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TRANSFORMABLE WARNING CLOTHING FOR CHILDREN WITH ACTIVE LIGHT SOURCES

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Abstract:

Warning clothing for children should meet several requirements in the field of safety and functionalities. Technical and technological development has brought many different benefits. One of them are active light sources that can be used to improve the visibility of the user of given clothing products in situations, where the risk of being invisible is high. Therefore, the transformable clothing with the use of side emitting polymer optical fiber increases the child visibility in the traffic compared to the situation, when the safety was guaranteed only by reflective materials. The scientific problem to be solved was the design of transformable clothing, followed by the integration of traffic light systems with transformable children's clothing, which should increase the child's safety on the road. Transformability, as a feature of the product, should not interfere with the child's visibility. At a later stage of work, visioility tests on the transformable children's clothing set prototype were carried out according to the proposed research methodology. The visibility of system has been assessed both from the point of view of the arrangement of traffic light elements as well as their optoelectronic parameters, such as illuminance, the color of the optical fiber cover, and so on.

Keywords:

Transformable clothing,; children clothing,; SEPOF,; warning clothing,; active light sources

1. Introduction

The active, carefree lifestyle of children and their unconsciousness about the dangers in the everyday life, and in particular related to participation in the road traffic requires from designers of children's clothing products meeting specific requirements that will prevent the health and life risks of small users. The principles of designing the transformable children's clothing have been taken into account the implementation of a set of transformable children's clothing, which consists of jacket and bib shorts. In this product, various types of fasteners have been used, such as zip fasteners, press studs, buttons, and cords. With the help of these accessories, you can get a vest, coat; additionally, the hood can be transformed into a sailor-type collar or sack. There is a possibility to get a dress from a dungarees style dress, skirt, short trousers, and a backpack with a bib.

In the proposed clothing, in addition to reflective tapes, light signaling systems in the form of side emitting polymer optical fiber (SEPOF) were added. Optical fibers produced by the Czech company SCILIF SunFibre have its light source in the high-performance SMD LEDs with a transparent lens mounted that focuses the light on the fiber along its axis, and the optical fiber is contained in a characteristic textile coating. They were used to apply their potential to increase the safety of children in the traffic, because a well-visible person is a safe person [1-8].

The selection of research area was not accidental, but resulted from the lack of comprehensive analysis of transformable clothing intended for children, which also serves as the warning clothing.

2. Characteristics of transformable clothing model with SEPOF system

A set of transformable clothing for children, which consists of jacket and pants, is made based on the PN-EN 1150 standard – *Protective clothing, high visibility clothing for non-professional use, test methods and requirements.* The dungarees and bib pants are made of blue-colored background material, on which stripes around the trunk are made of fluorescent yellow material, the width of which is 50 mm. In contrast, the reflective material was used in the form of strips, the width of which is 25 mm [9].

For manufacturing the set of transformable warning clothing for children (Figure 1), the main material used as the background material was soft blue fabric of 290 g/m^2. Also, the same type of fabric was used as a fluorescent material with a yellow color, which has a mass per square meter of 310 g/m^2. This material meets the requirements set out in the PN - EN ISO 20471: 2013-07 standard and is used by producers of warning clothing (Table 1). In addition, 3M 8940 reflective tape was used as the reflective material, which meets specific photometric requirements contained in the PN - EN ISO 20471: 2013-07

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Table 1. Characteristics of materials

Characteristics of materials					
Children's clothing transformable	**Material**	**Raw material composition**	**Surface mass**	**Security (standards, certification)**	**Other parameters**
A set of warning transformable children's clothing (jacket and dungarees)	Softshell (blue color)	95% polyester 5% elastane	290 g/m^2	By technical card EN 13688:2013	Waterproof 8000 mm Ventilation 3000 mVP
	Softshell (fluorescent yellow)	100% polyester	390 g/m^2	By technical card EN 13688:2013	Waterproof 6000 mm Ventilation 3000 mVP

standard regarding the surface density of reflectivity coefficient R [10].

The set of transformable children's clothing, which also functions as the warning clothing, incorporating active light sources in the form of SEPOF, has its source of light in the high-performance SMD LEDs with a transparent lens that focuses the light to the fiber along its axis (Figures 2 and 3).

3. Investigation of illuminance of transformable warning clothing for children

The SEPOF system has been installed onto the transformable set of children's warning clothing (Figures 2 and 3). These optical fibers are not permanently sewn, but fixed into the product, so that they can be unfastened as needed. This is especially important for small users, due to their active lifestyle, and consequently, subjecting the clothing to the specific maintenance processes. According to the manufacturer, SEPOF can be washed at temperatures up to 40°C; therefore, the solution is to attach SEPOF to the clothing with the Velcro tape.

