Functionality and wearing comfort

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Two important factors for cleanroom compatible undergarments

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The so-called cleanroom compatible undergarments have become increasingly important in recent years. Various studies have shown that both particulate and microbiological contaminations emanating from humans can be significantly reduced by suitable undergarments (often also called underwear). However, a lack of employee acceptance was many a time an obstacle to the introduction of this garment component.

The following explanations show that it is perfectly feasible to combine wearing comfort and cleanroom technical functions in one garment system.

Cleanroom suitable undergarments (often consisting of trousers and T-shirt) are ideally made of purely synthetic fibres to ensure the highest possible abrasion resistance. In order to keep particle and fibre emission as low as possible in daily use, the undergarments should also be properly cleaned (and replaced after a defined period of time). During the washing process, whether carried out internally or by an external service provider, it is important to ensure that no other garments and/or a wrong washing procedure, contaminate the cleanroom compatible undergarments excessively (= cross-contamination)

From the wearer's point of view, however, wearing comfort is usually the focus of his/her decision criteria. Perception of perspiration, touch/haptics (softness of the material), odour nuisance are important aspects, which decisively influence the acceptance of a cleanroom garment concept by the employees. The question that therefore inevitably arises is: Can both „things" – functionality AND wearing comfort – be reconciled?

Wearing comfort

Most of the known studies on the topic of „Wearing comfort and cleanroom garments" were primarily limited to the analysis of textiles for the production of cleanroom garments and here mainly on the topics of water-vapour permeability (= breathability) and thermal conductivity. Only Dr. G. Roos, in his then function as medical officer at Siemens (plant Regensburg) at the time, had the combination of undergarments plus cleanroom garments tested for wear physiological properties more than 25 years ago. With the results of these studies, he subsequently decisively determined the corresponding garment concept. A similar approach was taken up again by Dastex and commissioned a corresponding study by the Hohenstein Institutes. For the various test series, an unitary cleanroom garments, a cleanroom fabric with very good properties in terms of water-vapour permeability and thermal conductivity as well as high filtration efficiency was used.

Among them, three different materials for the production of undergarments were extensively studied and evaluated with regard to their wearing comfort properties.

The materials

The following combinations were studied:

PES blended fabric, combination 1 (Fig. 1)
outside: garments made of a fabric of 98% polyester and 2% carbon, mass per unit area (weight) approx. 113 g/m^2
inside: undergarments made of a fabric of 100% polyester, very light and soft (silk-like), mass per unit area approx. 95 g/m^2

PES blended knitted fabric, combination 2 (Fig. 2)
outside: garments made of a fabric of 98% polyester and 2% carbon, mass per unit area approx. 113 g/m^2
inside: undergarments made of a special knitted fabric of 100% polyester, with silver ions and functional fibres, very soft, mass per unit area approx. 140 g/m^2

PES blended fabric – 100% cotton, combination 3 (Fig. 3)
outside: garments made of a fabric of 98% polyester and 2% carbon, mass per unit area approx. 113 g/m^2
inside: undergarments made of a typical simple cotton knitted fabric, mass per unit area approx. 140 g/m^2

Main areas of analysis

In order to calculate a so-called wearing comfort rating, various properties were studied in detail on these combinations.

- **Measurement of the water-vapour resistance**
- **Measurement of the short-term water-vapour absorption capacity**
- **Measurement of the buffer effect against liquid sweat and the transport of sweat**
- **Measurement of the wetting index**
- **Measurement of the buffer effect on water (only for combinations 2 and 3)**
- **Calculation of a thermo-physiological wearing comfort rating (also only for combinations 2 and 3)**

In order to exclude the influence of any textile finish, all samples were washed 10 times in advance in accordance with the material. In the course of the test series, it quickly became apparent that each of the combinations had strengths and weaknesses in individual criteria. Thus it was clear that there will be no combination that will be fundamentally superior to the others. Rather, the aim was to find out which of the three combinations could show the „most balanced overall performance" across all evaluation criteria.

- **Measurement of the water-vapour resistance**

In terms of garment physiology, the lowest possible water-vapour resistance is recommended. In comparison, combination 1 showed clearly better results than combinations 2 and 3 (2 and 3 were classified as „equal" within the measuring accuracy).

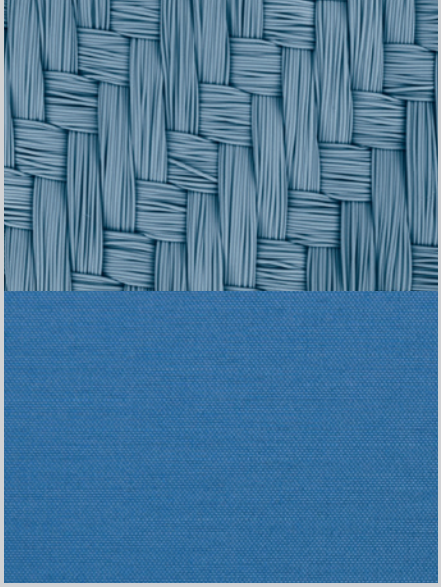

Fig. 1: Combination 1
above: polyester/carbon fabric
below: pure polyester fabric

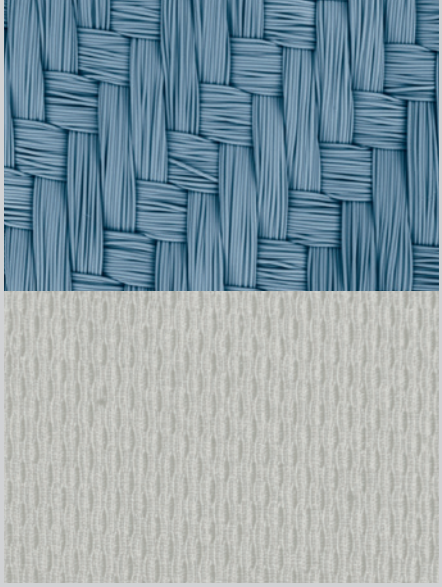

Fig. 2: Combination 2
above: polyester/carbon fabric
below: pure polyester knitted fabric

