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Study of Indoor Air Pollution Caused by Reclaimed Fibers

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ABSTRACT
Mopping fabrics from reclaimed fibres are using widely due to its low cost. But it can produce health hazard indoor pollution due to shedding of visible and invisible fibres. Most of mopping cloth used are blends of cotton and polyester (70:30). The experimental study was performed on Martindale Abrasion Tester considering three parameters – GSM of mop fabric, Level of Load applied during mopping, time (duration of mopping process) and Cycle (Repetition of same mop fabrics multiple times) to study the percentage of shed fibers from fabrics. A Box-Behnken design with four factors and each with three levels has been used. The study shows that the major contributing parameter causing higher fiber loss was found to be lowest GSM of mop fabrics. The combined effect of Load and GSM was found to be major parameter which increases fiber loss. With higher mopping time and lower GSM, increases the fiber loss. The fiber length distribution was measured for shedded fibers with the help of magnifying glass and was found in the range of 0.6-1.2 mm along with small visible and invisible fibre fragments whose cumulative effects may cause serious indoor pollution if ventilation provided in roomis not proper or lack of ventilation.
Key-words: Byssinosis, Shedding, Cotton dust, Indoor pollution, Abrasion, Reclaimed Fibers

I. INTRODUCTION

With the growing population in the world, a variety of textile products are in use by the people to perform theirvarious day to day activities. So, there are many reasons for the recycling of waste from textile processes and products for the conservation of resources, to protect the environment and to enter an era to develop low-cost textile products. With the gaining popularity of non-conventional

spinning-reclaimed fibres are well suited to making rotor-spun, friction-spun and coverspun yarns to produce fabrics for garments and household textiles as well as for simple technical applications.However, if we compare with virgin fibres, reclaimed fibres show different characteristics. The damage they suffer during production entails a wide spectrum of fibre lengths with a high share in short fibres(Alok etal., 2018).These facts are supported by the findings of the researchers (NBhowmick and S Ghosh, 2007).

The situation maybe worsened when cotton or cotton blend products from reclaimed fibres are used for rubbing with another surface. The weak fibres may break easily in to two or more parts, may create invisible small fragments of fibre lengths, even end up with fibre dust due to abrasion. Unfortunately, these household textiles are gaining popularity day by day due to low cost for mopping. The matter is concerned when the cleaning space is lagging behind the proper ventilation.The cumulative effects of frequent mopping with time may deposit invisible cotton fibre fly, cotton dust. Persons exposed to cotton dust particles while breathing fibres, on the other hand, may develop a sequence of acute and chronic symptoms known as Byssinosis. The kind and intensity of the negative consequences connected to suspended particles are determined by the particulate concentration, the presence of other pollutants in the atmosphere, and the period of exposure. Particulate diameters (more than 10 µm and less than 2 µm) determine how the human respiratory defence mechanism defends itself against foreign chemicals. Approximately 40% of particles of 1 to 2 µm are retained in the bronchioles and alveoli of the lungs (Bhowmick N and Ghosh S, 2008).So, our present study only concentrated whether theproducts from reclaimed cotton blends how far suitable for mopping purpose.

II. MATERIAL AND METHODS

Cotton-Polyester (70/30) mopping fabrics made from reclaimed fibres were used for purpose of the present study. Three types of fabrics having GSM 200,290 and 380 were taken as per the commercially available mopped fabrics. The experimental study was done by varying the required external parameters to analyse their influence on fiber loss percentage and finally length distribution of shedded fibres in visible and measurable range with magnification.

Preparation Of Sample

The fabric samplesizes used for the experiments were prepared as per theweight of mop fabric(gm): 13 ± 0.05 irrespective of different gsms and to keep fabric within same area for mopping to avoid noise. To prevent any fraying of the testing sample's fibres and yarns during mopping, the edges of all sides were sewn with a fine quality polyester filament yarn with high-speed sewing machine at 1000 rpm with 5 stiches per inch. The number of sampleswere taken as per the Box-Behnken design of experiments.Thestrain gauge load cellswere used for estimation of approximate level of load applied during mopping process as well as to determine the fibre loss. A millimeter graph paper and a magnifying glass of high-resolution power is also taken for measuring the fiber length distribution of shedded fibers after mopping process.

