EFFECT OF WASHING ON THE FRICTIONAL PROPERTIES OF COTTON FABRICS

BY

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1. INTRODUCTION:

The literature of friction of textile fabrics shows that the effect of washing of cotton fabrics on its surface frictional properties has not been examined. During the laundring of these fabrics various types of detergents are used to assist in cleaning and removing soil and dirts. The effect of these detergents on surface frictional properties is not known, and no informations are available to show the changes which may occur in these properties.

The study of the frictional properties of cotton fabrics after repeated washing is of a great importance, since the change in these properties as a result of washing may affect cloth comfort, or may cause irritition especially for fabrics that comes into contact with the skin, such as underwear and towels.

In the present work a plain cotton fabric has been laundered for a certain number of washes and the relationship between the frictional force and the pressure was examined at a slow speed of 5 cm/min and under pressure ranging between 1.25 and 51 g/cm^2. These friction tests were carried out for fabric sliding against itself (dry and wet) and against an aluminium polished surface. Also the relationship between the frictional properties and the physical properties of the fabric, such as surface hairiness and fabric hardness was examined.

2. SPECIFICATION OF FABRIC USED.

The specifications of the fabric used are as foll
Plain weave, ppi = 43-45; ends/inch = 47-48, weight p

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3. BLEACHING PROCESS

The fabric used has been bleached before being washed. All the bleaching processes were carried out in a winch machine and after the last rinse the samples were spun in the spin dryer and then hung to be dried in the drying room.

3.1. Bleaching with Hydrogen Peroxide.

The bleaching liquor recipe (per litre) is as follows:- 7.0g silicate, 0.5g N_a OH, 1.8g N_a CO_3, 0.2 cc Hospapol CV (wetting agent), and 15 cc H_2O_2 (35%).

The bleaching liquor was raised to temperature of between 49°C and 54°C and the cloth was then run through the bath for approximately 5 minutes to obtain the initial saturation of the cloth. The temperature was then raised gradually to the boil in 30 minute. This temperature was maintained for 1 hr.

With respect to the antichlor treatment, no after treatment was needed. The cloth was rinsed thoroughly by running through warm and then cold water.

4. LAUNDERING

There were 5 meters of the unbleached fabric and 5 meters of each of the 4 bleached fabrics. Each of these 5 meters lengths was cut into 1 meter length so the different number of laundering could be made. The number of launderings were 20, 50 and 100 by the standard laundering.

5. THE FRICTIONAL FORCE - PRESSURE RELATIONSHIP

The frictional force (static) was measured at various pressures ranging between 1.25 and 51g/cm^2, from the frictional force-distance of sliding curves the maximum starting peak was taken as the static frictional force. For all combinations examined, i.e. fabric against itself (dry and wet), and fabric against a polished aluminium surface, the best relationship found to fit the results between the frictional force (F) and the pressure (P) is in the form of; $\mathrm{Log}_{10} F_s = n_s \mathrm{Log}_{10} P + a$, where a and n_s are constants for the combination of surfaces in conteact. The values of (a) and (n_s) for bleached cotton fabric sliding against itself and against a polished aluminium surface at 20, 50 and 100 washes are given in Table (1). Also given in Table (1) the values of (a) and (n_s) for unbleached fabric sliding against itself in the dry state.

For fabric sliding against itself (Table 1) one may observe that the two costants (a) and (n_s) are affected by the number of washes, as the number of washes increases the value of (a) decreases, while the constant (n_s) increases and reaches to a value of 0.85. Also one may observe that high values of (a) are associated with low values of (n_s) and vice versa. Similar trends were found for unbleached cotton fabric sliding against itself in the dry state.

When the lower surface (which was the same fabric) was replaced by a polished aluminium surface, there was a large drop in (a) and a large increase in the constant (n_s), which reached to a value of 0.95. Also in this case one may observe that high value of (a) are associated with low values of (n_s) and vice versa. This is in agreement with the above findings for bleached and unbleached cotton fabric sliding against itself.

In the above three cases one can observe that the value of the costant (n_s) which is known as the deformation index according to the adhesion theory of friction of solids ranging between 0.666 and 0.950 which falls within the range proposed by the adhesion theory.

