The Influence of Vibrations Generated by Handheld Household Appliances on Temperature Changes of User Hands

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Abstract

The paper presents an analysis of influence of vibrations generated by small hand-held household appliances on temperature changes of hands. To visualize thermal changes of operators' hands a thermographic camera was used. During the tests values of acceleration of device handle vibrations at points of contact with operators' hands were recorded simultaneously. It has been observed that even during short periods of work the hand temperature changes significantly. The biggest recorded change was equal to 3°C. The tests have shown that the influence of vibrations is in this case sensed more strongly particularly by fingers and a wrist. The analysis of results has shown purposefulness of pointing out synergistic influence of vibrations and thermal changes caused by commonly available appliances on a human body.

Keywords: vibrations, thermography, household appliances

1. Introduction

Harmful influence of vibrations generated by tools and devices on a human body has already been known for a long time. Manufacturers of tools generating high level vibrations used, for example, in industry must follow standards defining permissible levels of vibrations. The employer allowing the employees to use such tools must also follow standards defining maximum allowable working time. The situation is different as regards household appliances of daily use. In manuals there is very little or no information about vibration levels or the harmful influence on a human body [1].

The paper presents an analysis of influence of vibrations on temperature changes of hands of operators of such equipment. During the tests two models of electrical blenders rated among small household appliances were tested. Determination of vibration levels and thermographic measurements were conducted simultaneously. Based on the obtained results an analysis of the influence of vibrations on temperature changes of hands was carried out. The devices under investigation are used to crumble and blend groceries. During work they are being held with one hand. Blender number 1 weighs 600g, and blender number 2 weighs 650g – Figures 1 and 2. The devices are designed to work under high and changing load depending on the crumbled groceries. Because of fast heating up of working elements inside the housing, blenders are designed only for short time work. Manufacturers recommend to use the device for no longer than 2 minutes at a time, and then to wait until the blender cools down.

There are no age limits for using blenders. The devices are readily available. The manufacturers, however, make reservations that the use of such equipment by children should take place only under strict supervision of adults [1].

Research has shown, that even a short-time use of blenders causes pain in the area of fingers and a wrist and changes in hand temperature. It has been found that vibrations generated during work with a blender may increase the risk of Raynaud's disease or phenomenon.

2. Raynaud's disease and phenomenon

Changes in the human body caused by exposure to vibrations depend among other things on the point of their penetration into the body. General vibrations penetrate into the human body through feet, pelvis, back or sides, whereas hand-arm vibrations penetrate through upper limbs [2, 3].

Hand-arm vibrations may cause adverse changes in the osteoarticular, cardiovascular or nervous systems and there may appear vasomotor disorders and pain of different localization. These changes compose an occupational disease called a vibration syndrome [2, 4, 5].

When it comes to the osteoarticular system there occur narrowing of articular spaces, calcification of joint capsules, changes in the periosteum and bone matrix. Neurological disorders include mainly disturbances of sensation and touch, and even numbness or tingling of fingers [4, 6, 7]. Hand-arm vibrations may also cause local body temperature changes, particularly at the area of direct contact with the vibrating device.

Vibration syndrome, called also a white finger disease occurs the most often among persons working in construction and automotive industries, and also, for example, among dentists. One of the possibilities of the course of the vibration syndrome is Raynaud's disease and phenomenon, where a spasm of finger arteries occurs, which is triggered by cold or emotional stress (Raynaud's syndrome or phenomenon) [8].

Raynaud's phenomenon is a vasomotor disorder consisting in changing of skin color of fingers and hands. It consists in three stages: during the first one there occurs a sudden demarcated paleness, lasting several minutes, then, in the second stage, the affected area goes blue, and finally, in the third stage, it goes red often with numbness and pain [8].

Raynaud's syndrome is caused by a spasm of unchanged arteries or by reduced blood flow through finger arteries, which accompanies other diseases. These changes may be caused by connective tissue disorders, occupational exposure, drugs and chemical compounds, compression syndromes, and other diseases not falling into any of the above mentioned groups. Primary Raynaud's (idiopathic, i.e. where the symptoms occur by themselves and not in association with other diseases) is called Raynaud's disease.

