Physical and mechanical properties of materials of life vests for people with disabilities

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Abstract. The main requirements for life vests (buoyancy, durability, light weight, resistance to sea water and petrochemicals etc.) are met due to the right choice of materials for the outer parts of the articles. The current article presents some findings of the research into the main physical and mechanical properties of materials for outer parts of life vests designed for physically challenged people. On the basis of the research the authors have grounded the selection of materials to meet the requirements of the existing regulatory and technical documentation for the production of textiles of the relevant range.

A life vest (LV) is an individual life-saving device which is used in aquatic environments. Life savers referring to devices of the type of life “jackets” are divided into several categories, and each country uses its own classifications according to different features (figure 1,2).

![Figure 1. Types of life vests by functional purpose (in Russia).](image-url)
Figure 2. Categories of life vests according to the intended purpose (European standard).

Issues related to manufacturing high-quality life and swimming vests for people with severe disabilities are yet to be adequately examined and thus urgent for the Russian Federation, whereas they have long been commercially available abroad.

The category of severely disabled people includes those with significant combined disorders of the musculoskeletal system and central nervous system, which may be accompanied by intellectual disabilities, spastic and convulsive states, inability to control the position of the head, violations of respiratory reflexes.

In this investigation we selected the type of life vest for the disabled that was designed according to Technical Specifications (TS) 13.92.29-001-71873909-2018 [1] (patent for invention RU 2702212 C1, 04.10.2019. Patent application No. 2018135823 dated 10.10.2018). Range of application: swimming / floating of severely disabled people, elderly people, people who cannot swim and are afraid of water, people who lost consciousness during a shipwreck, etc [2]. The vests have been tested on various categories of disabled people in swimming pools, water parks, and open reservoirs and have become widely used as they meet high functional requirements.

According to the technical requirements of GOST standard 22336-77 “Life Vests”, a fabric made of chemical or natural fibers with a strength limit of at least 755 N/5 cm and no less than 589 N/5 on the weft should be used as a top material for manufacturing these products. The attachment of the slings to the parts of the product must be strong and withstand a load of up to 3200N.

One of the main requirements for life vests is their buoyancy. Buoyancy is provided by the use of foamed materials (foam, Styrofoam, etc.) and air tanks. Water absorption of foamed materials in life vests for 24 hours should not exceed 5% [3]. Thus, fabrics with high water resistance is preferable as a material for the outer parts of the vest.

The materials used for manufacturing life vests must be resistant to the effects of sea water, oil and petroleum products, as well as to the effects of ultraviolet radiation and rot.

Due to the fact that the main purpose of these LV is their use by the severely disabled, the design (figure 3) provides towing (load P1) and cargo (load P3) loops for lifting or lowering a person into the water from the side of the pool or vessel, and transportation loops (load P2) for towing along the shore of the reservoir or the edge of the pool. Belts and loops of the vest must withstand the appropriate load without collapsing, and the seams of the connection to the product must not be destroyed [4].
Figure 3. Water life vest for people with disabilities a – the back side (front view), b – the chest side (front view).

The selection of materials for testing was made with taking into account the above requirements. Oxford and Taslan fabrics of various densities were selected as outer parts materials [5], and slings were used for towing, cargo and transport loops [6].

All the selected materials are made of synthetic fibers derived from plain weave (rapeseed and matting). To give the fabrics water-repellent properties, the inner side of the fabric was treated with impregnations. Oxford and Taslan fabrics made of nylon fiber are strong, light, resistant to chemicals, wear-resistant, heat-resistant, dry quickly when wet, and are not subject to rot.

The study of the main physical properties of top materials «table 1» was carried out according to such indicators as the surface density (GOST standard 3811-72), thickness (GOST standard 12023-2003), water permeability and breaking load. The water permeability of the selected samples was tested according to GOST R 51553-99 by hydrostatic pressure maintained by the fabric. The water pressure was applied from the bottom of the point sample at three points before the moment of water penetration. Breaking load of the samples and their elongation at break were determined according to GOST 3813-72 in dry and wet conditions. Elementary samples were cut out along the warp and weft threads and subjected to stretching until the moment of rupture.