When the relationship between the frictional force and the pressure, i.e. $\mathrm{Log}_{10} F_s = a + n_s \mathrm{Log}_{10} P$ is transfered back to its original form, i.e. $F = K.P^n$ it is in agreement with the relationship found for polymeric materials sliding against itself and against other surfaces, for fibre assemblies (webs), and for metals sliding against itself at low loads (in the range of 200 g).

Table (1): Values of (a) and (n_s) for bleached cotton fabric sliding against itself.

Number of Washes	(a)	(n_s)	State
20	+ 0.116	0.780	Dry - bleached
50	+ 0.208	0.733	Dry - bleached
100	+ 0.002	0.850	Dry - bleached
10	+ 0.238	0.696	Dry - unbleached
50	+ 0.206	0.771	Dry - unbleached

Table (2): Values of (a) and (n_s) for washed cotton fabric sliding against Aluminium surface.

Number of washes	(a)	(n_s)	State
10	- 0.547	0.918	Dry
50	- 0.577	0.950	Dry

In the case of solids the constant (n_s) is known as the deformation index and it describes the type of deformation of the real areas of cotact (if purely elastio n_s = 0.67 and if purely plastio n_s = 1). The values of (n_s) obtained for fabric (bleached and unbleached) sliding against itself and against aluminium surface indicates that the deformation of the real areas of cotact is neither purely elastic, nor purely plastic, but something intermediate between the two.

6. RELATIONSHIP BETWEEN COEFFICIENT OF FRICTION AND PRESSURE.

The coefficient of friction (static or kinetic) is defined according to the second law of friction, as the ratio of the frictional force to the normal load applied between the surfaces in contact. According to this the values of the static coefficient of friction u_s were calculated at the various pressures used. The values are plotted against the pressure for bleached cotton fabric washed for 20, 50 and 100 times when it slide against itself in the dry state, and for 100 laundered fabric sliding against itself in the wet state, in Figs. (1) and (2) respectively.

From the plots one may observe for the dry and wet fabrics sliding against themselves, that the coefficient of friction is not constant but pressure dependent. As the pressure decreased the coefficient of friction increased. Also from the plots one can observe that as the number of washes increased the coefficient of friction tended to decrease and reached its lowest values after 100 washes.

With respect to the effect of wetting on the value of the coefficient of friction the results obtained (as may be seen from Tables (3) and (5) show that the coefficient of friction increased at all pressures used. The average increase over the range of pressures used is about 200 percent.

The values of the coefficient of friction for bleached fabric (washed for 20, and 50 times) when it slide against itself and against aluminium surface are given in Tables (3), and (4) respectively. From Table (4) one may observe that the values of u_s are much lower than that obtained for the fabric sliding against itself. The average reduction in the u_s values over the range of pressures used reached to about one third the value for the fabric sliding against itself.

In fact the above trends of u_s with pressure, and the effect of the number of washes, and the nature of surface in contact on the coefficient of friction may be explained in the light of the physical properties of the fabric or the combination of surfaces in contact.

Since friction tests are carried out under normal forces (or pressures), therefore one would expect that the compression properties of the surfaces of contact have its influence on the magnitude of the frictional force and consequently the coefficient of friction. For soft materials sliding against another soft material the area of contact will be large, and hence will be the force required to shear it, while for hard material sliding against another hard material the area of cotact will be small and hence will be the frictional force, or in other words the coefficient of friction.

The compression tests carried out on the fabrics tested (using the Shierly thickness meter) showed that fabric hardness increased after 50, and 100 washes. Fabric hardness is defined as the ratio of P_2-P_1/t_2-t_1, where P_2 and P_1 are two arbitarly pressures, and t_2 and t_1 are the fabric thickness at these pressures respectively. The values of the hardness (H) for 20, 50, and 100 landered fabric are 539, 689, and 729 $g/cm^2/mm$. respectively. For unbleached cotton fabric the hardness of the fabric increased from 344 to 442.8 after 50 washes.

With respect to the effect of wetting on u_s it is known that water has its influence on cellulose rigidity, water destroy some of the rigidity of the cellulose hence it becomes soft and easily deformed under external pressure. This would lead to an increase in the real area of contact, hence the area to be sheared, and cocequently the force to shear it.