Secondary Raynaud's is called Raynaud's phenomenon and is associated with other diseases [8].

3. Vibration measurement

Vibrations of blenders at the point of contact with an operator's hand were parametrized by rms values of frequency weighted vibration accelerations measured in three perpendicular directions (Figure 1), defined according to ISO 5349-1986 standard [9], and vector sum determined by means of equation (1). Vibration measurements were performed according to requirements and guidelines of international standards [10, 11].

The work of a blender depends to a large extent on the kind of groceries being processed, their consistency, degree of preliminary chopping, etc. It is also difficult to guarantee repeatability of working load of the device. That is why all the tests were conducted with blenders working **without load**.

A triaxial piezoelectric transducer mounted on a grip for hand-arm vibration measurement and vibration analyzer SVAN 912 were used for measurements (Figure 1).

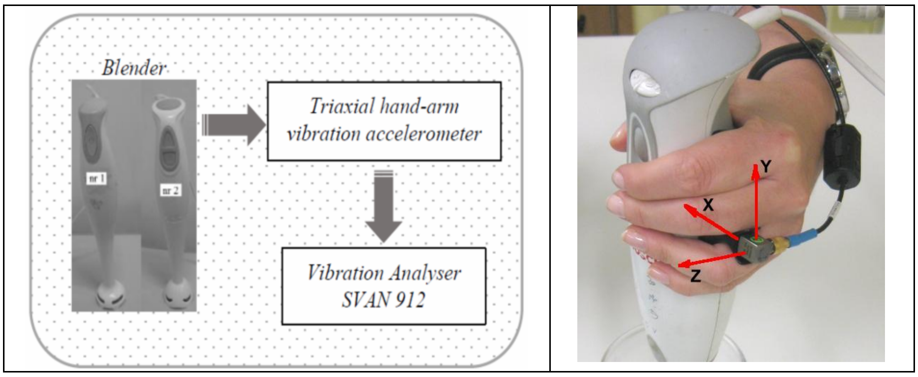

Figure 1. Measurement of vibrations

The vector sum of frequency weighted rms vibration accelerations (hand-arm weighting filter) was determined using Equation (1) [3]:

$$a_c = \sqrt{a_x^2 + a_y^2 + a_z^2} \tag{1}$$

where:

a_c – vector sum of weighted rms accelerations [m/s^2]

a_x, a_y, a_z – weighted rms values of vibration accelerations measured in directions x, y, z [m/s^2].

The value of the vector sum of vibration accelerations measured in three directions was equal to 0.66 m/s^2 for blender 1, and 1.28 m/s^2 for blender 2. Hence, the level of vibrations for blender 1 is almost 50% lower than the one for blender 2.

4. Thermographic testing

Thermography is a non-contact method for measurement of temperature distribution on the surface of the object under investigation. The value of radiant power of infrared radiation emitted by an object is being subordinated to the respective color of visible light. For thermographic inspection the long-infrared range is used, particularly the wavelengths between 3 μm and 13 μm [12, 15, 16].

The image which appears on the radiation detector of a thermographic camera is transformed into an electrical signal directed to reproducing or recording systems [12, 15, 16]. As a result one obtain thermal images, called *thermograms*, which are carriers of information about the temperature of the observed object [13, 14].

Using thermographic methods it is possible to visualize pathology of peripheral vessels, among others Raynaud's disease [12, 15, 16].

Thermographic inspection was conducted using camera FLIR T620sc (Figure 2). The influence of vibrations on changes of hand temperature was analyzed based on the obtained thermograms. The tests were performed under normal climatic conditions (temperature 22,1°C, relative humidity 41,5%).

