reflects the degree of expansion. The cotton textile industry including ginning units, spinning units and weaving & processing, produce wastes, which have intrinsic value of almost Rs. 100 million per year. This relates to only one type of solid waste of textile industry. It is estimated that the total solid wastes, including those of man-made fibres, and rags which are collected in huge quantities, when recycled would amount to Rs. 300 million per year. The other wastes in the textile industries, for example chemicals and dyes have been estimated between Rs. 300 to 350 million per year. There are about 270 registered composite mills in our country.

Klein classified cotton fibers used in short-staple spinning as virgin fiber (from ginning mill), clean waste, comber waste, recycled fibers from dirty waste, and fibers torn out of hard waste (roving, yarn, and twisted threads) .. Broken ends of sliver, lap, web, and filter strippings from draw frame, roving frame, ring spinning frame, and rotor spinning frame are known as clean waste, having more than 95% of good fiber. Comber and roving wastes' good fiber ratio is around 95–97%. Wastes generated in blowroom machines, and cards are dirty wastes with 35–55% good fiber ratio. Besides, another dirty waste, flat and filter stripping waste, has a higher amount of good fiber (65–80%). As the waste fibers

are processed in different number of machines and therefore stressed fibers, their good fiber content is less than virgin fibers. For this reason, spinners prefer to feed the waste fibers into normal spinning process, in a controlled manner, with a constant percentage in order to avoid quality variations. Generally, wastes arising in the mills can be returned to the same blend from which they arose; comber wastes are mostly used in rotor spinning. In carded ring-spun yarn and fine rotor-spun yarn production, waste fibers can be used, up to 5%, but for combed yarns, waste fiber ratio can be lower, up to 2.5%. Higher waste fiber amounts can be used for medium and coarser rotor yarns, about 10 and 20%, respectively.

Several types of wastage are found during the processing of row cotton in spinning mill 12-13% wastage are produced for card process and 25-30% wastage are produced for combed process. The names of different wastage are given below

S.No	Waste Generated from various unit Operations	Sub Classifications
1	Blow-room of waste = [3%]	i. Droppings-2 ii. Lap waste.
2	Carding of waste = [3-5%]	i. Droppings-1 ii. Sliver waste iii. Vaccum waste.
3	Draw frame of waste = [0.5%]	i. Sliver waste.
4	Lap former of waste = [0.5%]	i. Lap waste ii. Sliver waste iii. Vaccum waste.
5	Comber of waste = [12-18%]	i. Lap waste ii. Noils iii. Vaccum waste.
6	Simplex of waste = [0.5%]	i. Roving waste ii. Sliver waste
7	Ring frame of waste = [2-3%]	i. Pneumafil ii. Hard waste iii. Roller lapping iv. Sweeping v. Vaccum waste
8	Winding section of waste = [1%]	i. Hard waste.

<u>Hard waste</u>

The hard waste occurs mostly at the final stage, ie, in post spinning process (Cone winding machine). These hard wastes are not reusable in spinning industry.

- The hard waste level obtained in cone winding machine ranges from 0.3 to 0.8 per cent.
- The hard waste level obtained in warping machine ranges from 0.1 to 0.4 percent
- The hard waste level obtained in weaving machine ranges from 0.1 to 0.6 percent

Since huge amount of yarns are processed through winding, warping and weaving machine, the quantity of hard waste generated every day also higher. Nearly 100kg of hard wastes are generated every day in a textile composite mill.

Major reasons for the high hard waste at cone winding machine are

- Inadequate maintenance of machinery
- Clearer cuts in automatic cone winders
- Cop rejection
- Repeaters
- Wrong work practices in Ring frame and cone winding
- Materials handling & housekeeping

The technologies developed by various research institutions in our country have been implemented in various textile mills which have resulted in pollution control and biogas generation.

Table 1 – Characterisation of waste generated from spinning mills

Waste type	Fibre content (%)	2,5% SL* (HVI) (upper length) (mm)	50% SL (mm)	ML* (AFIS) (LCT length) (mm)	Fibre hooks (%)	SFL* (mm)	SFA* (%)	SFC* (AFIS short fibre amount) (%)	Staple gradient (HVI uniformity ratio)
Blow room	45.74	25.27	9.24	15.62	5.3	7.26	56.4	38.0	38.4
Card	82.44	21.69	6.71	7.79	1.2	2.81	78.0	76.6	33.0
Sliver	82.11	27.63	11.62	11.04	0.4	11.04	44.5	15.0	42.0
Fabric	80.89	22.64	8.46	13.36	8.4	6.07	57.2	47.6	39.6
Weaving	99.41	27.67	12.50	20.59	4.8	10.38	42.5	17.4	42.5

Figure 2 –Various waste generated from the spinning mills

The present communication describes the making of composite materials using chrome shaving waste and weaving mill waste as the filler. Besides additive material was also used along with the chrome shaving and hard weaving mill waste. The influence of chrome shaving waste and hard weaving waste with rubber material on the physico-mechanical properties of the composite were studied and compared with those properties of commercial products.