Design of experiments

Fabrics were selected according to the run obtained in the Box-Behnken Design and Experiments.The Box-Behnken Design of Experiment is used to reduce the number of runs with center point of 3. Box-Behnken response surface design is used for the investigation of the effects of numerical process parameters. The four process parameters which were considered in this study for optimization: Time (mins), Cycle, GSM and Load(Pressure). Three levels (low, medium, and high) are chosen for each process parameter.The level of load is calculated manually by applying pressure on an Electronic Load Cell as mopping process is done and average approximate values in range is taken for experimental study. The process parameter levels are chosen from this range based on a literature review and experimental findings(Ghosh S & Bhowmick N, 2007) and it is tabulated in Table 1. Scheme of Experimental runs are shown in Table 2. The amount of fibers loss was calculated in each case by weighing fabric samples before and after the experiments.

Table1. Process parameters and their levels.

Factors	Levels		
	Low	Medium	High
	-1	0	+1
Level of Load (kg)	Low(L) (1.6- 3.2)	Medium(M) (3.3-5.0)	High(H) (5.1-7.4)
GSM	200(L)	290(M)	380(H)
Time(min)	1	2.5	5
Cycle	1	3	5

Table 2. Schemes of experimental runs

Standard Order	Load Level (kg)	GSM	Time (min)	Cycle
13	0	-1	-1	0
2	1	-1	0	0

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19	-1	0	1	0
14	0	1	-1	0
22	0	1	0	-1
4	1	1	0	0
23	0	-1	0	1
21	0	-1	0	-1
15	0	-1	1	0
1	-1	-1	0	0
12	1	0	0	1
16	0	1	1	0
25	0	0	0	0
11	-1	0	0	1
7	0	0	-1	1
18	1	0	-1	0
5	0	0	-1	-1
27	0	0	0	0
6	0	0	1	-1
20	1	0	1	0
26	0	0	0	0
10	1	0	0	-1
3	-1	1	0	0
17	-1	0	-1	0
8	0	0	1	1
24	0	1	0	1
9	-1	0	0	-1

III. RESULTS AND DISCUSSION

Table 3 demonstrates the Box–Behnken experimental design and the quantity of fibre loss surface response in terms of percentage fiber loss.In Table 4, Analysis of Variance (ANOVA)table is shown for the fiber loss percentage to check the model significant. From the table it is found that the model is sig-

nificant, and it is checked by comparing its p-value with 0.05 at 95 % level of significance. And it is found to be significant in several factors and interactions among them.

The GSM of the fabrics is a major significant element impacting the fibre loss percentage, as shown in Figure 1a, the Pareto chart derived from readings in the experimental investigation. While analysing with the interaction parameters it is found that the combination of level of load and GSM is the most significant factor which is causing fiber lossto a greater extent.Fiber loss decreases with increase in GSM. As the value of GSM increases the extent of fiber loss in increases. This is due to in low GSM mop fabrics the fiber is loosely attached as the area of rubbed surface is higher when load is applied and get more distorted during this process as compared with the higher one. On increasing Load level,the fiber loss percentage is also keeps increasing as more rubbing causes due to more load applied between friction surface and fabrics.Fiber loss increased in with increase in load level.On increasing Load level, the fiber losspercentage is also keeps increasing as morerubbing causes due tomore load appliedbetween friction surface and fabrics.Fiber loss increased in with increase in load level. From Surface plot it is clearly observed that load level is more significant parameter that affect-

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ing fiber loss.Fiber loss increased in with increase in load level.From Surface plot it is clearly observed that load level is more significant parameter that is affecting fiber loss. Also with increase of time fiber shedding increases with due weakening of fibers while continuosly rubbing for a long time which causes fiber to shed from the surface of fabrics.As seen clearly from surface plot that load level is most significant factor affecting fiber loss.Also, on repetition of this process up to several cycles causing more fiber loss from one cycle to two cycle. This is because of the fibers weakened after several cycles tend to release out of fabrics when applied load to it. With increase in GSM the fiber loss percentage keeps decreasing as the contact area between rubbed surface is decreases and the interlacingbetween warp and weft is loosely weaved which create high fiber loss during mopping
process. And with time its strength gets weakened as the fiber gets ruptured after several time of rubbing and its nature of ruptured is found more in case of low GSM.

