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ELECTRIC HEATING CLOTHING FOR MOTORCYCLISTS

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ABSTRACT

In recent years motorcycling becomes more and more popular. It is known that even in relatively warm weather, moving air is cooler and constant exposure to wind when riding may cause a chilling effect that leads to hypothermia. Motorcyclists may lose the ability to concentrate and react on changing traffic conditions when they have hypothermia. We propose the use of electric heating elements in the jacket so that motorcyclist comforts increase. This element receives the energy from the worked engine of the motorcycle. It is located between the two fabrics layers (top and lining) and is made of nichrome wire. The heating is carried out by connecting this element with the power supply system of the motorcycle. In research, we use two types of packages that differ by top fabrics and two connection circuits. The studies were carried out in three different environmental conditions (air temperature, wind speed, and air humidity). Standard test methods were used for performance testing. The effectiveness of electric heating elements used in underwear space for increasing the thermal properties of motorcyclist clothing is proven. It was established that the use of an electric heating element is effective only with a thermocontroller in the electrical circuit. The results of our investigation confirmed the effectiveness of electric heating elements being used in motorcyclist jackets.

KEYWORDS

Motorcyclist clothing; Hypothermia; Heating element; Comfort.

INTRODUCTION

The riding gear market studied was valued at USD 10.65 billion in 2020, and it is projected to be worth USD 15.84 billion by 2026, registering a compound annual growth rate (CAGR) of 6.84% during the forecast period [1]. The increasing demand for premium motorcycles has led to an increase in spending on motorcycle clothing as well as protective gear such as helmets, gloves, jackets, knee and elbow guards, spine guards, pants, and footwear. Over the next three years, motorcycle clothing will record a 3,8% growth rate in terms of revenue, the size of the global market will reach $ 117.90 billion in 2026 [2]. Moreover, protective gears are thicker than conventional clothing with waterproof closures and pockets, zips, higher collars, and are even fitted out with armor. Demand for innovative products that offer efficient use and safety features is growing among the consumers that leading to increases in spending on R&D to offer innovative products with added safety features [3].

Today there is known a wide range of motorcyclists clothing designs which depends on the type of motorcycle (for a certain kind of sports or used in everyday life). Clothing for motorcyclists is classified into 3 groups:

1. Nonprotective (clothing creates a barrier against weather conditions: wind, rain, snow, etc.);
2. Nonprotective but clothing is equipped with protectors marked CE on the shoulder, knee, back, or cubits;
3. Protective (clothing with protection by the use of plastic protectors, connected to each other).

There are some basic requirements for motorcyclists' clothing. First of all, clothing should be reliable, because of increasing human traumatism during competitions, accidents, and falls. Nowadays, the requirements of reliability are provided by the protective inserts and technological elements of clothing (silhouette, shape, cut) [4, 5]. Protective gear has a second important purpose - comfort. Uncomfortable gear can distract from riding but properly fitting protective gear will help to stay comfortable when encountering various riding conditions. Ergonomic requirements in terms of comfort, fit, and ease of movement should not create safety hazards. For example, jackets with external pockets or straps may snag on the motorcycle or other vehicle in a crash [6].

It is essential to design/develop the right clothing for motorcycle riders. Very little research is being carried out in this field. The invention is more concerned with

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society, reducing injuries during accidents, safeguarding the lives of the people, protecting animals (minimizing the usage of leather), motivating interdisciplinary projects, and preferably for the wellbeing of humans [7]. Most research in motorcyclist clothes is related to development the helmet [8], to improving the visibility [9, 10] and safety [11] of bicyclists. Some papers report the effect of protective clothing on wear comfort [12, 13]. They are emphasis on improving the protective fabric`s resistance with better comfort properties [14] such us permeability, moisture management and thermal resistance.

Thermal comfort is one of the essential components of motorcyclist wear. Even in relatively warm weather, moving air is cooler and constant exposure to wind when riding may cause a chilling effect that leads to hypothermia [15]. Hypothermia is a condition of subnormal body temperature that can cause loss of concentration, slowed reactions, and loss of smooth, precise muscle movement. It`s possible to lose the ability to concentrate and react to changing traffic conditions. From the other point clothes that are just right for cold weather may be too hot once you stop.

