A STUDY OF FRICTIONAL PROPERTIES OF A WASHED COTTON FABRIC.

BY

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1. INTRODUCTION:

The textile fabric during its use is exposed to soiling. To remove soil and dirts the fabric is washed. Washing may be carried out by hand or by washing machines, and in both cases a cleaning material is used. The process of washing includes friction between the fabric and itself, the fabric and any other dissimilar fabric and the fabric and the internal surface of the washing machine in the case in which a washing machine is used for the process of washing.

The literature of fabric physics lacks informations about the behaviour of the fabric during the washing processes and about the changes which may occur to the fabric as a result of washing. Informations about frictional properties of fabrics are of a great importance since the forces generated on the fabric during washing will determine the degree of soil removal and hence cleaning. Also knowing the type and the magnitude of these forces will help in determining the power consumption during washing, and the rate of abrasion of the fabric.

The study of the frictional properties of fabrics in general is of a great importance, especially in the case of fabrics that comes into contact with the skin, such as underwear towels and bed covers. High friction may cause irritation and creates a feeling of discomfort to the wearer.
In the present investigation the frictional properties of a plain cotton fabric that has been washed for several times were examined and reported. The friction tests were carried out samples of the fabric against itself and against a highly polished aluminium surface(simulation to the internal surface of the washing machine) under pressure ranging between 1.25 and 26 g/cm^2 and a sliding speed of 3 m/hr.

2. Fabric Used.

A plain cotton fabric with 19 ends/cm and 18 picks/cm and weighing 210 g/m^2 was used in the present investigation.

3. Bleaching of Fabric.

The fabric used in the present investigation has been bleached before washing. All the bleaching preocesses were carried out in a winch machine. After the last rinse the samples have been hydro-extracted, then hung to dry in the drying room.

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3.1. Bleaching with Hydrogen Peroxide.

The bleaching liquor recipe (per litre) is as follows:-
7 gram silicate 0,5 gram caustic soda, 1.8 gram Na_2CO_3, 0.2 cm^3 Hospapol CV (wetting agent) and 15 cm^3 H_2O_2 (35%).
The bleaching liquor was raised to temprature of between 49 °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 minutes. This temperature was maintained for 1 hour.
With respect to the antichlor treatment, no after treatment was needed. The was rinsed thoroughly by running through warm and then cold water.

4. Laundering.

There were five meters of the unbleached fabric and five meters of each of the four bleached fabrics. Each of the five meters lengths was cut into one 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. Apparatus Used for Measuring the Frictional Properties of a Fabric.

The apparatus used in the present investigation is designed by the author and fully described elsewhere[1]. The apparatus enables the study of the frictional properties of any fabric sliding against itself and against any other surface.

6. Friction Force-Displacement Curves of Cotton Fabric Sliding Against Itself and Against Aluminium Surface.

Shown in Fig.(1) the type of friction force-displacement curve obtained for washed cottin fabric sliding against itself and against a polished aluminium surface under pressure ranging between 1.25 and 26 g/cm^2. When the fabric slides against itself or against aluminium surface the frictional resistance rises up and reaches a maximum which is known as the static friction, then falls down to a lesser value which is known as the dynamic frictional resistance and at that level the fabric is sliding.

It was observed during friction test that a considerable drop occurs in the frictional force (static and dynamic) by repeated sliding over the same specimen. The percentage drop decreases after the third run, therefore all measurement of friction force were taken from that run.

7. Friction Force-Pressure Relationship.

Over the range of pressures used, i.e. between 1.25 and 26 g/cm^2, the frictional force (static and dynamic) was found to relate well to the pressure (P) by a logarithmic relationship in the

