Particle release

of cleanroom wipes in the dry state

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Presentation of a new test method and comparison with previous test methods

Working in a controlled environment is hardly conceivable without the daily use of cleanroom suitable wipes. For the routine cleaning processes of a wide variety of surfaces, for wiping clean objects, for picking up spills or applying disinfectants – wiping agents are needed everywhere, with which, if possible, no additional contaminants should be introduced into the process. The aforementioned possible applications make it clear that a wide variety of requirements are placed on wipes for cleanrooms. A comprehensive overview is provided by VDI 2083 Part 9.2. One of these basic requirements is abrasion resistance/particle release. To illustrate the importance of this criterion, a brief risk assessment is provided first (Fig. 1).

Example calculation on the subject of surface area

The typical wipes often used in cleanrooms have a base area of 9 x 9 inches (≈ 23 x 23 cm) ➜ approx. 0,053 m².

Assuming that 300 wipes are needed per day, this results in an area of approx. 15.9 m² per day, and extrapolated to a week (5 working days), an area of approx. 80 m².

With 220 working days per year, this results in a wipe area of approx. 3,500 m², or approx. 7,000 m², because the top and reverse sides have to be taken into account. 7,000 m² of surface area that is locked in the cleanroom and used there!

**The example calculation clearly shows the importance of choosing the right wipe and the knowledge of its particle release/abrasion resistance.
This inevitably leads to the following questions:**

1. **How low in contamination are the wipes when delivered and how much contamination do they release under stress in a dry state?**
2. **How high is the risk of contamination being transferred from the wipe or from the wipe to the surface to be cleaned?**

Fig. 1: Risk assessment – example calculation on the topic of area

The following explanations deal with the first question. With regard to the second question, a new type of test bench is currently under development, which, when completed, will open up the possibility of better risk assessment in relation to different surface conditions, in conjunction with the values already determined. The complexity of these issues is also shown by the different approaches and test methods that already exist.

In VDI 2083 Part 9.2, for the test criterion Particle release and particle abrasion, in Annex A5 Wipes, among other things, reference is made to the test method „Particle release and particle abrasion". Annex A5 refers, among other things, to the test load according to DIN EN ISO 9073-10 and the test procedure according to VDI 2083 Part 9.2. In Annex B4 Wipes, the biaxial shake method according to IEST-RP-CC004.3 (Sec. 6.1.3 Biaxial shake test / Sec. 6.2.1 Liquid particle counter) is also mentioned. In order to be able to consider the test methods with a view to their practical relevance, the application of cleanroom wipes is first considered more closely. Subsequently, the methods mentioned will be briefly examined.

Use of cleanroom wipes

A cleanroom wipe is removed from its packaging and then, at least according to the recommendation, used according to a specified folding and wiping technique (Fig. 2).

Fig. 2: Fold and wipe technique

Here the wipe is folded and unfolded several times and wiped over the surface to be cleaned. Using this technique, one wipe can be used to clean eight lanes, for example.

Test method according to IEST-RP-CC004.3 – Particle release in the wet state

A widely used test method for the determination of particulate emission is given in the Recommended Practice of the US-American Institute IEST, IEST-RP-CC004 (currently valid version: 4.4) „Evaluating Wiping Materials Used in Cleanrooms and Other Controlled Environments".

Here, a distinction is made between releasable particles that are already on the surface and generated particles that are released by mechanical energy. The higher the mechanical stress, the steeper the stress/strain curve raises. With the help