Thus, an improvement of the clothing for motorcyclist thermal properties is important. As the result of literature analysis for the project by the Centre for Accident Research & Road Safety [16] the key elements to be considered in evaluating the weather protection provided by motorcycle clothing was established. The main ones are the provision to allow insulation from cold temperatures and ventilation in heat and the design and fit to reduce flapping and wind buffeting which forces warm air out. Still there is a gap in investigation the possible ways to increase the thermal resistance of clothes for motorbikers.

There are four types of personal heating garment: electrical heating garment (EHG), phase change material (PCM) garment, chemical heating garment (CHG), and fluid/air flow heating garments [17, 18]. Currently, the personal heating garment has some visible drawbacks, e.g., battery performance cannot meet the requirements of long exposure in cold conditions in EHGs; the temperature cannot be controlled in chemical heating pads; released latent heat has little effect on the human body in both microencapsulated and packaged PCM heating garments; and liquid/air flow heating systems limit human activities. Compared with other types EHGs are expected to have a promising future.

There are several papers presenting research results in heating garment development regarding clothes design as well as heating elements creation and production.

Song et al [19] study the possibility to use electrically and chemically heated garments in order to improve the thermal comfort of university students in a cold classroom. For EHG, five electrical heating pads were attached to the inner side of the vest (two at the waist, two at the scapula, and one at the lower back), and two additional heating pads were located in the kneecaps. It was found that heated clothing ensembles could significantly improve both the overall-body thermal comfort (evidenced by the significantly elevated mean skin and body temperatures and improved the whole-, upper- and lower-body thermal and comfort sensations) and the local-body thermal comfort (evidenced by the significantly elevated finger temperature, finger blood flow, and finger dexterity, and improved thermal sensations at hands and feet).

The development in the electrical heating garment is going in the direction of wearable heating systems [20-22]. The flexibility of the heating system is very important since the users'/system structures are mostly irregular shaped. Heating with non-flexible systems may cause great heat losses due to less contact. For this reason, textile-based heating systems are an added advantage because of the efficient heat delivery mechanism by wrapping the structure due to its flexibility. For example, knitted heating fabrics of plain, rib, and interlock structure were designed and fabricated by using silver plating compound yarns and polyester staple fiber spun yarns [23]. By taking and analyzing infrared temperature images strong linear correlations can be observed between surface maximum equilibrium temperature and power consumption density as well as between power consumption density and inner equilibrium temperature of mimetic clothing. Such materials will have wide application prospects in the active warming field because of a lot of advantages, such as an even surface temperature field in the heating process, structure simplicity, flexibility, etc.

Havelka et al [24] focused on the possibilities of the application of electric heating built directly into clothing for seniors, especially for clothes designed for a cold environment. The proposed heating system based on embroidery with using hybrid threads can be used especially in winter clothing, but can also be used for home-use clothing or everywhere it is disadvantageous or inappropriately to increase the ambient temperature.

The purpose of the work is to create a wind-, water-resistance, and heat protective jacket for a motorcyclist not only due to the properties of textile materials. We propose a method of increasing the thermal properties of motorcyclists' clothing, namely, through the use of electric heating element in the suit. This element receives the energy from the worked engine.

Table 1. Characteristics of textiles.

Textile code	Fabric structure (weave)	Material composition [%]	Weight (Areal density) [g/m2]	Thickness [mm]	Count [warp · weft⁄cm]	Fineness of yarn (linear mass), warp/weft, [tex]
Top fabric						
T1	twill2/2	PES – 100	145	0.18	75/41	9.7/12.1
T2	multiple twill	PES – 100	180	0.32	65/43	20.4/13.3
Lining fabric						
L	twill2/1	PES – 100	99	0.15	65/39	8.3/8.3

MATERIALS AND METHODS

Textile materials

This paper deals with clothing for motorcyclists of the first group – “non-protective” – clothing that creates a barrier against only weather conditions: wind, rain, snow, etc. As the top layer, polyester fabric used for clothing was selected. Top fabrics have water repellency treatment. Characteristics of textiles are shown in Table 1.