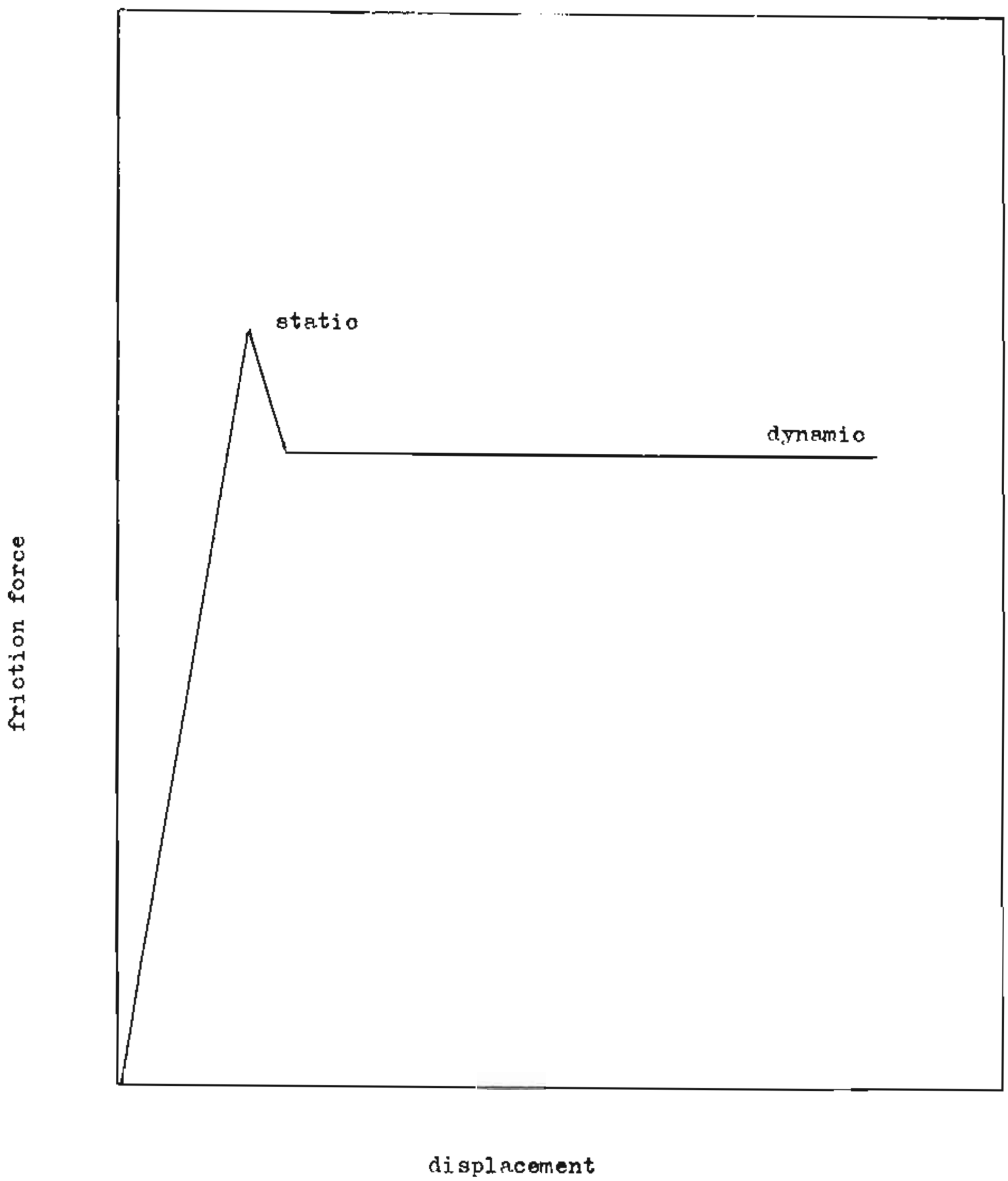


Fig.1.

form of; Log F = m + n Log P, where m and n are constants for the combination of surfaces in contact (fabric against itself and fabric against aluminium surface).
Given in Table (1) the values of m and n as determined from the static and dynamic parts of the frictional force-displacement curve. This is for fabric sliding against itself and against aluminium surface in the dry and wet state at various number of washes.
Plotted in Fig.(2) all values of m and n as determined from static and dynamic states of sliding. From the plot it is evident that there a general trend between m and n, high values of m are associated with low values of n and vice-versa. Also from Table (1) one may observe that after 100 washes the constant n which is known as the deformation index increased in value, while the constant m followed an opposite trend.
When the lower surface which was the same fabric was replaced by a highly polished aluminium surface, both m and n changed considerably, m has become negative and low in magnitude while n increased and reched a value of 0.937.

The relationship obtained between the frictional force (F_s and F_d) and the pressure (P) is in agreement with that for metals[2] (at a normal loads less than 200 grams) and for polymeric materials and fibre assemblies[3] (fringes of fibres and fabrics) sliding against themselves and against other dissimilar materials and surfaces. The values obtained in the present work for the deformation index n ranging between 0.565 and 0.937. These values are within the range proposed in the adhesion theory of friction[2].
According to the adhesion theory of friction[2], friction arises from adhesion at the real areas of contact and to start sliding these junctions must be sheared. The frictional force is accordingly proportional to the area of contact and the constant of proportionality includes the shear strength of the formed junction. In the case of polymeric materials the area of contact[3] is load and time dependent. When a load is applied the area of contact will deform till it becomes capable of carrying that load, the deformation of the area may be plastic or elastic. When the deformation of the real area of contact is elastic the deformat.on index is equal to 0.67 (or 0.56 depending on the shape of the real area of cotact) while when plastic is equal to 1.0.
The values obtained for n in the present work falls between the limits proposed by the adhesion theory. This is not surprising since textile materials are materials of visco-elastic nature, hence one would expect the deformation of the real area of contact to be intermediate between the elastic and plastic limits.

Plotted in Fig.(3) the values of the deformation index as determined from the static and dynamic states of sliding for various combinations examined in the present work.

From the figure it is evident that n_s and nd are well correlated; i.e. high values of n_s are always associated with high values of n_d may be due to the difference in the number of contacts formed before and during sliding and to the way by which these contacts are formed.

Table(1): Values of m and n for washed cotton fabric sliding against itself and against aluminium surface.

number of washes and state of fabric		m	n	state of sliding
10-unbleached	s	0.656	0.614	dry-fabric against itself
	d	0.538	0.565	
50-unbleached	s	0.503	0.661	" "
	d	0.315	0.634	
10-unbleached	s	0.448	0.855	wet-fabric against itself
	d	0.345	0.855	
20-bleached	s	0.365	0.709	dry-fabric against itself
	d	0.260	0.670	
50-bleached	s	0.559	0.666	" "
	d	0.364	0.677	
100-bleached	s	0.091	0.775	" "
	d	-0.069	0.753	
100-bleached	s	0.648	0.864	wet-fabric against itself
	d	0.521	0.881	
20-bleached	s	-1.298	0.937	dry-fabric against aluminium
	d	-1.244	0.846	
50-bleached	s	-1.278	0.925	" "
	d	-1.314	0.903	

