Influence of electron radiation on the physical and mechanical properties of a nonwoven fabric made using Spunlace technology

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Abstract. The effect of electron radiation on the physical and mechanical properties of Sontara nonwoven fabric produced using spunlace technology has been studied. The initial raw material for the manufacture of materials using this technology, as a rule, are viscose, polyester, polypropylene and cellulose fibers. Such nonwovens are highly breathable and are therefore used in disposable surgical gowns and suits. Since radiation can be used to sterilize disposable surgical gowns, it is important to assess the resistance to ionizing radiation. It was found that the Sontara brand material is resistant to the effects of ionizing radiation - the physical and mechanical characteristics of the material (breaking load and relative elongation) in the longitudinal and transverse directions of the web do not significantly change when irradiated with absorbed doses up to 60 kGy. It should also be noted that a cloth with a basis weight of 68 g/m² has a significant smell of strength after radiation sterilization.

1. Introduction

One of the most popular and promising technologies for the production of nonwovens at the present time is the spunlace technology. It was developed by Dupont in the 1950s, but has become widespread since the 1990s. One of the main advantages of this technology is that for the production of cloth, you can use fibers that are completely different in nature - viscose, polyester, polypropylene and cellulose fibers and other fibers [1-4]. Also, in the last 10 years, developments have appeared in which biodegradable fibers, for example, from polylactic acid [5–7] or from chitin [8], have begun to be used in the composition of nonwoven materials produced using spunlace technology.

Another advantage of this technology is the very method of obtaining the canvas. Using the Spunlace technology, the fibers are bonded into the web by water jets beating under high pressure from the nozzle beams. In this case, the fibers of the canvas are entangled and bound together. It is thanks to this method of bonding that spunlace nonwoven material has a set of unique properties, among which, first of all, it should be highlighted - high breathability, softness and good tactile sensations, close to natural fabrics, breathability, tear resistance, lint-free structure [9-14].

By adjusting parameters such as fiber composition, water pressure, web density, a huge variety of nonwoven materials for various purposes can be obtained.

To obtain a canvas, often not one type of fiber is used, but a combination of two types. For example, cotton or cellulose can be combined with polypropylene, polyester, and rayon fibers, or rayon with polyester or polypropylene fibers. In such cases, one type of fiber provides the required strength to the web, while the other provides a pleasant tactile sensation and softness.
The composition determines the ultimate use of the material. According to world practice, spunlace can be used in various sectors of the national economy (table 1).

**Table 1. Application of spunlace nonwovens.**

| Market sector       | Product type                               | Basic list                                      |
|---------------------|--------------------------------------------|------------------------------------------------|
| Hygiene             | wet wipe base                              | baby wipes, cosmetic wipes, sanitary napkins, household wipes, universal masks |
|                     | absorbent layer of a hygiene product       | feminine hygiene bags, baby diapers, absorbent sheets |
|                     | other products                             | make-up removal discs, breast pads              |
| Medicine            | surgical clothing and underwear            | dressing gown, trousers, shirts, T-shirts, undershirts, apron, shoe covers, headwear, fixing strip, mask, pillowcase, duvet cover, underwear, sheet, diaper, napkin, cover, oversleeve, bib, waste bag |
|                     | dressings                                  | bandage, plaster cast, plaster bed             |
|                     |                                            | plaster, analogue of gauze, bandages for fixation |
| Cosmetology         | clothes and linen                          | bathrobe, kimono, peignoir, hat, towel, napkin, sheet, collar, headband, mask, underwear, cover |
| Industry            | wiping materials (mechanical engineering, printing, food industry, paint and varnish industry, etc.) | polishing cloths, napkins, absorbent cloths, clothes, cleaning cloths, clothes |
|                     | protective clothing (petrochemical, paint and varnish, pharmaceutical, food and other industries) | overalls, suits, robes, hats, shoe covers |
|                     | base (leather industry, flooring)          | artificial leather, oilcloths, tufted coverings, linoleum |
|                     | cushioning, lining material (light industry) | ready-made clothes, leather goods, footwear |
|                     | insulating (shielding) material (furniture industry) | upholstered furniture, mattresses |
|                     | filter cloths                              | air filters, fluid filters, oil filters |
|                     | upholstery, interlining (automotive)       | doors, seats |
| Hotels, restaurants, cafes, transport | cutlery                                   | tablecloths, napkins, towels |
|                     | linen (including headrests)                | sheets, duvet covers, pillowcases, covers |
| Household           | wiping materials                           | floor rags, window rags, dish rags, car wash rags, other dry / wet cleaning rags, napkins, tablecloths |
|                     | cutlery                                    | towels, curtains |
|                     | other products                             | towels, curtains |
| Construction        | geotextile                                 | road construction |