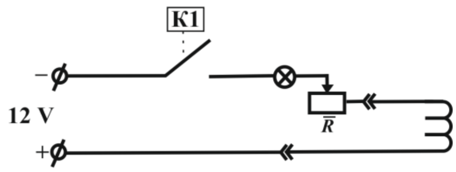
Electric heating element

Ukrainian assortment of jackets for motorcyclists with a warming lining does not allow provide comfortable conditions that satisfy ergonomic requirements (boundary temperature range of the human body from 36.8°C to 37.2°C [25]; a temperature of the underwear space from 29°C to 32°C). If the temperature goes beyond these limits, it leads to various physiological and behavioral changes in the human body, which are aimed at resuming the boundary temperature [26-28].

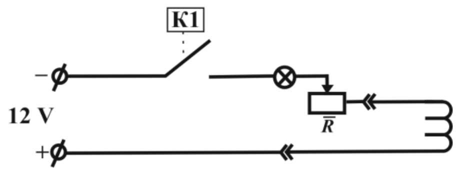
We propose to use the electric heating element in the jackets. The size of each heating element is 10x16 cm. This element is located between two layers of lining fabric and is made of nichrome wire. A nichrome spiral is a heating element in the form of a wire twisted in a spiral for compact placement. The wire is made of nichrome, a precision alloy, the main components of which are nickel (80%) and chromium (20%). The length of the nichrome wire is 2.0 m, the diameter is 0.8 mm, it is folded in a zigzag (spiral). The minimum temperature parameter of the heating element is 30°C, and the maximum is 50°C. During washing, the heating element is pulled out. The heating is carried out by connecting this element with the power supply system of the motorcycle. In research, we use 2 connection schemes (Fig. 1(a, b)) of the heating element to supply system, which is shown in Fig. 2.

Connection scheme №1 (Fig. 1(a)): heating element is connected to the motorcycle battery using electric wires, through a tumbler switch and a resistor.

Connection scheme №2 (Fig. 1(b)): heating element is connected to the motorcycle battery using electric wires, through a tumbler switch and thermocontroller. TCXRE digital thermocontroller was used. The thermocontroller allows regulating the temperature of the heating element. This, in turn, allows to control and give the air temperature in the underwear space.



(a)



(b)

Figure 1. Connective scheme of the electric heating element with a power supply system of the motorcycle: (a) connection scheme №1; (b) connection scheme №2.

Figure 2. Connection of the electric heating element with a power supply system of the motorcycle.

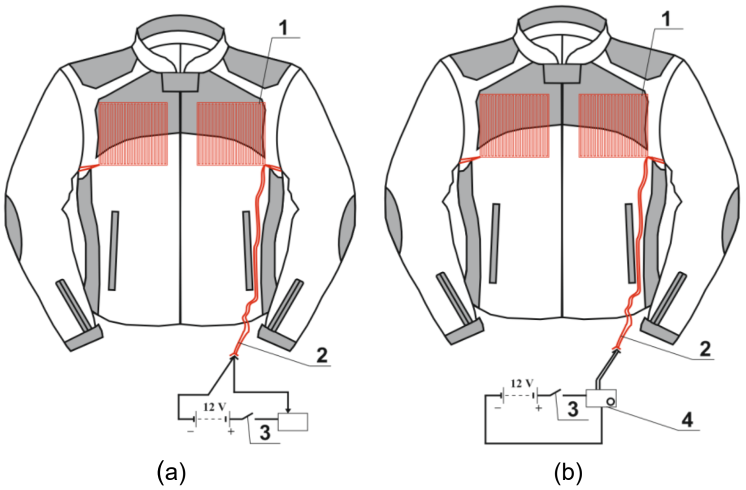


Figure 4. Design of motorcyclist`s jacket with electric heating element: (a) connection scheme №1 (1 - heating element; 2 – wire; 3 – tumbler switch), (b) connection scheme №2 (1 - heating element; 2 – wire; 3 – tumbler switch, 4 – thermocontroller).

Textile packages

Two types of packages that differ of top fabrics were investigated (Fig. 3):

- package A –T1 + (L + electric heating element + L);
- package B – T2 + (L + electric heating element + L).

The electric heating element is located between the two layers of lining fabrics L.

