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An apparatus for quantification of light and temperature cutting ability of curtains

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An apparatus has been designed and developed to measure the light cutting/absorbing ability of curtains and to provide useful information on their temperature cutting ability. The apparatus is provided with various light sources with light, temperature and humidity detectors. The reproducibility of results, and effect of intensity of light (MBTL light source) on light and temperature cutting ability of six different fabric samples have been studied. The light and temperature cutting ability of the knitted fabric is found to be lower than that of woven and black out curtain fabric samples.

Keywords: Air permeability, Black out curtain, Bulk density, Light cutting ability, Porosity, Temperature cutting ability

1 Introduction

A curtain is known to block or obscure light or drafts or water (shower curtain). Curtain made out of coated fabric consists of standard uncoated fabric with an opaque rubber backing applied to the rear of the fabric to provide improved light absorption/cutting ability. Such fabrics are referred to as block out coated, and the curtain made out of this is called blackout curtain[1]. Blackout curtains' primary purpose is to reduce light emitted into room, up to 99.9% of it. These curtains are particularly beneficial for those who generally sleep during the day, such as night shift workers. These curtain also help to preserve heat/thermal energy in the room which otherwise lost through windows. In other words, blackout curtains provide the heat insulation and light absorption/reflection properties.

No standard equipment is available to test the behaviour of these materials with regard to light cutting/absorbing and heat/insulation property under the natural/artificial light. Besides this, the temperature of a room continuously varies from dawn to dusk because of the continuous variation in outside temperature. The temperature cutting ability of the fabric should therefore be evaluated considering the continuous change in the outside temperature. At present, the ability of curtain fabric to cut/absorb light with its heat and insulation property is checked visually by keeping the fabric in front of eyes against the sun light and then studying whether the light is passing through the fabric or not. As this method is highly subjective, it is not possible to ascertain the exact value of light and heat/temperature cutting ability of curtains. Hence, there is a need to develop an apparatus which eliminates the subjective evaluation. In this study, an apparatus has been developed to quantify the light and temperature cutting ability of textile material at varying light intensities and temperatures. The application of this newly developed apparatus and its consistency / reproducibility results are discussed in this study.

2 Materials and Methods

2.1 Description of Apparatus

To simulate outdoor and indoor conditions, two stainless steel insulated chambers with a small opening on one side of each chamber (to resemble a window) were fabricated and then joined together with an insulating material. In one of the chambers (Chamber A) outdoor conditions were created by providing different sources of light. The light emitted from the source reaches the other chamber (Chamber B) through the window to simulate indoor conditions. The test specimen with the help of a frame is suitably placed in the window. It consists of light sources, heating device, light, temperature and humidity detectors, and light intensity controller (to adapt different lighting conditions of outside or in room, the

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light intensity is changed with the help of a controller). Computer with suitable software is provided to capture the data and interpret the results.

The instrument is designed[2] in such a way that it can work from ambient temperature to 50°C. The relative humidity of the chambers is maintained by placing standard chemical solutions. The line diagram and photograph of the instrument is given in the Fig. 1.

2.2 Evaluating Light and Temperature Cutting Ability of Fabric Samples

To study the effect of incident light intensities (3650 - 8540 lux) on the light cutting ability, one type of fabric (Kn_1) was selected. The minimum incident light intensity obtained from the MBTL light source was 3650 lux. Below this intensity MBTL light source was not working. Then six types of fabric samples were used to test their light and temperature cutting ability. The mass per unit area and thickness of the samples were measured using standard test methods ASTM D3776 and ASTM D1777 respectively. An average of 10 readings was taken for each test. The air permeability of the fabric samples was tested as per BS 5636. The mean air permeability was averaged from 20 observations for each fabric samples.