Table 3. Experimental results of BoxBehnken analysis for amount of fiber loss percentage

Run	LoadLevel (kg)	GSM	Time (mins)	Cyc-le	Weight of mop fabric(gm)	Amount of Fiber Loss %
1	H	L	2	3	13 ± 0.05	0.61
2	H	H	2	3	13 ± 0.05	0.29
3	M	M	1	1	13 ± 0.05	0.35
4	M	H	2	5	13 ± 0.05	0.30
5	M	M	2	3	13 ± 0.05	0.45
6	M	L	2	1	13 ± 0.05	0.44
7	M	M	3	5	13 ± 0.05	0.48
8	L	M	1	3	13 ± 0.05	0.33
9	M	H	3	3	13 ± 0.05	0.29
10	L	M	3	3	13 ± 0.05	0.30
11	L	M	2	1	13 ± 0.05	0.31
12	M	H	2	1	13 ± 0.05	0.21
13	M	M	3	1	13 ± 0.05	0.36
14	M	L	2	5	13 ± 0.05	0.53
15	L	L	2	3	13 ± 0.05	0.41
16	M	M	1	5	13 ± 0.05	0.42
17	M	L	1	3	13 ± 0.05	0.46
18	H	M	2	1	13 ± 0.05	0.39
19	H	M	3	3	13 ± 0.05	0.41
20	M	M	2	3	13 ± 0.05	0.44
21	H	M	1	3	13 ± 0.05	0.42
22	M	M	2	3	13 ± 0.05	0.46
23	L	M	2	5	13 ± 0.05	0.38
24	L	H	2	3	13 ± 0.05	0.22
25	H	M	2	5	13 ± 0.05	0.47
26	M	L	3	3	13 ± 0.05	0.52
27	M	H	1	3	13 ± 0.05	0.22

Table 4. Experimental results Martindale Abrasion Testerto analyse amount of fiber loss percentage

S.No	GSM	Pressure kN/m^2	Cycle	Time (min)	% Fiber Loss
1	200	3	90	2	0.21
2		6	90	2	0.55
3		9	90	2	0.70

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4		3	90	2	0.14
5	290	6	90	2	0.34
6		9	90	2	0.51
7		3	90	2	0.12
8	380	6	90	2	0.25
9		9	90	2	0.34

The test standard used for performing this experiment was ASTM D3389-15. The motion used in this Martindale tester was Lissajous motion. The speed at which these experiments is performed is 45 cycle/mins. Three load was taken to applied some pressure on sample during motion i.e., of 3 kN/m^2 bar. Table 4, describes the percentage fiber loss achieved while performing several tests on different mop fabrics. All the tests carried out for 2 mins considering a fact to have a proper information regarding several mop fabrics used in this experiment. As clearly seen from results that for 200 GSM fabric i.e low GSM fabric is having maximum percentage fiber loss. On decreasing the level of pressure bar, the percentage fiber loss keeps decreasing.

Table 5.ANOVA Table for percentage fiber loss

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**	
Model	14	0.250967	0.017926	25.92	>0.0001	Significant
Linear	4	0.231600	0.057900	83.71	0.000	
Load	1	0.034133	0.034133	49.35	>0.0001	Significant
GSM	1	0.172800	0.172800	249.83	>0.0001	Significant
TIME	1	0.002133	0.002133	3.08	0.105	
CYCLE	1	0.022533	0.022533	32.58	0.000	Significant
Square	4	0.014367	0.003592	5.19	0.012	
Load*Load	1	0.007500	0.007500	10.84	0.006	
GSM*GSM	1	0.009633	0.009633	13.93	0.003	
Time*Time	1	0.0006533	0.006533	9.45	0.010	
Cycle*Cycle	1	0.003333	0.003333	4.82	0.049	Significant
2-Way Interaction	6	0.005000	0.000833	1.20	0.368	
Load*GSM	1	0.004225	0.004225	6.11	0.029	Significant
Load*Time	1	0.000100	0.000100	0.14	0.710	
Load*Cycle	1	0.000025	0.000025	0.04	0.852	
GSM*Time	1	0.000025	0.000025	0.04	0.852	
GSM*Cycle	1	0.000000	0.000000	0.00	1.000	
Time*Cycle	1	0.000625	0.000625	0.90	0.361	
Error	12	0.008300	0.000692			
Lack-of-Fit	10	0.008100	0.000810	8.10	0.115	
Pure Error	2	0.000200	0.000100			
Total	26	0.0259267				