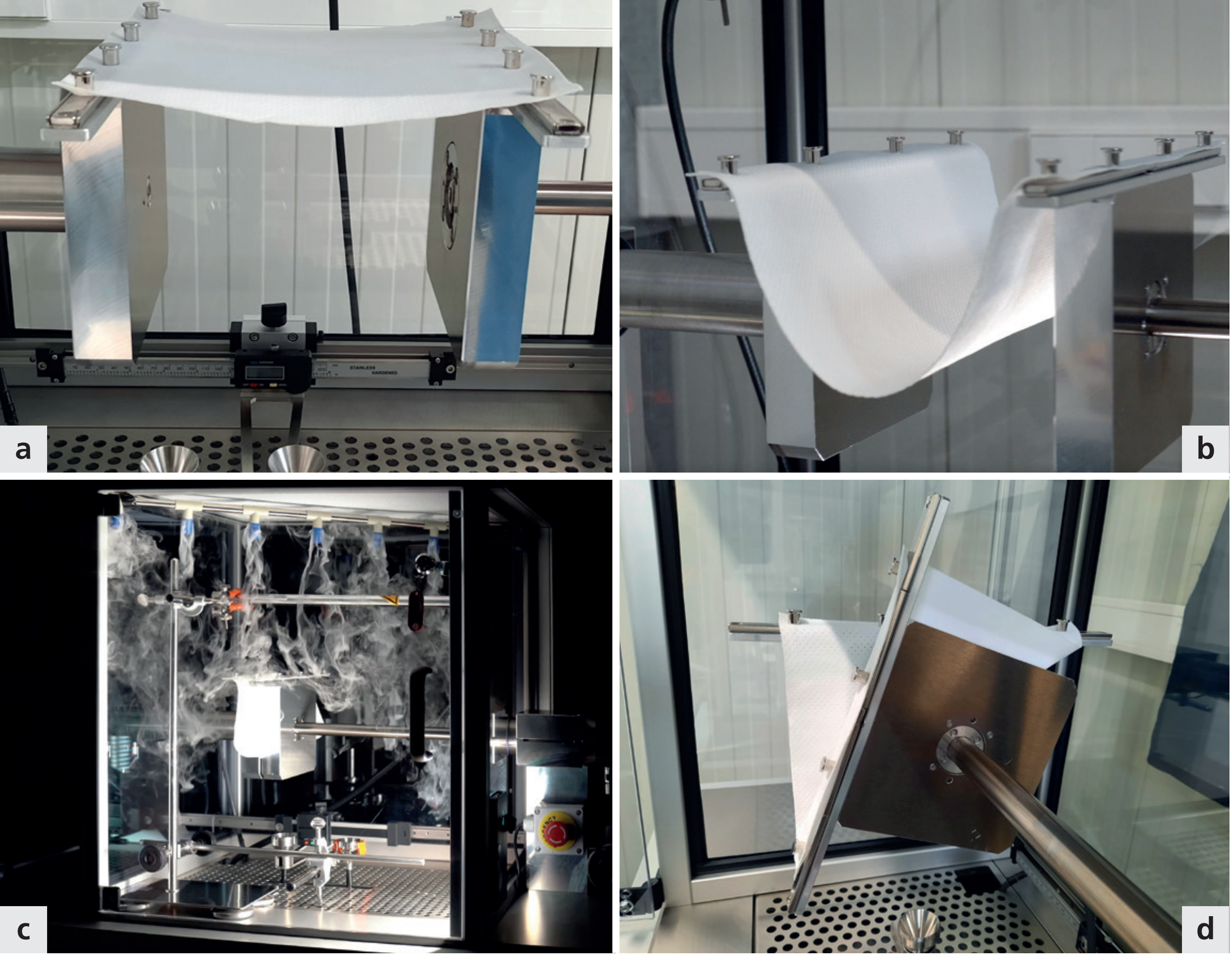


Fig. 3: a. Flat clamped cleanroom wipe in initial position; b. Folding movement; c. Flow visualisation and fully folded; d. Rotational movement

of the described tests, two points of the curve are determined. For this purpose, the wipe is placed in a test solution under cleanroom conditions and then shaken using an orbital shaker (Sec. 6.1.4) or biaxial shaker (Sec. 6.1.3). With the resulting force effect, the particles should be dissolved in the liquid.