2 Materials and Methods

2.1 Materials

Isoprene rubber, EPDM rubber were used for preparation of composite materials, Zinc oxide and Stearic Acid as an activator &Pilcure CBS, Pilcure MBTS &Pilcure TMT as an accelerator and other chemicals like sulphur used is laboratory grade. Chrome shaving waste was collected from the leather industry and the spinning wastes are collected from spinning mill.

2.2 Pre-treatment of the Chrome shavings

Normally chrome shavings are acidic in nature. To remove the acidity, the chrome shaving wastes collected from the leather industry were treated with aqueous ammonia, 1% solution of urea and sodium bicarbonate followed by washing with water and drying under sunlight for 24 hours. The dried chrome shaving fibres were turned into fine particles by using strap cutting machine and stored for further use.

2.3 Pre-treatment of the hard weaving millwaste

The collected hard weaving mill wastes are washed with water and soap oil for 2 hours and drying under sunlight for 24 hours. The dried hard weaving mill waste were turned into fine particles by using strap cutting machine and stored for further use.

2.4 Preparation of soling material

Rubber Composites of six different compositions were made using isoprene and/or EPDM rubber along with the treated chrome shaving and hard weaving mill waste as filler. The detail compositions are presented in Table 1 and Table 2. Table 1 presents the three different compositions of rubber Composites, TA, TB and TC. Table 2 presents the sole compositions similar that of TC but the Isoprene and EPDM rubber proposition is changed as 60/40,70/30 & 80/20.

Table 2: Trial with Isoprene & EPDM Rubber and chrome shavings

Composition of the different Trials			**Role of the material**	**Quantity (Phr)**
Trial-A (TA)	**Trial-B (TB)**	**Trial-C (TC)**		
Isoprene rubber	EPDM Rubber	Isoprene + EPDM rubber	Base polymer	100
Chrome shaving	Chrome shaving	Chrome shaving	Solid waste / filler	25
Weaving hard waste	Weaving **hard** waste	Weaving **hard** waste	Solid waste / filler	25
Zinc oxide	Zinc oxide	Zinc oxide	Activator	10
Stearic acid	Stearic acid	Stearic acid	Activator	4
CBS	CBS	CBS	Accelerator	1

MBTS	MBTS	MBTS	Accelerator	1
TMT	TMT	TMT	Accelerator	0.5
Sulphur	Sulphur	Sulphur	Vulcanising Agent	5
$CaCO_3$	$CaCO_3$	$CaCO_3$	Filler	10

Table 3: Trial with Isoprene & EPDM Rubber and chrome shavings

Composition of the different Trials			Role of the material	Quantity (Phr)
TD	**TE**	**TF**		
Isoprene rubber	Isoprene rubber	Isoprene rubber	Base polymer	60/70/80
EPDM Rubber	EPDM Rubber	EPDM Rubber	Base polymer	40/30/20
Chrome shaving	Chrome shaving	Chrome shaving	Solid waste / filler	25
Weaving hard waste	Weaving hard waste	Weaving hard waste	Solid waste / filler	25
Zinc oxide	Zinc oxide	Zinc oxide	Activator	10
Stearic acid	Stearic acid	Stearic acid	Activator	4
CBS	CBS	CBS	Accelerator	1
MBTS	MBTS	MBTS	Accelerator	1
TMT	TMT	TMT	Accelerator	0.5
Sulphur	Sulphur	Sulphur	Vulcanising Agent	5
CaCo3	**CaCo3**	**CaCo3**	**Filler**	**10**

To prepare the sole samples, accurately weighed quantities of the ingredients were fed to a two roll rubber mixing mill (with roller dimension D=220mm and L = 450 mm) maintained at a temperature of 47-67 °C and rolling at a speed of 15 rpm. Composite of 5–6 mm thickness were made and stored at room temperature.

The above experiments were carried out in the curing temperature around 140–160 ºC and curing time around 5 to 12 minutes in the compression moulding machine. Corresponding female and male mould halves were used in this process. A pre-weighed charge cut were placed inside the mould. To facilitate polymerization (or cross-linking) and consolidation of composite material an appropriate pressure force were maintained. During this compounding process proper nip cap and cuts were maintained in order to get the uniform compounding.

