Analysis of the effect of ionizing radiation on the properties of bulk nonwoven material

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Abstract. At the moment, there is a wide range of bulky nonwovens for various purposes on the market. One of the important areas of using such materials is healthcare. In particular, bulky nonwoven materials are intended for the manufacture of wound dressings, evacuation kits for newborns. Disposable medical devices of this kind are usually subjected to radiation sterilization. As is known from earlier studies, radiation sterilization significantly affects the performance of nonwovens. In this regard, for nonwoven materials for medical use, an important characteristic is the stability of indicators after exposure to radiation sterilization.

As a result of the study of bulk nonwovens Holofiber ® after radiation radiation in the dose range from 20-60 kGy, there were no significant changes in operational performance. The stiffness increased by an average of 3-10%. The stiffness indicators after ionizing radiation according to GOST 24684 also meet the requirements. The value of electrification increased due to an increase in the static field under the action of ionizing radiation. It is worth noting that the values of electrification are within the norm established by GOST 32995. The breaking load varies from 1-5%. Thus, non-woven materials Holofiber ® PROFI, article P 35191, Holofiber ® SOFT, article P 5197, Holofiber ® SOFT, article P 5200 are recommended for the production of medical devices.

1. Introduction

Nonwovens are widely used for the needs of modern healthcare. They are absolutely indispensable for the manufacture of disposable soft medical equipment - medical clothing and underwear, masks, napkins for various purposes, plasters, etc. The listed products use thin materials (no more than 2 mm thick), with a surface density of 10 to 80 g/m² [1-4]. Typically, such materials are produced by spunblown technology or spunlace technology. Bulk nonwovens can be made by aero-dynamic method [5, 6]. Such materials with a thickness of up to 3 cm with a surface density of 100 to 300 g /m² are used for the manufacture of soft wound dressings, and can also be used for the manufacture of napkins, diapers with high absorbency.

Disposable soft medical equipment, as well as wound dressings, must be sterilized. The radiation method is often used to sterilize such items - one of the highly productive, industrial sterilization methods [7, 8]. However, it is known that radiation sterilization significantly affects the characteristics of nonwoven materials obtained from polymers that are unstable to the effects of ionizing radiation. Such polymers, for example, include polypropylene, which, as it should be noted, is one of the main types of polymer raw materials for the manufacture of fibers and nonwovens. In this regard, numerous
studies are being carried out aimed at increasing the radiation resistance of polymer fiber raw materials [9-13].

As you know, radiation sterilization primarily leads to a decrease in the strength properties of nonwoven materials – breaking load under uniaxial and spatial tension [14, 15]. Changes in the characteristics of nonwoven materials based on polypropylene obtained by spunblown technology have been studied in sufficient detail. There are practically no studies devoted to the study of the effect of ionizing radiation on the properties of bulk nonwoven materials. Considering that polypropylene fibers can also be used in the composition of such nonwoven materials, the study of the effect of radiation sterilization on the properties of bulk nonwoven materials is relevant.

For bulk nonwoven materials, in addition to strength properties, stiffness and electrification are important characteristics, since such materials are used to make products that are in direct contact with human skin. Thus, the purpose of this work is to study the effect of ionizing radiation on the properties of bulk nonwoven materials.

2. Materials and methods
The objects of research are non-woven materials produced by the Russian enterprise LLC "Termopol":
- holofiber® PROFI article P 35191, surface density 100 g/m²;
- holofiber® SOFT, article P 5197, surface density 150 g/m²;
- holofiber® SOFT, article P 5200, surface density 300 g/m².

The objects of study were sterilized on a radiation installation "Electronic Sterilizer" with an electron accelerator UELV-10-10-S-70, in a dose range of 20 kGy, which ensures the death of spore-forming bacteria. In earlier works [3-8] it was found that due to the peculiarities of the packing of products made of nonwoven materials, an increased radiation dose of up to 60 kGy can be obtained. Thus, the studies were carried out in the range of absorbed doses from 20 to 60 kGy.