The bulkiness of the fabric samples depends upon the mass per unit area and thickness. The bulk density of the fabric (g/m^3) was calculated using the following equation[3] :

Bulk density=M/T

where M is the mass per unit area of the fabric (g/cm^2); and T, the thickness of the fabric (cm). Porosity of the fabric depends upon the volume of air entrapped in the material which can be given by the following equation[3] :

Porosity (%) = $1-[d_F/d_f] \times 100$

where d_F is the bulk density of the fabric (g/cm^3); and d_f, the density of fibre (g/cm^3). The density of the polyester fibre is assumed as 1.38 g/cm^3.

The properties of the fabric samples are given in Table 1. It is clear from the table that sample Kn_1 is single jersey knitted fabric (66 courses/ inch, 42 wales/ inch) of 190 g/m^2 mass and 56 $cc/s/cm^2$ air permeability, while samples Wv_1 (mass 230 g/m^2) and Wv_2 (mass 290 g/m^2) are woven fabrics (jacquard

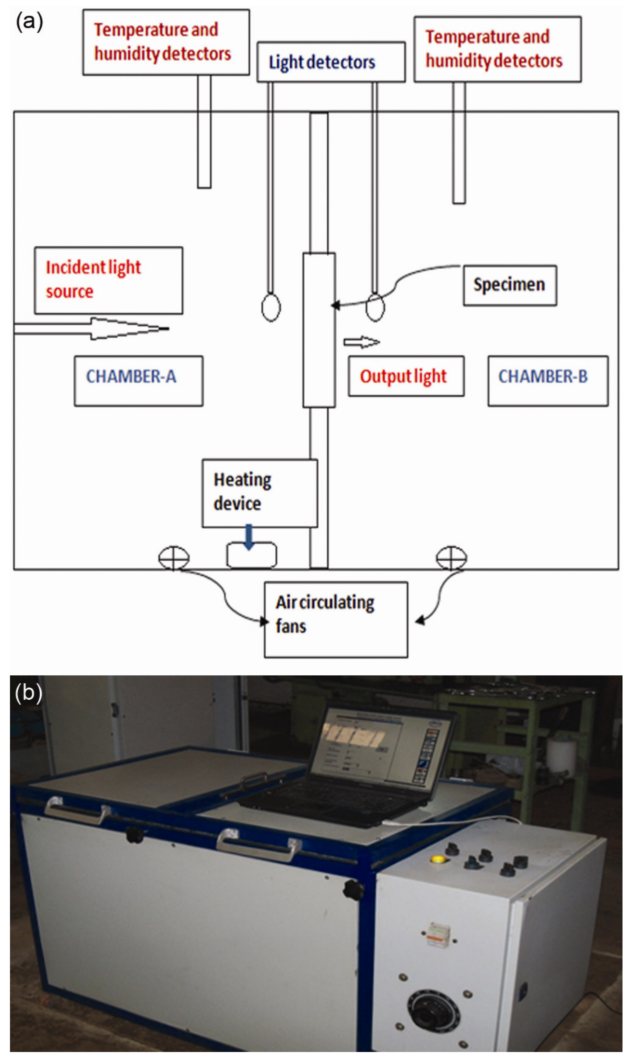

Fig.1 — (a) Line diagram of instrument and (b) photograph of instrument to determine heat and light cutting ability of curtain

Table 1 — Properties of polyester fabric samples

Sample	Sample code	Mass, g/m^2	Thickness, mm	Air permeability, $cc/s/cm^2$	Bulk density, g/cm	Porosity, %
Knitted	Kn_1	190	0.51	56.0	0.373	72.97
Woven	Wv_1	230	0.42	2.0	0.548	60.29
Woven	Wv_2	290	0.72	15.5	0.403	70.79
Blackout woven[a]	Blc_1	440	0.68	0.1	-	-
Blackout woven[a]	Blc_2	470	0.74	0.0	-	-
Blackout woven[a]	Blc_3	495	0.78	0.0	-	-

[a] Single side coated woven fabric.