The test liquid is then checked for particles. Technical data, which determined by means of test methods following the IEST-RP-CC004 recommendation, are not automatically comparable with each other. Different test solutions can be used, which influence the particle release through their respective properties. Also the use of different measuring devices is also described. The influencing variables mentioned therefore make it difficult to compare the results. Although the test procedure according to IEST-RP-CC004.3 Sec. 6.1.3 in connection with Sec. 6.2.1 is mentioned in VDI 2083 Part 9.2, i.e. the biaxial shake test and the evaluation by means of a Liquid Particle Counter, a closer look at the technical data does not show that the results are comparable.

However, a closer look at the technical data does not always recognise exactly which methods were used. Values determined by means of test methods according to IEST-RP-CC004 are several million particles (≥ 0.5 µm) per square metre.

In relation to the risk assessment carried out previously (Fig. 1) and the approx. 7,000 m^2 wipe surface in the cleanroom, it quickly becomes clear that there would be no cleanroom industry if this number of particles were actually released. On closer examination under the aspect of realistic measurement, it also becomes clear that a wipe in real, everyday use is not used in anything like the way it is shaken in a test solution in the test method. In conclusion, it can therefore be said that the recommended measurement method is not without controversy among experts. In our opinion, the measurement methodology is not in step with actual practice.

Test methods based on DIN EN ISO 9073-10 – Particle release in the dry state

The Gelbo-Flex method according to ASTM F392 is actually used to test the crease resistance of packaging films and is intended to simulate the mechanical stresses on the film during its life cycle. DIN EN ISO 9073-10 describes a modified Gelbo-Flex method for the „analysis of fibre fragments and other particles in the dry state" of non-woven fabrics. In the method described here, a tube is made from the test sample, which is glued accordingly. This is only one point, which is why this modified method was not adopted one-to-one, but developed further. The other adapted test benches that already exist were evaluated in more detail. On the basis of the available information and a closer look at the individual parameters, it was decided to establish a further developed test method.

The optimised new test method

The newly developed test bench described below is used in a clean test environment. Manual interventions are carried out in appropriate cleanroom garments. The test bench is located inside a test chamber, which has its own Filter Fan Unit (FFU) for targeted flow around the test specimen.

Inside the chamber there is a fixed support element and a counter-rotating lifting linkage with a rotatable support, via a linear motor above. How the test method differs from other existing ones, is described in the following eight distinguishing features.

**Distinguishing feature 1:
No gluing, no cutting, no folding**

The test specimen is clamped flat in the holders under controlled cleanroom conditions (Fig. 3a). The flat clamping is to ensure that the loose particles can be detected and do not get caught in another layer of the wipe.

**Distinguishing feature 2:
Attempt to apply a realistic mechanical load**

Rotation and compression movements are performed using a fixed test programme (Fig. 3). In determining the procedure, the preserved instructions for the folding and wiping technique (Fig. 2) is applied, which is common practice in the cleanroom. Based on this, the number of folding processes was defined. The rubbing during wiping was simulated by the rotary movements in contact. The aim is to remove impurities from the surface of the wipe by mechanical stress of the wipe, which are then captured underneath the wipe.

**Distinguishing feature 3:
Use of two Optical Particle Counters**

Initial tests have shown that the use of two separate measuring points highlights possible differences between different wipes more clearly and also simplifies the interpretation of the measured values. Furthermore, it is ensured that both the particles generated during folding and those generated during friction are detected in the best possible way.

The flow visualisations carried out during implementation clearly showed, that no strong eddies formed above the measurement points despite the wipe movements and thus no dead spots were formed above the isokinetic testing probes of the optical particle counters (Fig. 3c; The entire video is available at https://www.dastex.com/produktportfolio/reinraumtuecher/).

**Distinguishing feature 4:
Unique airflow**

Furthermore, the flow visualisations showed that, due to the FFU installed above the device and the perforated plate installed below it, a continuous airflow from top to bottom in the direction of the measuring points is guaranteed at all times.

**Distinguishing feature 5:
Ionisation unit**

During the first tests, measurements were taken with an electric field meter, which confirmed the expected clear charge build-up during the tests. Therefore, an ionisation unit was integrated below the FFU above the test specimen to ensure that the particles do not adhere to the surface of the cloth due to the static charge, but are transported away and detected with the ionised air.

