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Measuring human hair friction with a crossed fibres test setup

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ABSTRACT – Using a crossed fibres contact configuration, reciprocating sliding tests with single human hair fibres were carried out. The sliding direction, the normal load, and the crossing angle were the main parameters of the investigation.

1. INTRODUCTION

Human hair friction depends on many different factors. The combability and softness of hair can be attributed to the frictional behaviour of hair in contact with hair or other hair device materials.

Different methods have been developed and applied in order to study the frictional properties of human hair. Schwartz and Knowles [1] used the static mandrel and the capstan setup to measure the friction between hair fibres and between hair fibres and other materials. Combability measurements with bunches of hair were conducted by Garcia and Diaz [2]. On the nano-scale, atomic force, scanning probe, or friction force microscopy can be used for characterizing the frictional behaviour of single hair fibres [3, 4].

Nevertheless, owing to the curved and irregular surface of human hair, measuring the frictional behaviour, in particular between two single hair fibres, can be very difficult. Additionally, the problem of positioning and aligning the single hair fibres with respect to each other or the counterpart is not an easy task.

In order to overcome the challenge of positioning and moving a pointed tip along the longitudinal axis of the single hair fibre, a crossed fibres contact configuration was applied. Using the proposed setup, the influence of the sliding direction, the normal load, and the crossing angle on the kinetic coefficient of friction have been studied.

2. METHODOLOGY

2.1 Experimental setup and procedure

As a test setup, a crossed fibres contact configuration was used. A schematic representation of the setup is shown in Figure 1.

The tests were carried out on a linear reciprocating nanotribometer. By measuring the deflection of a dual beam cantilever with high resolution capacitive sensors, the friction force (tangential force in y direction) was determined during the test. Due to the irregular sample surface geometry, force feedback control was enabled during all tests, so that a comparatively constant normal load could be achieved.

All tests consisted of 10 linear reciprocating cycles with an amplitude of 0.5 mm (in y direction) and a maximum linear velocity of 0.002 cm/s. The normal load ranged from 3 to 9 mN. The crossing angle, defining the orientation of the lower sample with respect to the upper one, was varied between 30 and 150°.

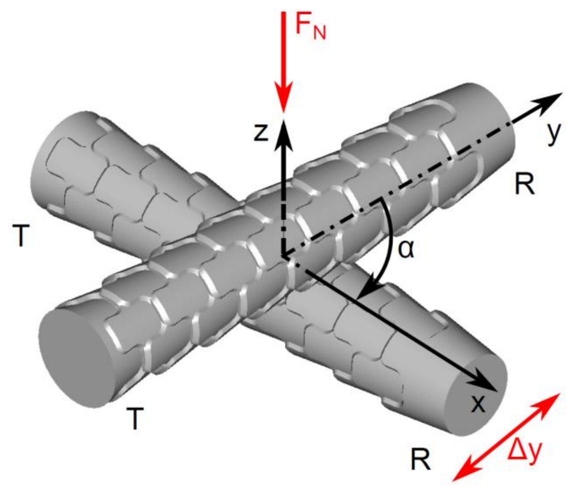

Figure 1 Crossed fibres test arrangement

During the 10 cycles, a stabilization of the friction force has been observed. Therefore, only the last 5 cycles were considered for the calculation of the coefficient of friction (ratio of the friction force to normal force). The average kinetic coefficient of friction was calculated using the absolute values of the coefficient of friction during the steady state period in the displacement range from −0.2 to 0.2 mm.

2.2 Test Samples and Preparation

For the experiments, untreated Asian black human scalp hairs from a male subject were used. Hair samples of 2 mm length were fixed on flat sample holders arranged in parallel with only a small section exposed for testing.

Two different contact pairings under dry conditions were investigated. The first one included the contact between two single hair fibres (approx. diameter 0.08 mm) and the second one between a single hair fibre and a polyamide fibre of 0.40 mm diameter. For the pairing with the polyamide fibre, the fibre was attached to the lower sample holder. The considered orientations of the single hair fibres are depicted in Figure 1 (T: hair tip, R: hair root). Additionally, the texture of the hair surface is indicated.

3. RESULTS AND DISCUSSION

3.1 Influence of the sliding direction

The time evolution of the kinetic coefficient of friction and the pairing of a single hair fibre and a polyamide fibre for one cycle is illustrated in Figure 2. The first half of the cycle corresponds to sliding in positive and the second half in negative y direction.

