Spectrum Analysis of Charging of Human Body during Walking

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Abstract: Human body is charged during walking. Continuous monitoring of the body voltage has been made using an induction electrode set on ceiling of a room. The induced voltage is dependent on material of shoes, as expected, and in average, the value is a few hundred volt. The induced voltage of 500 V can cause lift off of particles deposit on surface when finger, or part of body is closed. Suspended particles could also be attracted electrostatically, causing higher chance of infection. The induced voltage waveform is different for person or manner of walking, even the same foot-wear is used. In this study, spectrum analysis was made on the acquired voltage, and frequency component was compared. The voltage spectrum of 4 different persons, and 3 different walking patterns of one person were obtained, and their correlation was compared. The results indicate that the spectrum is different with person. Among the tested 4 persons, identification can be made using the correlation of the induced voltage while walking. This monitoring method is simple, and can be used to monitor safety against electrostatic hazard.

1. Introduction

It is well known that human body is electrostatically charged during walking. There are several standard methods to measure the voltage of human body while walking.[1][2] In these methods, human body is connected by wire to a plate electrode, and a surface voltage meter measures the voltage of the plate electrode.

In this study, wireless method has been used to monitor the human voltage while walking. A metal electrode is used, being set on ceiling or wall. When charged body approaches to the electrode, induction charge appears. Using an electrometer having high input impedance, the voltage due to the induction can be measured.

The human voltage fluctuates according to the movement of walking. The body voltage is sensitive to the movement of feet, especially the spacing between a foot and ground, since the body voltage $V = Q / C$ (Q: charge of the body, C: capacitance between the body and the ground. Body voltages sometimes exceed 10 kV, and these high voltages should enhance suspended particles in air, including bacteria and viruses. To reduce the chance of infection, it may also be important to keep the human voltage below a certain level.

Practically, continuous monitoring of voltage of human body is necessary for various factories, and "wireless monitoring" of the voltage is preferable for workers. The monitoring system may also be used to detect invaders, and to insure security.

In this study, a simple continuous monitoring system was used, and characteristics of the human voltage have been studied.

2. Experimental apparatus[3]

A metal mesh of 90 cm x 120 cm was set on ceiling of a room. An electrometer (Keithley) was used in the voltage mode to measure the induced voltage of the metal mesh as shown in Fig.1. At the output of the electrometer, a low pass filter of 0.1 sec time-constant was inserted to cut electro-magnetic noise from commercial power line.

The floor of the room was covered by vinyl cloth for floor finishing. Surface resistivity was about 2.2 G-ohm. (Denoted as A)

For comparison, grounded aluminum foil was used to cover the floor. (Denoted as B)

8 different foot-wear was used including sneakers, sandals, slippers, and Japanese traditional footwear made of wood (Geta), and bare foot was also measured.

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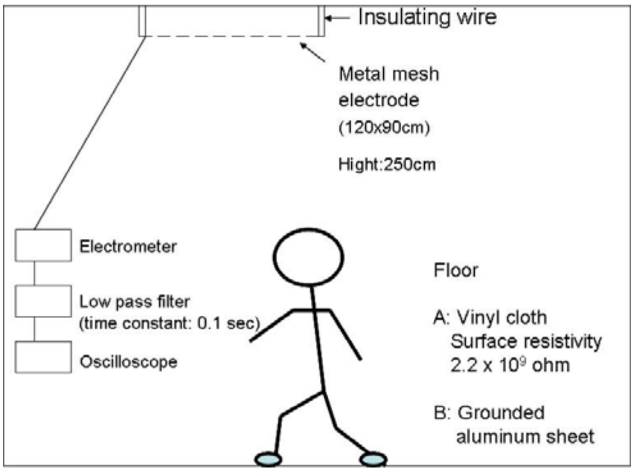