The following performance indicators of nonwovens after exposure to radiation sterilization were studied: breaking load under uniaxial tension, bending stiffness, and electrostatic field strength.

The breaking load at uniaxial tension was determined in accordance with GOST R 53226 on a Zwick / Roell / BT1-FR2.5TH.140 tensile testing machine.

Bending stiffnesses were evaluated on an MT-360 device in accordance with GOST 30435-96 (ISO 5628-90).

The strength of the electrostatic field was studied on the meter of the strength of the electrostatic field ST-01, tests were carried out in accordance with SanPiN 2.4.7./1.1.1286-03, MUK 4.1 / 4.3.1485-03.

To study the structure of Holofiber® nonwoven material before and after radiation sterilization, an Altami MET Z / ZMT metallographic microscope was used for studies in reflected light.

3. Results and discussions
In fig. 1.a graph describing the effect of the absorbed radiation dose on the breaking load of nonwovens with different areal densities is presented.

It is interesting to note that materials with an areal density of 100 and 150 g/m², that is, with a difference in density of 1.5 times, do not significantly differ in strength. Apparently, this is due to the composition of the fibers used in the material. For materials of the SOFT brand, the strength of materials of 300 g/m² is naturally twice the strength of a material with a density of 150 g/m².

Irradiation and an increase in the absorbed dose of ionizing radiation up to 60 kGy does not affect the breaking load in any way (the indicator varies from 1-5%). That is, the studied materials are resistant to the effects of radiation sterilization.

For woven and nonwoven fabrics, flexural stiffness is an important performance indicator. In the course of the work, the rigidity of samples of nonwoven materials before and after treatment with radiation was investigated. As can be seen from the presented figure 2 a, the surface stiffness coefficient increases insignificantly, on average by 3-10%.
A known disadvantage of synthetic materials is electrification. Radiation sterilization can increase the potential for generating static electricity on surfaces, which is undesirable for medical devices. In fig. 2 b shows a graph of the dependence of electrification from the effects of radiation exposure.

Studies show that the effect of ionizing radiation on nonwovens leads to an increase in the electrification of nonwovens Hollofiber® PROFI, article P 35191 (surface density 100 g/m$^2$) and Hollofiber® SOFT, article P 5197 (surface density 150 g/m$^2$) in 1.6 and 1.3 times, respectively. For nonwoven material Hollofiber® SOFT, article P 5200 (surface density 300 g/m$^2$), electrification after radiation exposure with an absorbed dose of 60 kGy increases 5 times. Nevertheless, it should be...
noted that the values of electrification are within the limits of the norm established by GOST 32995-2014. Bulk nonwoven samples were also examined using a metallographic microscope. The research results are shown in Fig. 3.

![Photographs of the structure of a nonwoven fabric obtained with a metallographic microscope before (a) and after (b) exposure to electron radiation absorbed by 60 kGy](image)

**Figure 3.** Photographs of the structure of a nonwoven fabric obtained with a metallographic microscope before (a) and after (b) exposure to electron radiation absorbed by 60 kGy.

A detailed study of the location and interlacing of the fibers allows us to note that the ionizing radiation did not lead to any visual changes.

4. Summary

As a result of the study of Hollofiber bulky nonwoven materials after exposure to electron radiation (the range of absorbed doses from 20-60 kGy), there were no significant changes in performance indicators. Breaking load varies from 1-5%. The hardness increased by an average of 3-10%. In general, materials after exposure to ionizing radiation meet the stiffness requirements of regulatory documents.

The value of electrification for all studied materials increased, however, the values of indicators are within the normal range established by GOST 32995. Thus, NM Hollofiber® PROFI (surface density 100 g/m²), article P 35191, Hollofiber® SOFT (surface density 150 g/m²), article P 5197, Hollofiber® SOFT, article P 5200 (surface density 300 g/m²) can be recommended for the production of medical devices.

5. References

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