weave) having air permeability of 2.0 and 15.5 cc/s/cm^2 respectively. The ends/picks of Wv_1 and Wv_2 samples are 172/ 58 and 168/ 42 per inch respectively with 150 denier polyester filament yarn in warp and 500 denier polyester filament yarn in the weft. The samples Blc_1 (mass 440 g/m^2), Blc_2 (mass 470 g/m^2), and Blc_3 (mass 495 g/m^2) are blackout single side coated woven fabrics with almost zero air permeability. The bulk density of Kn_1, Wv_1 and Wv_2 fabric samples along with their porosity are also shown in the Table 1. It is clear that the porosity of the Kn_1 fabric sample (72.97%) is higher than those of the Wv_1 (60.29%) and Wv_2 (70.79%) fabric samples. With same yarn denier in warp and weft and with same weave, the cover factor of Wv_2 is expected to be lower than that of Wv_1 and hence the air permeability and porosity of this sample are expected to be high. The bulk density and porosity of Blc_1, Blc_2 and Blc_3 samples were not determined, being the coated samples.

Each specimen was mounted on the sample holder and exposed to a MBTL (Mercury tungsten blended lamp) light source (6580 lux incident light intensity) for 1 min. The intensities of light (incident and output) in both chambers were measured at every 0.2 min intervals with the help of various detectors and dedicated software. Average of these results was taken. The effects of folds (layers) of Kn_1, Wv_1 and Wv_2 samples on light and temperature cutting ability were also evaluated.

3 Results and Discussion

3.1 Effect of Incident Light Intensity on Light Cutting Ability:

The effect of different incident light intensities on light cutting ability of Kn_1 fabric has been assessed. The study is carried out for 1 min at 0.2 min interval. Total five readings were taken. Finally, the average of five readings of incident and output light intensity was taken. On the basis of average incident and output light intensity, light cutting ability in percentage was determined (Table 2).

From the Table 2 it is clear that there is no significant change in the light cutting ability percentage of Kn_1 fabric by changing incident light intensity. The light cutting ability of the Kn_1 fabric is found to be 44.8 - 50.0% for 2090 - 8540 lux incident intensities. The average light cutting ability of the Kn_1 is 47.2% (Table 2).

3.2 Light Cutting Ability of Different Fabric Samples

Figure 2 shows the relationship between incident light fall on the fabric and output light intensities

Table 2 — Effect of varying incident light on light cutting ability

Average incident light intensity, lux (Chamber-A)	Average output light intensity, lux (Chamber-B)	Light cutting ability %
3650	1949	46.6
4090	2200	46.2
5040	2782	44.8
6580	3507	46.7
7540	3860	48.8
8540	4270	50.0

Average light cutting ability 47.2.

