BRUSH BRISTLE STIFFNESS PERFORMANCE USING TRIBOMETER

Prepared by

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INTRO

Brushes are among the most basic and widely used tools in the world. They can be used to remove material (toothbrush, archaeological brush, bench grinder brush), apply material (paintbrush, makeup brush, gilding brush), comb filaments, or add a pattern. As a result of the mechanical and abrasive forces on them, brushes constantly have to be replaced after moderate use. For example toothbrush heads should be replaced every three to four months because of fraying as a result of repeated usage. Making the toothbrush fiber filaments too stiff risks wearing away the actual tooth instead of soft plaque. Making the toothbrush fibers too soft makes the brush lose its form faster. Understanding the changing bend of the brush, as well as the wear and overall change in shape in the filaments under different loading conditions is necessary to design brushes that better fulfill their application.

IMPORTANCE OF TRIBOLOGY TESTING OF BRUSH STIFFNESS

A reliable measurement of the brush bend is needed in order to be able to quantify the amount of brush fraying. This provides a useful tool to directly compare brush heads with different types of filaments and geometries. Tribology can provide important insights both about individual filaments and the brush system as a whole. Furthermore the effect of diverse lubricants, different loading conditions, and various brushed materials can be determined. The depth sensor can provide valuable information about the evolution of the filament-surface interface over time. These results can be applied to any solid-to-solid interface that loses its shape over time from abrasive or mechanical forces using a custom pin fixture.

MEASUREMENT OBJECTIVE

In this study, we showcase the capacity of Nanovea Tribometer for measuring the depth change of custom toothbrush fixtures with different stiffnesses against a smooth aluminum surface in the presence of a toothpaste slurry lubricant, which makes it an ideal tool for evaluating brush bending and wear under different loading conditions. The Nanovea Tribometer can be customized to simulate a wide variety of different wear and friction conditions with various types of motion.

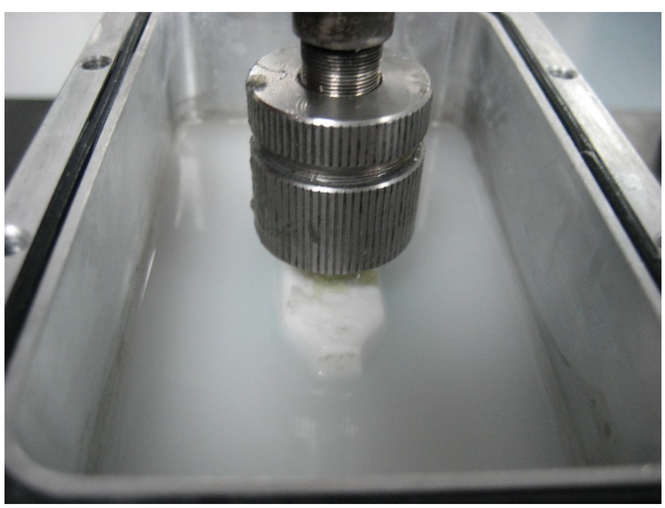

Fig. 1: Tribology measurement of a toothbrush head inside toothpaste slurry lubricant

TEST PROCEDURE

A customized toothbrush head pin was created by attaching a standard toothbrush to a 10 mm steel ball that had been flattened on one side. This procedure could be used for any similarly sized object, in order to create a customized pin fixture. The brush was put in a lubrication cup that was filled with toothpaste slurry (as shown in Fig. 1). In this case, the brush was in contact with the bottom of the flat aluminum cup. The brush-ball system was tested using a linear reciprocating setup. The depth sensor was used to determine the vertical deflection of the toothbrush filaments at each point in the cycle. Two different brushes, with 'soft' and 'firm' stiffness were compared. The test parameters are summarized in Table 1.

Parameter	Value
Load	8 N
Test Duration	120 min
Speed	100 rpm
Amplitude	2 mm
Total Distance	48 m
Pin	Toothbrush (soft, firm)
Lubricant	Toothpaste Slurry
Temperature	24°C

Table 1: Test parameters of the depth measurement.

RESULTS AND DISCUSSION

The summary of the results of the two tests can been seen in Table 2. The test was conducted for two hours, which was the same as 48 meters of reciprocating linear wear. As expected, a much higher depth change was seen in the soft brush than the firm brush over the two hour interval. (The bend rate calculated here is an average over the entire test, whereas in reality, as will be seen from Fig. 5, the rate was much higher in the beginning of the test and slowed down as it progressed).