Design of motorcyclist's jacket

The design of the motorcycle jacket is shown in Fig. 4(a, b). The heating element (1) is located at the top of the front of the motorcycle's jacket. Using electric wires (2), through a tumbler switch (3) and a thermocontroller (4) (in case of Connection scheme №2) it is connected to the motorcycle battery. This arrangement of the heating element in the jacket is due to the fact that during the movement of the motorcycle, the cold air flow through the front of the jacket partially penetrates under the space between the jacket and the body of the motorcyclist and cools it (Fig. 5). The presence of a heating element in the jacket heats the air under the jacket. Cold air, which partially penetrates through the jacket while the motorcycle is moving, mixes with the heated air. This avoids hypothermia in the motorcyclist. However, the presence of a heating element without a thermocontroller can lead to overheating of the space under the jacket. To prevent this phenomenon, a thermocontroller was connected to the electrical circuit (Fig. 4 (b)).

Methods

Structural parameters. Studies of the structural parameters of the fabrics were conducted according to standard methods:

- ISO 3801:1977. Textiles — Woven fabrics — Determination of mass per unit, length, and mass per unit area [29]
- ISO/TR 11827:2012 Textiles — Composition testing — Identification of fibers. [30]

Spray test. The spray method is a primary technique for the evaluation of water repellency of fabric as per ISO 4920:2012 Textile fabrics — Determination of resistance to surface wetting (spray test) [31]. A spray test of fabric samples subjected to waterproofing treatment was evaluated using a spray-type water repellency tester. For tests, 5 samples were taken from different places of the textile material without wrinkles. Each test specimen was conditioned at 21 ± 1 °C and 65 ± 2% relative humidity for a minimum of 4 h before testing. Each specimen was assigned a rating corresponding to the nearest level on the rating chart (Fig. 6).

Air permeability. The air permeability [mm/s] of fabrics was determined and calculated by the equation according to ISO 9237:1995 [32]. Ten parallel measurements were carried out for each fabric variant. The mean values are used for the analysis.

The fabric samples were placed in the standard atmosphere, which was 21 ± 1 °C and 65 ± 2% relative humidity, for 24 h.

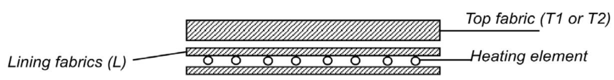


Figure 3. Scheme of the package of the motorcycle jacket.

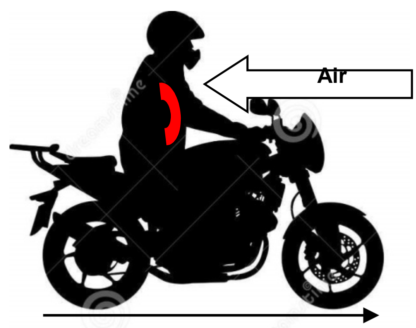


Figure 5. Scheme of motorcyclist movement.

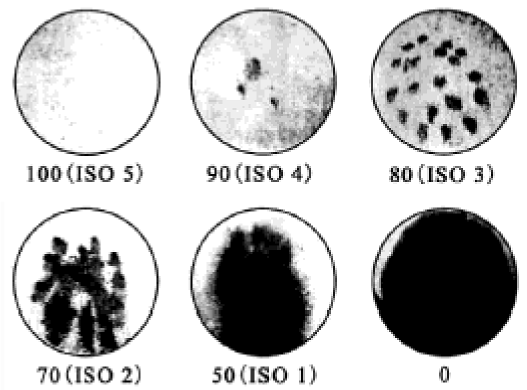


Figure 6. Standard spray test ratings [31]: 100 (ISO 5) No wetting of the specimen face; 90 (ISO 4) Slight random wetting of the specimen face; 80 (ISO 3) Wetting of specimen face at spray points; 70 (ISO 2) Partial wetting of the specimen face beyond the spray points; 50 (ISO 1) Complete wetting of the entire specimen face beyond the spray points; 0 Complete wetting of the entire face of the specimen.

Table 2. Air permeability and water resistance of textiles and packages.