s = static

d = dynamic

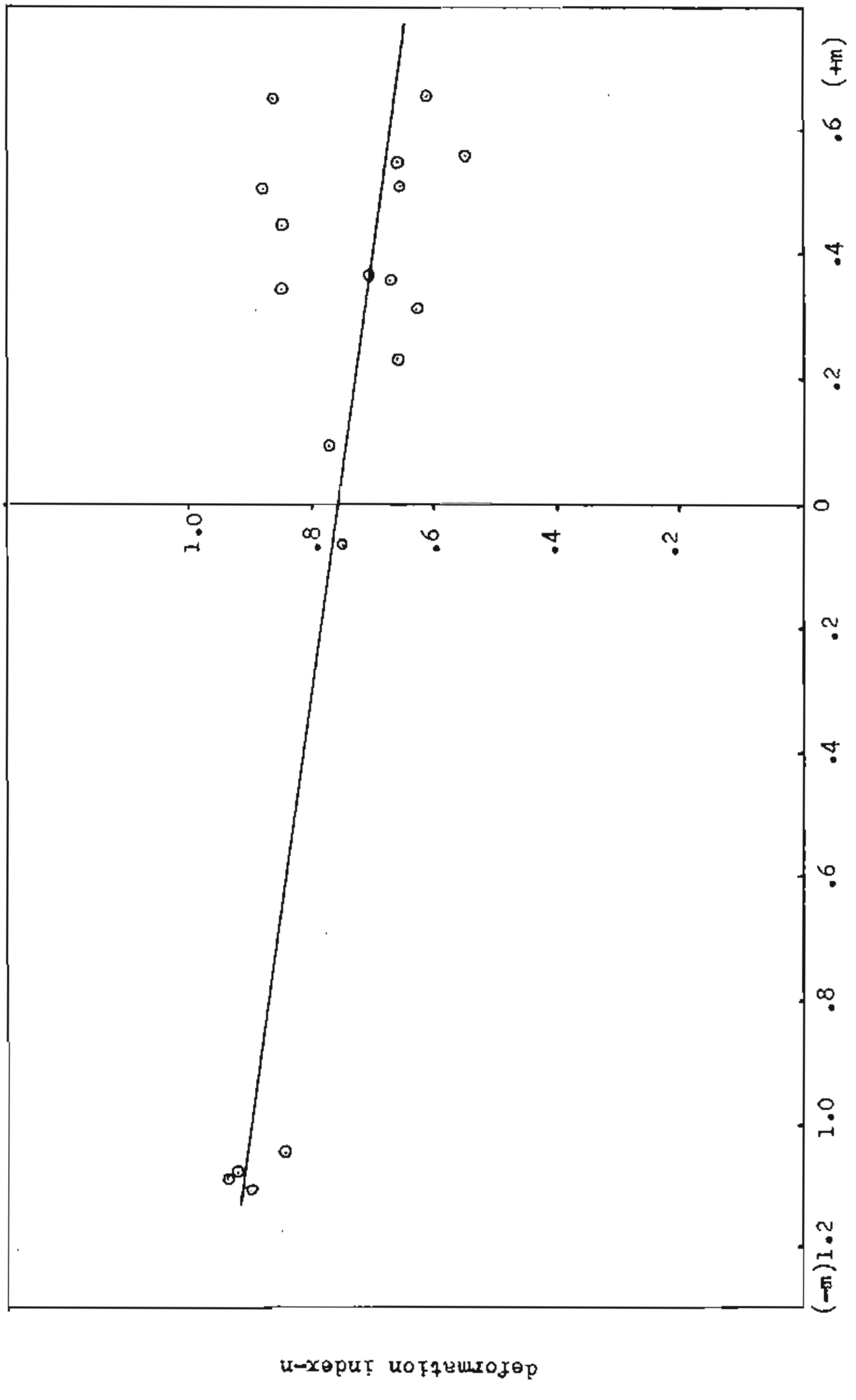


Fig.2.