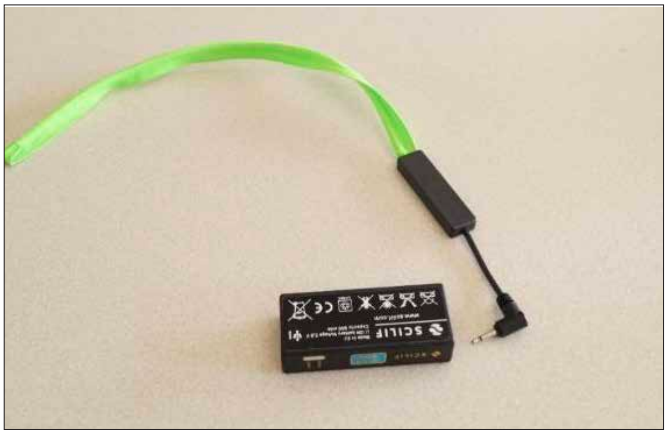

Figure 2. View of SEPOF fiber optics with a control unit (own study).

Figure 1. Design of set of transformable warning clothing for children with elements of SEPOF: (1) background material, (2) fluorescent material, and (3) reflective material (own study).

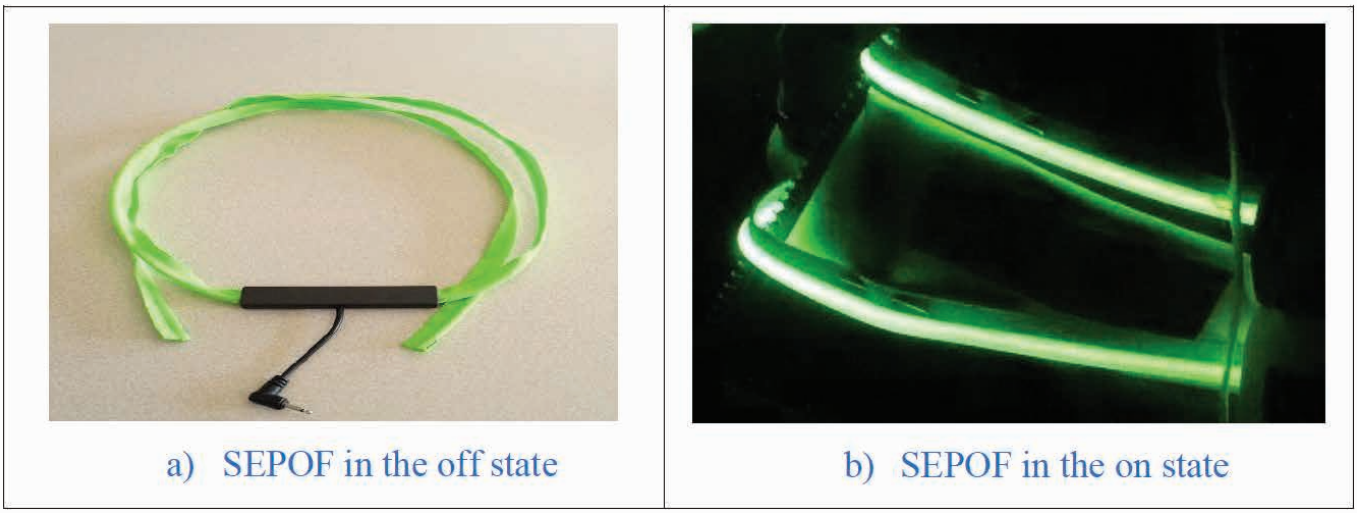

Figure 3. View of SEPOF: (a) SEPOF in the off state and (b) SEPOF in the on state (own study).

3.1. Distribution of SEPOF in the transformable clothing for children – models A and B

Arrangement diagram of SEPOF systems (Figures 4, and 5) has been designed in such a way that it does not hinder or prevent the transformation process of clothing products and perform its current functions, without causing restrictions of the light emission by SEPOF. Model A means the maximum version of lightening, while model B means the minimum version of lightening.

3.2. Description of measurement method

Measurements of light intensity of children's transformable warning clothing with mounted SEPOF were made with the use of luxmeter at the full room darkness, at 22°C and 50–65% of relative humidity. The child's dummy was dressed in the transformable set of warning clothing equipped with active light sources like it would be done in real conditions.

Then, to stabilize the light, all SEPOF elements fixed in the tested product were switched on, in the continuous light mode at the maximum nominal power. After 3 min, the luxmeter was switched on, and the light intensity was measured for specific angles (0°, 45°, 90°, 135°, and 180°) of manikin position and the values of light intensity E [3] were determined. 0° means the back position of the manikin to the light source (Figure 6). These measurements were carried out in the aforementioned manner for SEPOF in the textile shells in different colors: green, blue, white, yellow, and red.

3.3. Results of light intensity of SEPOF system in different color

The set of transformable warning clothing for children, in which active light sources were installed in the form of SEPOF, underwent research process to determine the intensity of their lighting. Three research measurements were made for each variant.