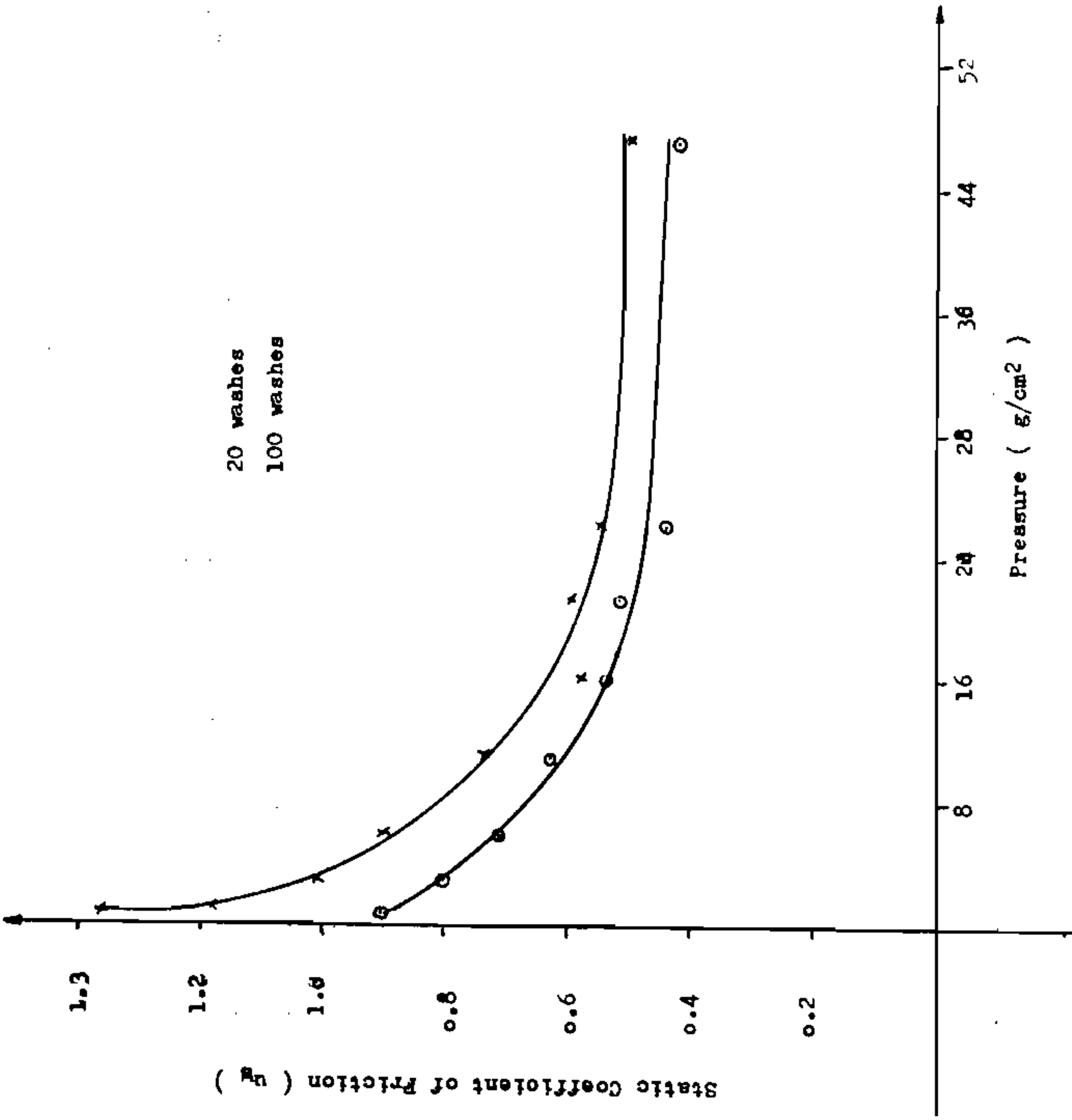
20 washes
100 washes
Static Coefficient of Friction (u_s)
1.3
1.2
1.0
0.8
0.6
0.4
0.2
8
16
24
28
32
44
52
Pressure (g/cm^2)