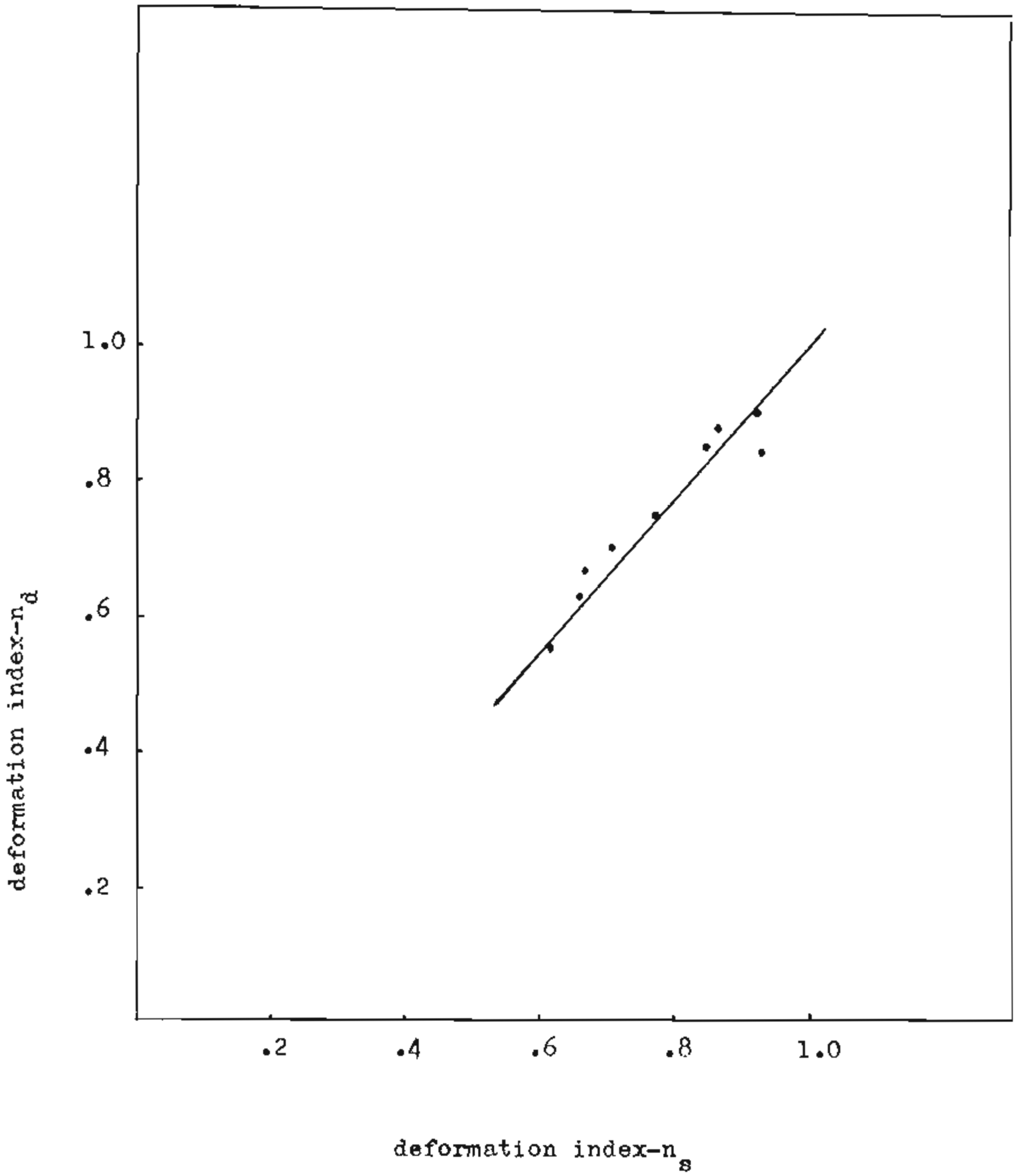
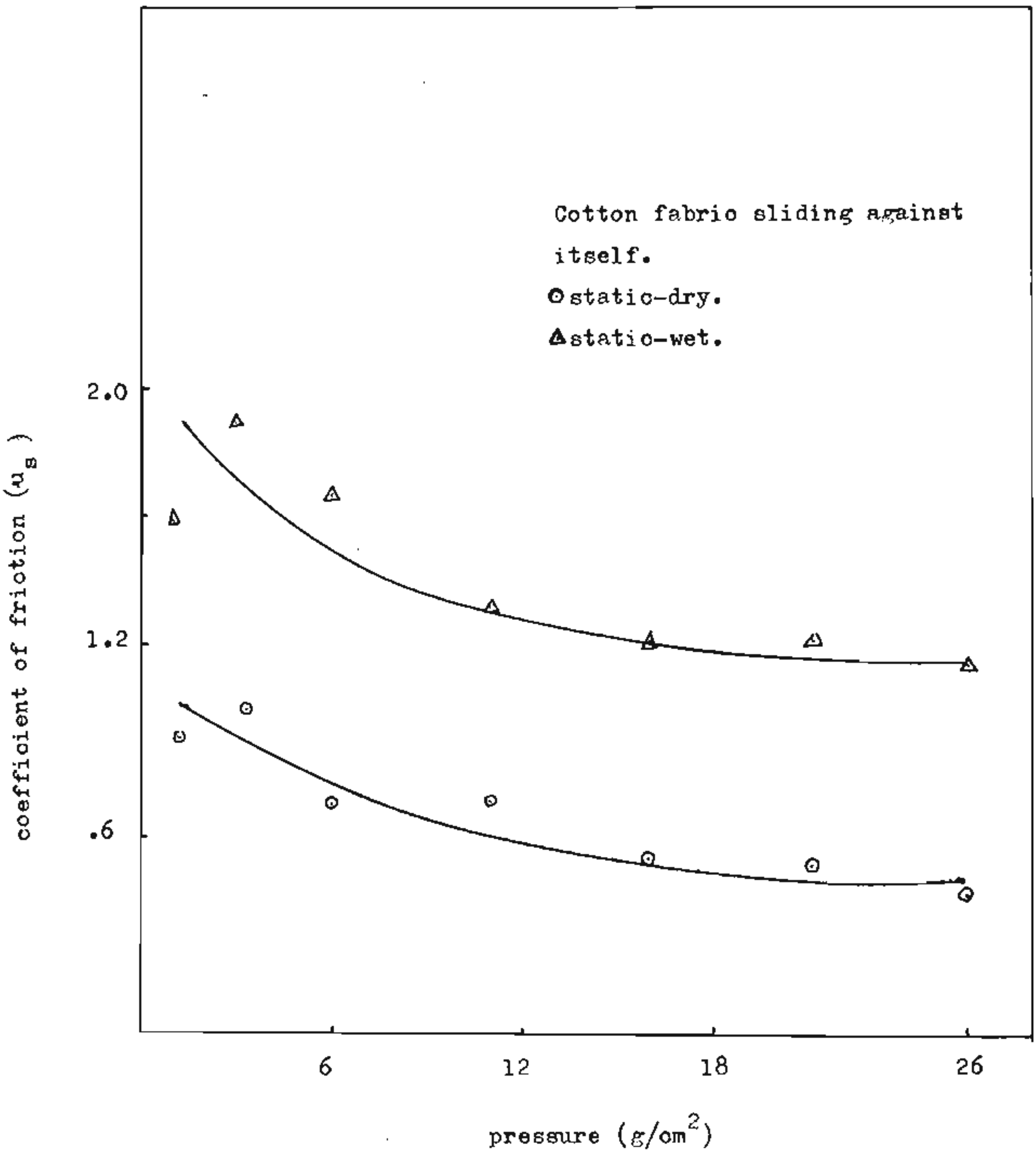


Fig.3.