Table 5, shows ANOVA table in which the model is seen significant as we have compared its p- value with 0.05 at 95 % los. From which it shows that it is less than 0.05 which means model is significant and also by comparing other p-value for other parameters including interaction parameters are also found to be significant through this table.

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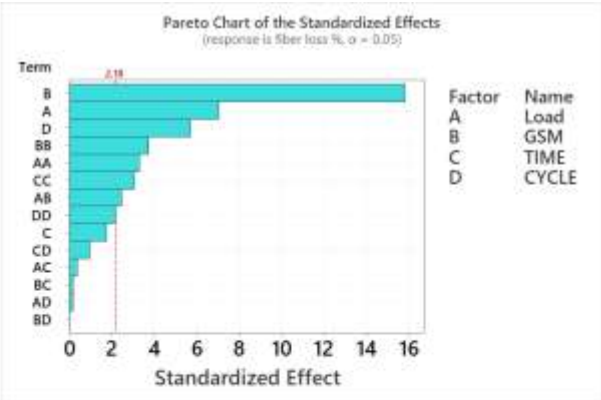
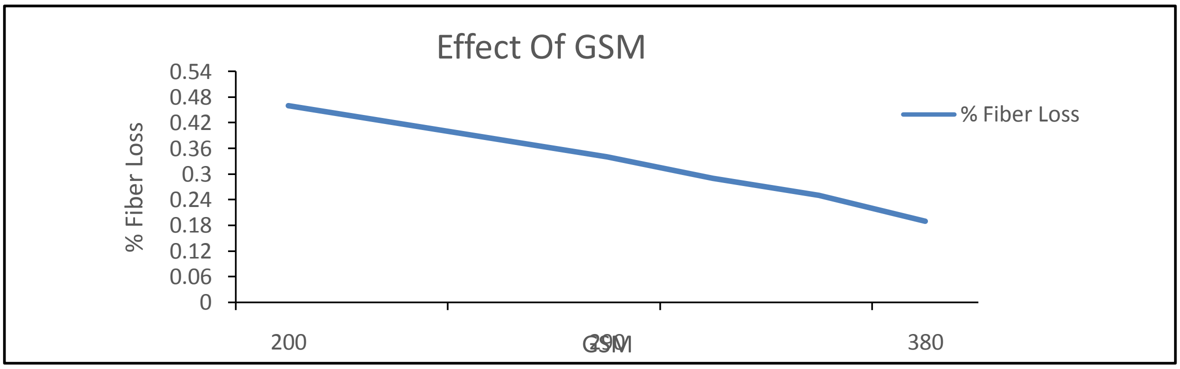
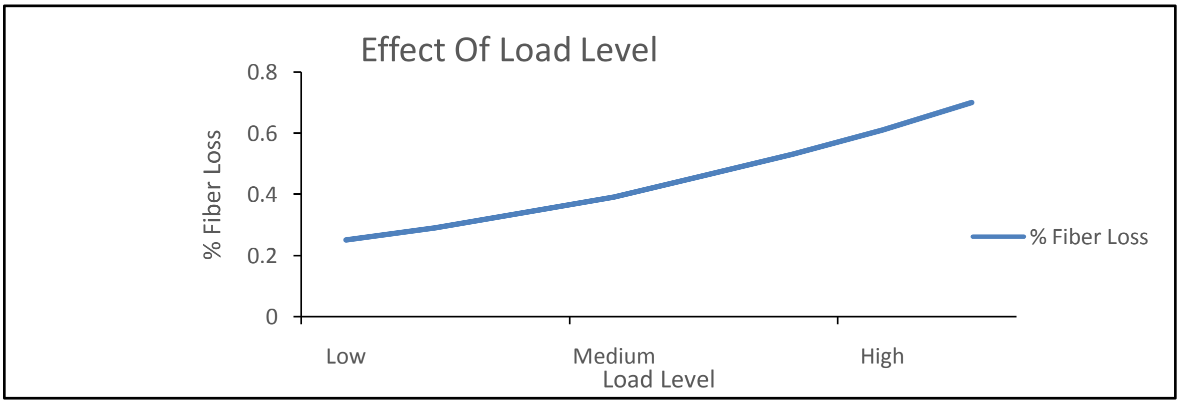