Sample	Depth Change (mm)	Bend Rate x10^{-4} (mm/Nm)
Firm Brush	0.172	4.479
Soft Brush	0.282	7.344

Table 2: Results of toothbrush depth measurements

Fig. 2 and Fig. 3 show the evolution of brush depth over the course of the test for the firm and soft brush. There are two primary depth changes occurring here. Firstly, the brush filaments are being deflected from their normal positions over the course of each back and forth motion during each cycle. This is shown more clearly in Fig. 4.

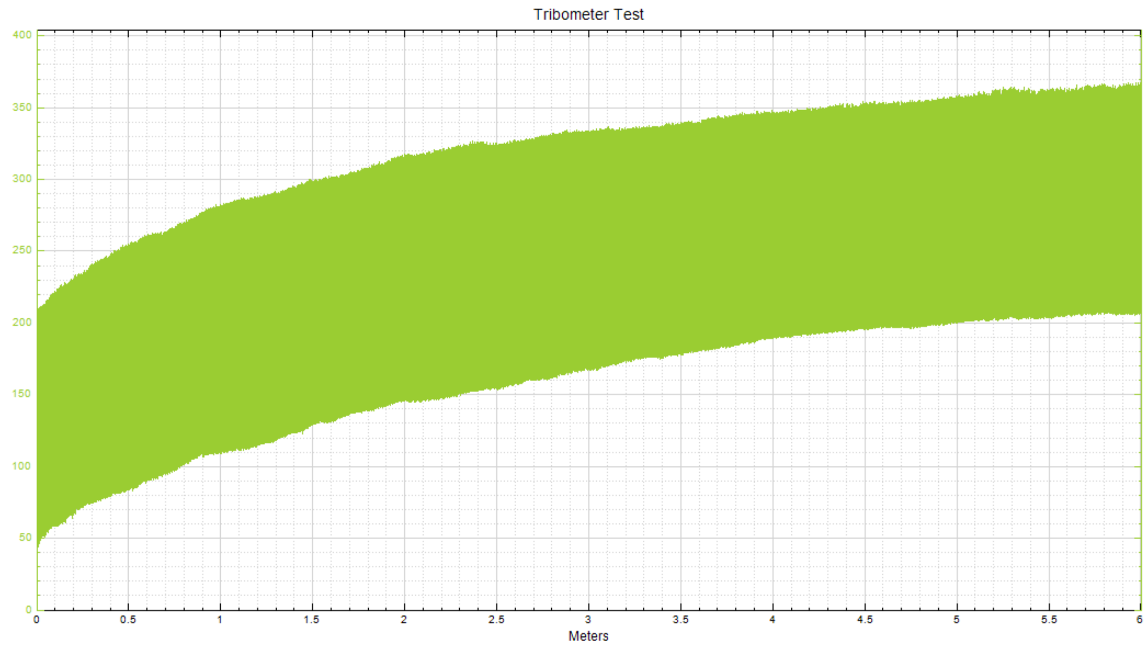

Fig. 2: Evolution of firm brush depth

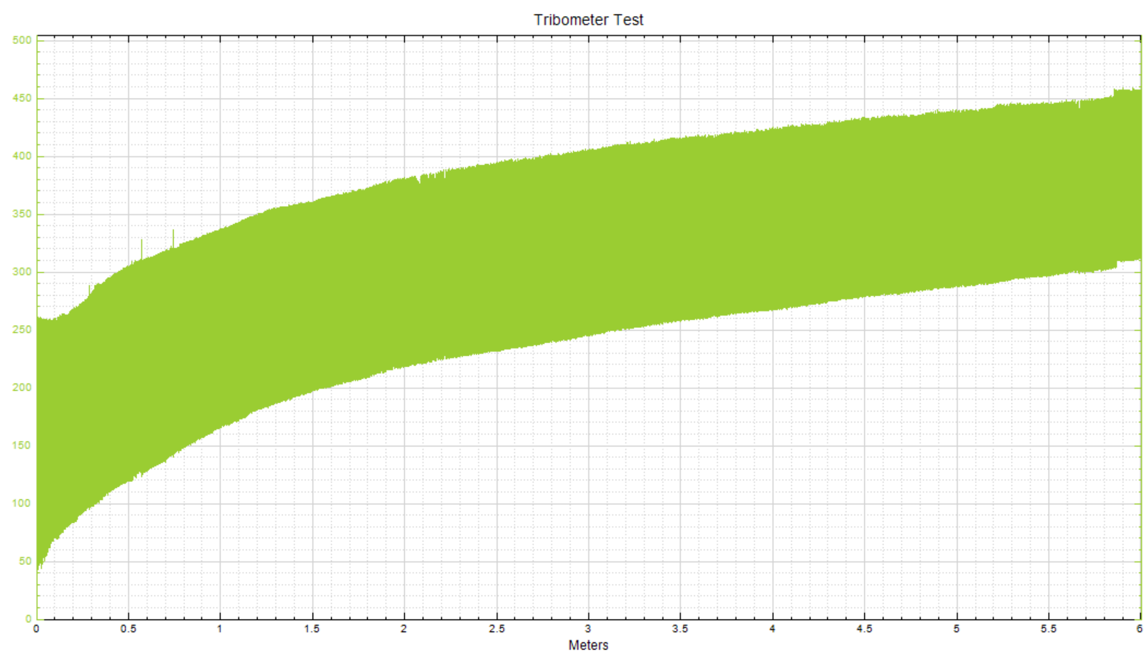

Fig. 3: Evolution of soft brush depth

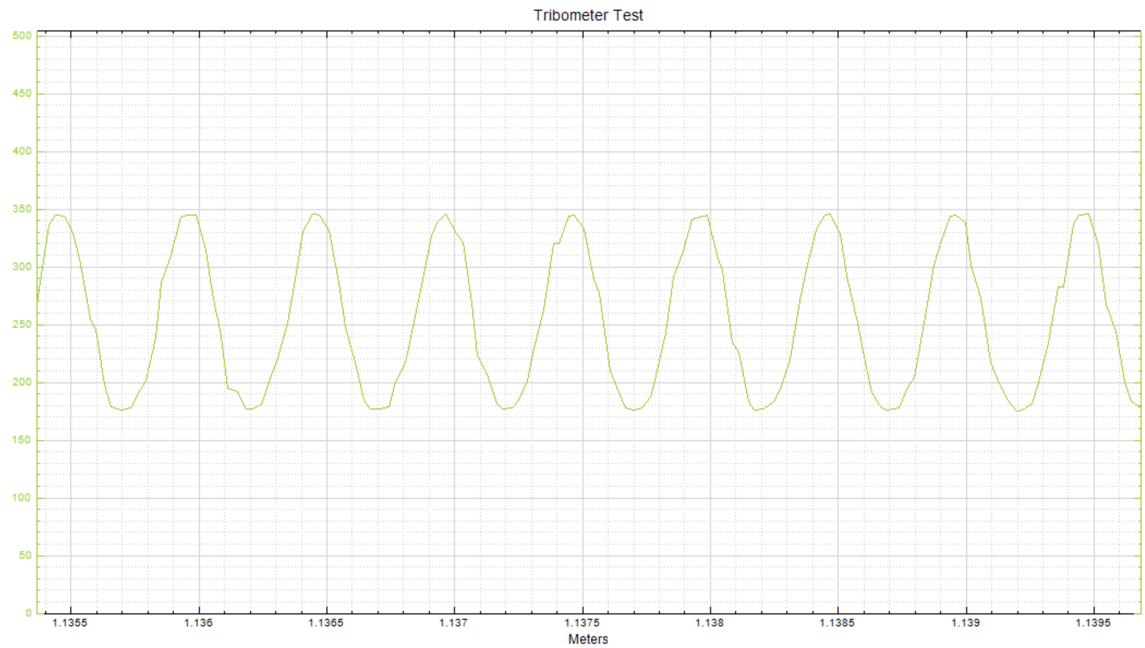

Fig. 4: Zoomed in portion of soft brush plot

At the same time, over the course of the test, the deflection of the brush filaments steadily increased. Comparing the same part of the back and forth reciprocating cycle over all 12,000 cycles shows that the overall brush bend continuously increases. This parameter was called 'bend rate' in Table 2. Fig. 5 shows a comparison of the brush deflection during the middle portion of each cycle. The trend is clear. Both brushes deflect more with more wear, but the soft brush deflects at a greater rate than the firm one. As the brush filaments bended more, the brush stiffness increased, decreasing the bend rate. This can be seen from the decreasing slope of each graph towards the end of the test.

