ASSESSMENT OF THE FABRIC'S WEAR BY SOUND MEASUREMENTS ON SOLDIERS UNIFORMS

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ABSTRACT

This study focuses on the evaluation of fabrics friction sound using two different approaches (instrumental and sensory) to analyze the influence of fabric wear on friction sounds. For this purpose, four fabrics were selected and have undergone multiple washes (up to 50). A specific device reproducing the human arm motion is used to produce and record the fabric friction sounds. From these recordings, some acoustic parameters like the total noise level can be determined. Meanwhile, a sensory panel dedicated to hearing assessed the friction sounds by several attributes. This paper identifies the significant correlations between acoustic, mechanical and sensory properties.

Key Words: Friction sound, fabric wear, sensory analysis

1. INTRODUCTION

Wear of fabrics has a strong impact on their properties; a garment is usually worn out by abrasion or by repeated washes. Usually a decrease of mechanical properties and visual damages can be observed. In addition, when a person is moving or walking, the friction under arms or between legs will generate some fabric friction sounds and an additional wear. These sounds can be evaluated and described and it is important to analyze physical parameters of characterization as well as the human sensations and perceptions of the sounds.

Several experimental devices have been developed to generate and record the friction sound. Eunjou and Gilsoo [1] analyzed the relationship between mechanical properties of fabrics and their sound spectra. They showed that fabrics sound spectrum varies according to fabric material and properties. Others studies showed that the sound properties of fabrics depends on many parameters like the weave pattern or the surface roughness [2].
Existing devices can generate friction sounds only in one direction which does not match the real conditions. Thus, Latroch and Yosouf [3] developed a system which reproduces the human arm movement to simulate the friction between arms and torso. In our study, we used this device to record the friction sounds and characterize them [4].

Friction sounds can be seen as noise disturbances that will necessarily generate some reactions when they are perceived. In their study, Cho and al [5] measured the human sensations thanks to the Zwicker's psychoacoustic parameters (loudness, sharpness, roughness and fluctuation strength). These parameters allow to subjectively describe the fabric friction sounds. In this paper, we chose to conduct a sensory analysis through the descriptive analysis method [6].

Given this background, the aim of this study are to objectively describe the fabric friction sound using some physical parameters (as the level of the total sound) and some specific attributes in order to convey the human perception of the sounds.

2. MATERIALS AND METHODS

2.1 Characteristics of the evaluated fabrics

In this study, four different fabrics have been studied. Their characteristics are presented in Table 1. In order to study the influence of the fabric wear, seven samples were obtained from each material; the samples are worn out by multiple washes (from 0 to 50 washes) according to the European standard (EN ISO 6330) [7]. All the washes were performed in the same conditions in terms of washing product, loading weight and cycle temperature.

Table 1. Characteristics of fabrics

Fabric N°	Material	Weave pattern	Number of yarn/cm, Warp	Number of yarn/cm, Weft	Yarn count, Warp (Tex)	Yarn count, Weft (Tex)	Fabric weigh (g/m²)
1	Polyester/cotton	Satin 5	24	20	63	60	258
2	Kermel	Plain	27	23	34	25	202
3	Kermel	Plain	28	27	22	19	180
4	Kermel	Twill 3	26	21	36	34	213

2.2 Friction sounds recording

Acoustic measurements are achieved using an experimental device developed by Yosouf and Latroch [8]. This device placed in an anechoic booth and presented in Figure 1, is equipped with a system reproducing the human arm motion thanks to two samples rubbing together; one sample is fixed and the other one is mobile. Both samples are placed above a silicone surface which reproduces the human skin. In adddition, an acoustic isolation made of polyurethane foam is placed around the recording system to avoid any external perturbation. Regarding the acquisition chain, a 1 inch microphone Brüel & Kjaer (type 4190) is used to detect the friction noise of the fabric specimen; the sound recording is performed thanks to a Brüel & Kjaer amplifier (type 2606) and a DAT recorder (Teac LX-10).

The acoustic evaluation conditions are the same for the whole study. Duration of tests is around twenty seconds.Some parameters were experimentally defined according to human arm movement measured on volunteers. These parameters, i.e. , the speed (0.56 m/s), the motion arm movement scanning angle and the friction surface (90 cm²) are constant. The pressure between the two samples is also fixed (1.67kPa) and controlled by a FlexiForce sensor type A401 with a circular sensing area of 25.4 mm diameter).

