

THERMAL INSULATION FOR APPAREL

FIELD

This invention relates to thermal insulation for apparel worn in low temperature environments.

5 BACKGROUND

Apparel worn by persons in low temperature environments to reduce heat loss from the person to the environment typically comprises three layers: an inner lining worn against the skin or another layer of clothing, an outer layer typically referred to as the shell, and a thermal insulation layer provided between the lining and the shell. The layer of thermal insulation
10 serves to reduce heat loss from the person via irradiation, thermal conductivity and convection.

Reduction of convection heat loss may be realized by creating air traps and minimizing pore size in the thermal insulating layer and also making the thermal insulation layer denser. While it is possible to reduce heat loss by convection almost to zero, comfort to the wearer will be
15 compromised as the apparel will be not breathable.

Reduction of irradiation heat loss is important as a major part of heat from the human body is lost by this channel. All irradiated heat passing through a barrier is divided into three parts: reflected, absorbed and transmitted. Application of heat absorption materials in thermal
20 insulating apparel is a known approach to reduce heat loss by trapping heat in the garment. For example, different nanoparticles of zinc, aluminium or stainless steel have been known to be added in small proportions (e.g. 0.05-0.1%) for heat absorption. Laminated fabrics with functions of accumulating heat and preserving heat are also known. Carbon micro powder is a popular additive to make fibers/fabric heat accumulating. However, while heat absorption
25 certainly improves thermal insulation, the absorbed heat will still be transmitted through the clothing layers or simply dissipated. Moreover, added particles in insulating fibers quite often increase thermal conductivity of such fibers, and as a result the absorbed heat is being lost via conduction instead. Heat reflection is another perspective for development of advanced thermal insulating materials. Different methods of heat reflection have been known for use in
30 thermal insulation of apparel, such as incorporating glass microbeads or providing metallic dots or net to reflect infrared radiation. However, such methods would naturally increase the cost of the garment.

Thus, while existing thermal insulating apparel are able to sufficiently reduce heat loss from

their wearers, there is still a demand for reduced garment cost and bulk while retaining or improving thermal insulation of such apparel.

SUMMARY

5 According to a first aspect, there is provided a thermal insulation for apparel worn in a low temperature environment; the thermal insulation comprising a non-woven composite comprising a mixture of polyoxadiazole fibres and polyester fibres, the non-woven composite reducing heat loss from a wearer of the apparel to the low temperature environment.

10 Weight percentage of the polyoxadiazole fibres may range from 1% to 50%.

Weight percentage of the polyoxadiazole fibres may range from 2% to 20%.

Linear density of the polyoxadiazole fibres may range from 1 denier to 60 denier.

15 Length of each of the polyoxadiazole fibres may range from 20 mm to 100 mm.

Specific density of the non-woven composite may range from 40 g/m² to 300 g/m².

20 The non-woven composite may further comprise fibres of at least one of: polyethylene fibres, polypropylene fibres, biocomponent fibres and natural fibres.

According to a second aspect, there is provided apparel to reduce heat loss from a wearer of the apparel to a low temperature environment, the apparel comprising the thermal insulation of
25 the first aspect.

BRIEF DESCRIPTION OF FIGURES

In order that the invention may be fully understood and readily put into practical effect there shall now be described by way of non-limitative example only exemplary embodiments of the
30 present invention, the description being with reference to the accompanying illustrative drawings.

Fig. 1 is a graph of reflection of polyoxadiazole, cotton-glass and polyester.

Fig. 2 is a graph of absorbance of polyoxadiazole, cotton-glass and polyester.

Fig. 3 is a graph of transmittance of polyoxadiazole, cotton-glass and polyester.

35 Fig. 4 is a graph of temperature of non-woven polyester fabric and non-woven composite fabric comprising polyester and polyoxadiazole during irradiation and cooling.

DETAILED DESCRIPTION

Exemplary embodiments of a thermal insulation for apparel worn in low temperature environments will be described below with reference to Figs. 1 to 4. By low temperature environments, it will be understood that the environment is at a temperature lower than 22°C,
5 more likely lower than 15°C.