Fig.1

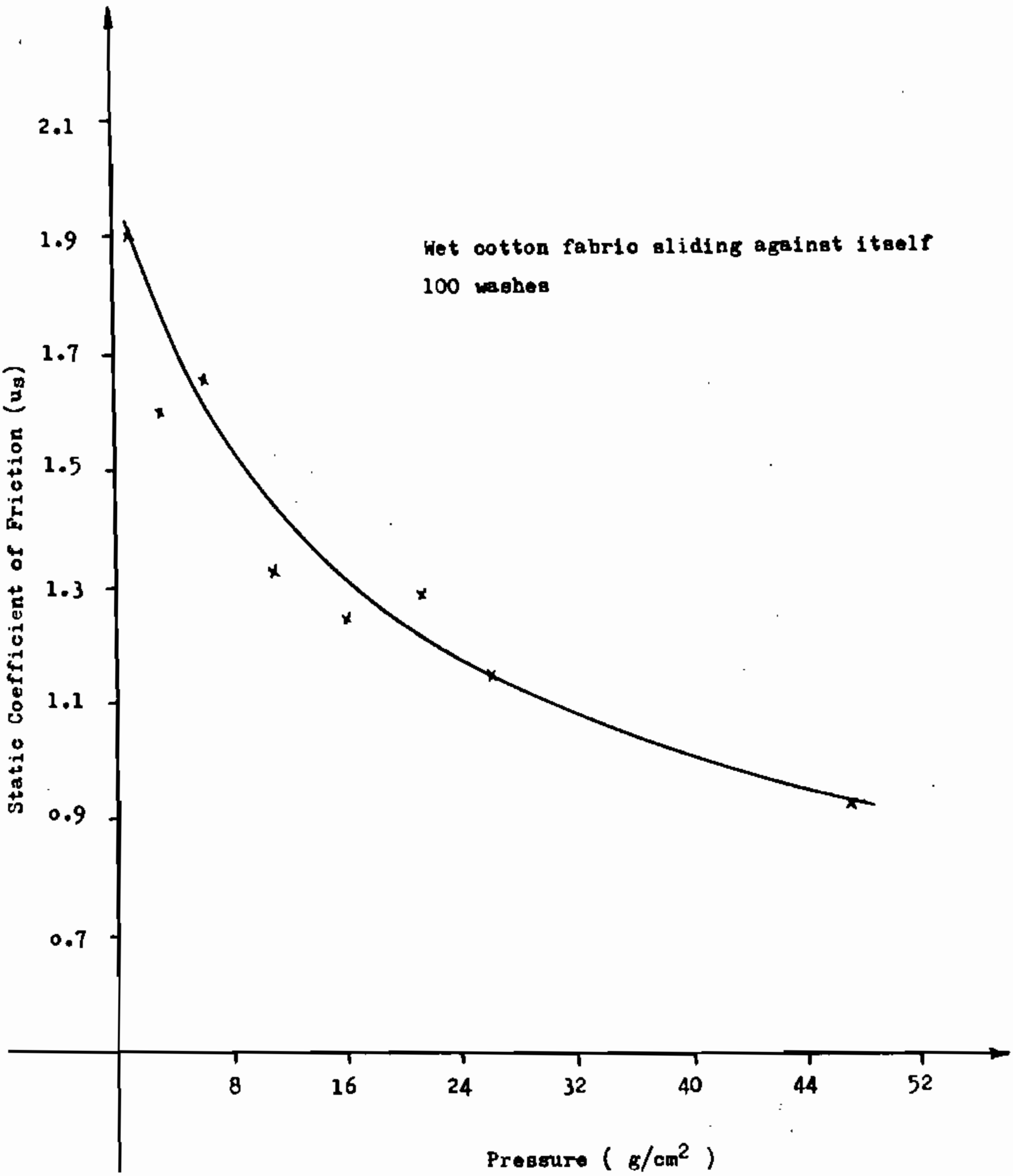
Static Coefficient of Friction (us)
2.1
1.9
1.7
1.5
1.3
1.1
o.9
o.7
Wet cotton fabric sliding against itself
100 washes
8
16
24
32
40
44
52
Pressure (g/cm2)

Fig.2

Table (3): Values of u_s of cotton fabric sliding against itself (dry).

Pressure (g/cm^2)	Static coefficient of friction		
	Number of washes		
	20	50	100
1.25	1.280	1.640	0.920
3.50	1.040	1.143	0.800
6.00	0.917	0.916	0.717
11.00	0.737	0.864	0.620
16.00	0.578	0.656	0.541
21.00	0.607	0.643	0.524
26.00	0.558	0.587	0.442
51.00	0.500	0.550	0.420

Table (4): Values of u_s of cotton fabric sliding against Aluminium Surface (dry).