Historically, the first major market for spunlaced materials was the market for disposable medical devices. First of all, these are materials for the manufacture of disposable surgical clothing and underwear and dressings. For the manufacture of surgical gowns and suits, non-woven materials based on cellulose and polyester are used [15-18].
The popularity of spunlace materials for the manufacture of surgical clothing and underwear is due to the comfort of the products when worn, since these materials are breathable. When performing long-term operations, surgeons prefer products made of materials using this technology. Recently, spunlace nonwovens have been competing with cheaper polypropylene based nonwovens produced by spunmelt. However, the latter have their drawbacks - first of all, these are poor breathability, and secondly, the difficulty when using one of the industrial methods of sterilization - radiation sterilization.

Surgical gowns and suits must be sterile. For sterilization of disposable nonwoven products, as a rule, one of two industrial sterilization methods is used - either radiation or gas method. Each of their sterilization methods has advantages and disadvantages. For example, gas sterilization does not in any way affect the technical characteristics of products, while radiation sterilization can lead to a decrease in the strength characteristics of some materials. On the other hand, there are sets of clothes and underwear where plastic wrap is used in the construction of the product, and there are risks that the sterilizing gas may not penetrate into all areas of such sets. A manufacturer of surgical clothing and underwear chooses a sterilization method, taking into account all the nuances, including the location (remoteness) of the sterilization center. In some cases, the upper limit of the specified range may be higher, depending on the type of product and the characteristics of the sterilization unit.

It is known that radiation sterilization leads to the destruction of a number of polymers that are used for the manufacture of a wide range of materials and medical products. For example, such polymers include polypropylene. It degrades when exposed to radiation [19–24].

Earlier, we studied in detail the effect of ionizing radiation on the properties of nonwoven materials obtained by the spunmelt technology [25-28]. Despite the fact that the fibers used for the manufacture of surgical clothing and underwear (the aforementioned polyester and cellulose fibers) are inherently resistant to the effects of ionizing radiation, nevertheless, the behavior of these materials after irradiation has been little studied. It is also of practical interest to identify for each specific material the most sensitive to radiation indicators (the so-called characteristic indicators of radiation resistance) by which it is possible to control the properties of spunlace nonwovens after sterilization.

Thus, the purpose of this work was to determine the effect of electron radiation on the physical and mechanical properties of a nonwoven fabric produced using the spunlace technology.

2. Materials and methods
Sontara nonwoven fabric manufactured by Beijing Soonercleaning Technology Co. Ltd., China. The areal density of the material was 68 g / m².

Determination of the strength and elongation at uniaxial tension of the nonwoven fabric according to GOST R 53226-2008 was carried out on a tensile testing machine Zwick/Roell/BT1-FR2.5TH.140. For surgical clothing and underwear, as well as, respectively, for non-woven materials from which clothing and underwear are produced by the requirements of EN 13795-2011, the lower tensile strength is established. The value of the index should be at least 20 N. The width of the samples should be 5 cm. Testing of nonwoven fabric is carried out in the longitudinal (machine) and transverse directions of the fabric. The strength of wet samples is also evaluated, since surgical clothing and undergarments may become wet during use. Conditioning of wet samples was carried out in EN 29073-3 in distilled water.

Irradiation of the samples was carried out on a radiation-technological installation "Electronic sterilizer" with an electron accelerator UELV-10-10-s-70.