Cotton fabric sliding against itself.
static-dry.
static-wet.
2.0
1.2
.6
coefficient of friction (μ_s)
6
12
18
26
pressure (g/cm^2)

Fig.5.

11. T.Mansoura Bulletin June 1980.

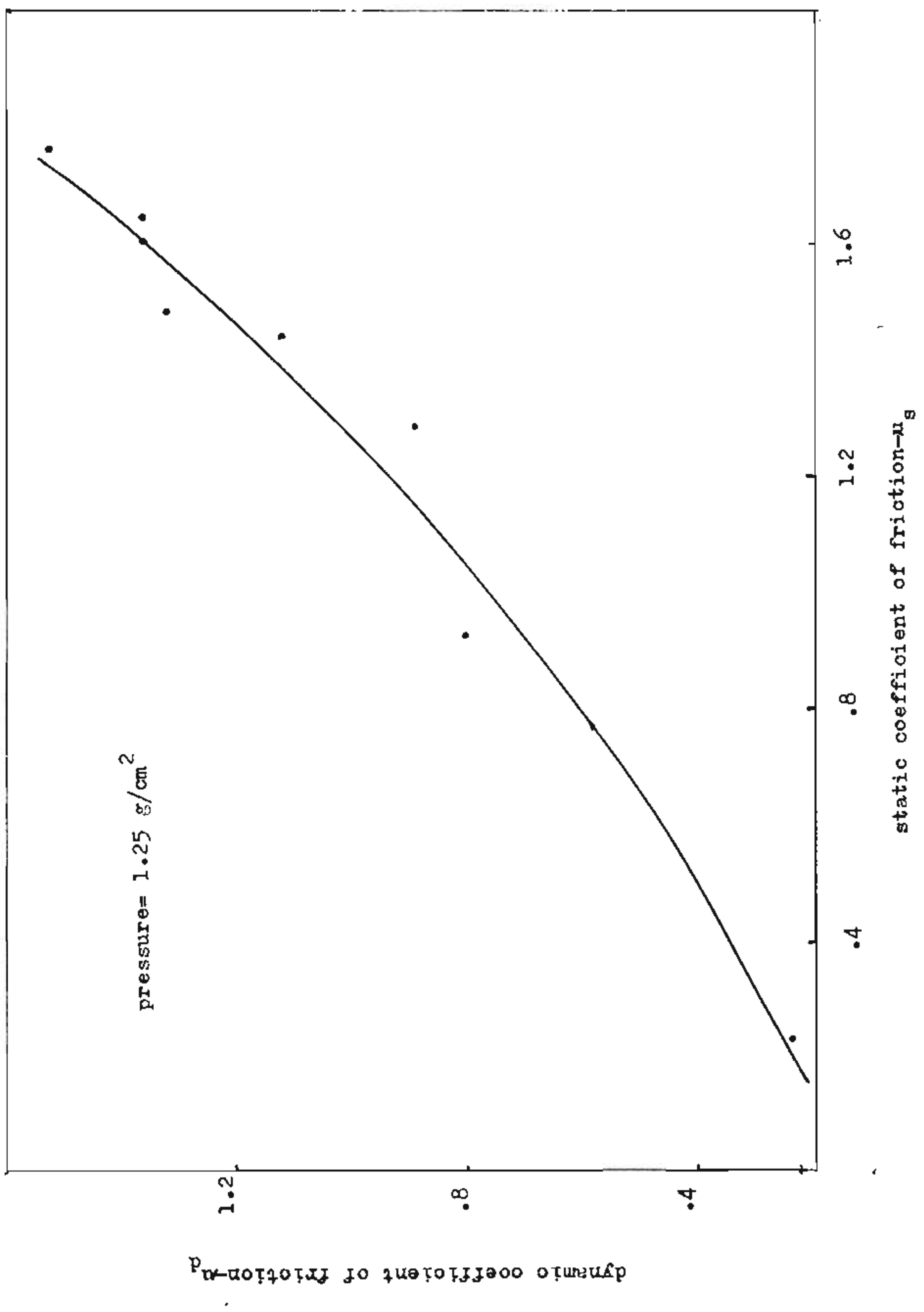


Fig.6.