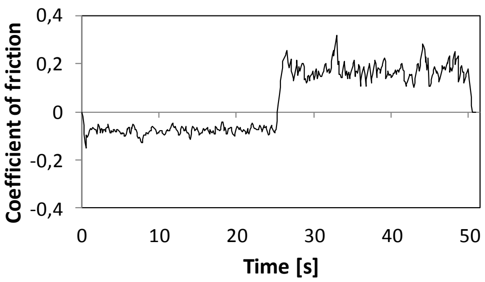

Figure 2 Coefficient of friction for one cycle at a normal load of 9 mN and a crossing angle of 90°

In positive y direction, the coefficient of friction shows a much more stable evolution, whereas in the opposite direction larger oscillations can be observed. Furthermore, the coefficient of friction in the direction of the scales is much smaller than in the opposite direction. This behaviour can be attributed to the texture of the hair surface and the orientation of the cuticle scale-like structure, as indicated in Figure 1.

3.2 Influence of the Normal Load

The dependence of the coefficient of friction on the normal load for both sliding directions and a constant crossing angle of 90° is illustrated in Figure 3.

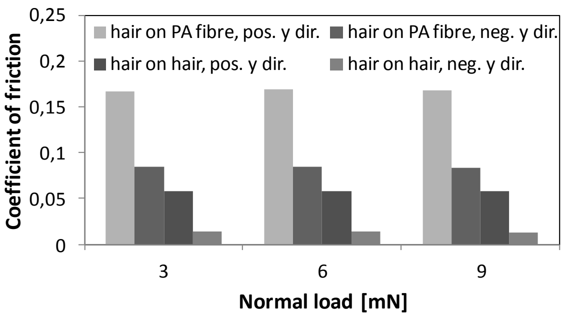

Figure 3 Coefficient of friction for different normal loads and a crossing angle of 90°

The results show, that the coefficient of friction is independent of the applied normal load in the considered range. Obviously, the investigated contact pairings follow Amonton-Coulomb's friction law.

For both contact combinations (hair on hair and hair on polyamide fibre), the directional behaviour due to the texture of the hair surface is evident. For hair on hair, the coefficient of friction in negative y direction is more than four times higher and for hair on polyamide fibre about two times higher. In addition, the friction between single hair fibres is much smaller than between a hair and a polyamide fibre.

3.3 Influence of the Crossing Angle

Figure 4 shows the coefficient of friction for different crossing angles and a constant normal load between two single hair fibres. Again, a sliding direction dependent frictional behaviour for all angles can be clearly seen.

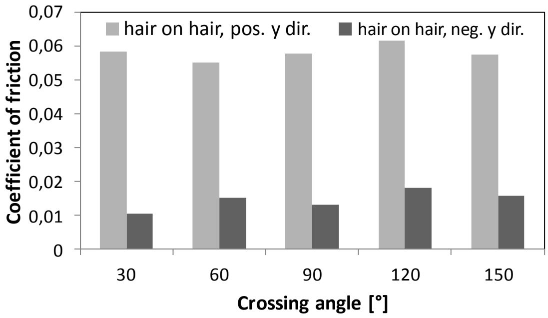

Figure 4 Coefficient of friction for different crossing angles and a constant normal load of 9 mN

Comparing the results for the different crossing angles indicates no distinct trend. The coefficients of friction for crossing angles greater than 90° are slightly higher compared to angles less than 90°. A possible explanation for that could be the orientation of the cuticle scale-like structure. For angles greater 90°, this scale-like structure has an opposite orientation, which could lead to a higher frictional resistance in positive y direction.

4. CONCLUSIONS

The introduced test setup allows a simple positioning and aligning of fibre-like test samples. It has been demonstrated that the frictional characterization of single hair fibres in contact and also of a single hair fibre in contact with a polymeric fibre is possible.

All tests confirmed the anisotropic and direction dependent frictional behaviour of hair. The coefficient of friction showed no dependence on the normal load in the considered range. A definite influence of the crossing angles on the frictional behaviour has not been observed and needs further investigation.

Moreover, other important factors (e. g., shampoo treatments), which can influence the frictional behaviour of hair, must be taken into account.

5. REFERENCES

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