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ASSESSMENT OF THE SMOOTHNESS OF SURFACES WITH AN ACOUSTICAL PROBE.

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Abstract

The feeling of smoothness during the touching is delivered when the finger is rubbed on the surface. A static contact cannot provide such an information. The roughness noise, that is the friction noise generated during the sliding of two rough surfaces, is therefore the key phenomenon for the feeling of smoothness. To this end, a tribo- acoustical probe has been designed. This is a sort of artificial finger whose load is controlled and equipped with a microphone to measure the Sound Pressure Level. When rubbing the probe on various surfaces, it is possible to compare the acoustical level and therefore to assess the relative smoothness of the surfaces. Among them, some results are presented on skins with different ages, on different parts of the body, on skins before and after cleaning by acetone. Finally, this method is applied to assess the efficiency of cosmetics.

1. INTRODUCTION

The assessment of the smoothness of a surface is an important task for several manufacturing processes. The quality of clothes, leathers, the fineness of polishing of hard surfaces such as wood, plastic and more generally all objects intended to be in contact with humans, the efficiency of cosmetics [1] are some examples of industrial applications which require an objective measurement of smoothness.

The goal of this study is to design a physical probe intended for the measurement of the smoothness of surfaces. It is based on the acoustics. The friction noise generated when rubbing a thin membrane on the surface to be tested, is recorded. This technique is applied to various surfaces and objects and provide an efficient tool to compare surfaces of the same material.

2. ASSESSEMENT OF SMOOTHNESS BY FINGERS

The assessement of smoothness of a surface is a complex process. It involves a particular gesture of hand for the acquisition of physical data, but in the mean time, the ambience around the person, his psychological state as well as his own taste can modify the perception. Fot instance, it is well-known that some textures like peach skin can be very unpleasant for somebody and pleasant for others. Indeed, a physical probe can only assess the raw information without taking into account the psychological aspects of the perception.

The finger is able to assess several physical parameters such as the temperature and the hardness of the surface [2]. But the finger also contains some dynamical receptors. In Table 1 is summarized the mechanical skin receptors contained in fingers. It is clear these receptors can measure a wide frequency band from very low frequencies up to 1.2 kHz. We can easily imagine that the sensation of smoothness results from a complex combination of these four receptors.

Table 1. Skin receptors.

Receptor	Frequency band	perception type
Merkel	0.3 - 3 Hz	pressure
Messner	3 - 50 Hz	shaking
Ruffini	15 - 400 Hz	stretching
Pacini	10- 1200 Hz	vibration

3. ROUGHNESS NOISE

Friction noises are generally classified in two categories [3]. The mechanical instabilities such as squeak of doors, break squeal, the ringing of wine glass and so on. These stick-slip instabilities are generated under strong contact pressure. The second type of friction noise is called roughness noise and provided by the dynamical contact of two rough surfaces. The small shocks between antagonist asperities generate vibration into the solid which, in turn, are responsible of the radiated sound. This phenomenon occurs under light contact pressure and is characterized by a wideband noise (almost a white noise). This is this second type of friction noise which is involved when rubbing the fingers on an object.

The physics of roughness noise is related to the dynamics of the so-called multi-contact interfaces. The physical processes involved in this phenomenon are not yet fully understood. Several experimental studies are available in the literature. They generally aim to measure the physical laws such as the dependence of roughness noise with the sliding speed, the roughness and the normal load. A law widely encoutered is [4, 5],

$$L_p = 20 \log_{10} R_a^{\alpha} V^{\beta}, \tag{1}$$

with both α and β near unity. This relationship highlights the fact that the dependence of the Sound Pressure Level with the sliding velocity is as much important as the roughness.

4. DESCRIPTION OF THE APPARATUS

The apparatus for the measurement of smoothness is described in this section. Figure 1 shows the principle of the apparatus and its main components which are the surface roughness, the resonator and the sensor. Another example a similar apparatus intended for the measurement of roughness of surfaces is presented in Reference [6].

The surface roughness is imposed by the surface to be tested.

A thin spherical membrane plays the role of the resonator. When rubbing the sphere on the tested surface, the vibration is generated in the resonator. Its role is to amplify the sound since the natural noise of soft surfaces is indeed very low. But in the mean time, the membrane also filters the noise. Roughness noise is a white noise and thus the power spectral density of the recorded noise is just the white noise filtered by the frequency response function of the resonator. The influence of the contact on eigenfrequencies has been studied in References [7, 8]. But for the purpose of the present study, there is no relevant information contained in the spectrum of the response.

The sensor is a 1/4" microphone. Since the spectral information is not sought, it is not necessary to record audiograms. The Sound Pressure Level is the only information necessary for the assessment of the smoothness.

This apparatus is patented [9].

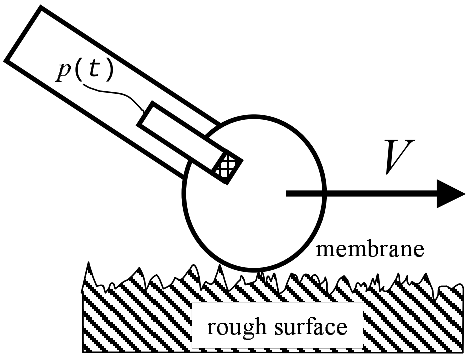

Figure 1. Sketch of the acoustical probe. The smoothness is assessed when rubbing the resonator (thin sherical membrane) with speed V on the rough surface to be tested. The acoustical pressure $p(t)$ of the resulting friction noise is measured with a microphone. The Sound Pressure Level is representative of the smoothness of the surface.