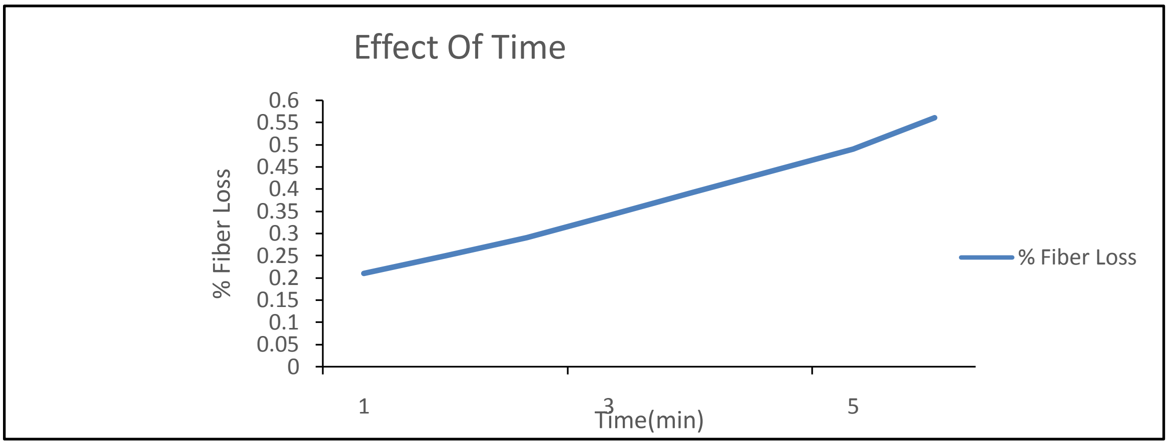
Figure 1. Standardized impacts on % fibre loss in a Pareto chart.



(a)



(b)

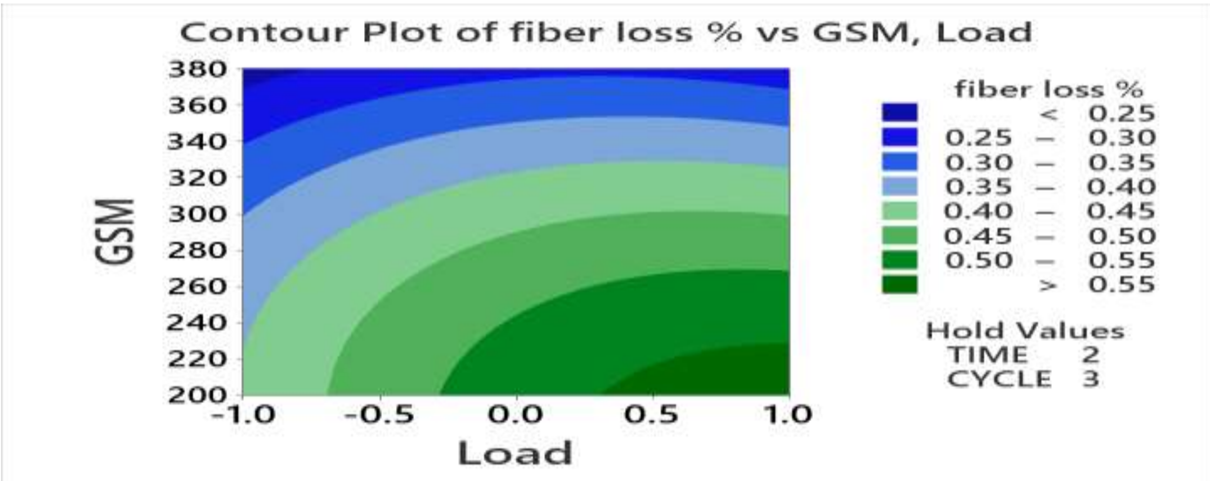


(C)