Composites of different compositions, TA, TB, TC, TD, TE and TF were made following the above mentioned procedure.

2.3 Characterization techniques

The morphology of the prepared composite materials was characterized using Scanning Electron Microscopy (SEM make: Phenom world, model: phenom Pro). Physico-mechanical properties of the sole materials were studied using Universal Test Machine (INSTRON, model: 3369/J7257), Bata Flexing Resistance (SATRA, Model: STM 612) and Leather Sole Abrasion Tester (SATRA, Model: STM 140).

3 Results and Discussions

3.1 Scanning Electron Microscopic (SEM) Study

The SEM Micrographs of the fractured cross sections of the tensile tested specimens of TA, TB,TC,TD,TE and TF are presented in figure 1.

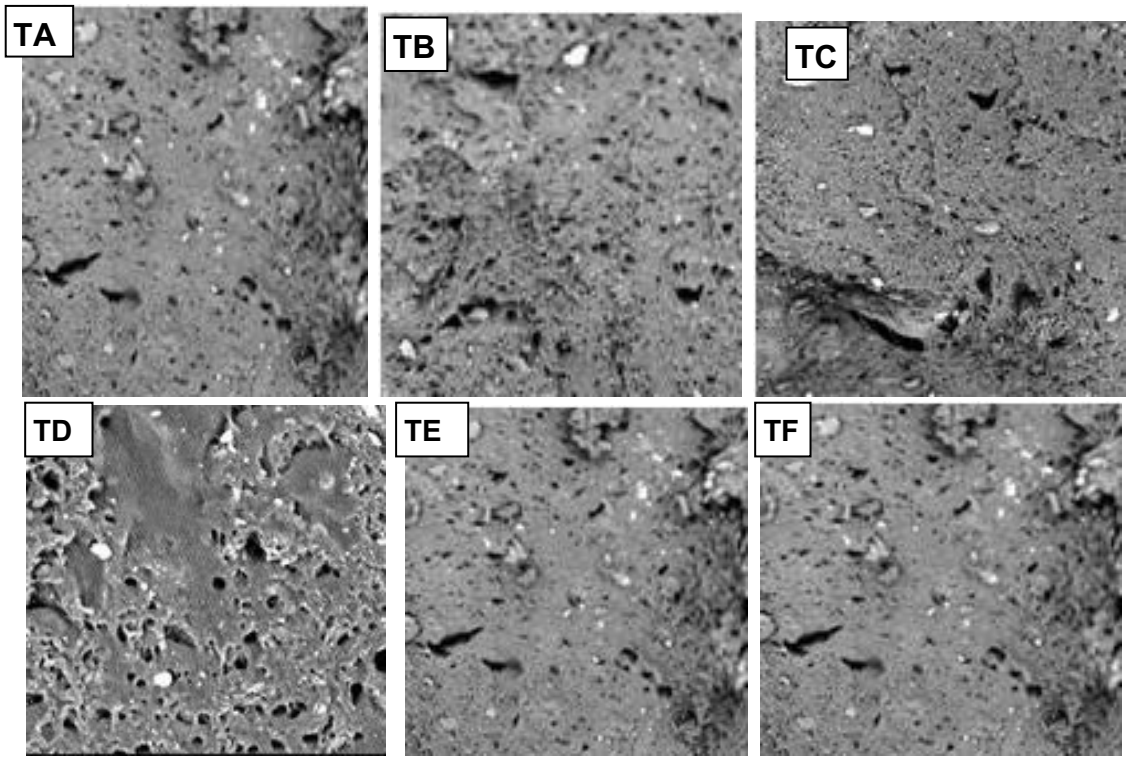

Figure 3: SEM Images of Trial TA, TB, TC, TD, TE & TF

Above SEM images of the fractured cross sections of the tensile tested specimens of TA, TB,TC,TD,TE and TF. The SEM images of the experiment I and experiment II are shown in the above Fig. 3. The SEM images of sample TA, TB and TC show aggregation of fibre due to blending of Isoprene and EPDM with chrome shavings and weaving hard waste. The SEM image reveals that in all three samples chrome shavings and weaving hard wastes are intermingled with polymers and also can be seen that in all the six samples chrome shavings and weaving hard wastes are closely knitted.

3.2 Physico-Mechanical properties

The prepared soling materials were subjected to physic-mechanical testing to study the properties like, abrasion resistance, tensile strength, percentage of elongation at break, hardness, density and flexing endurance. The values obtained for these properties were compared with those properties of the control sole sample. The control sole sample is a commercial rubber sole obtained from AGGU Composites Pvt Ltd, Ranipet, Tamilnadu, India. The physico-mechanical properties of the control sole material are tabulated below:

Table 3: Values of physico-mechanical parameters of the control sole sample(as per SATRA standard).