Pressure (g/cm^2)	Static coefficient of friction u_s	
	Number of washes	
	20	50
1.25	0.240	0.240
3.50	0.271	0.286
6.00	0.275	0.279
11.00	0.264	0.223
16.00	0.209	0.219
21.00	0.205	0.226
26.00	0.223	0.202
51.00	0.181	0.200

Tabor[1] found that immersing nylon blocks in water destroys some of the rigidity of the polymer leading to high frictional resistance during sliding. This was attributed to the increase in the area of contact between surfaces of nylon blocks.

For fabric sliding against aluminium surface the large drop in the coefficient of friction could be attributed to the large drop in the number of contacts between surfaces. This may be due to the reduction in the number of hairs involved in the contact zone or due to the increase in the rigidity of the combination formed from the fabric and the aluminium surface. For fabric sliding against itself the hardness of the combination is much lower than for a fabric and a hard aluminium surface.

7. RELATIONSHIP BETWEEN FABRIC COEFFICIENT OF FRICTION, AND SURFACE INDEX (b).

To relate the above trends in the coefficient of friction after washing for the fabrics under consideration, to the surface properties and the bulk properties of the fabric the index (b) proposed by Bogaty[5] was used. This index is determined from the compression properties of the fabric. Bogaty proposed this index to describe the nature of the surface of the fabric, i.e. hairiness of the surface. According to Bogaty high values of (b) indicate high hairiness and vice versa.

In the present work the values of (b) was calculated from averaging the values of (b) over all the range of pressures used (0.166 and 125 g/cm^2), instead of averaging the values at low pressures only as Bogaty proposed. This has the advantage of combining all mechanisms involved in compression, i.e. from the collapse of fibres at low pressures to the compression of the bulk of the fabric at high pressure.

The values of (b) for bleached cotton fabric after 20, 50 and 100 washes are given in Table (6). From the table one can observe that the values of (b) are positive in the three cases, Table (5): Values of u_s for wet cotton fabric sliding against itself(100 washes).

Pressure (g/cm^2)	Static coefficient of friction u_s
1.25	1.91
3.50	1.60
6.00	1.67
11.00	1.32
16.00	1.25
21.00	1.29
26.00	1.15
51.00	0.922

Table (6): Values of surface Index (b) and fabric Hardness (H).

Number of Washes	Hardness (H)	(b)
0	539	0.389
50	689	0.352
100	729	0.232

and that the value of (b) decreases with the increase of the number of washes. The drop in the value of (b) after 100 washes is about 40 percent.

Tables (6) and (3) show the value of (b) and the corresponding values of u_s at 20 and 100 washes. From the tables one may observe that the occured decrease in the index (b) is associated with a decrease in the coefficient of friction at all pressures used. These results indicate that by repeated washing the number of protruding hairs (or fibres) decrease. This would lead to low values of u_s at low pressures. Also that fabric hardness increases (this has been confirmed by the compression test which showed that the hardness of the fabric increased from 542 $g/cm^2/mm$ at 20 washes, to 729 $g/cm^2/mm$ at 100 washes). The increase in fabric hardness and the decrease in fabric hairiness will result in less number of contacts, and hence less friction.

8. CONCLUSIONS

1) For washed fabrics sliding against itself or against aluminium surface the frictional force may be related to the pressure (p) by a linear relationship in the form of:-

$$\text{Log}_{10} F = a + n_s \text{Log}_{10} P$$

where a and n_s are constants for the combination of surfaces in contact.

2) The value of the deformation index (n_s) was found to range between 0.696 and 0.95 which falls within the range of (n_s) proposed by the adhesion theory of friction.

3) The coefficient of friction (static) is not constant as proposed by Amontons law, but pressure dependent. As the pressure decreases the coefficient of friction increases.

4) The coefficient of static friction of cotton fabric increases by wetting.

5) The static coefficient of friction of fabric depends on the hardness of the combination of fabric and surface in contact.

As the hardness of the combination increases, the coefficient of friction decreases.

6) The surface index (b) has a strong relationship with the coefficient friction. High values of (b) are associated with high values of coefficient of friction and vice versa.

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