Textile code	Air permeability, [mm/s]	Water repellency
Top fabric		
T1	3.1±0.1	80 (ISO 3)
T2	2.9±0.1	90 (ISO 4)
Package		
package A	2.9±0.1	-
package B	2.4±0.1	-

Air temperature. The temperature in the underclothing space was determined under real conditions: at night; motorcycle Yamaha YZF-R6; the road with asphalt covering. Driving speed was varied from 10 to 60 km/h. Air temperature was varied from 10 to 20 ± 2°C with an interval of 5°C, wind speed ranging from 0 to 4 m/s. The temperature in the underclothing space was measured by a thermocouple, which is connected to the digital thermometer WSD-10. The thermocouple was located at the level of the upper part of the front in the area of the heating element. Ten parallel measurements were carried out for each fabric variant. The average values are used for the analysis.

RESULSTS AND DISCUSSION

Air permeability and water repellency of fabrics

According to the requirements for motorcycle jackets, the air permeability of the top fabric should be minimal and provide a barrier to cooling the space under the clothes and the body of the motorcycle rider. It can be seen from the results in Table 2 that the top fabric T2 has a low level of air permeability compared to fabric T1.

The water repellency of top fabrics was measured using a spray tester. It can be seen from the results in Table 2 that the top fabric T2 has a better water repellency compared to fabric T1. Analysis of the textile water resistance (Table 2) shows that the fabric T1 corresponds to level 3 (descriptive scale according to ISO 4920: 2012 – Wetting of specimen face at spray points). In turn the fabric T2 corresponds to level 4 (descriptive scale according to ISO 4920: 2012 – Slight random wetting of the specimen face).

These investigations allow choosing for further investigations as top fabric in a package the fabric T2 that has low air permeability and better water repellency properties. The study of the air permeability of the packages (package A and package B) showed that package B has less breathability than package A (Table 2). And taking into account that the top fabric T2 has better water repellency, therefore, package B was chosen for further research.

Temperature in the space under clothing

The temperature in the space under clothing measurements was done only for package B, according to the previous results of air permeability and water resistance (Table 2). The studies were carried out in three variants by different environmental conditions (Table 3 and Fig. 7). The input data are air temperature (Tair, [°C]), wind speed (v_{wind}, [m/s]), and air humidity (W, [%]). The experiment was carried out for several days under different environmental conditions.

The analysis of the results (Fig. 7) showed that the temperature changing in the space under the clothes is similar for variant of investigations №1, №2, and №3 (Connection scheme №1 –without thermocontroller). As the speed of the motorcycle increases to 60 km/h, the temperature in the space under the clothes decreases by 3.5 – 5.0 °C. At the same time, starting from a speed of 40 km/h, the change in temperature in the space under the clothes was not a statistically significantly different. The use of heating element (Connection scheme №1 – without thermocontroller) allows to maintain the temperature under clothing in the range of 41.0 – 45.0 °C, thus excluding hypothermia (less than 35 °C), but leads to overheating of the motorcyclist's body. The temperature in the space under the clothes, where the heating element is switched off, is about 20 °C - these are not comfortable conditions [33, 34], either.

To exclude overheating of the body when the heating element was turned "on" and to maintain comfortable conditions in the underwear space (temperature of the underwear space from 29 °C to 32 °C), a thermocontroller was connected to the electrical circuit (Fig. 1. b). To test the effectiveness of using a heating element with the thermocontroller turned "on", an experiment was carried out under the same conditions as when the thermostat was turned "off". The temperature of the thermocontroller was set at 32 °C as such that corresponds to the maximum comfortable temperature of the underwear space. The results of the study with the thermostat turned "on" and the heating element turned "on" are presented in Table 3 and Fig. 7 (Line 3 – heating element "on", thermocontroller "on").