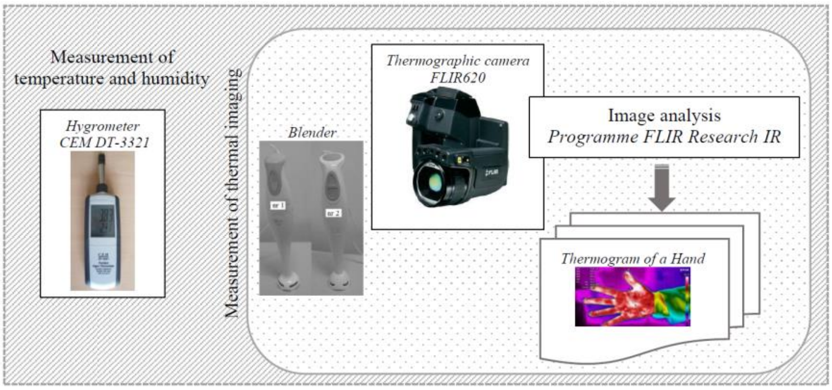

Figure 2. Measurement system for thermographic measurements

A single measurement consisted in imaging of the operator's hand before the use of a blender, and hand temperature changes directly after the use of the device. The tests were conducted on a group of four persons. Based on the obtained thermograms the temperature on fingertips was determined. Additionally, a line was drawn along the metacarpus to visualize temperature changes in the middle of the hand. To every finger was assigned a number as follows: thumb – 1, index finger – 2, middle finger – 3, ring finger – 4 and little finger – 5.

Figures 3 and 5 show thermograms of hands of persons tested before the use of the blender, directly after its use, and after 30s and 60s for blender 1 and 2 respectively. Figures 4 and 6 show the values of hand temperatures for these persons before and 30s after the use of the blenders.

The average change in finger temperature after the use of device 1 is 1.64°C, whereas for device 2 it equals to 2.02°C. Figure 7 shows differences in fingertip and metacarpus temperatures for persons tested between the values obtained before and 30s after the use of both blenders.

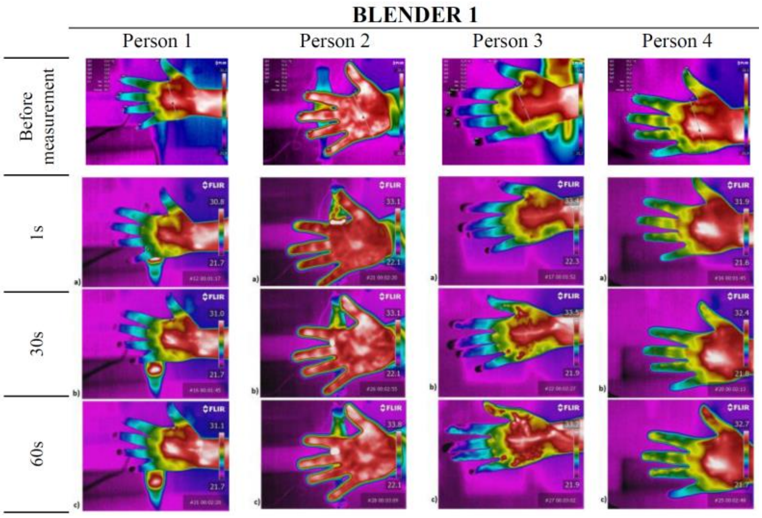

Figure 3. Thermograms of hands of persons tested before and after use of blender 1