Figure2. (a) Effect of GSM on percentage fiber loss. (b) Effect of Load Level on percentage fiber loss. (c) Effect of Time on percentage fiber loss

In Figure 2a, with increase in GSM of fabric, fiber loss percentage keeps decreases. This is because as increase in GSM, fabrics are more closely packed which gives less area of abrasion while rubbing. In Figure 2b, with increase in level of load applied, fiber loss increasing vastly. This is quite obvious as having more load applied created high rubbing action between surface and fabric which causes more fiber loss. In Figure 2c, with increase in time, fiber loss percentage keeps increasing. This is because of the interaction between surface and fabrics keeps abraded while rubbing continuously for a long time.

(a) Contour Plot of fiber loss % Vs GSM, Load



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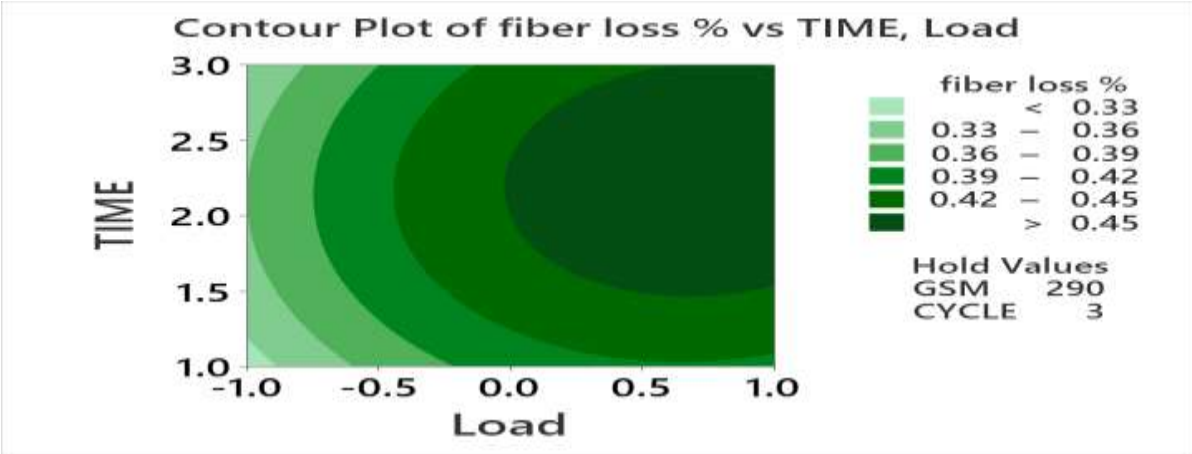
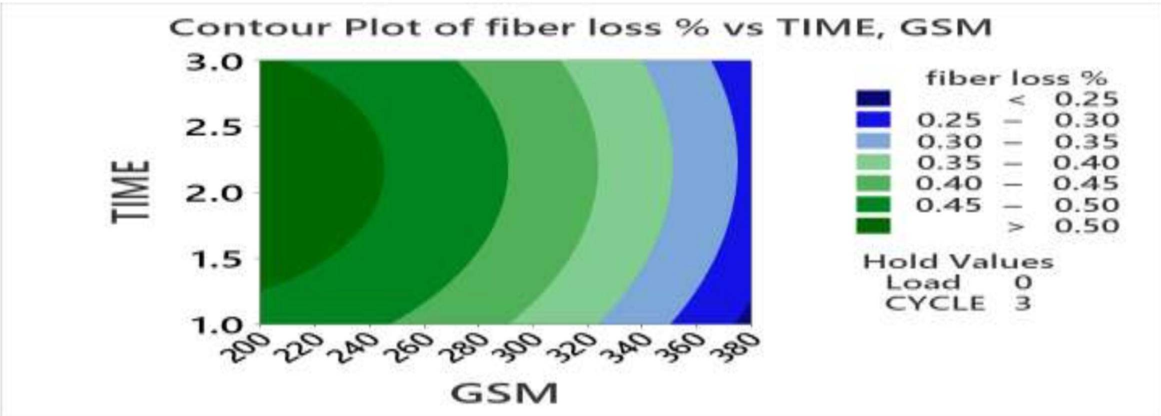
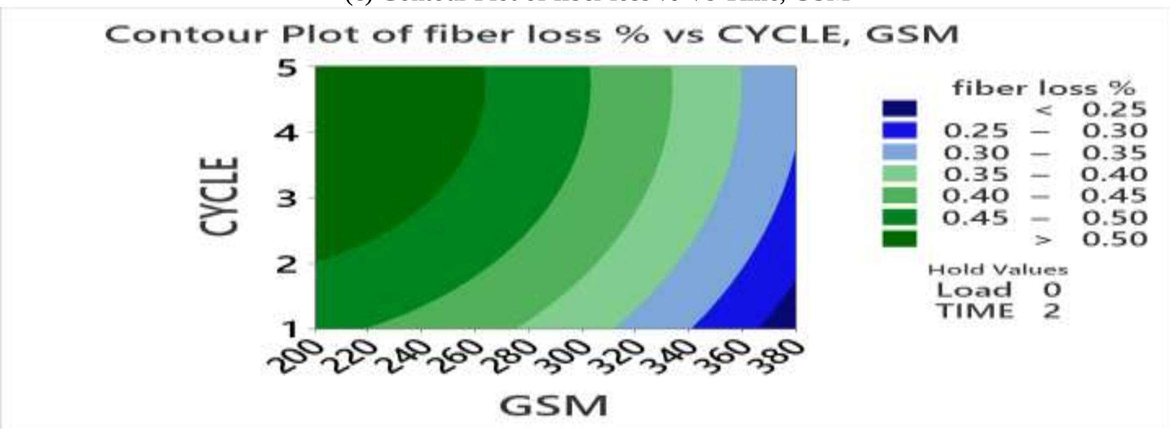