Fig.1 Measurement of induction voltage of human body during walking

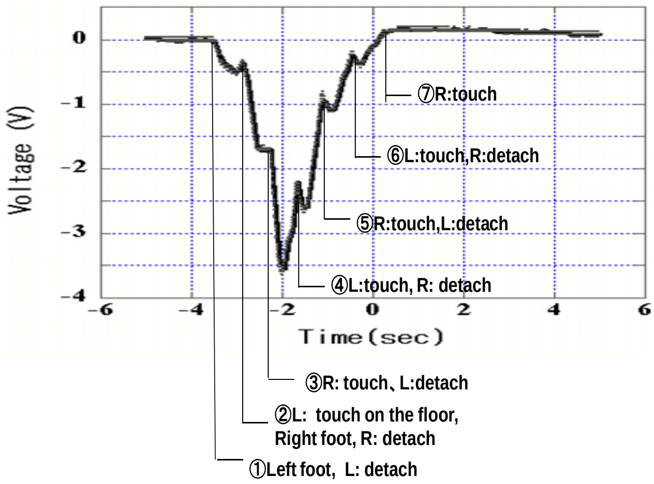
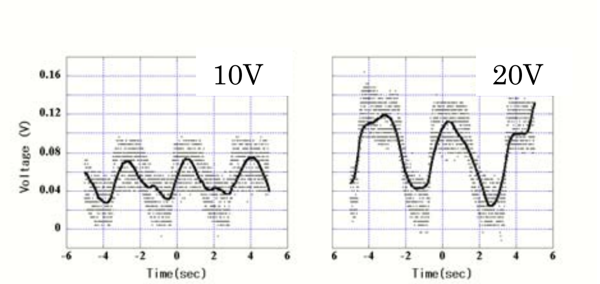


Fig.3 Induction voltage of human body walking under the metal mesh electrode
(A: vinyl cloth floor, slipper with rubber sole)

3. Experimental results

3.1 Calibration of the measured induced voltage

Under the mesh electrode, a human stood up and 10 or 20 V dc voltage was applied to the human body periodically. The induction voltage appeared due to this dc voltage application, as shown in Fig. 2. This ratio is determined by the capacitances between the electrode and ground, and the human body and the electrode. In this experimental condition, the human voltage was about 250 times of the measured induced voltage at the mesh electrode.



(0.02 V /div and 2 sec /div)

Fig.2 Calibration of the measuring system

3.2 The induction voltage

Figure 3 shows an example of the induction voltage due to charged human voltage during walking. The floor A, and the rubber slippers (sole is made of rubber) were used.

When the human approached to the metal mesh electrode, the induction voltage appeared. ① When Left foot (L) detached the floor, the induction voltage increased. ②L touched on the floor, the voltage decreased slightly, then Right foot detached the floor and the voltage increased (between ② and ③). The maximum voltage appeared when the human body was just under center of the electrode, and one foot (L) detached from the floor (between ③ and ④). Peak voltage was -3.6 V, which corresponded to -900 V of the human body voltage.

Figure 4 shows example of the induced voltage with different foot wears. Fig.4 (1) is the same as Fig.3 for comparison with other conditions. A is on the vinyl cloth floor, B is on grounded aluminum sheet.

In (1)-B, the maximum voltage observed is -3.0 V. The results indicate that, even floor is grounded and is conductive, human body can be charged well with the rubber slippers.

Figure 4 (2) shows the induction voltage with bare foot. Both A and B shows lower voltage of less than 0.1 V.

Figure 4 (3) shows the induction voltage when the sole made of wood (Geta) is used. Compare to that of rubber, the induction voltage in A (on vinyl cloth) is low, and in B (on grounded aluminum sheet) the voltage is about the same as that of bare foot.