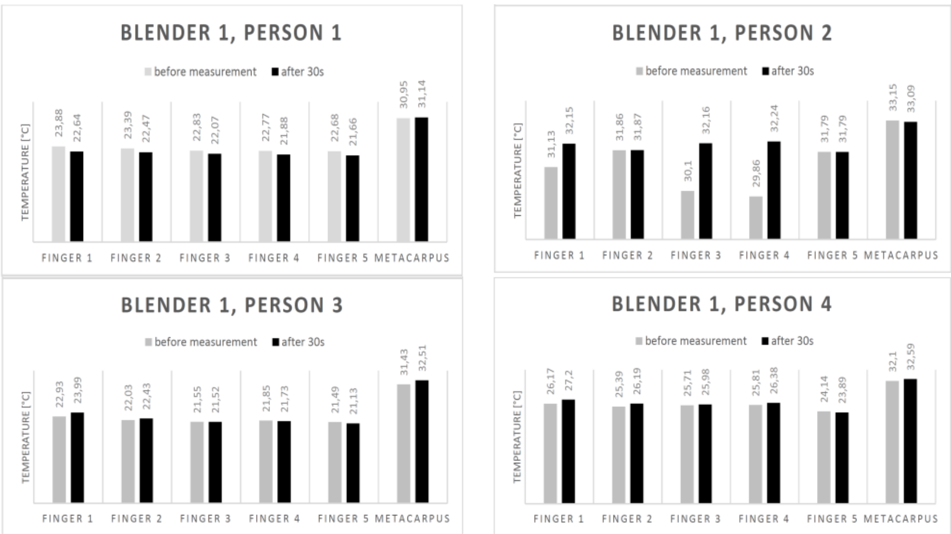

Figure 4. Values of hand temperatures for persons tested before and 30s after use of blender 1

In case of blender 1 and person 1 30s after the use of the device a decrease in fingertip temperature and an increase in metacarpus temperature were observed. Two from the four persons being tested (persons 3 and 4) had slight variations in temperature directly after the use of the equipment. Only in one case (person 2) the fingertip temperature increased significantly and the metacarpus temperature decreased compared to the temperatures before the test.

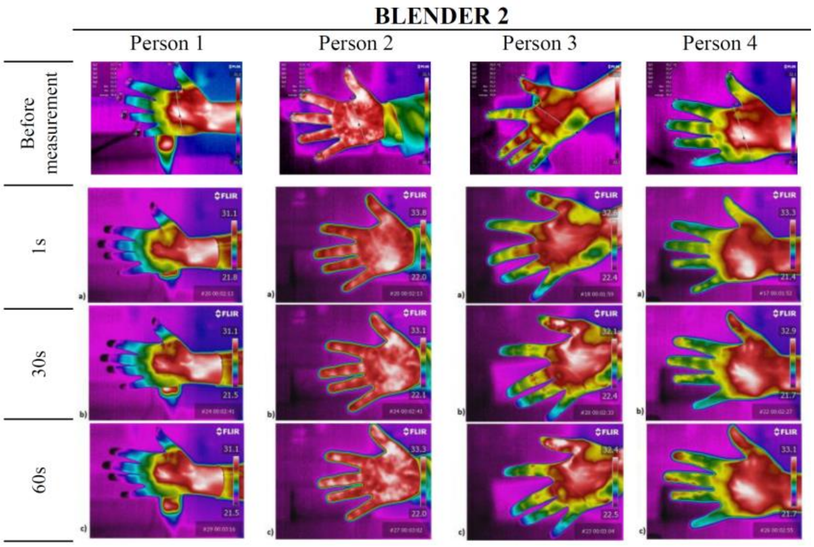

Figure 5. Thermograms of hands of persons tested before and after use of blender 2