(b) Contour Plot of fiber loss % Vs Time, Load



(c) Contour Plot of fiber loss % Vs Time, GSM



(d) Contour Plot of fiber loss % Vs Cycle, GSM

Figure 4: Interation effect between the process parameters taken for experimental study.

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The effect of GSM and Level of Load with respect to percentage fiber loss is evaluated in Figure 4a. At lower GSM with increase of Level of Load, the fiber loss % increases with a very higher rate. When increase in GSM from lower to higher, the amount of fiber loss is keep decreasing follow with the increase of level of Load. The increase in fiber loss at lower GSM with Level of load has better influence with the increasing level of load with respect to GSM. Considering these two parametres main affecting paramters which causing higher fiber loss is GSM as compared to Level of load.

The influence of Time and Load was analysed and is given in Figure 4b. The percentage fiber loss is keep increasing with increasing level of load in keeping any GSM of fabric. With increase in Time, the trend is followed as the same as fiber loss keeps increasing while increasing other factors. Ultimately both the factors have some influence in percentage fiber loss.The Figure 4c, shows the impact of Time with GSM on percentage fiber loss. On increasing time from 1 to 3 mins, the fiber loss keeps increasing regrading with GSM of fabrics and different trend is followed for different GSM of fabrics like in case of lower GSM fabrics, fiber loss keeps increasing at a higher rate asrespect to GSM but as the GSM of fabricsincreases a different trend is shown i.e. fiber loss keep on decreasing with increase in GSM of fabrics.

In Figure 4c, the effect of GSM with Cycle of fabrics used in mopping process with percentage fiber loss is shown. As in case of lower GSM fabrics as the Cycle increases i.e.fabric is being used more no. of times for mopping process, the fiber loss keeps increasing. As the number of Cycle increases fiber loss goes up. And the same trend is follows for higher GSM mop fabrics but amount of fiber loss is high for lower GSM as compared to higher one.