**Distinguishing feature 6:
Measuring time**

In order to obtain meaningful results, the measuring time is one of the influencing factors. The measuring time per individual measurement is ten minutes – in our experience, a wipe is not used for longer. The movement sequence described above is performed once per minute.

**Distinguishing characteristic 7:
Reproducibility of the results**

In order to guarantee statistical certainty despite the short measurement period, the sample count is chosen very high. In the studies carried out so far, tests were carried out in four different alignments in order to be able to make a statement about differences with regard to the two fabric sides and alignments (differences depending on texture and type). The samples were taken from three different production lots per wipe type. For each alignment and lot, 30 wipes were studied. The sample count is therefore 360 wipes per item.

**Distinguishing characteristic 8:
Evaluation**

Due to the large data set and the study of the wipes in different orientations, it is possible to answer a wide variety of questions. Depending on this, the individual data can be evaluated and compared. The results presented in this publication provide a rough overview.

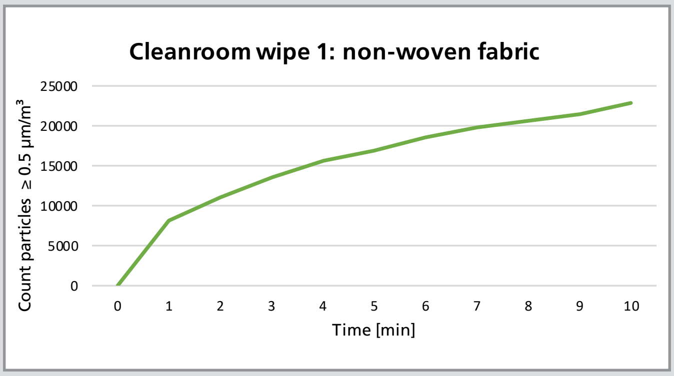
Little wipe basics: Non-woven fabrics vs. cleaned knitted fabrics

Non-woven wipes have different properties depending on their composition

Designation	Type	Average value*	
		Particles ≥ 0.5 µm/m³	Particles ≥ 5.0 µm/m³
Cleanroom wipe 1	non-woven	16,867.87	712.41
Cleanroom wipe 2	non-woven	2,510.20	205.29
Cleanroom wipe 3	non-woven	3,876.71	214.20
Cleanroom wipe 4	cleaned knitted fabric	11.05	0.64
Cleanroom wipe 5	cleaned knitted fabric	9.47	1.62
Cleanroom wipe 6	cleaned knitted fabric	4.48	0.12
Cleanroom wipe 7	cleaned knitted fabric	11.41	1.48
Cleanroom wipe 8	cleaned knitted fabric	2.03	0.07

Table 1: Overview of results

* from 7,200 individual measured values each (2 optical particle counters x 10 minutes x 30 samples x 3 batches x 4 alignments) – values extrapolated to m^3 to illustrate differences.



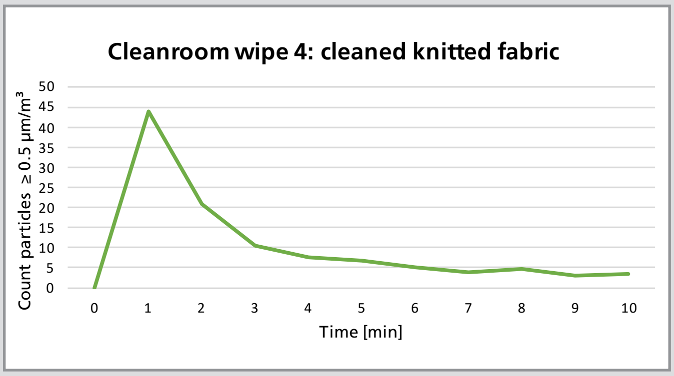


Fig. 4: Comparison of non-woven fabric and cleaned knitted fabric (1 minute ≙ 1 measurement and movement sequence)

(mechanical resistance, liquid absorption and binding in the wipe, tensile strength, surface stability, etc.).

