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New Textile Concepts for Use in Control of Body Environments

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Summary

Double layer, or three dimensional, textile constructions have been manufactured for some years by Heathcoat in the form of spacer fabrics based on a warp knitted construction and also woven double layer products used in the civil engineering industry. The upper and lower layers of such products are interconnected with common threads during the manufacturing process.

In this paper, I hope to convey the new functional products that are becoming available in double layer constructions from the John Heathcoat textile company.

The R&D Department at Heathcoat have developed a series of novel composite fabrics based on double layer substrates, categorised for discussion as follows:

Woven:
1. Coated – no spring support
2. Coated with spring support

Warp and Weft Knitted:
3. Spring support, no coating
4. Spring support, coated both faces.

A specific design is chosen for weaving the following Category 1 fabric so that the single and double layer sections are formed in alternating rows. A specially controlled application of an impervious coating is then bonded to one face, as shown in Figure 1.

If the cavities formed by the double layer sections are sealed at one end and air is blown into the open ends, the selected porosity of the non-coated face will allow inflation which forms a series of cylindrical cavities; air will then issue from the whole area of the porous face of the cavities. An application of this concept has been developed with MAFF funding, and demonstrated to be very effective, for the localised cooling of food on conveyer lines. In addition to maintaining the chilled state of the food, bacterial challenge studies found virtually no contamination of the area from a high concentration of introduced bacteria.

A major benefit of this system is that it allows the operative to work in ambient temperature conditions since there is not a need for the current practice of chilling the whole room.

Other areas of application are being pursued where localised control of temperature and bacterial contamination are of interest.

The limiting characteristic of this category product however is that, in applications where the localised air delivery product is likely to encounter points of external pressure to the surface or sharp bending of the fabric, the inflated cavities will collapse at those points and restrict or prevent air-flow along them. To overcome this, helically coiled plastic springs are inserted into the double layer cavities.
A range of springs, made from Delrin acetyl resin, have been investigated with the help of DuPont polymers and Figure 2 shows just a few of the profiles produced. Typical diameters are 5 to 10 mm.

The modified properties of the composite, imparted by the springs, are unique and open up new functionalities for garments and footwear.

Category 2 consists of double layer woven fabric with an impervious coating on one face as before but now with the plastic springs inserted into the cylindrical cavities.

If air is supplied, through a manifold, into the ends of the cavities it will issue from the whole of the porous face of the composite, see Figure 3.

This concept is being developed by the Defence Logistics Organisation in the UK, who have funding from the MOD for optimising the design of a microclimate garment. This will incorporate work by TNO in the Netherlands, who will continue the human factor studies in their environmental chamber trials, and composite optimisation by Heathcoat. Such a forced air system would allow natural cooling of the body through latent heat of evaporation of sweat and Hohenstein skin model studies will also be made by DLO.

The use of coiled plastic springs, as opposed to perforated plastic tubes for instance, maintains the essential textile characteristics in the product of flexibility, stretch and drape whilst showing, with the springs used so far, a crush resistance of greater than 20 tons per square meter. This means that a person can lie, sit or stand on the product without collapse of the air-carrying cavities. Garments containing such panels are durable to being washed in a domestic washing machine.

Figure 4 shows the first demonstrator vest trials by TNO, in conjunction with past studies done by Defence Clothing and Textiles Agency on air-cooling garments, have shown that this composite structure fabric is the way to proceed for a practical microclimate system which can be worn by the dismounted infantryman.

Re-design of a number of features is planned. For instance the re-chargeable power pack, which currently weighs a reasonable 800g, could be significantly lighter in weight with the same power output if the most modern battery systems are used. The portable system would last for eight hours in the field before any re-charging of the power pack at the vehicle is needed.

The air delivery manifold system from the lightweight plastic pump and filter unit will be condensed into the garment probably as a spring supported fabric tube and, if necessary, replaceable silica gel sachets will allow dry air to be supplied over the skin in conditions of high ambient humidity. No problems are expected with air filtration situations since the rate of air exchange demanded by this system is relatively low.