The results of light intensity of SEPOF systems in different color of the textile coating mounted and different angles of position of dummy (0°, 45°, 90°, 135°, and 180°) in models A and B are presented in Figures 7–9.

Analyzing the results of studies on the intensity of SEPOF lighting for particular angles of rotation of the child's dummy position, it was noted that for models A and B the highest mean illumination is shown by SEPOF systems in the white textile coating. On the other hand, the smallest mean value of illuminance is for light elements with the blue colour of textile cover (Figures 7—9).

When assessing the intensity of illumination of active light sources in the transformable set of children's warning clothing, its highest value was obtained at the angle of test object setting at 45° from the back regardless of SEPOF textile coating color. However, the lower mean intensity value was observed for the angle of the manikin position of 90° in relation to the light source (Figures 7—9).

4. The road visibility test

4.1. Description of measurement method

The measurement of visibility of the child's manikin dressed in the transformable warning clothing with the mounted SEPOF system in the road traffic was carried out in a place that allowed for a clear observation of test objects. Therefore, the visibility measurements took place at night hours (approx. 8 p.m.) on the street that was not illuminated in any way by constant light sources, lights in motion, brightly lit areas, and moonlight. On the straight road, the test facility was located at a distance of 1 km from the vehicle, which was used to assess the manikin visibility. During measurements, the car with the low beam headlights was moving at a speed of 50 km/h (Figure 10). During the test, the following measurements were made:

- Object visibility at a distance of 1 km between the vehicle and child's dummy wearing the transformable warning clothing with SEPOF system and how it was noticeable to the driver,

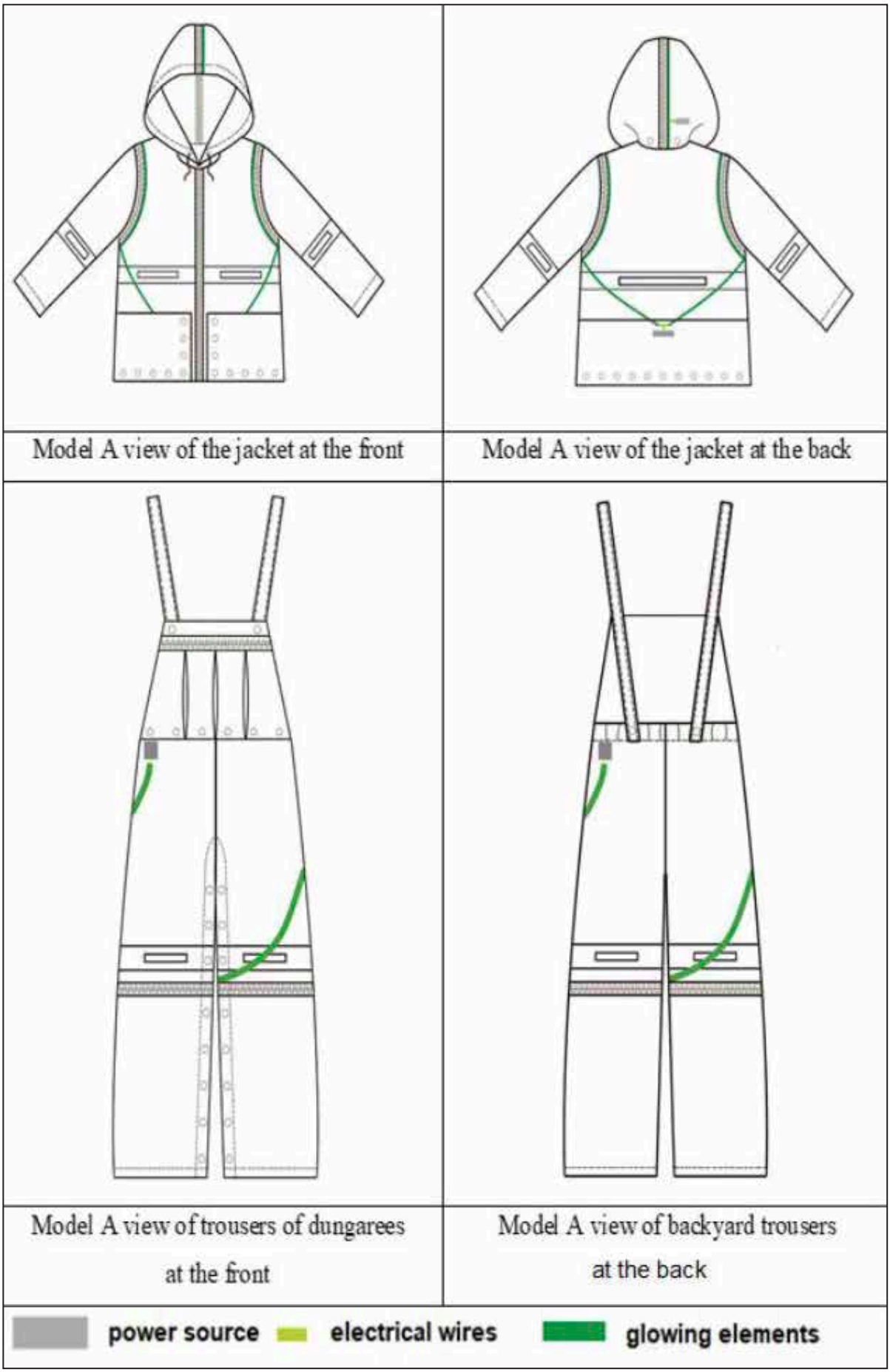

Figure 4. Schematic arrangement of SEPOF in model A.