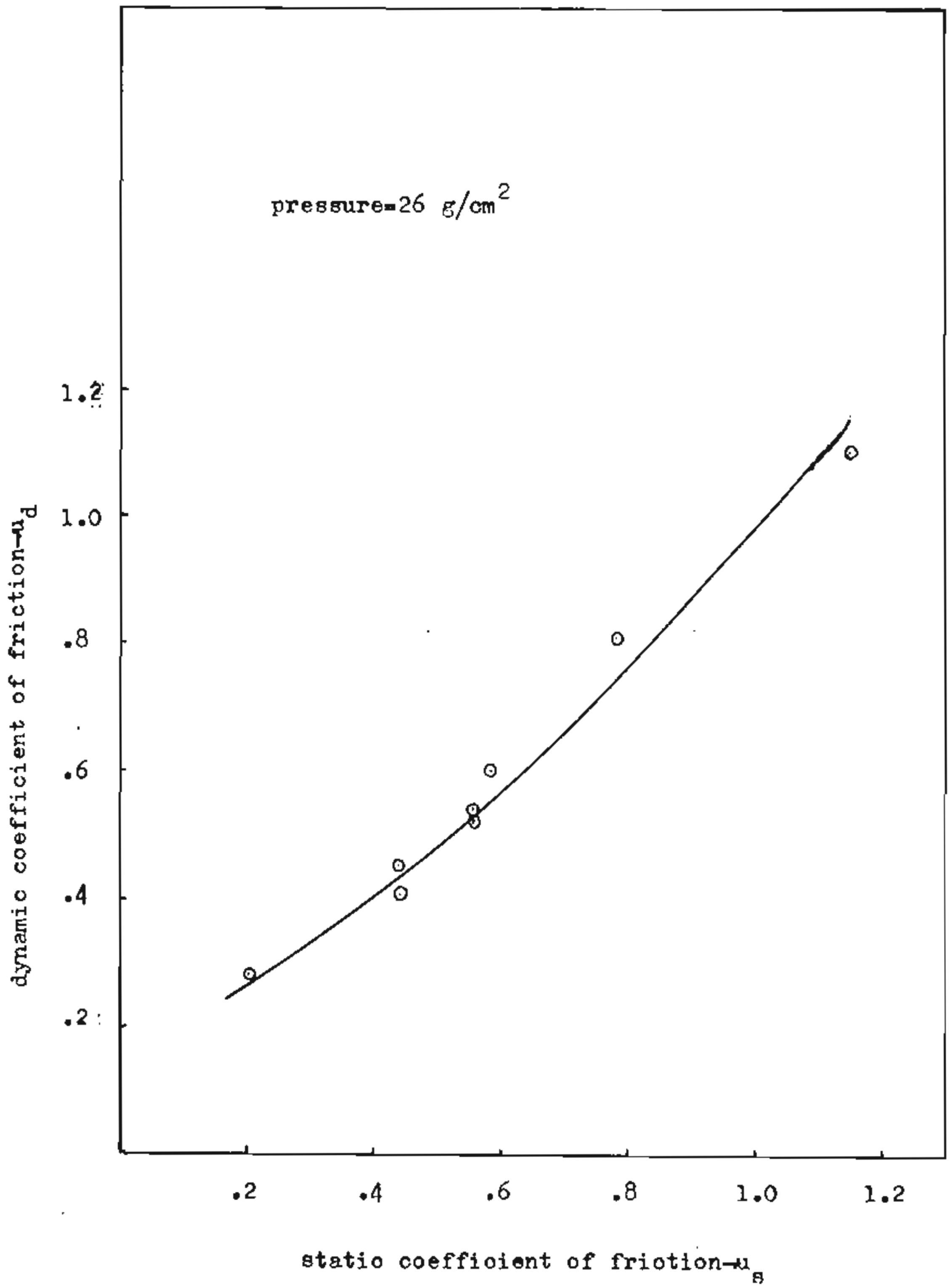

pressure=26 g/cm2
1.2
1.0
.8
.6
.4
.2
dynamic coefficient of friction-ud
.2
.4
.6
.8
1.0
1.2
static coefficient of friction-us

Fig.7.