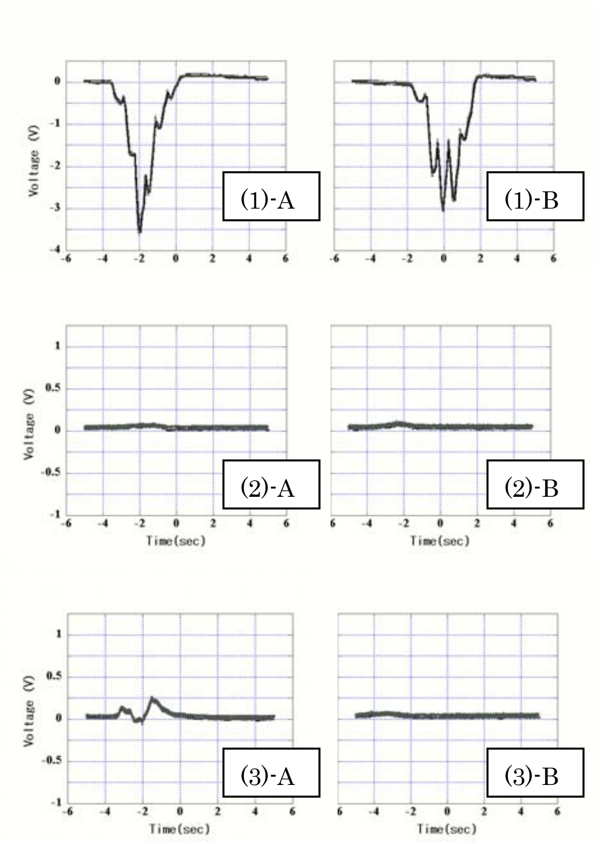
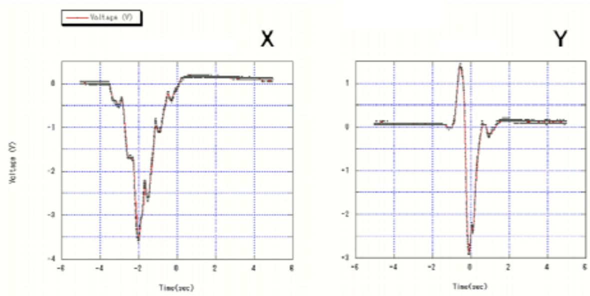


Fig.4 Example of induced voltage
(1) Rubber slippers (2) Bare foot (3) Japanese clogs A: Vinyl Floor B: Grounded Al-foil



(1) (2)

Fig.5 Difference of the pattern of the induction voltage while walking (comparison of two persons using the same slippers and the same floor condition)

Figure 5 shows difference of the pattern. In both cases, floor was A and the same slipper with rubber sole was used. (1) and (2) were different. This could be due to difference of manner of walking.

3.3 Spectrum analysis of the voltage

Fourier transform was made on the measured waveform of the induction voltages. A low-pass filter with its time constant of 0.025 sec was used at the output of the electrometer. Induction voltage of 4 person (A, B, C, D) was measured. Induction voltage of one person, D, with different walking manner was also measured.

Figure 6 shows the spectrum of the induced voltage of A - D. Each point is an average of 8 measurements. Vertical axis is the frequency component (Arbitrary Unit), and the horizontal axis is the frequency (Hz). The peak around 1.8 Hz corresponds to one step, and 0.9 Hz to two steps. Higher frequency components more than 2 Hz could add original characteristic pattern to the induction voltage.

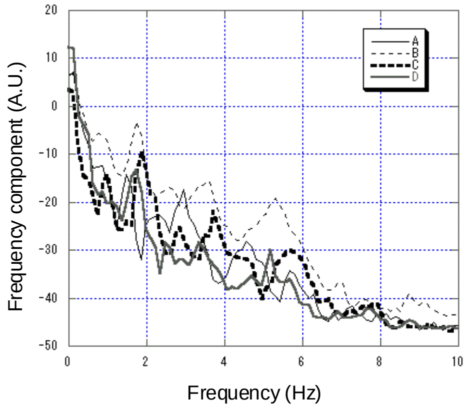


Fig. 6 Spectrum of the induction voltage for 4 different persons (Averaged value of 8 measurements)

The spectrum shown in Figure 6 is affected by the speed of walking. The spectrum can therefore be normalized using the frequency of one step. Figure 7 shows a normalized spectrum by the frequency corresponding to one step (around 2 Hz). The co-relation was calculated, and the same tendency was confirmed.

3.4 Co-relation of the spectrum

Co-relation of the obtained normalized spectrum has been calculated for different person. Table 1 shows the co-relation between the averaged value of A and the normalized spectrum of single measurement of A - D. The co-relation is high between the same person, A.

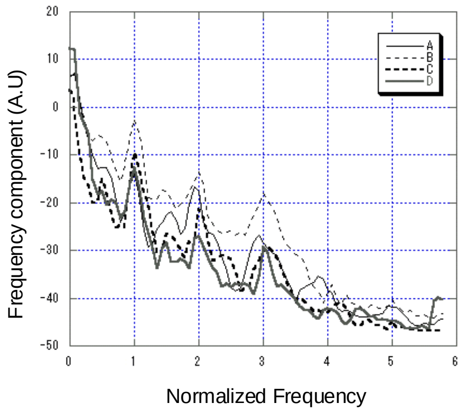


Figure 7 Normalized spectrum of the induction voltage

Table 2 shows the co-relation between the averaged value of D, and single measurement of different walking manner of D (D-1, D-2, D-3) and A, B, C. The co-relation was the highest with the same person, even the person intentionally changed the manner of walking.