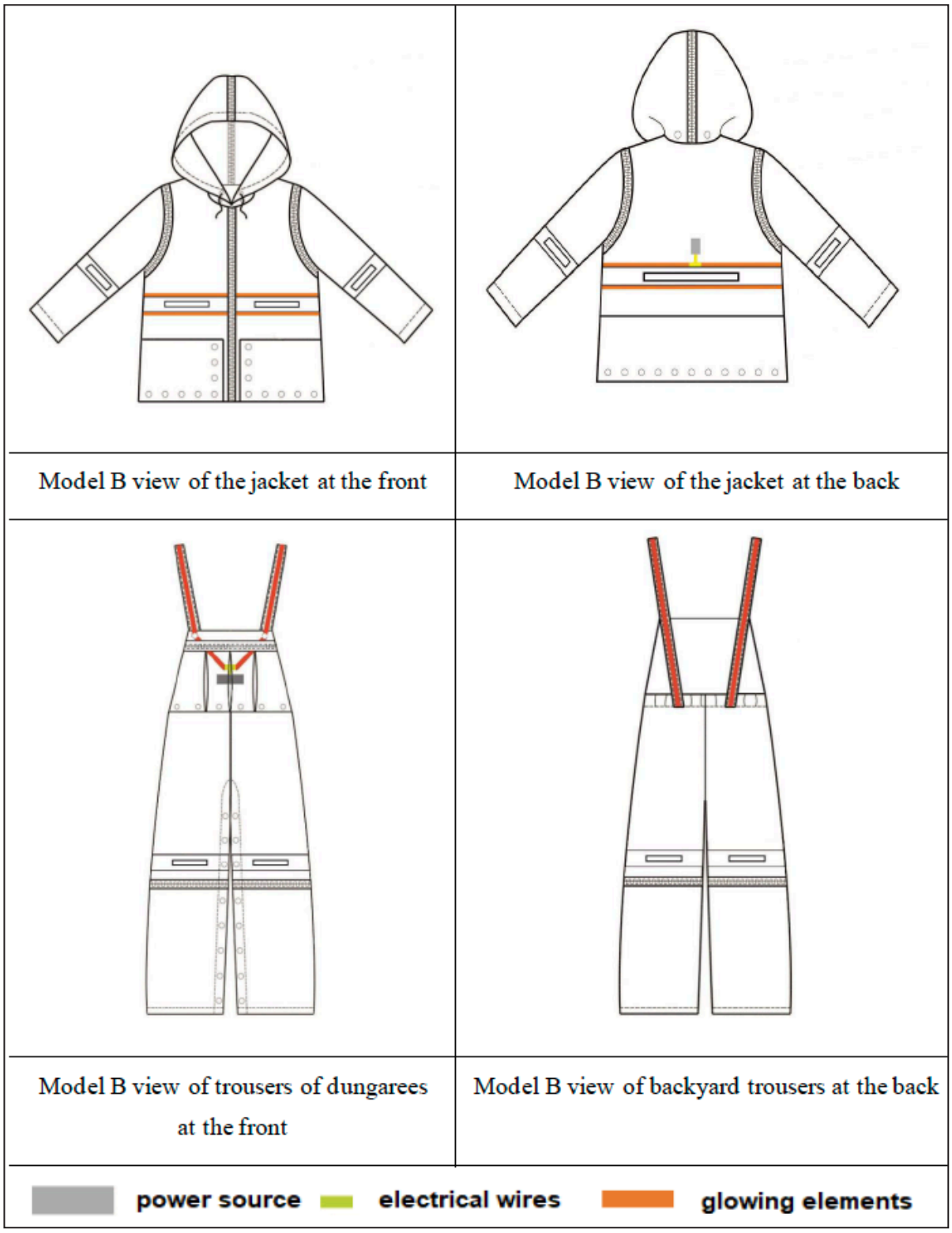

Figure 5. Schematic arrangement of SEPOF in model B.

- Observation from which distance (x1) the silhouette of child's dummy dressed in the transformable clothing with SEPOF was visible,

- Observation from which distance (x2) the research object dressed in the transformable clothing without SEPOF system was visible.