Table 1. Comparative analysis of the main physical properties of the top materials.

| Fabric     | Surface density, g/m² | Thickness, mm | Water permeability, kPa | Breaking load of the warp, kN | Breaking load of the weft, kN | Elongation at break along the warp, % | Elongation at break along the weft, % |
|------------|-----------------------|---------------|-------------------------|-------------------------------|-------------------------------|-------------------------------------|-------------------------------------|
| Oxford PVC 1 | 154.0               | 0.18          | 137.53                  | 0.860                         | 0.832                         | 38.37                               | 23.16                               |
| Oxford PU 2  | 112.4               | 0.13          | 1.77                    | 1.962                         | 0.820                         | 29.61                               | 21.57                               |
| Taslan 1    | 133.6               | 0.22          | 1.97                    | 0.509                         | 0.223                         | 29.58                               | 13.50                               |
| Taslan 2    | 132.9               | 0.19          | 4.16                    | 0.660                         | 0.952                         | 30.76                               | 23.30                               |
| Taslan 3    | 103.0               | 0.17          | 5.18                    | 0.668                         | 0.633                         | 38.01                               | 35.65                               |

The sample of Oxford PVC 1, impregnated with polyvinyl chloride on the inner side, is characterized by the lowest water-permeable characteristics (highest water resistance) and a sufficiently high breaking load. The sample of Oxford PU 2, internally impregnated with polyurethane, though best at breaking
load parameter, showed unduly high water permeability (insufficient water resistance). Taslan samples 1, 2, and 3 failed to meet the requirements of GOST 22336-77 "Life vests" because of the low breaking load. In all the tested samples, the loss of strength in the wet state equals 0%.

The selected samples of top material were tested for breaking load and elongation of plain and double seams when the tensile load was located along the seam and for breaking load when stretching was perpendicular to the seam (Table 2). Further, pre-selection of the most preferred threads for joining the seams was carried out [7]. Comparative analysis of 45ll reinforced threads and 70l Dacron threads showed the strength of Dacron threads exceeding 20 times and elongation exceeding 1.2 times as compared to reinforced threads. The seams were stitched in accordance with GOST 28073-89 with Dacron threads.

**Table 2. Comparative study of the strength of connecting seams.**

| Type of Seam | Breaking Load, kN | Elongation, mm |
|--------------|-------------------|----------------|
|              | Oxford PVC        | Oxford PU      |
| Plain seam   | 0.709             | 0.791          |
|              | 0.567             | 0.562          |
|              | 0.511             | 23.833         |
|              | 33.183            | 34.21          |
|              | 6                 | 29.667         |
|              | 31.016            |                |
| Double seam  | 2.342             | 1.717          |
|              | 1.312             | 1.242          |
|              | 0.654             | 104.558        |
|              | 86.744            | 93.96          |
|              | 6                 | 73.932         |
|              | 35.00             |                |
|              | 0.515             | 0.518          |
|              | 0.263             | 0.449          |
|              | 0.330             | 18.358         |
|              | 22.012            | 22.74          |
|              | 9                 | 22.012         |
|              | 26.299            |                |

The comparative study showed that the strength of connecting linen seams exceeds the strength of plain seams by 1.3-3 times, and their elongation, respectively, exceeds that of plain seams by 1.2-4 times, which suggests the preference of processing the seams of the product with double, single stitches with Dacron threads. Studies of strength along the seams and perpendicular to the seams have shown that the highest strength is found in samples of Oxford fabrics.

For LV loops, the use of textile slings made of synthetic polyester tape allows to meet the requirements of GOST since they are resistant to moisture, heat and light, and have low hygroscopicity. The strength of the slings is quite high, the breaking load of the belt slings reaches 10000 N, also they have high wear resistance and low weight.

Fastening of slings to product details should be carried out in overhead adjusting seams with Dacron threads in order to increase the strength of the connection. The use of the principle of continuous connection of the cargo loop with the hip belts ensures that the load is transferred from this loop to the hips when a person is being transferred to or out of the water.

To study the ways of connecting the ends of transport loops and attaching them to the product, various types of joint seams have been considered (figure 4). The lines were performed according to GOST 29122-91.
According to the results of the experiments the best connection strength was shown by zig-zag stitching across the overlap length on each other of the ends of the loops (figure 4a), the second best was shown to be compound zigzag stitching on the ends (figure 4b) the lockstitch seam (figure 4d) was the third strongest, and the lowest strength was shown by the direct connection seam reverse stitching at the ends of the loops (figure 4c).

The results of the research into the basic physical properties of fabrics for use in life vests for persons with disabilities suggest that Oxford fabric impregnated with PVC is relevant as a top material due to the following properties:

- its weight which is no less than 150 g/m2 ensures durability of the product and all welded joints;
- its high permeability constrains the wetting of internal fillers for life vests;
- the lightness of the whole structure;
- high resistance to sea water and petroleum products due to the use of synthetic fibers.

References
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