It is not possible to clean non-woven products after the manufacturing process. It can be concluded from this that contaminants generated during the manufacturing process can also be found in large numbers in the end product.

Knitted fabrics, on the other hand, can be decontaminated. The factors that influence the purity of the end product include the liquor ratio (= number of wipes to volume of washing liquid), the quality of the washing water, the detergents used, the number of final rinse cycles and the drying process.

Depending on the requirements and application, a wide range of products can be selected for the cleaned knitted fabrics. The main distinguishing features are the mass per unit area, the type of knitting and the edge processing. All these points can in turn have an influence on the particle release, among other things.

First results and their discussion

The fundamental difference between non-woven fabrics and cleaned knitted fabrics described above is reflected in the results (see Table 1).

For the samples of non-woven cleanroom wipes 1 – 3, the averaged values (2,510 – 16,868 particles ≥ 0.5 µm/m³) are many times higher than for the cleaned, knitted cleanroom wipes (2 – 11 particles ≥ 0.5 µm/m³). In addition to the production pressure conditions, the higher particle emission of the non-woven wipes could also be attributed to the higher mechanical load during the twisting and compression movements. Although the movements are identical, the load is higher than with the smoother knitted fabric wipes, due to their higher surface roughness. However, the wipe also experiences this „higher load" in real use.

Based on the data shown (Fig. 4 left), it is clear that the non-woven wipes release more particles with each measurement and movement cycle.

As can be seen in the microscopic images (Fig. 5 above), the non-woven structure of

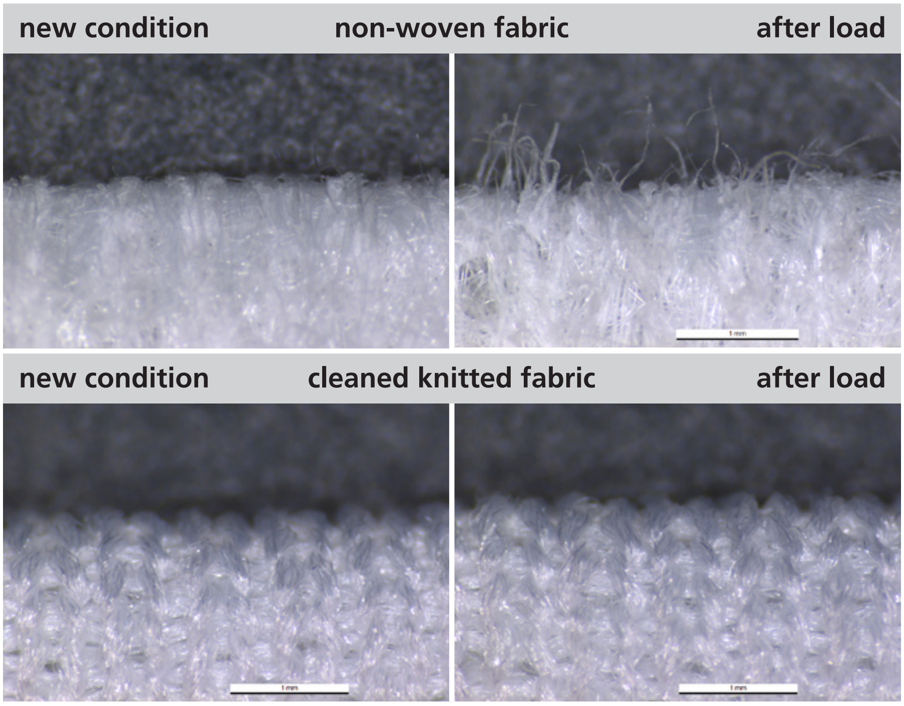
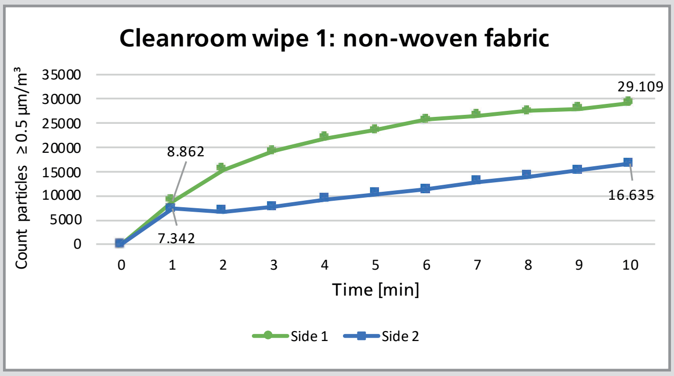