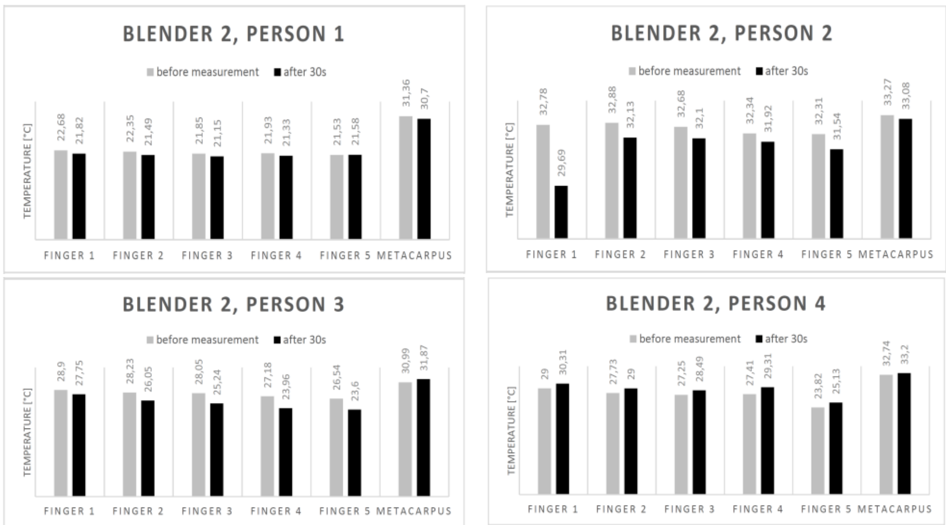

Figure 6. Values of hand temperatures for persons tested before and 30s after use of blender 2

In case of all persons tested, excluding person 4, it was observed that the fingertip temperature was higher before the use of blender 2 than 30s after its use.

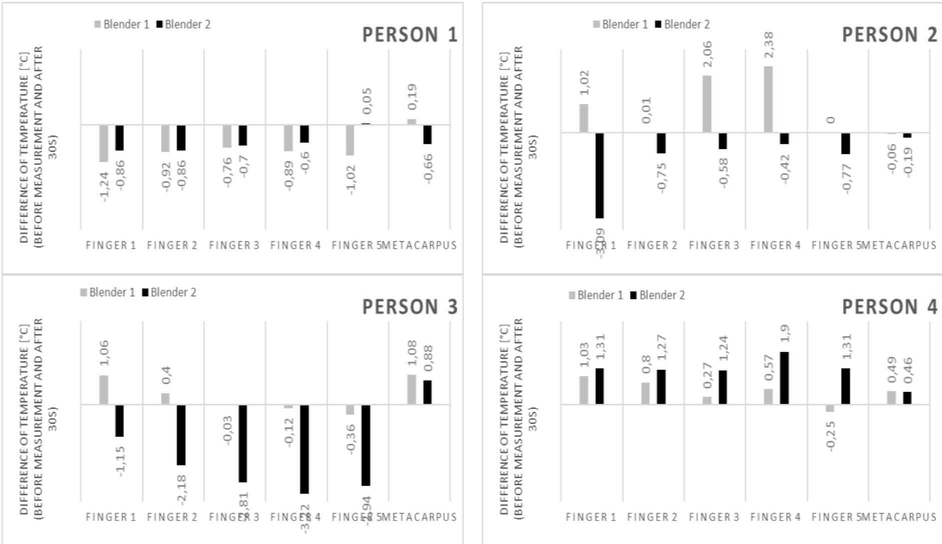

Figure 7. Differences of fingertip and metacarpus temperatures for persons tested between the initial values and the values measured 30s after use of the device

5. Conclusions

The analysis of thermograms has shown that hand temperature is an individual feature. Thermograms of hands may differ for every person, which does not indicate an illness, but it is a natural phenomenon.

In every investigated case there was a change in hand temperature due to the fact of use of a small household appliance. The influence, however, was not identical for every person tested. In most cases a decrease in fingertip temperature was observed compared to the initial temperature. The highest recorded temperature change was equal to about 3°C. The metacarpus temperature was rather increasing. This may result from the way of holding the device and from warming up the device by itself.

The design of the device and the way it is held force compression on blood vessels of fingers and causes their ischaemia manifested by temporary decrease in temperature, and then its increase, when the compression is relaxed. During the tests it was observed, that the temperature did not return fast to its initial value. In most cases for the device with the lower level of vibrations the temperature change was smaller than that for the device, which level of vibrations was twice as high. This indicates the relationship between the level of vibrations generated by such devices and temperature changes of their operators' (users') hands.

The conducted tests have also shown that it is necessary to pay more attention to the influence of vibrations generated by household appliances on a human body.

Acknowledgments

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