3. Results and discussions
As can be seen from the given data, the material of the Sontara brand is isotropic - the strength in the transverse direction of the web is significantly lower (two times) than in the longitudinal direction (Fig. 1). The longitudinal, machine direction of the web or warp is the direction of the web in which the threads are parallel to each other along the entire length of the web. The transverse direction of the fabric or weft, respectively, is the direction of the threads perpendicular to the warp. The relative
elongation of the samples in the longitudinal and transverse directions of the web is also significantly different - the relative elongation in the transverse direction is two times higher than in the longitudinal direction (Fig. 2).

As can be seen from the data presented (Fig. 1 and 2), ionizing radiation does not significantly affect the physical and mechanical characteristics of the Sontara nonwoven fabric.

Testing of irradiated samples showed that an increase in the absorbed dose up to 60 kGy does not affect the breaking load of the web in the transverse direction of the web. The tensile strength of the material along the base of the fabric decreases uniformly. Under irradiation with an absorbed dose of 60 kGy, the decrease in strength was 20%. Moistening of the material does not lead to a significant change in the observed patterns (Fig. 1 b).

Figure 1. The dependence of the tensile strength the relative elongation in tension in the dry (a) and wet state (b) of the spunlace material on absorbed dose of electron radiation.

Electronic radiation also practically does not affect the relative elongation of the nonwoven fabric (Fig. 2 a, b). A slight decrease in elongation is observed when sterile samples are stretched in the longitudinal direction.

In general, the material of the Sontara brand is resistant to the effects of ionizing radiation and has a significant margin of safety.

The coefficients of isotropy for breaking load and relative elongation (the ratio of the value of the index in the machine direction to the value of the index in the transverse direction of the web) were calculated (Table 1).
Figure 2. The dependence of the tensile strength the relative elongation in tension in the dry (a) and wet state (b) of the spunlace material on absorbed dose of electron radiation.

It should be noted that the isotropy of materials is not a standardized indicator; nevertheless, this information can be useful when planning the cutting of materials for the production of disposable surgical drapes, and is also an additional analyzed indicator for studying the properties of nonwoven materials.

Table 2. Coefficient of isotropy of samples of Sontara brand material for breaking load and relative elongation.

| Isotropy coefficient | Radiation dose (kGy) |
|----------------------|----------------------|
|                      | 0        | 10       | 20       | 30       | 40       | 50       | 60       |
| Elongation           |          |          |          |          |          |          |          |
| Dry (M ± m)          | 0.49±0.02 | 0.49±0.03 | 0.48±0.01 | 0.43±0.02 | 0.43±0.03 | 0.41±0.01 | 0.42±0.03 |
| Breaking load        | 2.14±0.08 | 2.58±0.31 | 2.67±0.18 | 2.65±0.16 | 2.14±0.08 | 2.58±0.31 | 2.67±0.18 |
| Wet (M ± m)          | 0.51±0.05 | 0.53±0.05 | 0.47±0.01 | 0.41±0.01 | 0.43±0.00 | 0.37±0.01 | 0.43±0.04 |
| Elongation           | 2.12±0.12 | 2.23±0.25 | 2.33±0.11 | 2.05±0.07 | 2.23±0.05 | 2.12±0.23 | 2.03±0.10 |
| Breaking load        |          |          |          |          |          |          |          |

The severity of the isotropy index in terms of breaking load and relative elongation, depending on the radiation dose, is insignificant, which indicates the resistance of the materials under study to radiation exposure.

4. Summary

Thus, in this work, we have analyzed the effect of ionizing radiation with absorbed doses of 0-60 kGy on the physical and mechanical properties of medical nonwoven fabric of the Softess brand, obtained using the spunlace technology. It has been established that the Softess brand material is resistant to the effects of ionizing radiation - the physical and mechanical characteristics of the material (breaking load and relative elongation) in the longitudinal and transverse directions of the web do not change significantly when irradiated with absorbed doses up to 60 kGy. It should also be noted that a cloth with a surface density of 68 g / m2 has a significant margin of safety after radiation sterilization. A characteristic indicator of the radiation resistance for a given material is the uniaxial tensile strength in the longitudinal and transverse directions of the web.
5. References

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