Fig. 5: Microscopic images non-woven fabric vs. cleaned knitted fabric before and after mechanical stress



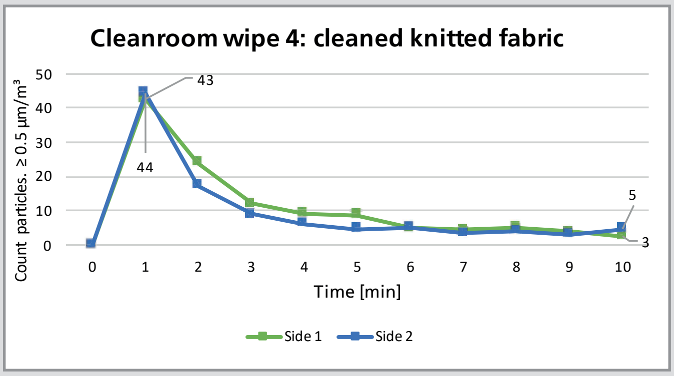


Fig. 6: Side differences – comparison of non-woven and cleaned knitted fabric (1 minute ≙ 1 measurement and movement sequence)

the non-woven wipes is clearly roughened by the mechanical stress. This leads to fibre breaks and loose fibre ends and thus to free particles and fibres.

Furthermore, it is conceivable that due to the structural change (as a result of the mechanical stress), particles that were not adhered to the upper layer, but to the inside, are released.

With regard to Fig. 4, it should also be added that the particles that come loose from the knitted fabric directly in the dry state in the first three to four minutes are also released into the cleanroom. Whereas it is conceivable that the full particle number is not released when a non-woven wipe is used for a short time.
It should be noted, however, that even in the first few minutes a knitted fabric releases significantly fewer particles than a non-woven wipe.

With the cleaned knitted fabrics, the tendency could be observed that these show the highest particle release in the first three to four measuring and movement cycles, as can be seen on the right in Fig. 4. This effect is particularly pronounced with double-layer wipes. This indicates loose particles that come off directly. Afterwards, only a few particles are detected. This illustrates that, due to the stable knitted fabric, hardly any fibre fragments form even under mechanical stress, which is also shown in the microscopic image (Fig. 5 below).

Different results depending on the orientation

The following diagrams show exemplarily how different the particle release of the cleanroom wipes per side can be. Fig. 6 on the left clearly shows that the mean values hardly differ during the first measurement and movement cycle. Side 1 emits an average of 8,862 particles ≥ 0.5 µm/m^3 and side 2 7,342 particles ≥ 0.5 µm/m^3. From measurement and movement cycle number 2, the values diverge significantly. In the 10th cycle, side 1 emits 29,109 particles ≥ 0.5 µm/m^3 on average, almost twice as many particles as side 2 with an average of 16,635 particles ≥ 0.5 µm/m^3.

In comparison, the average values of side 1 and side 2 are almost identical for the cleaned knitted fabrics, as exemplified in Fig. 6 on the right.