13. T.Mansoura Bulletin June 1980.

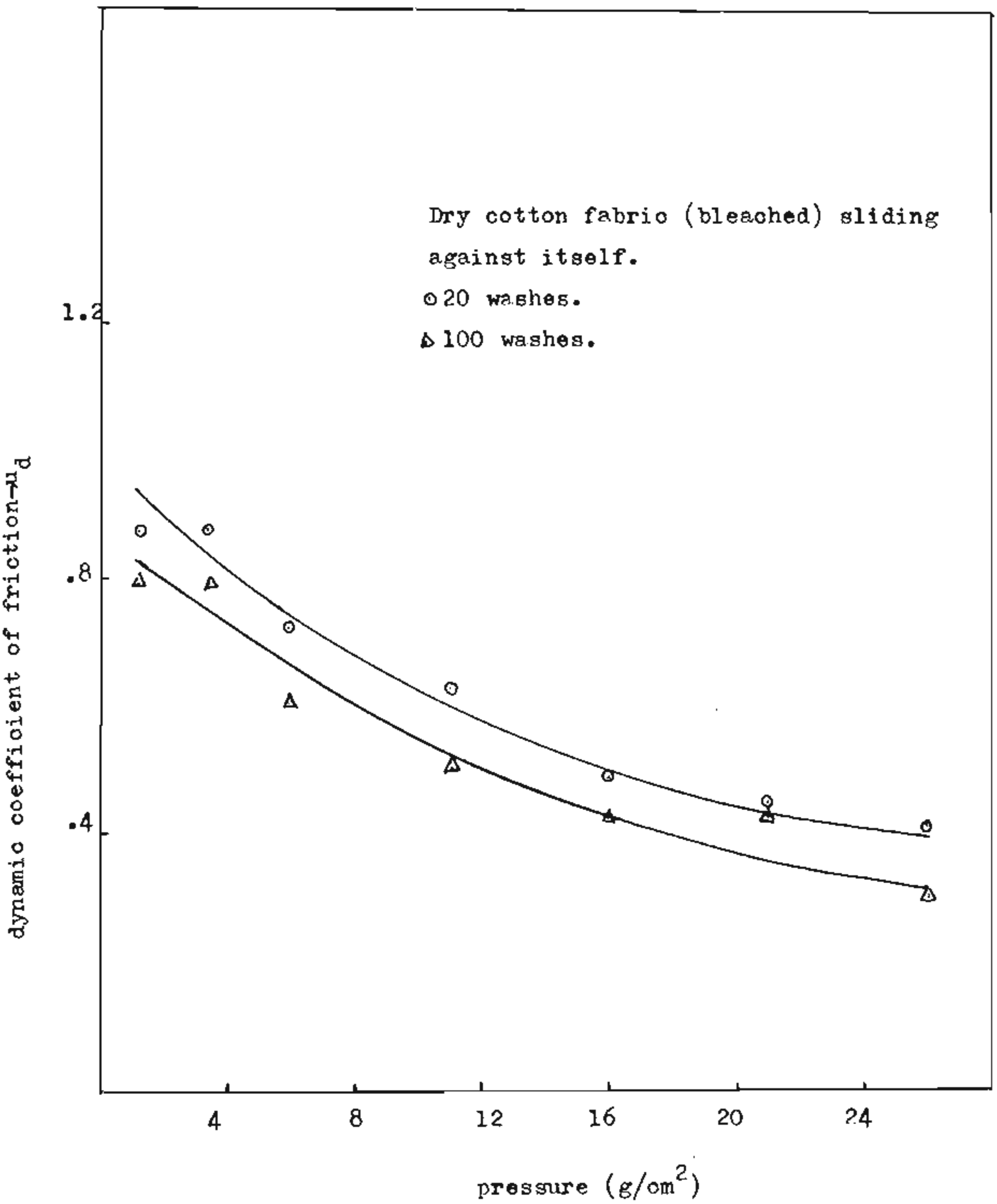


Fig.8.

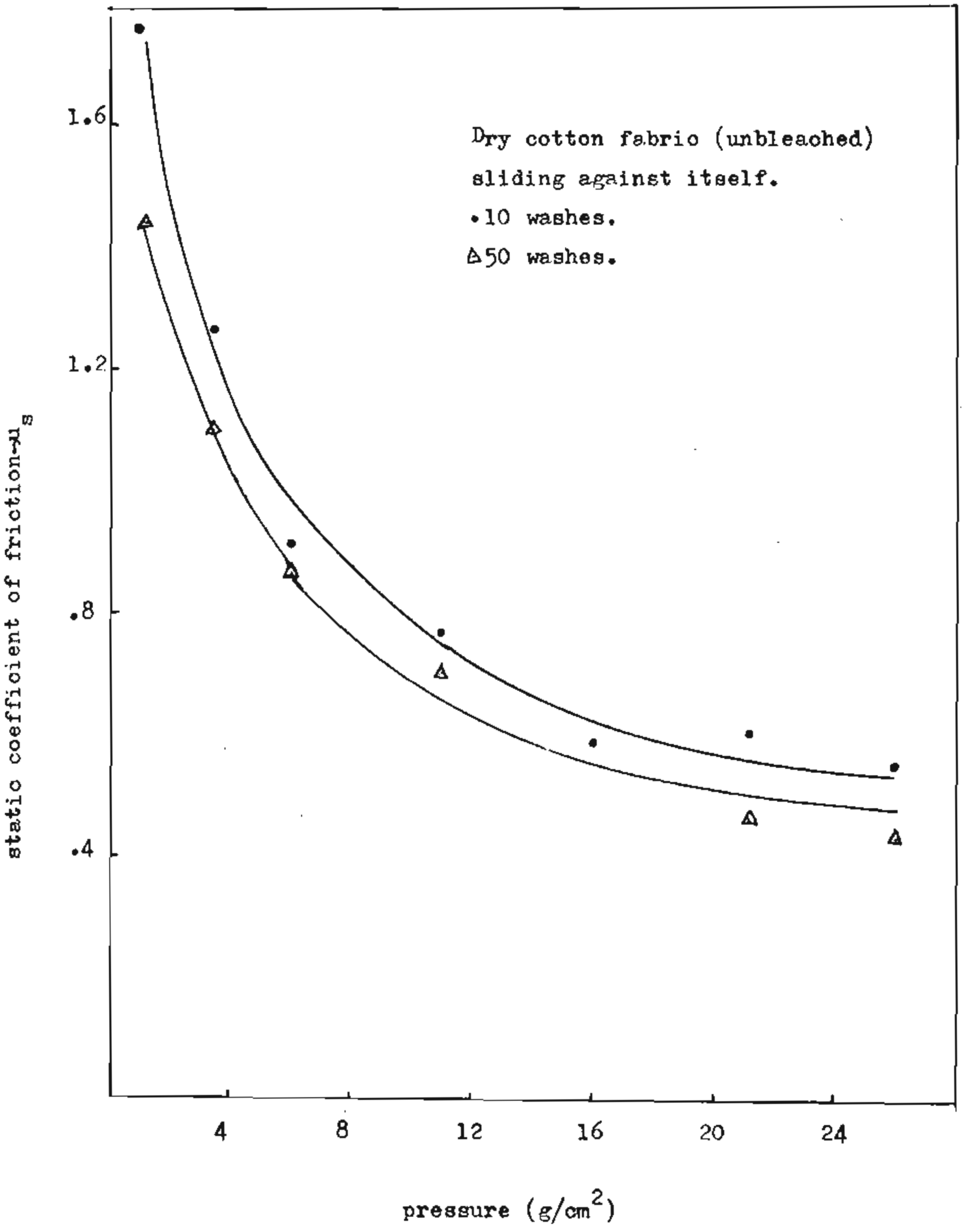

Dry cotton fabric (unbleached)
sliding against itself.
•10 washes.
△50 washes.
1.6
1.2
.8
.4
static coefficient of friction-μ_s
4
8
12
16
20
24
pressure (g/cm^2)

Fig.9.

Table(2): Values of static and dynamic coefficient of friction of bleached cotton fabric sliding against itself(dry).

pressure	number of washes			
	20		100	
g/cm^2	u_s	u_d	u_s	u_d
1.25	1.280	0.880	0.920	0.800
3.50	1.040	0.886	1.000	0.800
6.00	0.917	0.733	0.717	0.617
11.00	0.737	0.636	0.700	0.518
16.00	0.578	0.500	0.541	0.438
21.00	0.607	0.464	0.524	0.440
26.00	0.558	0.423	0.442	0.308

Table(3): Values of static and dynamic coefficient of friction of dry and wet washed cotton fabric sliding against itself.