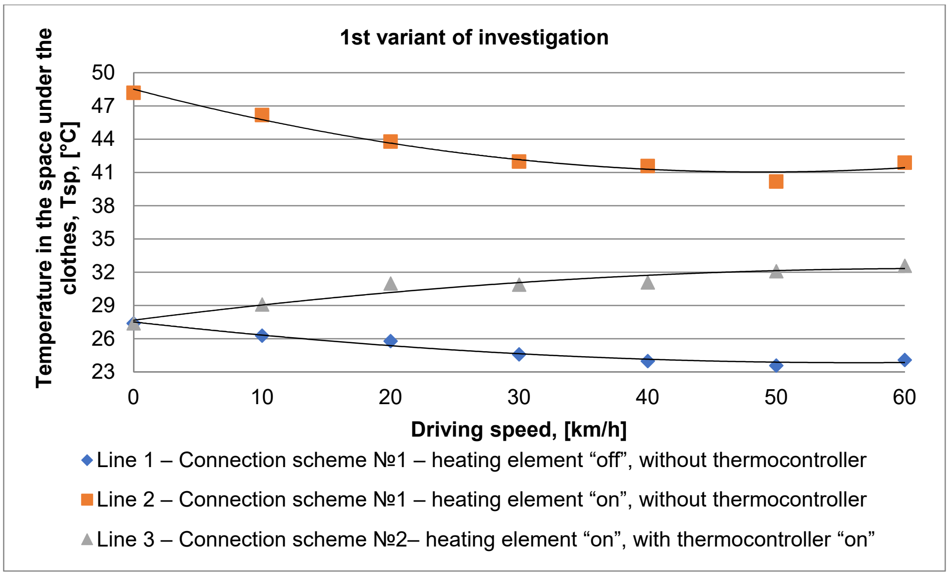
The analysis of the results for Connection scheme №2 – thermocontroller "on" showed that the temperature changing in the space under the clothes is similar for variants №1, №2 and №3. The character of the curves (Line 3 - heating element "on", thermocontroller "on") differs from the character of the curves (Line 1 and Line 2) in Fig.7. The temperature under the clothes initially rises, then it stabilizes and, due to the thermocontroller, is maintained at the level of 32 ± 0,5 °C. This temperature is the comfortable temperature of the underwear space, which does not cause hypothermia and overheating of the motorcyclist's body.

The obtained results showed that the jacket design, package composition and the use of an electric heating element with thermocontroller provide the thermophysiological comfort of the motorcyclist's body in the considered range of environmental conditions.

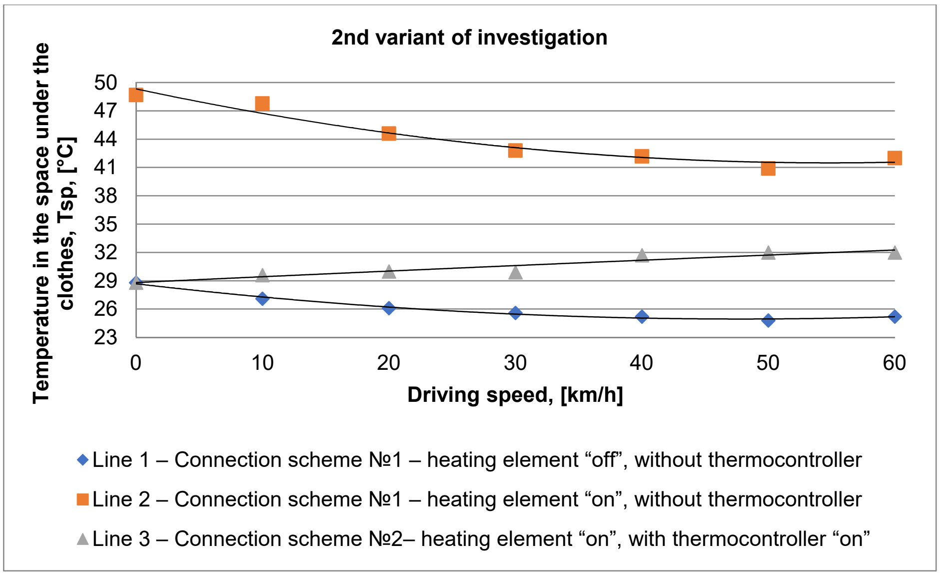
Table 3. Dynamic of temperature changing in the space under the clothes (package B).