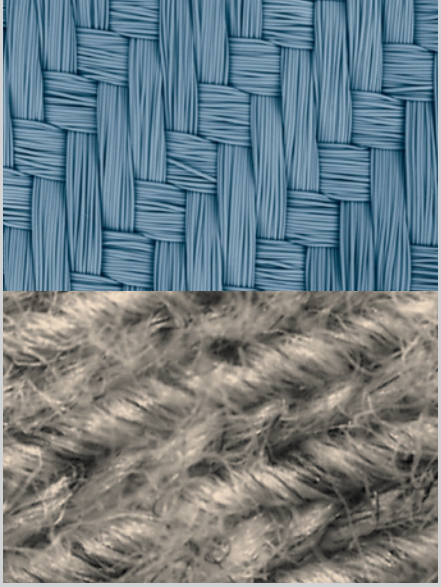

Fig. 3: Combination 3
above: polyester/carbon fabric
below: cotton

Measurement of the short-term water-vapour absorption capacity

In the interest of wearing comfort, the short-term water-vapour absorption capacity should be as high as possible. In this point, combination 3 clearly scored better than the other two. No absorption capacity could be measured for combination 1.

Measurement of the buffering effect on liquid sweat and sweat transport

The different textile structures and the differing thickness of the 3 materials (undergarments) also had quite different effects on the measurements of sweat transport and the buffering effect against sweat. As far as sweat transport is concerned, combination 1 is „ahead of the pack", the assessment is „very good", for the combinations 2 and 3, however, the assessment is only „satisfying".
On the other hand, combinations 2 and 3 have the better values for the criterion buffering effect (compared with liquid sweat); „very good" for combinations 2 and 3 and „good" for combination 1.

Measurement of the wetting index

If perspiration occurs, it is important to transport sweat away from the skin as quickly as possible. Therefore the side of the textile facing the skin should be as hydrophilic as possible. The absorption rate / absorption index is a measure of this. The two combinations 2 and 3 were classified as being of equal quality in this respect (as „very hydrophilic"). Combination 1 was assessed as „hydrophilic" and scored only slightly worse than the other two combinations for this criterion.

Measurement of the buffer effect on water (only for combinations 2 and 3)

Since no buffer effect against water/water-vapour could be determined metrologically for combination 1, this ultimately had the consequence that the intended calculation of an overall wearing comfort rating for combination 1 was unfortunately no longer possible.

The water retention capacity of combination 2 was rated „good" from a wearing physiological point of view. In contrast, the result of combination 3 was considerably less favourable than that of combination 2.

Calculation of a thermo-physiological wearing comfort rating (also only for combinations 2 and 3)

A thermo-physiological wear comfort rating was then calculated from the characteristic data determined as described above. The combination 2 achieved a value of 3.3 (➡ „satisfying"). Combination 3 achieved a score of 4.0 (➡ „adequate"). When interpreting the results, however, it is important to note that 2-layer combinations were evaluated here! Two-layer polyester or 1-layer polyester plus 1-layer cotton. For example, the resistance values add up (which had a significant influence on the sum scores). From a wearing physiological point of view, combination 2, a microfibre knitted fabric made of 100% polyester in combination with a cleanroom fabric on top, proved to be significantly better than the cotton T-shirt often preferred by the wearer.

Results

From the wearer's point of view, it would certainly be desirable for the textiles used to make undergarments to offer thermoregulatory properties. Ideally, they should have cooling properties when the sensation of heat is too high and, if necessary, a thermal insulating function when it becomes too cool for the wearer. Such textiles are already successfully marketed in the field of functional sportswear. In the microfibre knitted fabric described above (and another knitted fabric which is about to be launched on the market), these thermoregulatory functional properties were integrated from the outset.

A further, certainly interesting aspect is the often criticised „odour nuisance" caused by undergarments based on pure synthetic fibres. Here, too, there are now solutions available which invalidate this reason for rejection. Functional fibres and / or special textile finishes which inhibit increased germ growth ensure that sweat odours are „fought" already in the textile. At the same time, studies at recognised textile research institutes have shown that these textiles have no negative effects on the human skin and have therefore been classified as harmless to humans.

In addition to the above wearing comfort considerations, cleanroom technical aspects must now be included in the comprehensive assessment. Cotton garments under cleanroom garments mean a large amount of abrasion of fibres and fibre fragments, which increase the risk that the process in the cleanroom (and thus the product) is contaminated accordingly. Various studies have shown, in part impressively, that the risk of contamination can be reduced by up to 70 – 80% in direct comparison with cotton-based undergarments. Similarly clear advantages for the synthetic undergarments were also shown by the studies with regard to microbiological contamination risks. From a cleanroom technical point of view, the undergarments based on purely synthetic fibres can therefore be favoured at any time.

Conclusion

From today's point of view, functionality and wearing comfort can be combined very well in the manufacturing of undergarments suitable for cleanrooms.
Abrasion resistance, thermo-regulating properties and an antimicrobial effect are all aspects that meet the requirements of the cleanroom operator in the best possible way, but also satisfy the legitimate wishes of the wearer for the best possible wearing comfort. In addition to the above-mentioned properties, the requirement for antistatic / dissipative properties can also be fulfilled if required.

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