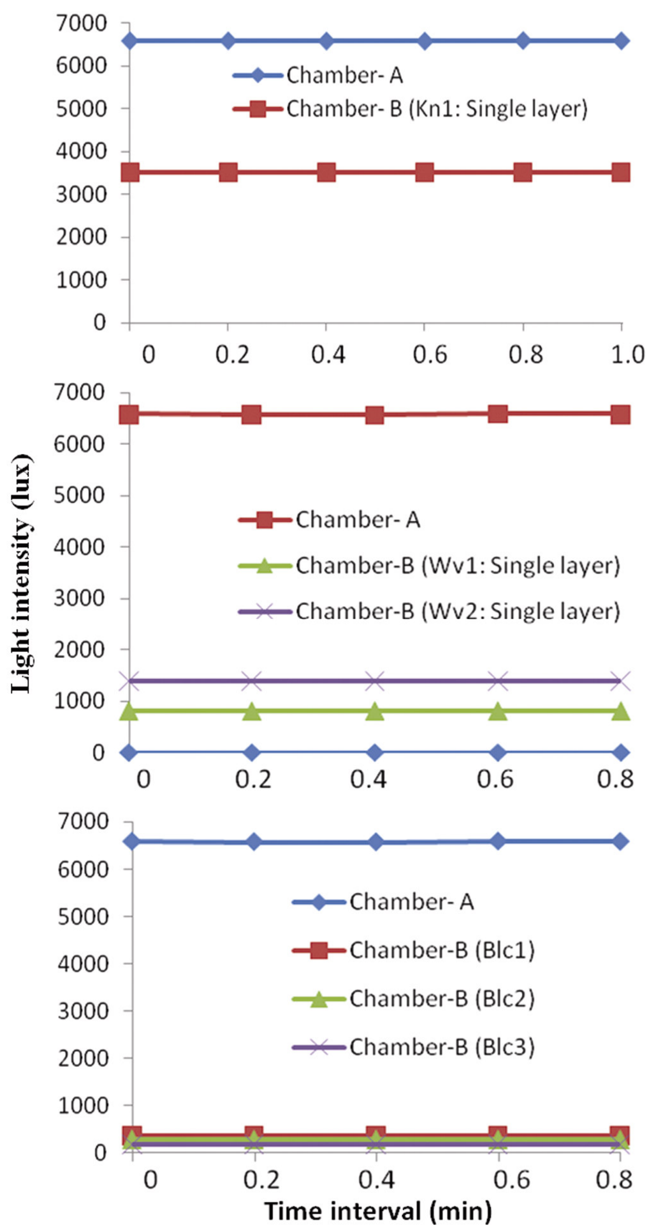

Fig.2 — Light cutting ability of different fabrics

coming out through the fabric and time intervals. It is clear that there is not a significant difference in the output light intensities at different intervals of times. Table 3 shows the average light cutting ability of various fabric samples. From the table it is clear that the light cutting ability of single layer Kn_1 sample (46.7%, Table 3) is lower than other samples. The reason of lower light cutting ability of this sample may be attributed to its higher porosity (72.97%) and air permeability (56.0 $cc/s/cm^2$) as shown in the Table 1. It is also observed from Table 3 that there is a increase in light cutting ability of Kn_1 sample, when double and triple layers of this sample were used. The triple layers of Kn_1 sample completely cut the light as indicated in Table 3. Woven or knitted fabric, as a porous material, enables the transmission of energy in the form of light and heat along with the liquids, gases and particles. The air permeability is depended on porosity of the material. The air permeability increases with the increase in porosity[4, 5] of the fabric.

Samples Blc_1, Blc_2 and Blc_3 show higher light cutting ability ranging between 95.7% and 97.5% (Table 3) as they have very low or zero air permeability as indicated in Table 1. All these samples are one side coated while other side uncoated. The low or nil air permeability indicates almost nil porosity in fabrics and thus these samples do not allow transmission of light. Samples Wv_1 and Wv_2 are woven fabric samples. The light cutting ability of Wv_1 (87.7 %) is higher than that of Wv_2 (78.9%) (Table 3). The reason of higher light cutting ability of sample Wv_1 may be due to the fact that it has lower porosity (60.29%) and air permeability (2.0 $cc/s/cc^2$) than Wv_2 (porosity 70.79%, air permeability 15.5 $cc/s/cc^2$). Due to lower porosity of Wv_1 than Wv_2 samples, the transmission of light through Wv1 fabric sample is low[3] and thus has high light cutting ability than Wv2 sample. It is also observed from Table 3 that the double layers of Wv_1 and Wv_2 samples cut light completely.