Variant of investigation	**Environmental conditions**	**Driving speed, [km/h]**	**The temperature in the space under the clothes, T_{sp}, [^{0}C]**		
			Connection scheme №1 Without thermocontroller"		***Connection scheme №2 Whith thermocontroller "on"***
			Heating element "off"	***Heating element "on"***	***Heating element "on"***
Variant №1	T_{air} ≈10^{0}C; v_{wind} = 4 м/s; W =94%	0	27.4	48.2	27.4
		10	26.3	46.2	29.1
		20	25.8	43.8	31.0
		30	24.6	42.0	30.9
		40	24.0	41.6	31.1
		50	23.6	40.2	32.1
		60*	24.1	41.9	32.5
Variant №2	T_{air} ≈ 15^{0}C; v_{wind} = 2 м/s; W =80%	0	28.8	48.7	28.8
		10	27.1	47.8	29.6
		20	26.1	44.6	30.0
		30	25.6	42.8	29.9
		40	25.2	42.2	31.7
		50	24.8	40.9	32.0
		60*	25.2	42.0	32.0
Variant №3	T_{air} ≈ 20^{0}C; v_{wind} = 3 м/s; W = 53%	0	30.6	49.0	30.6
		10	29.0	47.9	30.9
		20	28.2	46.6	31.5
		30	27.6	44.8	32.0
		40	26.5	44.1	32.2
		50	26.0	43.2	32.5
		60*	26.3	44.8	32.5

* 60 km/h – is the speed maximum for driving in Ukraine through cities and villages



(a)



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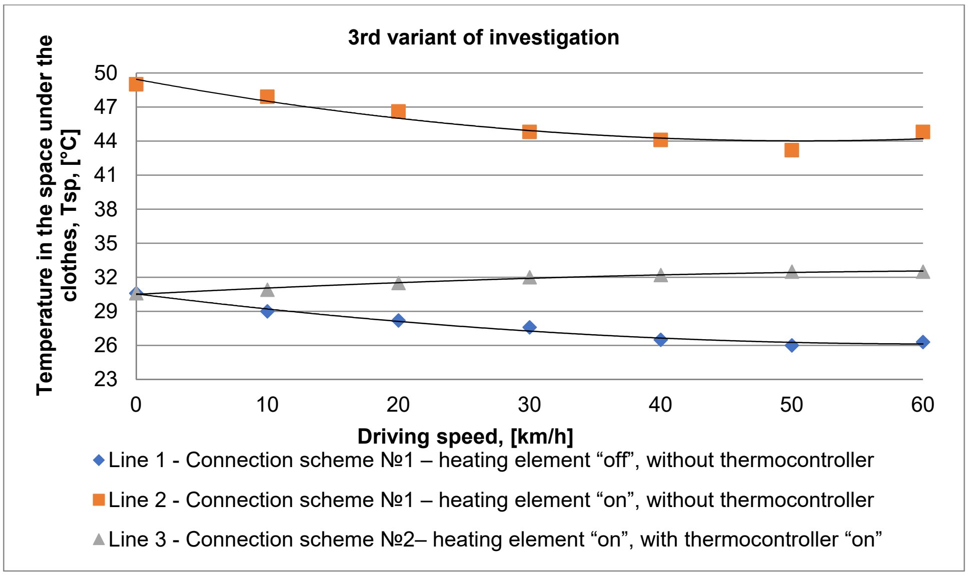

(c)

Figure 7. Temperature changing in the space under the clothes (Package B): (a) – 1st variant of investigation (environmental conditions: T_{air} ≈100C; v_{wind} = 4 м/s; W =94%), (b) – 2nd variant of investigation (environmental conditions: T_{air} ≈ 150C; v_{wind} = 2 м/s; W =80%), (c) – 3rd variant of investigation (environmental conditions: T_{air} ≈ 200C; v_{wind} = 3 м/s; W = 53%).

CONCLUSION

Thermal comfort is one of the essential components of motorcyclist wear. A chilling effect during riding could lead to hypothermia and cause loss of concentration. Alternatively, warm clothes that are just right for cold weather could become uncomfortable once you stop. Very little research is being carried out in motorcyclists clothing design that meet requirements for thermal insulation of body during motion. Our research has confirmed the effectiveness of electric heating elements used in underwear space for increasing the thermal properties of motorcyclist clothing. It was established that the use of an electric heating element is effective only with the thermocontroller in the electrical circuit. The thermocontroller allows to maintain a comfortable temperature in the underwear space and excludes hypothermia or overheating of the motorcyclist's body.

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