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Determination of Frictional Speeds by Arm Movement and Simulation of Frictional Sounds of Fabrics

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Abstract: This study identified the frictional speeds between the arm and trunk of a wearer in three different conditions: walking, jogging, and running. To analyze its acoustic properties, we simulated the frictional sounds of fabrics in conditions similar to real life. By analyzing shoulder angles in captured motion pictures, it was identified that the friction between the arm and trunk occurs within 10° of the shoulder angle along the center line of the trunk and the speed of the elbow reached the maximum within the friction range of shoulder angle. The average frictional speeds within 10° were found to be 0.62 m/s at walking, 0.95 m/s at jogging, and 1.78 m/s at running. The frictional sounds of two nylon coated fabrics were generated by these speeds. The noises were simulated based on the frictional speeds and times under three conditions. We calculated sound characteristics such as the sound pressure levels (SPL) and Zwicker's psychoacoustic parameter. The SPL values ranged from 85 dB at running to 88 dB at jogging. The values of loudness(Z) at walking and jogging were higher than that at running, but the fluctuation strength(Z) was increased by walking, jogging, and running, in that order. These results mean that the frictional sounds of fabrics at walking and jogging are noisier and less fluctuating than those at running.

INTRODUCTION

The frictional sound of fabric is generated when a fabric is rubbed against another. The coated fabrics used for a waterproof jacket tend to make much noise, which in some cases bothers not only the wearers but also others. In the previous studies of fabric sound, they did not consider the fact that a practical frictional speed and its fabric sounds are different from a real fabric sound generated by the rubbing between the arm and trunk of a wearer. The motion analysis system can measure and analyze the changes taking place in a human body's motion during walking, jogging, and running. The motion factor can be investigated according to speeds related to clothing friction, and we expect to find out the more accuracy frictional speed of clothing for measuring fabric sound.

The purpose of this study is to conduct a motion analysis to identify the speeds between the arm and the trunk while walking, jogging, and running, to simulate the frictional sound of fabric under conditions similar to real life, and to analyze the acoustic properties of frictional sound of fabric.

EXPERIMENTAL

Motion Analysis for Frictional Speeds of fabrics

• Upper-limb motions in walking(1.3m/s), jogging(2.5m/s), and running(4.5m/s) on a treadmill were captured by a motion analysis system (Falcon240, Santa Rosa).

• To analyze the angle of the shoulder and the speed of the elbow, four markers were attached to the shoulder, elbow, wrist, and pelvis.

• Participants were two males and two females (25 ~ 28 years)

Specimens

• Two nylon coated fabrics available for a sportswear were selected for specimens as shown in table 1.

Table 1. Characteristics of specimens

Speci-men	Fiber content	Finishing	Yarn Type (warp/weft)	Density (warp x weft)	Weave	Thickness (mm)	Weight (g/m²)
N1	Nylon 100%	PU Microporous Direct Dry Coating, Milky Coating	Filament/ATY⁺	168 x 53	Plain	1.23	16.73
N2	Nylon 100%	PU Microporous Direct Dry Coating	Filament/ATY	168 x 53	Plain	1.29	14.63

+ ATY: Air Textured Yarn

Recording and Analyzing Frictional Sounds of Fabrics

• Frictional sounds were generated by Measuring Apparatus for Fabric Noise (MAFN) and they were recorded by Pulse System (Type 7700, B&K)

• The sound spectra were analyzed by the fast Fourier transform (FFT) at frequencies ranging 0~17,350 Hz.

• Using the Sound Quality System (Type 7698, B&K), we calculated the Sound Pressure Level (SPL) and Zwicker's psychoacoustic parameters.

RESULTS AND DISCUSSION

Determination of Frictional Speed according to Various Movements

• The friction between the arm and trunk was identified to occur within 10° of the shoulder angle along the center line of the trunk, and the speed of elbow reached at maximum within the friction range of the shoulder angle (Fig. 1).

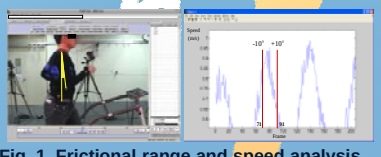


Fig. 1. Frictional range and speed analysis

•The average frictional speeds between the arm and trunk at the elbow were found to be 0.62 m/s at walking, 0.95 m/s at jogging, and 1.78 m/s at running.

Simulation of Fabric Sound by Frictional Speed

• Frictional sounds were simulated according to the frictional times by measuring the real wearer's movement (Table 2)

Table 2. Frictional times by motion analysis

Ranges of arm movement		-10° ~ +10°			All		
Wearer's activities		Walking	Jogging	Running	Walking	Jogging	Running
Time (second)	From front to back	0.09	0.06	0.02	0.36	0.21	0.19
	From Back to front	0.17	0.12	0.05	0.75	0.65	0.49

• Using the Cooledit (ver. 2.1), frictional sound was inserted during the frictional time within -10°~10° in the middle of all the arm swing times.

• One repeat (Fig. 2) of simulated sound was repeated for 5 seconds in walking, jogging, and running as presented in Fig. 3.

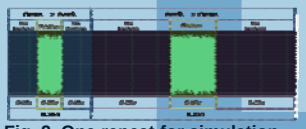


Fig. 2. One repeat for simulation of frictional sound according to arm's swing during walking

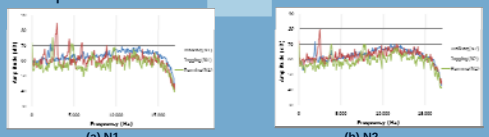
(a) Walking (b) Jogging (c) Running

Fig. 3. Simulation of fabric sound according to wearer's activities

Sound spectra of fabric according to arm movement

• The amplitude of sound spectra ranged between 40dB and 85 dB (Fig. 4)

• The peak of amplitudes of N1 and N2 showed from about 1 kHz to 6 kHz



(a) N1 (b) N2

Fig. 4. Spectra of frictional sounds according to movement types

Effects of Sound Characteristics at movement types

• The SPL value of the simulated fabric sounds at running weakened than those at walking and jogging (Fig. 5) because of fast frictional speed and short frictional time

• The values of loudness(Z) at walking and jogging were higher than that at running (Fig. 6(a)).

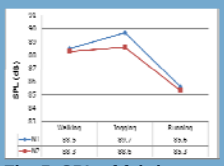
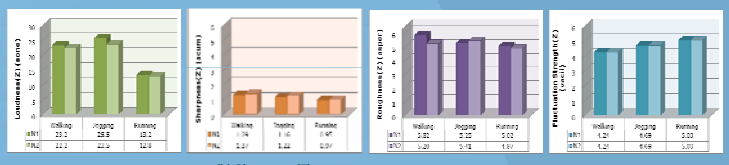


Fig. 5. SPL of fabric sound

•The values of sharpness(Z), roughness(Z), and fluctuation strength(Z) were about 1 acum, 5 asper, and 4 vacil, respectively (Fig. 6).



(a) Loudness(Z) (b) Sharpness(Z) (c) Roughness(Z) (d) Fluctuation Strength(Z)

Fig. 6. Zwicker's psychoacoustic parameters of fabric sound

CONCLUSIONS

In this study, we developed a method of determining the frictional speeds between the arm and the trunk according the wearer's activities in walking, jogging, and running through a motion analysis. We also analyzed the acoustic properties of frictional sounds by simulating the real frictional sound.

The exact frictional speeds identified according to the wearer's activity and the sounds of our clothing identified in this study may be very useful in investigating the subjective sensation or analyzing acoustic properties of clothing noise.

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