Table 3 — Light cutting ability of various samples

Sample code	Average incident light intensity, lux (Chamber-A)	Average output light intensity, lux (Chamber-B)	Average light cutting ability, %
Kn_1 (One layer)	6580	3507	46.7
Kn_1 (Two layers)	6580	350	94.7
Kn_1 (Three layers)	6580	0	100
Wv_1 (One layer)	6580	809	87.7
Wv_1 (Two layers)	6580	0	100
Wv_2 (One layer)	6580	1388	78.9
Wv_2 (Two layers)	6580	0	100
Blc_1	6580	364	95.7
Blc_2	6580	283	97.5
Blc_3	6580	178	97.3

3.3 Testing of Temperature Cutting Ability

The indoor temperature continuously varies from dawn to dusk. Therefore, the heat cutting ability of the fabric should be evaluated for the continuous change in the outside temperature. The instrument is designed in such a way that the temperature of the Chamber-A can be increased or decreased at a predetermine rate, to simulate outdoor condition and then measure simultaneously the temperature of Chamber-B, thus measuring specimen's temperature cutting ability. All the six samples were tested for temperature cutting ability. The initial temperature of the Chamber-A was set to 45°C. The results of temperature cutting ability of all the samples are given in the Fig. 3. It is clear that the temperature cutting ability of Kn_1 (single layer) is 2°C which is lower than other samples. The reason of low temperature cutting may be due to higher porosity and higher air permeability of the knitted fabric than other woven fabric. Higher porosity enabled sample Kn_1 to transfer heat and thus the temperature cutting ability is low. It is also revealed from the figure, that the temperature cutting ability of Kn_1 improves when double and triple layers of this sample are used. Samples Blc_1, Blc_2 and Blc_3 are having temperature cutting ability 7 - 8°C (Fig. 3) as these samples are coated on one side and have almost nil porosity as the air permeability is almost zero. Due to almost nil porosity the transfer of heat in the form of temperature is lower in these samples.

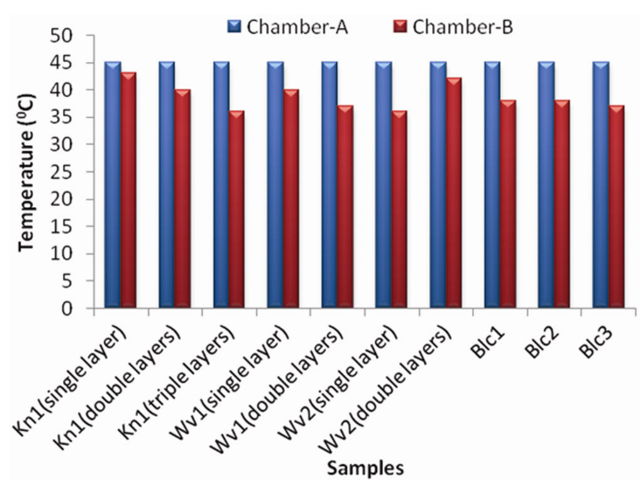

Fig. 3 — Temperature cutting ability of various samples

Similarly samples Wv_1 and Wv_2 are found to cut 5°C and 3°C temperatures respectively. The reason of higher temperature cutting of Wv_1 may be due its lower air permeability and porosity than Wv_2. However the double layers of Wv_1 and Wv_2 samples improve the temperature cutting ability.

4 Conclusion

4.1 The developed apparatus is successfully tested on 6 samples to quantify the light and temperature cutting ability. The developed apparatus replaces the subjective analysis by accurate measurement of light and temperature cutting ability of curtain fabric.

4.2 The light and temperature cutting ability of sample Kn_1 (Knitted) is found lower than that of other samples as it has higher porosity and air permeability than others, which allow to transmit more light and heat through this sample. The light cutting ability of this sample improves, when its double and triple layers are used.

4.3 The light cutting ability of the blackout fabric samples Blc_1, Blc_2 and Blc_3 are found to be more than 95% as all these samples are coated in one side and thus not allowing to pass air through them. As the air permeability is nil, there is no porosity and hence the transmission of light is very less through these samples.

4.4 The temperature cutting ability of blackout fabric samples Blc_1, Blc_2 and Blc_3 are found to be 7- 8°C as these samples have almost zero porosity; air permeability of all these samples are almost nil. Thus, the transmission of heat in the form of temperature through these samples is lower than other samples.

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