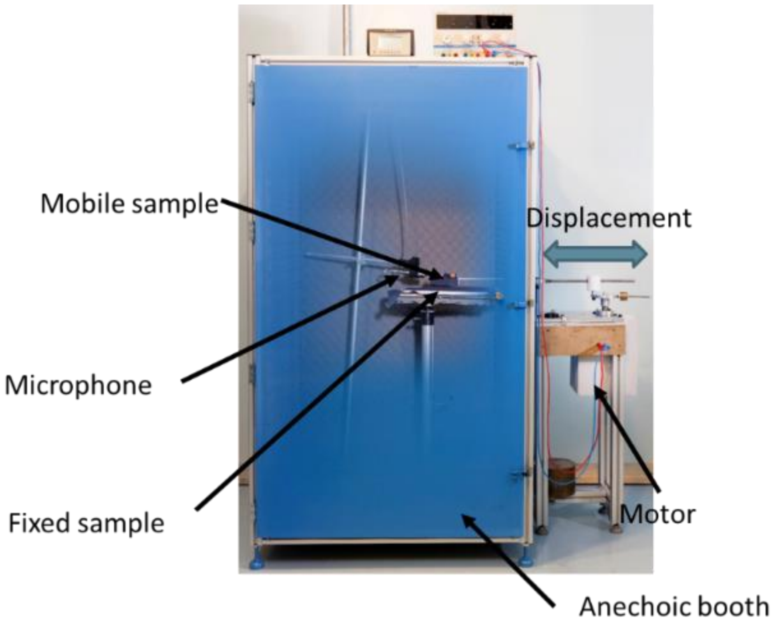

Figure 1. Experimental device

The processing of the sound is performed in three steps. Firstly, three seconds of the recording are selected using the Audacity® software. Secondly, the signal is processed by a high-pass filter. This filter will allow to delete the interference noises essentially in the low frequencies. Finally, the filtered sound signals are processed through FFT which allows to estimate the third octave band from 20 Hz to 20 kHz and to obtain noise level in dB.

2.3 Measurements of mechanical properties

The mechanical properties of the fabrics are measured thanks to the Kawabata Evaluation System (KES-FB) [9]. The fabrics were all conditioned during 24 hours in standard conditions (relative humidity HR%=65±5%, temperature T=20±2°C). According to Yosouf [10], only compression and surface properties have a significant influence on friction sound of fabrics. Therefore, compression and surface properties are measured thanks to KES-FB device. Compression properties are defined by five parameters; the compression linearity (LC), the compression energy (WC), the compression resilience (RC), the thickness at a pressure of 50 Pa (T_0) and the thickness at a 5 kPa pressure (T_M). The surface properties are described by three parameters, the friction coefficient (MIU), the mean deviation of friction coefficient (MMD) and the geometric roughness (SMD).

2.4 Sensory approach

Ten trained members of our laboratory performed the sensory characterization of fabric friction sounds. In order to assess the panel, the hearing acuity of each panelist was tested through an audiogram and their performances were checked according to three criteria. During the trainings sessions, the repeatability, the discriminatory potential and the homogeneity of panelists scores were analyzed.

Eleven fabric attributes (specific to friction sound evaluation) were selected after qualitative and quantitative reduction. To record the sensory attributes scores, a non-structured line scale was used, from 0 to 10. The list of selected attributes is presented in Table 2. From this list of attributes, a conventional sensory profile can be obtained for each sample.

Table 2. List of attributes

low-high	uniform-disharmonic	paced	abrasive
slow-fast	toiling-energetic	scraping	resonant
monotone-polyphonic	muffled-intensive	sawing	

3. RESULTS AND DISCUSSION

3.1 Level of total sound

The main parameter obtained thanks to the acoustic analysis is the level of total sound (LPT). this parameter is important in the objective description of friction sound. The evolution of LPT according to the number of washes undergone by each evaluated fabrics is presented in Figure 3.

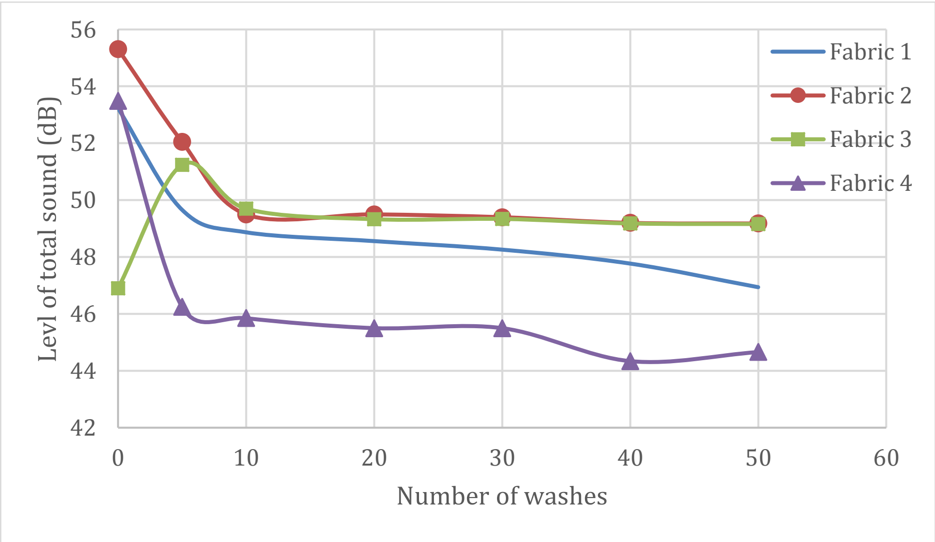

Figure 3. Evolution of the level of total sound according to the number of washes

This figure shows the strong influence of the first wash on the sound level. For three of the fabrics, the sound level quickly decreases while for the last one it increases during the first ten washes. For the fabric n°3, we can see a different trend; the sound level increases and then quickly becomes steady. An explanation of this phenomenon can be advanced by observing the surface hairiness of the fabrics. Indeed, this surface hairiness is not equal for all the evaluated fabrics; we can note that the fabrics with a high hairiness tend to have a lower noise level. The hypothesis is that the surface hairiness contributes to mute the friction sound of fabrics.