In the present application, the thermal insulation for apparel worn to reduce heat lost from a wearer of the apparel to a low temperature environment comprises a non-woven composite. The composite comprises a mixture of polyoxadiazole fibres and polyester fibres.
10 Polyoxadiazole reflects light in a wide range of spectra, almost twice exceeding the reflective capability of polyester and also exceeding the reflection of special reflecting fabrics such as cotton-glass (e.g. containing 30% glass), as shown in Fig. 1. Polyoxadiazole also absorbs electromagnetic waves in the UV and visual spectra, as well as in the infrared wavelength at a better absorption compared to polyester or cotton-glass fibres, as shown in Fig. 2.
15 Transmittance of polyoxadiazole is lower compared to both cotton-glass and polyester, as can be seen in Fig. 3.

By integrating the surfaces under each curve shown in Figs. 1, 2 and 3 and expressing these values (in the range 250nm to 2500 nm) normalized to polyester, it can be seen that
20 polyoxadiazole works like a heat cage and heat mirror at the same time, as shown in Table 1 below.

Material	Reflection	Absorption	Transmittance
100% polyoxadiazole fabric	1.5	5.2	0.2
cotton-glass fabric	1.6	1.8	0.6
100% polyester fabric	1	1	1

Table 1

25 The non-woven composite thermal insulation comprising a mixture of polyester fibres and polyoxadiazole fibres (and any other fibres as may be desired, such as polypropylene, polyethylene, natural fibres, biocomponent fibres) may be prepared by first mixing the desired amounts of each type of fibre to form a web of the mixture of fibres, using known methods in existing dry-lay or wet-lay processes to form non-woven materials. The polyoxadiazole fibres
30 are preferably provided as staple fibres of length ranging from 20 mm to 100 mm and having linear density ranging from 1 denier to 60 denier.

After formation, the web is bonded by known methods such as passing the web through conventional glue spraying machines or needle punching machines and so on, depending on which equipment is desired to be used to bond the web. Where biocomponent fibres are added to the non-woven composite in addition to the polyester and polyoxadiazole, after formation of the web, the web may be heated in an oven for thermal bonding of the fibres to take place if necessary.

Samples of the non-woven composite formed with different weight percentages of polyoxadiazole were prepared and their clothing insulation (clo) values determined, where $1 \text{ clo} = 0.155 \text{ K} \cdot \text{m}^2 \cdot \text{W}^{-1} = 0.88 \text{ R}$ (where R means $\text{ft}^2 \cdot ^\circ\text{F} \cdot \text{hr} / \text{Btu}$, R being a measure of thermal resistance or ability of heat to transfer from hot to cold through a material such as a layer of insulation). The higher the R or clo value of a material, the more the material can prevent heat transfer, i.e. better insulation. The polyester fibres used to prepare the samples had linear density of 1.5 denier and 38 mm cut length. As controls, a sample non-woven fabric of 100% polyester and a sample non-woven fabric of 100% polyoxadiazole were also prepared and their clo values determined. Table 2 below gives the clo value of the non-woven fabric samples that were all prepared to have a specific density of 100 g/m^2 .

Amount of polyoxadiazole fibres, % wt in non-woven fabric (any remainder being polyester)	clo
0	2.06
2.5	2.44
5.0	2.52
7.5	2.60
10	2.65
20	2.67
50	2.81
100	3.06

20

Table 2

During industrial formation of the non-woven composite, it is noted that adding less than 2% by weight of polyoxadiazole fibres may give rise to problems with homogenous distribution of the added polyoxadiazole fibres among the polyester fibres. Thus, it is preferably that the

amount of polyoxadiazole fibres in the non-woven composite should be greater than 2% by weight.

From Table 2 above, it can be seen that adding 2.5 % by weight of polyoxadiazole fibres to the non-woven fabric compared to using only 100% polyester fibres resulted in an increase in the clo or insulating property of the thermal insulation by 18.4%. Therefore, it can be concluded that thermal insulation can be improved by mixing polyoxadiazole fibres with polyester in the thermal insulation material. For example, when compared with a non-woven material made of 100% polyester with specific density of 100 g/m² and having clothing insulation (clo) measured by standard ASTM D1518-14 to be in the range 1.8-2.1, addition of only 5% of polyoxadiazole fibres to the non-woven polyester allows the clo values to reach as high as 2.1-2.5. In this example, improvement in thermal insulation is obtained with an increase in cost of the thermal insulation since polyoxadiazole fibres cost significantly more than pure polyester fibres.