Comparison of different non-woven wipes

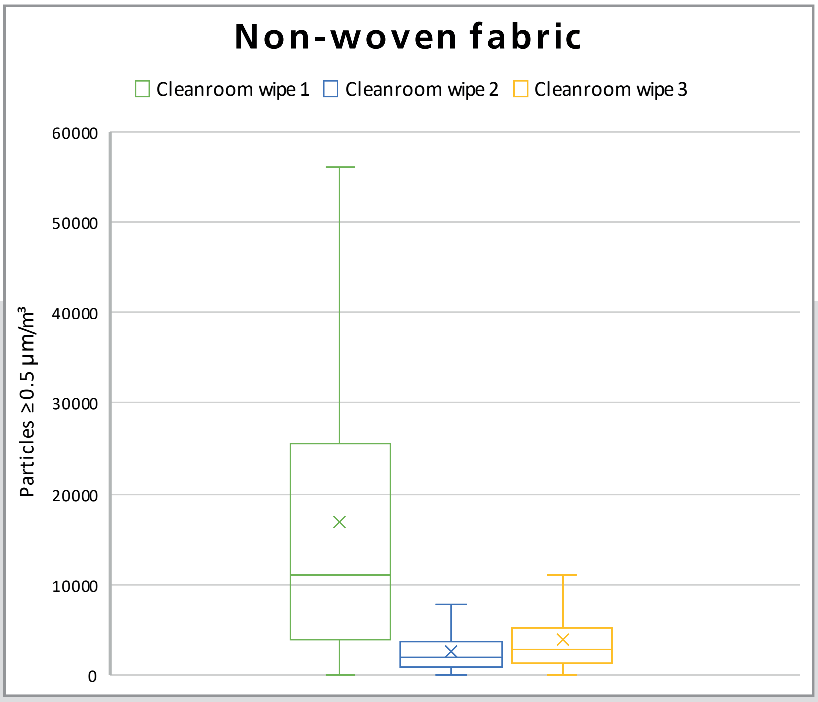
The results for the non-woven wipes show that there are cleaner candidates in this group as well. With an average of 2,510 particles ≥ 0.5 µm/m^3, cleanroom wipe 2 emits approx. 85% fewer particles than cleanroom wipe 1 with an average of 16,867 particles ≥ 0.5 µm/m^3. The boxplot diagram (Fig. 7: Comparison of cleanroom wipes with different non-woven wipes) also shows that the scattering of cleanroom wipe 2 is significantly lower.

Comparison of different cleaned knitted fabrics

The knitted fabrics consistently show a high degree of cleanliness. However, there are of course differences here as well. When looking at the mean values 2 to 11 particles ≥ 0.5 µm / m^3 (see Table 1), the differences initially appear minimal. In relation to the risk assessment (Fig. 1), however, these minimal differences become relevant again and should therefore not be underestimated.

Reflection and conclusion

As in most fields, there is no definitive measurement method. Since the beginning of the cleanroom industry, new test equipment and measurement methods have been constantly developed and established for a wide variety of issues. In order to obtain an overall picture of a cleanroom wipe and its suitability with regard to the most varied requirements depending on the application, it is advisable to analyse and compare data and measured values, which were determined by means of different test methods, in the context of the planned application and to draw appropriate conclusions. The measurement method described here is a further piece in the mosaic, which should help the cleanroom world to provide more information on the particle emission of consumer goods. As described, the test device is suitable for answering question 1 – How low in contamination are the wipes when



delivered and how much contamination do they release under stress in a dry state.

Interactions between the wipe and the surface to be cleaned are not taken into account. The test bench does not take into account interactions between the wipe and the surface to be cleaned, reactions with cleaning agents and disinfectants and, if applicable, gloves, the effects of mechanical energy that act on the wipe in addition to those simulated, and the question posed at the beginning – How high is the risk of contamination being transferred from the wipe or from the wipe to the surface to be cleaned.

This test bench is not limited to the study of wipes, but provides information on the release of particles from a wide range of cleanroom consumables under practical conditions of mechanical load and duration of use.

In addition to wipes, cleanroom papers have already been studied. Studies on the surface cleanliness of disposable garments such as face masks, non-woven hoods, overshoes, sleeve protectors, etc. are also conceivable.

Of course, the mechanical load for each consumable must be determined by considering the actual use. When using the same article sizes under identical conditions – which are created by the test bench – qualitative statements can be made with regard to the cleanliness level on delivery, as well as statements with regard to particle release under mechanical stress.

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Article published (in German)
ReinRaumTechnik 2/2023

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