The initials trials by TNO have demonstrated the need for improvement in ease of escape of the delivered air from the skin surface and this is expected to be achieved by cutting away sections of the coated layer in the fabric; this would leave alternating air delivery sections and air escape sections. Such an arrangement would also allow the microclimate garment to be worn without extra heat stress if the portable air pump system fails. See Figure 5.

Figure 6 shows Category 3 composites that consist of open mesh warp knitted double layer fabrics without an impervious coating but with springs inserted. This creates a very light-weight separator product with very high crush resistance for environments where an air gap has to be maintained even when high external pressure might be encountered. This type is under development for aesthetically acceptable impact protection pads.

Category 4 development (see Figure 7) incorporates the Category 3 product shown on the previous slide. Gas impermeable membrane such as butyl rubber, is bonded to both faces and sealed round the edges except for a one way valve. Air is withdrawn from the whole enclosed cavity layer to create a high vacuum. Total vacuum is easily possible without the springs collapsing and since the material volume content in the cavity is less than 5%, there is more than 95% vacuum space. With the presence of an
aluminised outer surface for reflecting heat, the opportunity for heat penetration through the composite is minimised.

The product offers a unique, very flexible, wrap round vacuum layer for heat and sound insulation and has potential application in preventing heat loss or heat gain in blanket or garment type products.

Further concepts covered by this series of patents involve effects from rotating the springs in the fabric cavities in two different modes. Textile fabric constructions are possible whereby very open surface cover sections alternate in the double layer cylindrical cavities with more solid cover areas. If the springs are designed to coordinate in their shape with this arrangement of the fabric, rotation of the springs in a non-screw manner will open and close the windows in the fabric, shown in Figure 8. If the rotation of the springs is controlled by temperature sensors, an intelligent fabric will result which has a variable climate and would react to prevailing climatic conditions.

An intelligent chameleon effect can also be produced using springs which have stripes of three different colours around their circumference. Rotation of the springs in a screw fashion will present a new colour impression to the windows with each one third revolution of the springs in the fabric.

Other novel functionalities with these constructions are in skin surface, or other surface, vacuum effect and also for fluid drainage from the body.

These concepts are covered by the following Heathcoat patents:

- Gas Delivery Device: EU App. No. 97308535.0
- Fabric with Helical Support: EU App. No. 99309484.6
- Adaptive Material: EU App. No. 00301728.2

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- Peter Deane: DuPont Engineering Polymers - Springs Development
- Richard Allen & Stuart Elton: DLO Caversfield - Microclimate Garment Development
- Dr. Emiel den Hartog & Peter Reffeltrath: TNO, The Netherlands - Microclimate Garment Testing
- Claude Maat: Bobet, Rouen, France - Specialist Coating
FIGURE 1

CATEGORY 1: WOVEN - COATED
NO SPRINGS SUPPORT

Air inflates the tubes and issues from the whole porous face

FIGURE 2

SELECTION OF SPRINGS

8 mm
FIGURE 3
CATEGORY 2: WOVEN - COATED SPRINGS SUPPORT

Fresh air is delivered to all areas of skin covered

ISSUING AIR FLOW

AIR IN

The spirals maintain air flow by preventing crushing of the cavities

The material is totally flexible

COATING

FIGURE 4
MICROCLIMATE VEST

PORTABLE PUMP AND BATTERY
FIGURE 5  CATEGORY 2 WITH SOME COATED SECTIONS CUT AWAY

FIGURE 6  CATEGORY 3: KNITTED WITH SPRINGS NO COATING
CRUSH RESISTANT

95% AIR SPACE
CATEGORY 4: VACUUM LAYER EFFECT
IMPERVIOUS BUTYL COATING ON BOTH FACES

REFLECTIVE FACE
HOT
COLD
EVACUATED AND SEALED

FIGURE 7

VARIABLE CLIMATE FABRIC
SEQUENCE OF ROTATION OF SPRINGS

WINDOWS OPEN → WINDOWS CLOSED

FIGURE 8