Alternatively, use of polyoxadiazole fibres in a non-woven composite with polyester can be applied to decrease weight and thickness of the thermal insulation in apparel without increasing cost, since, as a rule, weight of the non-woven composite can be reduced by 20% while retaining the same thermal insulation value by adding 2% to 7% of polyoxadiazole fibres in the non-woven composite. In this example, the increased cost of the polyoxadiazole fibres is offset by the total overall reduced amount of fibres (e.g. by 20%) needed to achieve the same clo value.

Adding a small quantity of polyoxadiazole fibres to non-woven polyester thermal insulation resulted in fast heating thermal insulation similar to that of carbon fibres, as verified by irradiating non-woven 100% polyester fabric and a non-woven composite comprising a mixture of polyester and polyoxadiazole fibres (95% polyester and 5% polyoxadiazole) with a lamp for 20 minutes followed by observation for another 20 minutes after switching off the lamp. As can be seen in the resulting temperature curves in Fig. 4, adding 5% by weight of polyoxadiazole to the non-woven composite saw a faster increase in temperature of the composite during irradiation compared to non-woven 100% polyester. A possible explanation for this may be that polyoxadiazole has a higher specific heat capacity than polyester at room temperature (1.42 J/(g×C) for polyoxadiazole compared to 1.10 J/(g×C) for polyester), and it can be also seen that in addition to good spectroscopic properties, polyoxadiazole is also

efficient as a heat accumulator. In addition, it can be seen that after switching off the lamp, the non-woven composite comprising polyoxadiazole fibres cooled down more slowly compared to pure polyester. Furthermore, as polyoxadiazole has a significantly lower thermal conductivity than carbon based fibres that are often used for fast-heating non-woven insulation, polyoxadiazole fibres cool down more slowly than carbon or other types of fibres that have higher thermal conductivity than polyoxadiazole, so that captured heat cannot escape from polyoxadiazole as quickly.

From the above, it can be seen that adding even a small amount (e.g. 2.5%) of polyoxadiazole fibres improve thermal insulating property of the non-woven composite thermal insulation for apparel. Adding higher amounts of polyoxadiazole fibres results in an increase in the insulation value of the thermal insulation. This feature can be used to increase thermal insulation of apparel with increase in price due to corresponding increase in the amount of polyoxadiazole fibres in the thermal insulation, or it can be used to reduce weight and bulk of the apparel without reducing thermal insulation of the apparel by incorporating polyoxadiazole to reduce the total amount of fibres in the thermal insulation.

Whilst there has been described in the foregoing description exemplary embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations and combination in details of design, construction and/or operation may be made without departing from the present invention. For example, while it has been mentioned that at least 2% by weight of added polyoxadiazole is preferred, the weight percentage of the polyoxadiazole fibres in the non-woven composite thermal insulation may range from 1% to 50%, or from 2% to 20%. While samples of the non-woven composite thermal insulation having specific density of 100 g/m² were prepared and studied for their clo values, the specific density of the non-woven composite thermal insulation for apparel may in fact be prepared to range from 40 g/m² to 300 g/m².

CLAIMS

1. A thermal insulation for apparel worn in a low temperature environment; the thermal insulation comprising a non-woven composite comprising a mixture of polyoxadiazole fibres and polyester fibres, the non-woven composite reducing heat loss from a wearer of the apparel to the low temperature environment.
2. The thermal insulation of claim 1, wherein weight percentage of the polyoxadiazole fibres ranges from 1% to 50%.
3. The thermal insulation of claim 1, wherein weight percentage of the polyoxadiazole fibres ranges from 2% to 20%.
4. The thermal insulation of any one of the preceding claims, wherein linear density of the polyoxadiazole fibres ranges from 1 denier to 60 denier.
5. The thermal insulation of any one of the preceding claims, wherein length of each of the polyoxadiazole fibres ranges from 20 mm to 100 mm.
6. The thermal insulation of any one of the preceding claims, wherein specific density of the non-woven composite ranges from 40 g/m² to 300 g/m².
7. The thermal insulation of any one of the preceding claims, wherein the non-woven composite further comprises fibres of at least one of: polyethylene fibres, polypropylene fibres, biocomponent fibres and natural fibres.
8. Apparel to reduce heat loss from a wearer of the apparel to a low temperature environment, the apparel comprising the thermal insulation of any one of claims 1 to 7.