Pressure	dry		wet	
g/cm^2	u_s	u_d	u_s	u_d
1.25	0.920	0.800	1.600	1.360
3.50	1.000	0.800	1.910	1.770
6.00	0.717	0.617	1.670	1.580
11.00	0.700	0.518	1.320	1.180
16.00	0.541	0.438	1.250	1.190
21.00	0.524	0.440	1.290	1.240
26.00	0.442	0.308	1.150	1.000

number of washes = 100

Table(4): Values of static and dynamic coefficient of friction of washed unbleached cotton fabric sliding against itself (dry & wet).

pressure g/cm^2	number of washes and state of fabric					
	10-dry		10-wet		50-dry	
	u_s	u_d	u_s	u_d	u_s	u_d
1.25	1.760	1.520	1.480	1.320	1.440	1.120
3.50	1.260	1.060	1.340	1.230	1.110	0.886
6.00	0.917	0.783	1.250	1.130	0.867	0.750
11.00	0.773	0.614	1.050	0.932	0.809	0.727
16.00	0.594	0.438	1.080	0.984	0.703	0.578
21.00	0.643	0.476	0.988	0.881	0.476	0.357
26.00	0.558	0.442	0.788	0.712	0.434	0.365

Table(5): Values of static and dynamic coefficient of friction of washed cotton fabric sliding against itself and against aluminium.

pressure g/cm^2	fabric against itself		fabric against aluminium	
	u_s	u_d	u_s	u_d
1.25	1.640	1.360	0.240	0.240
3.50	1.143	0.914	0.285	0.257
6.00	0.916	0.783	0.279	0.258
11.00	0.864	0.750	0.223	0.195
16.00	0.656	0.594	0.219	0.198
21.00	0.643	0.507	0.226	0.214
26.00	0.587	0.500	0.202	0.183

number of washes = 50

after 100 washes. This is for bleached cotton fabric. For unbleached cotton fabric that has been washed for 10 and 50 washes the hardness increased from 344 to 443 g/cm^2/mm.
The increase in the hardness of fabrics in contact will result in a reduction in the total area of contact. Add to this the reduction in the number of contacts arising from the protruding hairs involved in the contact zone. By washing the fabric looses many of the hairs protruding on the surface through abrasion against itself and against the aluminium surface of the washing machine. Hence the fibres will be fatigued and lost through slippage from the yarn and fatigued by mechanical strains (tension, bending and torsion). These factors together will lead to a considerable drop in the coefficient of friction.

The drop in the coefficient of friction by repeated washing does mean that the fabric is still suitable for wearing and skin cleaning or drying, this is because of the increase in fabric hardness, inother words the fabric has become stiff and the fibres became rigid. This will cause a feeling of discomfort to the user.

8.2. Coefficient of Friction of Washed Cotton Fabric Sliding Against Aluminium Suraface.

Given in Table (5) the values of static and dynamic coefficient of friction of washed cotton fabric sliding against itself and against a polished aluminium surface at various pressures.
From the table it is clear that when the lower surface (which was the same fabric) was replaced by a highly polished aluminium surface a considerable drop occured in the value of the coefficient of friction. Also it is evident from the table that the values of the coefficient of friction for fabric sliding against itself rather than against a highly polished aluminium surface falls within a wide range, while the opposite is observed when the fabric is sliding against aluminium. This is applies over all the range of pressures used and over the range of pressures between 1.25 and 6 g/cm^2. This range is usually used in the subjective tests of smoothness of fabrics. Therefore it is advised not to use highly polished surfaces when required to obtain values of coefficient of friction for fabrics that will be used in comparisons between subjective smoothness and measured smoothness; i.e. coefficient of friction.

The occured drop in the coefficient of friction (static and dynamic) when sliding occurs on aluminium surface is attributed to the reduction in the total area of contact as a result in the number of hairs involved in the contact zone and to the increase in the total rigidity of the combination formed from the fabric and the very hard aluminium surface. As a result of this the force required to shear the area of contact will be small, hence will be the coefficient of friction. These results are in agreement with that obtained for a wide range of textile fabrics sliding against perspex surface[1].

9. Conclusions.

1- For washed cotton fabric sliding against itself and against aluminium surface the frictional force (F) was found to relate well with the pressure (P) by a relationship in the form of; $\text{Log } F = m + n \text{ Log } P$, where m and n are constants.

2- The constants m and n are highly correlated, generally high values of m are associated with low values of n and vice-verse.

3- The values of the deformation index (n) fall within the range proposed by the adhesion theory of friction.

4- For washed cotton fabric sliding against itself and against aluminium surface, the coefficient of friction (static and dynamic) is not constant as stated by Amontons law, but pressure dependent. As pressure decreases the coefficient of friction increases and vice-versa.

5- For washed cotton fabric sliding against itself and against aluminium surface the static coefficient of friction is always higher than the dynamic coefficient of friction, also high values of static coefficient of friction are generally associated with high valuees of dynamic coefficient of friction.

6- A considerable drop in the coefficinet of friction of cotton fabric occurs by repeated wahsing.

7- The coefficient of friction (static and dynamic) increases by wetting.

8- The values of the coefficient of friction of washed cotton fabric sliding against itself and against highly polished aluminium surface ranging between 0.142 and 1.91, which are much higher than that of many metals and polymeric materials.

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2. Bowden, F.P. and Tabor, D., "The friction and lubrication of solids", Part II, Oxford University Press 1964.

3. Howell, H.G., Mieszkis, K.W. and Tabor, D., "Friction in Textiles". Butterworth Scientific Publications, London, 1959.