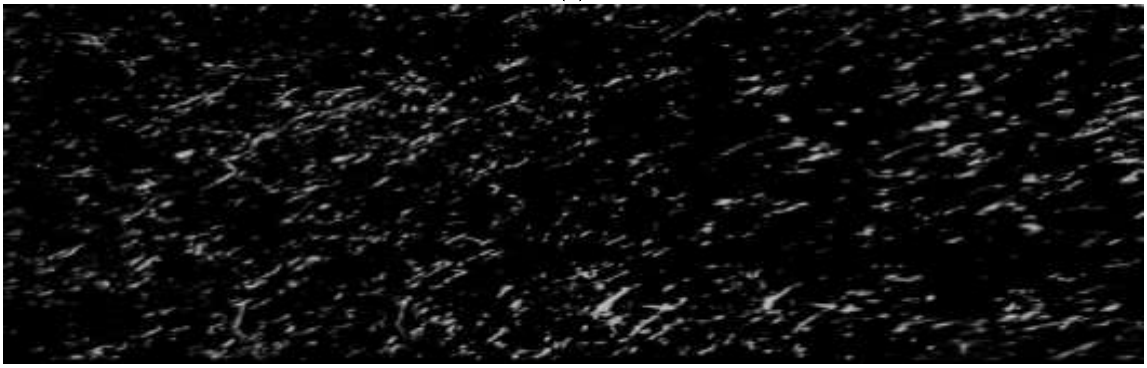
Fiber Length Distribution

To determine the length distribution of released fibre, a sample of fibre was pasted on a mirror to have a proper view as they are in very small size. So, Fibre loss obtained via different parameter were collected and its length distribution is analyzed manually with the help of Magnifying glass. Shedded fibres were collected on a plane mirror and with the help of Millimete**r** graph paper its range has been calculated. Range of shed fibre was around 0.6 mm to 1.2 mm i.e. 600 µm to 1200 µm.

Fig 5. Shedded Fibers Collected for Fiber Length Distribution

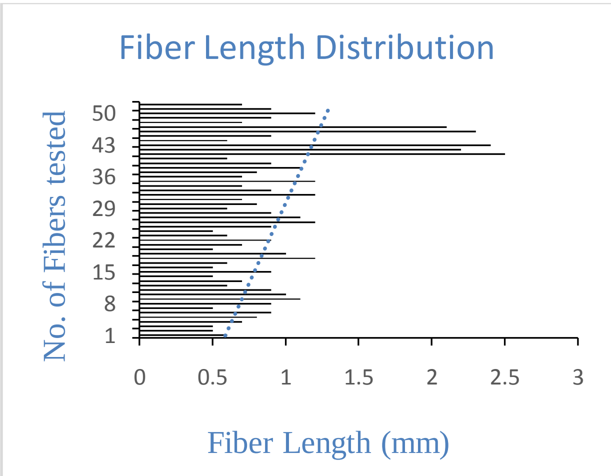
(a)

(b)



(c)

Fig 6. Fiber Length Distribution of shedded fibers with the help of magnifying glass



With fiber length distribution, the trend line shows between 0.6-1.2. As most of the fibers liberated was found to be in range of this only of which most of the fibers which are shedded are seen in the form of dust which are accumulated in the suspended air. These fibers are the one which is more responsible for indoor air pollution and mainly causing severe problems to human being imposed on it. These fibers suspended freely in the air and when the concentration of these fibres gets increased hence causing more effect to a person living in this room environment especially a person having some series lungs problem and breathing issue.

IV. CONCLUSION

- The major parameter affecting the amount of fibre loss was found to be the GSM of the fabric. Lower the GSM of the mop fabric higher is the amount of fiber loss percentage inn mopping process.
- Factor affecting mutually is the combination of GSM and the level of load applied during mopping process.
- Fiber released during this process are found to be in range of 0.6 to 1.2 mm majorly.
- These released fibers are highly subjected to breathing problems when inhaled during accumulation of these fibers in room's environment.
- Frequent mopping should not be done with reclaimed mop fabrics if there are chances of these phenomenon to occur as not having proper ventilation in room and regions where majorly dry weather are there and also in place where highly these can cause severe problem to health like in ICU or any place where a person should not get affected while having some serious problem already.

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