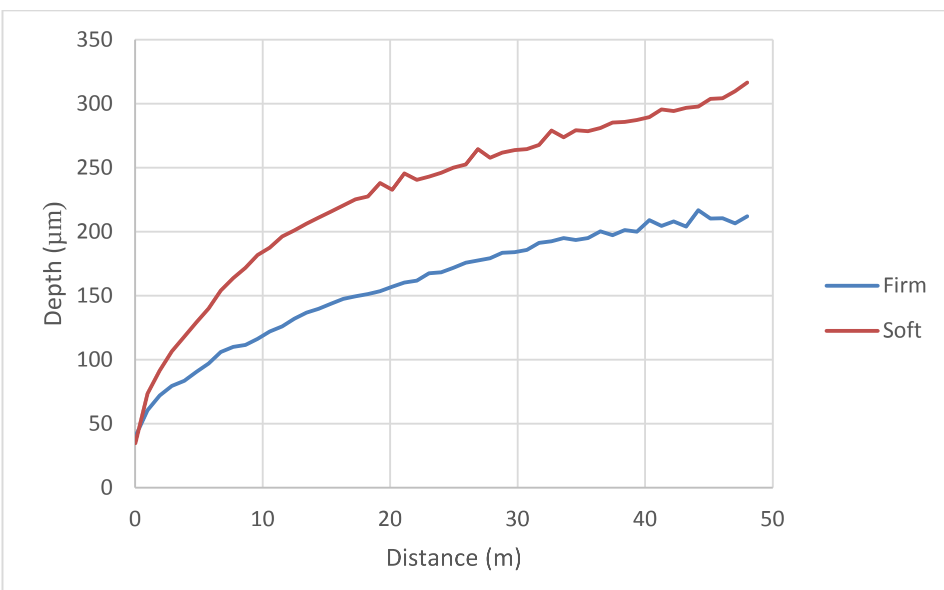

Fig. 5: Evolution of brush depth for firm and soft brushes at a single point in cycle

CONCLUSION

In this study, we show that Nanovea Tribometer can measure the depth, and thus vertical deflection, of a firm and soft toothbrush over the course of a 120 minute test. This measurement allowed for a better understanding of brush filament deflection for filaments of different stiffnesses.

The Nanovea Tribometer could similarly be used to design tests measuring the change in stiffness of brush filaments over different temperatures, humidities, loading conditions, movement directions, trim lengths, abrasive surfaces, and other conditions. Coupled with the Nanovea Profilometer and Nanovea Mechanical Testers, the bend recovery and fatigue resistance of both individual filaments and the brush system as a whole could be precisely measured. Nanovea systems can provide an invaluable source of information for all aspects of brush filament design.

The custom pin fixture allows for testing of all kinds of unique applications. Nanovea Tribometers can be highly customized for replicating precise operating conditions, offering precise and repeatable wear and friction testing using ISO and ASTM compliant rotative and linear modes, with optional high/low temperature wear, lubrication and tribo-corrosion modules available in one pre-integrated system. Nanovea's unmatched range is an ideal solution for determining the full range of tribological properties of thin or thick, soft or hard coatings, films and substrates.

Learn More about the Nanovea Tribometer and Lab Service

MEASUREMENT PRINCIPLE

TRIBOMETER PRINCIPLE

A flat or a sphere shaped indenter is loaded on the test sample with a precisely known force. The indenter (a pin or a ball) is mounted on a stiff lever, designed as a frictionless force transducer. As the plate slides in a linear reciprocating motion, the resulting frictional forces between the pin and the plate are measured using a strain gage sensor on the arm. Wear rate values for both the pin and sample may also be calculated from the volume of material lost during a specific friction run. This simple method facilitates the determination and study of friction and wear behavior of almost every solid state material combination, with varying time, contact pressure, velocity, temperature, humidity, lubrication, etc.

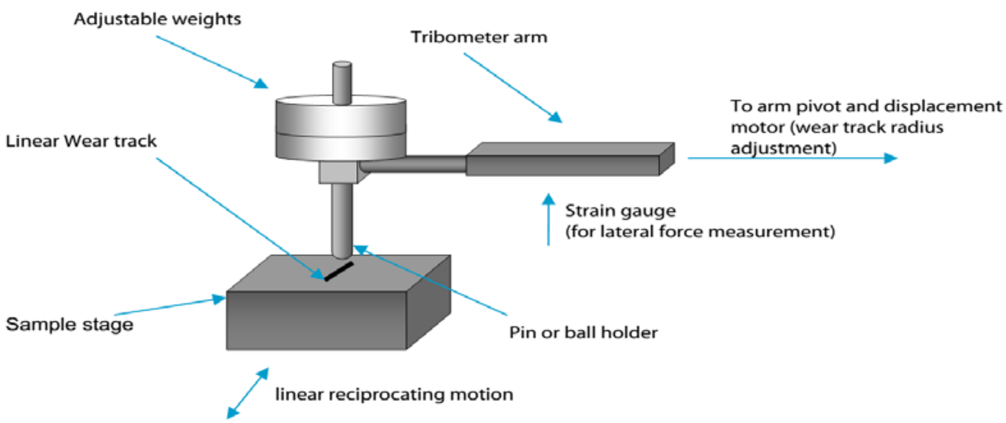

Fig. 2: Schematic of the reciprocating wear test.