3.5 Attachment of suspended particles

When human body is charged and voltage becomes high, suspended particles in air may more easily be attached on human body. Certain rate of suspended particles have charges, therefore, they should be driven by the electrostatic force due to the voltage of human body.

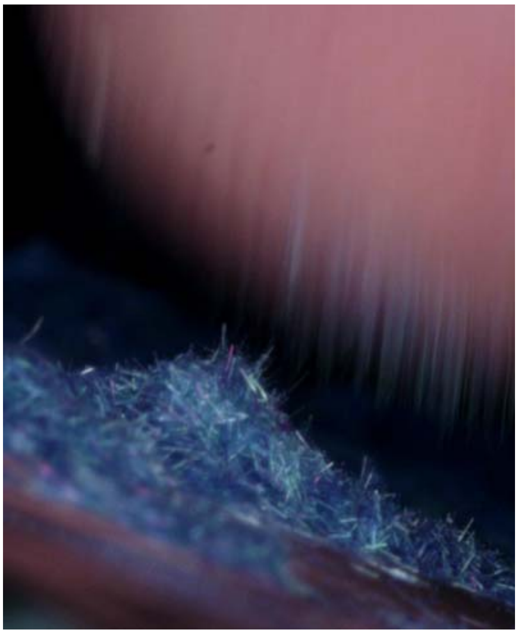
In order to demonstrate the enhancement of deposition of dust to charged human body, an experiment was carried out. The fibers of ca. 30 μm diameter and 200 μm length was put on a ground aluminum sheet, and a finger was approached to the fibers. The rubber slippers were put and walking motion was made. When the distance is about 2 to 1 mm, the fibers were lift and jumped to attach to the approaching finger, as shown in Fig.6 (a) and attached vertically to the finger along the electric field as shown in(b).

Table 1 Co-relation of the body voltage between A, and A-D while walking

	1st	2nd	3rd	4th	5th	6th	7th	8th
A	0.961	0.958	0.964	0.953	0.962	0.969	0.955	0.969
B	0.944	0.938	0.953	0.917	0.927	0.932	0.919	0.921
C	0.936	0.940	0.942	0.909	0.910	0.914	0.915	0.919
D	0.932	0.944	0.937	0.912	0.917	0.910	0.915	0.912

Table 2 Co-relation of the body voltage between D and different person A-C, different walking manner of the same person D-1, D-2, D-3

	1st	2nd	3rd	4th	5th	6th	7th	8th
A	0.931	0.895	0.937	0.948	0.916	0.916	0.973	0.918
B	0.922	0.889	0.929	0.913	0.895	0.899	0.946	0.877
C	0.942	0.917	0.950	0.928	0.922	0.914	0.960	0.902
D－1	0.964	0.956	0.983	0.982	0.972	0.980	0.975	0.970
D－2	0.951	0.941	0.962	0.953	0.941	0.943	0.969	0.925
D－3	0.941	0.947	0.960	0.961	0.954	0.950	0.952	0.940



(a) Attraction of the fibers by the finger

(b) Attachment of the fibers

Fig.6 Attachment of fibers to a finger of charged body (charged by walking)

4. Concluding remarks

Induction voltage was measured during walking. Continuous measurement of the induction voltage shows that the voltage changes with the movement of foot. When one foot is apart from the floor, the highest voltage appears. Pattern of the time change of the voltage, or frequency components of the voltage pattern could be different for each individual, and could be used to obtain more information from the voltage pattern.

Value of the induction voltage is affected by footwear. Sometimes, the voltage of human body exceeds 1000 V. This high voltage could enhance attachment of suspended particles, as well as particles attaching on wall or other objects due to induction charging. Those particles are pulled to hands and body. This point should be addressed, especially for hospitals and public spaces where chance of infection is high.

References:
[1] JIS L1021-16:2007
[2] ISO 6356:00
[3]T. Mizuno et al., Voltage measurement of human body while walking, Proc. Institute of Electrostatics, Annual Meeting,.171-172, 2008