3.2 Correlation between mechanical and acoustic properties

A Principal Component Analysis (PCA) [11] has highlighted some correlations between the level of total sound and the mechanical properties measured by the KES system. For each fabric, the correlation coefficients have been calculated; the Table 3 presents the results of the PCA.

Table 3. Coefficient correlation between the level of total sound (LPT) and others measured parameters

Fabric N°	Nb of washes	LC	WC	RC	T_0	T_M	EMC	MIU	MMD	SMD
1	-0.82	-0.84	-0.62	0.81	-0.61	-0.90	-0.53	0.91	-0.57	0.44
2	-0.72	-0.20	-0.48	0.94	-0.63	-0.88	-0.44	-0.21	0.62	0.41
3	0.488	0.51	0.80	-0.96	0.97	0.95	0.92	0.77	0.26	0.60
4	-0.694	-0.75	-0.84	0.98	-0.93	-0.89	-0.86	-0.85	0.59	0.66

The analysis of this table shows that the parameters RC (compression resilience) and T_M (thickness of fabric) have a strong relationship with the level of total sound whatever the fabric is. For these two parameters related to the surface hairiness of the fabric, the correlation coefficient exceeds 80%.

3.3 Sensory profiles

The panelists listened to each fabric friction sound of and assigned a score for each descriptor listed above. This highlighted the difference between the generated friction sound; each fabric presents a specific friction sound and thus a unique snake profile.
Figure 4 presents all the sensory profiles of the fabric n°1 for different numbers of washes. We can see that the profile of the raw fabric stands out from the others, which is consistent because the sound level is higher for this sample. For the other samples, the profiles show great similarities, which reflects the inability of the panelists to differentiate them.

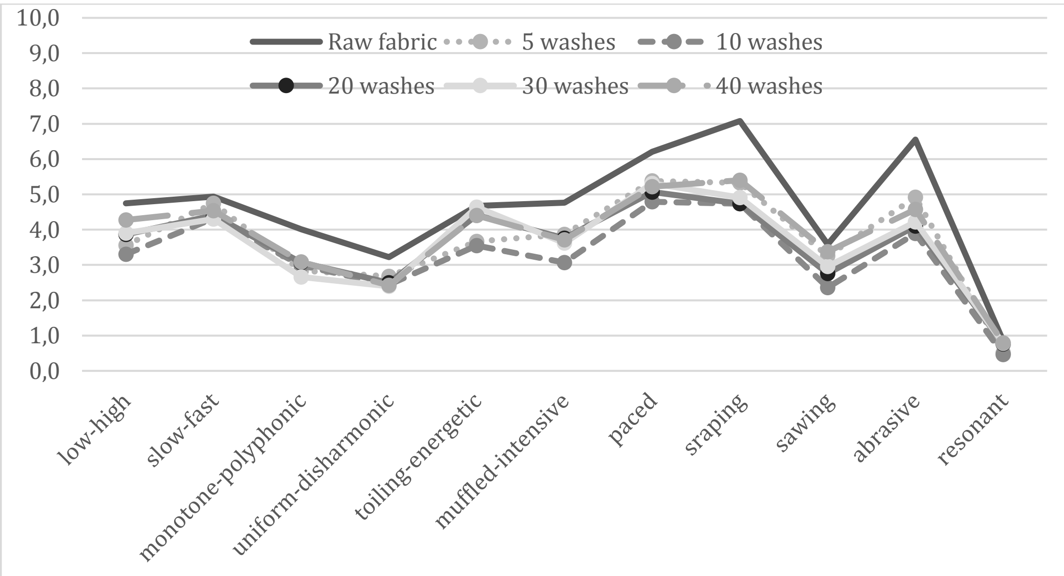

Figure 5. Sensory profiles of fabric No.1

4. CONCLUSION

This study led us to observe the strong influence of the fabricwear on friction sounds. The major influence is on the evolution of the total sound level, which tends to decrease with the number of washes. As a result, some strong correlations with mechanical properties can be noticed such as the correlation between LPT and RC.
In addition, the sensory approach carried out on friction sounds confirms that panelists were able to discriminate and evaluate them objectively. It has also showed that beyond five or ten washes, the human ear can no longer perceived differences between the friction sounds.
Correlations between instrumental and sensory approaches will be done as further work. In addition, some surface treatments such as silicone could influence the fabric's surface and thus the friction sounds generated**.**

5. REFERENCES

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6. ACKOWLEDGEMENT

This work was partly financed by a grant allocated by the region Grand Est. We gratefully acknowledge this support.