5. RESULTS ON SKIN

Various applications of this probe have been tested. However, in this Section, we describe some results on human skin for which smoothness is indeed an important stake for many people.

In Figure 2 is shown the influence of age on the frictional sound. Skin is more polished for young people, and also more smooth. During the aging, wrinkles become more deep and an anisotropy of lines begins to appear. Results of Figure 2 show that the difference of mean SPL is about 3 dB between the two populations of 15 persons.

In Figure 3 is shown the influence of the thickness of skin. The thickness of skin modifies the local hardness and therefore the sensation of smoothness. This can easily be checked by

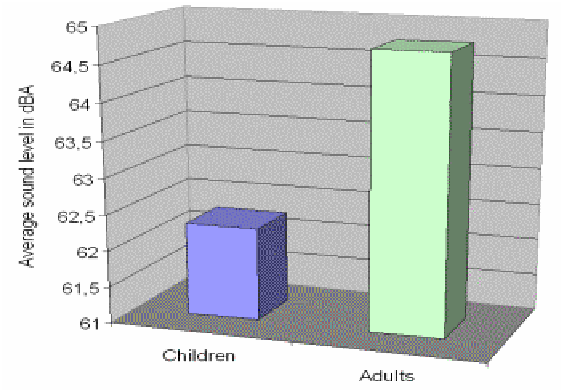

Figure 2. Influence of the age of skin. Averages of Sound Pressure Level of two populations of children and adults. Measurements on forearm.

pinching the skin of different parts of the body. Results of Figure 3 show a difference of mean Sound Pressure Level of 3.5 dB between calf (thick skin) and forearm (thin skin). These results are obtained from a population of 30 persons.

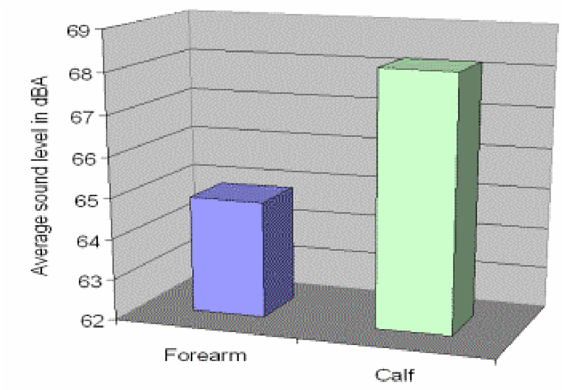

Figure 3. Influence of the thickness of skin. Sound Pressure Level of two parts of the body, forearm (thin skin) and calf (thick skin).

In Figure 4 is shown the influence of the lipid film on the surface of skin. This film can be temporalily removed by drying the skin with acetone. Results of Figure 3 show that the influence this film on forehead is about 4 dB.

In Figure 4 is shown some results of measurement intended to assess the efficiency of a cosmetic cream. The application of a cosmetic film first leads to a decrease of 10 dB of the Sound Pressure Level. This decrease remains stable up to 2 hours and then the level begins to slowly increase. After 4 hours, the Sound Pressure Level is only 4 dB lower than the initial state.

6. CONCLUSION

In this paper, we have presented an acoustical probe for the measurement of the smoothness of surfaces. This probe is based on an acoustical measurement of the friction noise created when rubbing the probe on the surface to be tested. The sound pressure level is the criteria proposed for the smoothness. However, due the physical dependence of the friction noise with

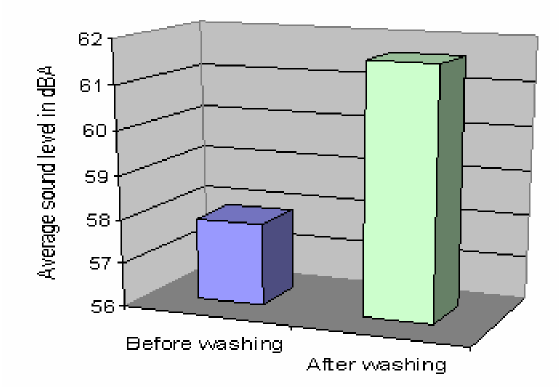

Figure 4. Influence of the lipid film. Sound Pressure Level before and after whashing the skin with acetone.

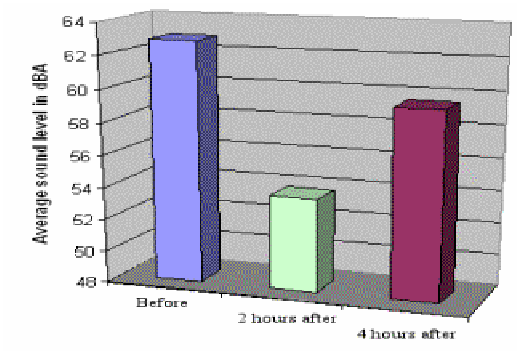

Figure 5. Example of measurement of the efficiency of cosmetic. Sound Pressure Level before application, after 2 hours and after 4 hours.

sliding speed, normal force and other physical conditions which can depend on the material to be tested, to respect a strict protocol is an imperative necessity. Under these conditions, the smoothness probe is able to compare and classify different surfaces made of the same material. This is a relative measurement of smoothness rather than an absolute measurement.

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