4.2. Results of visibility of warning clothing with SEPOF system

In the road visibility test, the set of transformable clothing for children was used, in which active light sources in the form of SEPOF were mounted. In addition, optical fibers installed in the product were in various colours such as white, yellow, red, green, and blue. The results of the visibility measurement of test object dressed in the transformable warning clothing (models A and B) are illustrated in Figures 11-13.

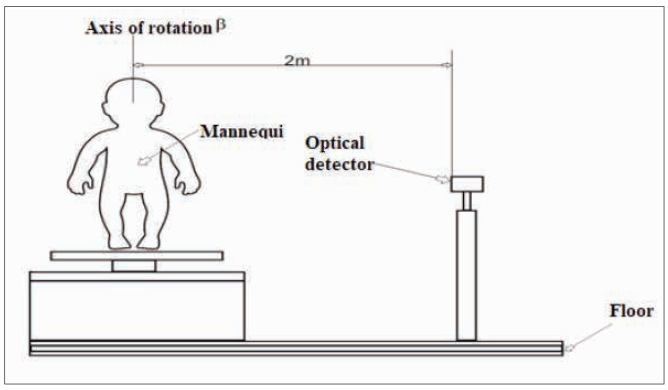

Figure 6. Diagram of the test stand (own study).

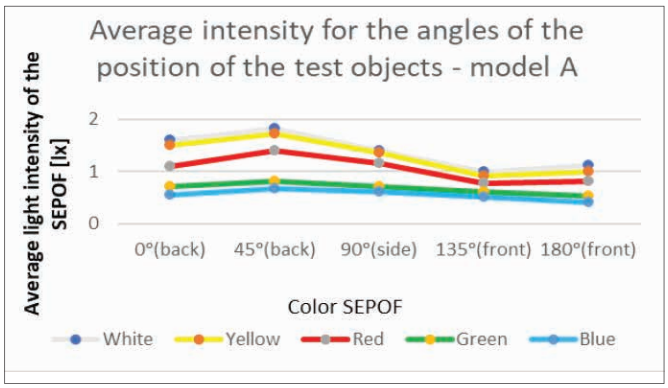

Figure 7. Average illuminance of SEPOF for test object angles – model A (own study).

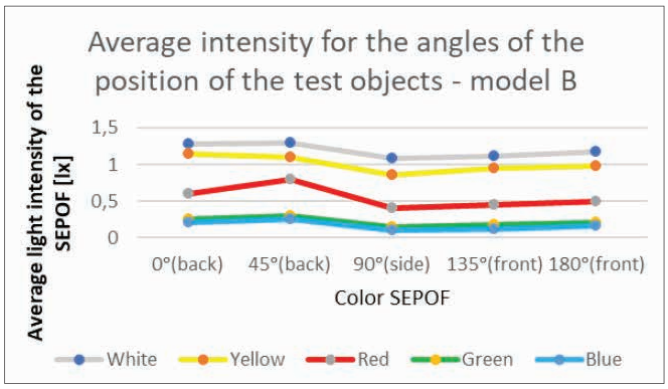

Figure 8. Average SEPOF illuminance for test object angles – model B – jacket (own study).

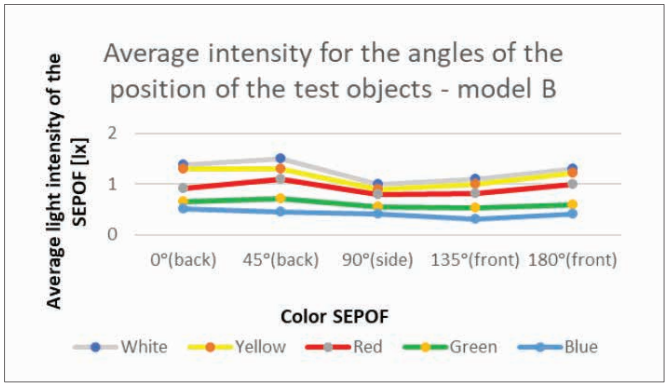

Figure 9. Average illuminance of SEPOF for test object location angles – model B – pants (own study).

Summing up the results of research on the visibility of set of transformable warning clothing for children with active sources (Figures 11–13), it can be stated that they show very positive

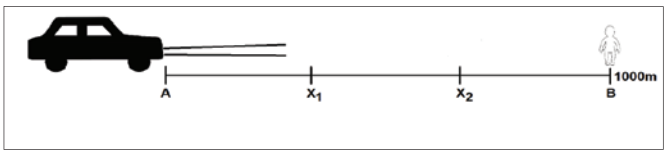

Figure 10. Diagram of test stand for measuring the object visibility (own study).