Sr.No.	Mechanical Properties	Values
1.	Tensile strength	8.0 MPa
2.	Percentage of Elongation	200 %
3.	Flexing endurance	50000 flexes
4.	Density	1.25 gm/cc
5.	Abrasion Resistance	150 mm^3
6.	Hardness	65 (Shore A)
7.	Thickness	0.6 mm

The physico-mechanical characteristics of the rubber Composites made using isoprene and/or EPDM rubber along with chrome shaving waste (as per the composition listed in table 1) are presented in table 4. The same characteristics of the rubber Composites made using mixture of isoprene and EPDM rubber along with chrome shaving waste and hard weaving waste with inorganic nanomaterials as filler (as per the compositions in table 2) are presented in table 5.

Table 4: Values of physico-mechanical parameters of the rubber sole samples prepared using chrome shaving waste as filler.

Sole Sample	Tensile Strength (MPa)	Elongation at Break (%)	Flexing endurance (flexes)	Density (gm/cc)	Abrasion Resistance (mm^3)	Hardness (Shore A)
Control	8.0	200	50455	1.16	148.22	65
TA	6.0	205	48220	1.01	120.98	62
TB	6.5	170	35500	1.37	395.20	67
TC	7.4	180	46225	1.24	290.25	65

The values presented in Table 4 show that the properties like, sole flexing (except TB), density, and hardness, of the sole samples prepared by using chrome shaving waste and weaving hard waste as fillers (TA, TB and TC) are comparable with those of the control sole sample. The abrasion resistance values of these Composites are much higher than that of the control sample. However, the values of tensile strength are lower (almost half) than that of the control sample.

Based on the physico-mechanical properties of the sole samples TA, TB and TC, the sole composition of TC was selected for further study. The another experiment were carried out by different proposition of Isoprene and EPDM rubber(60/40,70/30 &80/20) in order to achieve the desirable properties of soling material.

Table 5: Values of Physico-mechanical parameters of the rubber sole samples prepared using chrome shaving and weaving hard waste along with different proposition of Isoprene and EPDM rubber.

Sole Sample	Tensile Strength (MPa)	Elongation at Break (%)	Flexing endurance (flexes)	Density (gm/cc)	Abrasion Resistance (mm^3)	Hardness (Shore A)

Control	8.0	200	50455	1.16	148.22	65
TD	7.8	175	48523	1.25	310.00	67
TE	7.7	198	49056	1.20	302.25	66
TF	7.5	210	49876	1.18	300.45	65

The values of physic-mechanical characteristics presented in table 5 clearly show that increasing the proposition of isoprene along with the chrome shaving waste and weaving hard waste improves all the sole characteristics. All the sole samples in this trial showed almost similar tensile strength. Among the three trials(TD,TE & TF),the sole prepared by 70-Phr of Isoprene and 30-Phr of EPDM rubber showed excellent soling characteristics when compared with the control sole sample.

When we compare the final results, it is clear that Chrome shavings and weaving hard waste have good compatibility between Isoprene and EPDM rubbers. There is a gradual increase in Tensile strength when the isoprene rubber proposition incresed in this experiment. The maximum tensile strength obtained when the 70 Phr of isoprene and 30 Phr EPDM Rubber added with the chrome shavings and textile hard waste in this composition. This value is almost equal to the requirement of shoe soling material. The rest of the materials are shown slightly lesser tensile properties when compare to this composition. Elongation at break is almost same as using $CaCO_3$ filler in this composition. The value is between 192% to 205%, but the requirement is 150 % (control).Hence 70 Phr of Isoprene,30Phr of EPDM and 25 Phr of Chrome shaving with 25 Phr of weaving hard waste composition is consider for further developments.

4. Conclusion

Composite samples were successfully made using the chrome shaving waste and hard weaving waste with rubber and additives. The SEM images showed that the chrome shaving waste and hard weaving wasteshowed good compatibility with both isoprene and EPDM rubber. The samples with lesser proposition of EPDM rubber showed good physico-mechanical characteristics. However, incorporation of Isoprene and EPDM rubber along with the solid waste improved the tensile strength of the samples. Therefore, the 70-Phr of isoprene + 30-Phr of EPDM + 50-Phr of Leather and textile waste composite can be considered for further development, which in turn could be a sustainable way of making use of the hazardous solid waste generated by the leather and textile industry. Hence, it may be concluded that efficient use of the fibrous nature of waste from textile and Leather industry would avoid the environmental problem, and could be a source of sustainable value-creation from these solid wastes.

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