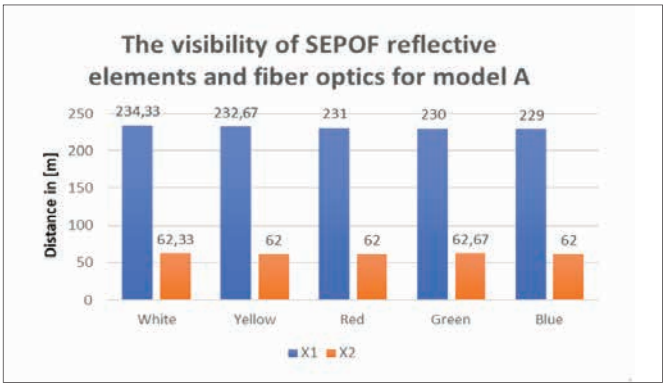

Figure 11. Dependence of visibility of reflective elements and SEPOF for model A – the clothing set (own study).

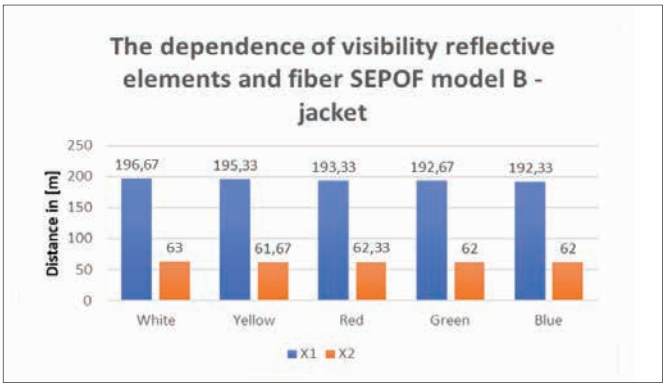

Figure 12. Dependence of visibility of reflective elements and SEPOF for model B – jacket (own study).

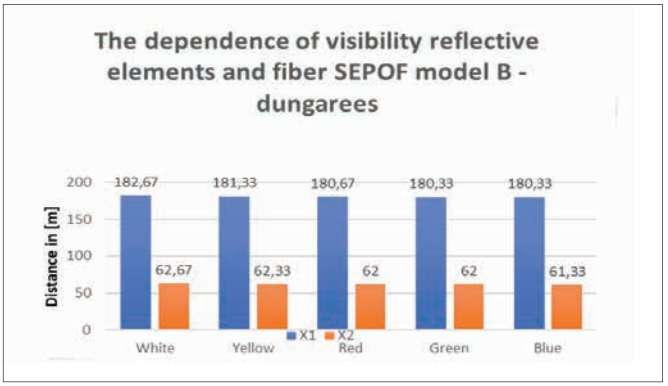

Figure 13. Dependence of visibility of reflective elements and SEPOF applied in the warning clothing for children – model B – dungarees (own study).

effects. The road traffic participant in the clothing product with mounted SEPOF was quickly noticed by the vehicle driver. At the distance of 1 km, the driver has been already informed by the light point that there was a certain object on the road. It should be noted and approaching more and more, its visibility increases. It is also worth noting that regardless of SEPOF installation (A and B) model, this point was almost the same for the observer; however, it paid a special attention to the red coating. In the case of SEPOF's textile coating, its impact

was noticeable. The white color gave the best visibility, and the smallest visibility was noticed for the blue color of coating. The tests carried out for clothes with SEPOF system in the maximum version (model A) allow improving the visibility by almost 200 m, in relation to the clothing without optical fibers, that is, approx. 400% compared to the version without optical fibers. The minimum version (model B) increases the visibility of about 120 m, which is about 300% in relation to the clothing without optical fibers (Figures 11–13).

4.3. Test of vehicle driver reaction

The visibility test of child dummy in the road traffic, which was dressed in the transformable warning clothing with mounted SEPOF optical fiber systems, was carried out in a place that allowed uninterrupted observation of test objects. Therefore, it was also assumed that measurements of visibility would take place at night at about 9 p.m. on one of the city's highways, which was illuminated by constant light sources. At that time, there was also no fog or any other precipitation that could affect the visibility measurement process and the test results obtained.

Before the research process, the SEPOF power sources were charged. The measurements of the visibility of the road test object dressed in the set of transformable warning clothing with mounted SEPOF optical fibers were taken at a temperature of about 15°C and the relative air humidity of 70%. The child mannequin was dressed in the transformable set of warning clothing equipped with active white light sources. Then to stabilize the light for 3 min, all SEPOF optical fibers fixed in the tested product were switched on in the continuous light mode at the maximum nominal power. The test object was set at one of the turns, and the reaction of drivers of vehicles that left the previous turn was observed. The observations were made on a sample of 20 randomly selected vehicle drivers, who were unaware of research going on. The observation process was conducted by three persons, one of which supervised the settings of test object and the other two observed and recorded the reactions of drivers.

4.4. Analysis of reaction of vehicle drivers

Observations of vehicle drivers' reactions were made for the child dummy wearing the transformable warning clothing for the maximum version of model A, in which the white SEPOF fiber optic at system was installed. The analysis of the aforementioned results of observational measurements indicates that drivers noticing the dummy dressed in the warning clothing with mounted SEPOF, reduce the speed of the vehicle, and additionally, one of the drivers stopped. Of the twenty cars observed, only for three of them we did not notice any reaction. The results are presented in Figure 14.

It can be seen in the aforementioned chart that 80% of motor vehicle drivers under the influence of observed test object showed perceptiveness and caution by reducing its speed. However, one driver, who accounts for 5% of respondents,

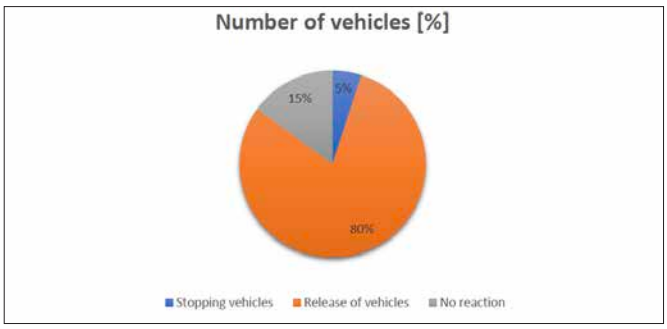

Figure 14. Drivers' reaction to the warning clothing with used SEPOF in the white cover in the maximum version – model A (own study).

stopped, because, as he said himself, the object interested him and thought that in the place of the "glowing object" the police is waiting. Unfortunately, three persons driving the vehicles did not react in any way to the "luminous object."

Summing up the conducted research, which took place in real conditions, it was noted that the use of active light sources in the form of SEPOF systems in the warning clothing increases the safety of road participants. It acts as a stimulus on the driver in such a way that he notices the existing danger signaling the object, which directly triggers the braking reaction of vehicle.

5. Transformation of children's warning clothing versus child's visibility

The arrangement of these is important, when designing the transformable warning clothing for children with integrated active light sources in the form of SEPOF. Due to the specificity of this type of clothing products, they must create specific systems that will not limit the appropriate lighting of transformable product and thus guarantee the full safety to the road participant. Therefore, the set of transformable clothing, which was the subject of research in this article in the aspect of visibility, was equipped with SEPOF in such a way that, as a result of various transformation options, it fulfills its specific functions, i.e., guarantees the safety of use.

In the transformable children's jacket, which can be transformed into a vest or a coat, fiber optics are mounted on the front and back in two versions. The first version, which applies to the model A, fiber optics are located from the back center, then around the underarm cut, and cross at the side to the front. Figure 15 presents various clothing products that were created as a result of the transformation of children's jackets, which shows the mounted SEPOF fiber optic system in the operating mode. In addition, a large role in the transformable children's jacket is also played by the hood, which can act like a sailor's collar or bag (purse).

The second version of the optical fiber distribution concerns the jacket in the model B, where the distribution of SEPOF system is parallel to the waistline along the sewn in belt of fluorescent material, which lighting is not disturbed in any way as a result of various transformation methods, as illustrated in the figure (Figure 15).

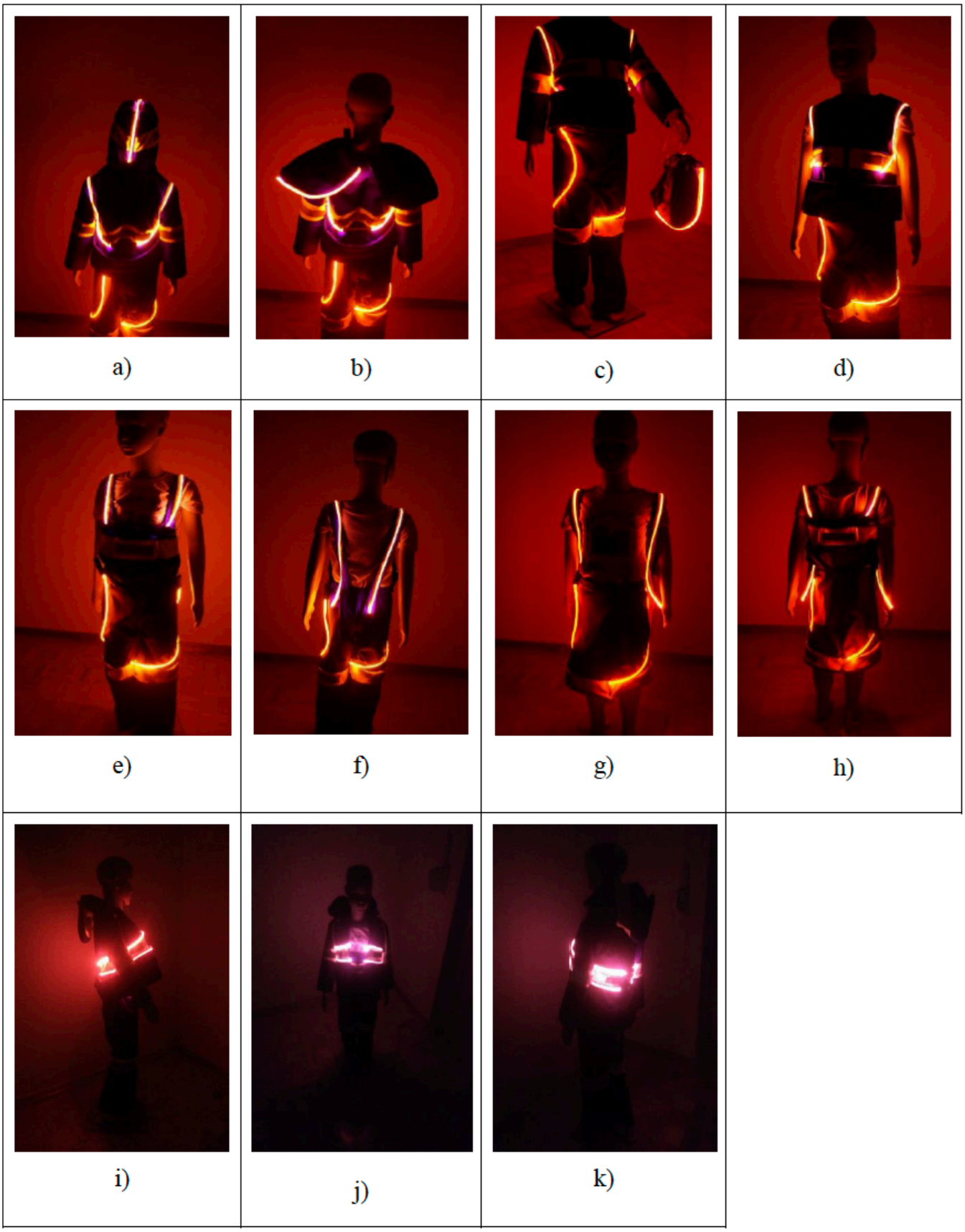

Figure 15. Arrangement of SEPOF optical fibers in the set of transformable warning clothing for children, (a) SEPOF optical fibers in the set of clothing in the rear view, (b) hood with SEPOF transformed into a collar, (c) hood with SEPOF transformed into a bag, (d) transformed SEPOF jacket for a vest, (e) SEPOF in trouser, (f) SEPOF in cotton braces, (g) trousers made of SEPOF transformed into a dress, (h) buffets made of SEPOF transformed into a backpack, (i) SEPOF transformed in a jacket, (j) a jacket made of SEPOF transformed into a coat, and (k) SEPOF in a transformable mantle (own study).

The transformation process can also be subjected to dungarees, resulting in short pants, a dress, a skirt, and shorts. These optical fibers have been installed in two variants. The first (model A) is located on the knee line and then on the sideline to the waistline. In the second variant (model B), the placement of SEPOF is on a harness from a buff, which thanks to the appropriate transformations, and can act as a backpack (Figure 15).

Transformations of transformable clothing have been shown to support the hypothesis that the inclusion of optical fibers does not limit the transformability of clothing products.

6. Conclusions

Conducted research analysis illustrates the effect of active light sources in the form of SEPOF, applied in the transformable set of warning clothing for children for their road safety.

This can be justified by concluding the conducted tests:

1. Laboratory tests of lighting intensity of SEPOF in different colours of textile coating allow noticing that the transformable warning clothing is of great importance in the aspect of ensuring the child's safety in the traffic. At the same time, it was noticed that the best illumination effects were obtained for SEPOF optical fibers in the white textile cover, and the lowest illumination – for the blue color of cover. On the other hand, utility research showed that although there are differences in the illuminance depending on the color, it does not matter, because the SEPOF optical fibers signal to the driver the participation of pedestrians in the road traffic from a distance at least 250 m.

2. The proposed methodology for testing the visibility has shown that SEPOF installed in the transformable warning clothing provide the traffic participant with much greater safety compared to reflective elements. Visibility tests for clothing with applied SEPOF optical fibers in the maximum version show that the visibility is about 200 m higher than for clothing with reflectors only. With the minimum version (model B), the visibility increases by approx. 130 m compared to the warning clothing without SEPOF fibers.

3. Research conducted in real conditions regarding the reaction of vehicle drivers in the field of visibility of transformable warning clothing with applied SEPOF optical fibers allows to state that it increases the safety of users in the road traffic. It was observed that the active light sources used in clothing products have an impact as a stimulus for drivers, directly causing a braking reaction of the vehicle.

4. The arrangement of SEPOF optical fiber systems in the transformable warning clothing does not eliminate the possibility of transforming the product into another.

The presented model of warning transformed clothing for children with the SEPOF system is an example of solving the problem of ensuring the best possible safety in road traffic for children.

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