

RESEARCH OF THE WEAR RESISTANCE OF ATHLETIC AUTUMN CLOTHING PACKAGES FOR MOUNTAIN TOURISM

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In mountain tourism conditions, clothing is simultaneously exposed to low temperatures, wind, precipitation, and a complex of mechanical loads (tension, bending, twisting, abrasion), which are cyclical in nature and are unevenly distributed over the product zones. The paper proposes a method for selecting clothing material packages (shell, insulation, and lining) for mountain tourists, taking into account a combination of external operating factors (temperature, humidity, wet cooling and freezing, wind and abrasive load) and internal factors (level of heat production, sweating, dynamic movements, and local pressures). The method is based on the zoning of clothing structural elements according to the types of operational loads and the use of a multi-criteria selection matrix that includes experimentally determined indicators: residual deformation under cyclic loading, the rheological characteristics of insulation materials under perpendicular compression in dry and moist conditions, and the fatigue resistance of material packages under combined effects of tension, torsion, and abrasion. The obtained results show that moisture and subsequent exposure to climatic conditions significantly change the deformation properties of insulation materials: natural materials exhibit an increase in rigidity, while synthetic insulation materials maintain more stable performance characteristics. It has been established that packages with synthetic insulation based on Thinsulate have minimal residual deformation in the elbow area and increased resistance to fatigue wear, which justifies their rational use in clothing for mountain tourism.

Keywords: mountain tourism, autumn clothing, material package, wear resistance, operational factors, abrasion, fatigue wear.

ИССЛЕДОВАНИЕ ИЗНОСОСТОЙКОСТИ ПАКЕТОВ ОСЕННЕЙ ОДЕЖДЫ СПОРТСМЕНОВ ГОРНОГО ТУРИЗМА

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В условиях горного туризма одежда одновременно подвергается действию низких температур, ветра, атмосферных осадков и комплекса механических нагрузок (растяжение, изгиб, кручение, истирание), которые носят циклический характер и распределяются по зонам изделия неравномерно. В работе предложен способ выбора пакетов материалов одежды (оболочка – утеплитель – подкладка) для горного туриста с учетом совокупности внешних факторов эксплуатации (температура, влажность, мокрое охлаждение и замораживание, ветровая и абразивная нагрузка) и внутренних факторов (уровень теплопродукции, потоотделение, динамика движений, локальные давления). Метод основан на зонировании конструктивных элементов одежды по типам эксплуатационных нагрузок и применении многокритериальной матрицы выбора, включающей экспериментально определяемые показатели: остаточную деформацию при циклическом нагружении, реологические характеристики утеплителей при перпендикулярном сжатию в сухом и увлажнённом состоянии, а также усталостную износостойкость пакетов материалов при сочетанном воздействии растяжения, кручения и истирания. Полученные результаты показывают, что увлажнение и последующее воздействие климатических условий существенно изменяют деформационные свойства

утеплителей: натуральные материалы характеризуются ростом жесткости, тогда как синтетические утеплители сохраняют более стабильные эксплуатационные характеристики. Установлено, что пакеты с синтетическим утеплителем на основе Thinsulate обладают минимальной остаточной деформацией в зоне локтевого сгиба и повышенной устойчивостью к усталостному изнашиванию, что обосновывает их рациональное применение в одежде для горного туризма.

Ключевые слова: горный туризм, осенняя одежда, пакет материалов, износостойкость, эксплуатационные факторы, абразивный износ, усталостный износ.

ТАУ ТУРИЗМІ СПОРТШЫЛАРЫНЫҢ КҮЗГІ КИІМ ПАКЕТТЕРІНІҢ ТОЗУҒА ТӨЗІМДІЛІГІН ЗЕРТТЕУ

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Тау туризмі жағдайында киім бір мезгілде төмен температураға, желге, атмосфералық жауын-шашынға және механикалық жүктемелер кешеніне (созылу, иілу, бұралу, тозу) ұшырайды, олар циклдік сипатта болады және өнімнің аймақтарына біркелкі бөлінбейді. Жұмыста сыртқы пайдалану факторларының (температура, ылғалдылық, дымқыл салқындату және мұздату, жел және абразивті жүктеме) және ішкі факторлардың (жылу өнімдерінің деңгейі, терлеу, қозғалыс динамикасы, жергілікті қысым) жиынтығын ескере отырып, тау туристері үшін киім материалдарының пакеттерін (қабық – оқшаулау – төсеу) таңдау әдісі ұсынылған. Әдіс жұмыс жүктемелерінің түрлері бойынша киімнің құрылымдық элементтерін аймақтарға бөлуге және эксперименталды түрде анықталған көрсеткіштерді қамтитын таңдаудың көп өлшемді матрицасын қолдануға негізделген: циклдік жүктеме кезіндегі қалдық деформация, құрғақ және ылғалданған кезде перпендикуляр қысу кезіндегі оқшаулаудың реологиялық сипаттамалары, сондай-ақ созылу, бұралу және тозудың бірлескен әсерінен материалдар пакеттерінің шаршауға төзімділігі. Нәтижелер ылғалдандыру және климаттық жағдайлардың кейінгі әсері оқшаулаудың деформациялық қасиеттерін айтарлықтай өзгертетінін көрсетеді: табиғи материалдар қаттылықтың өсуімен сипатталады, ал синтетикалық оқшаулау тұрақты өнімділік сипаттамаларын сақтайды. Thinsulate негізіндегі синтетикалық оқшаулау пакеттері шынтақ бүгілу аймағында минималды қалдық деформацияға және шаршауға төзімділіктің жоғарылауына ие екендігі анықталды, бұл оларды тау туризмі үшін киімде ұтымды қолдануды негіздейді.

Негізгі сөздер: тау туризмі, күзгі киім, материалдар пакеті, тозуға төзімділік, пайдалану факторлары, қажақты тозу, шаршап тозу.

Introduction

Mountain tourism is a type of sporting activity with increased demands on the functional and performance characteristics of clothing [1, 2, 3, 4]. In the fall season, operating conditions are characterized by significant temperature fluctuations, exposure to precipitation, wind loads and a high probability of mechanical damage to clothing [5, 6] when in contact with rocky surfaces, vegetation and elements of tourist equipment.

The wear resistance of material packages is one of the key indicators of the reliability of clothing for mountain tourism athletes, since the destruction or degradation of one of the layers leads to a decrease in the protective, thermal insulation and ergonomic

properties of the product as a whole.

The aim of this work is to study the wear resistance of material packages of autumn clothing for mountain tourism, taking into account external and internal operating conditions, as well as to assess the fatigue wear resistance of multilayer textile systems.

Materials and methods

Operating conditions and wear factors. The use of clothing in mountain tourism conditions is accompanied by the simultaneous influence of a complex set of factors that determine the intensity of material wear [2, 5, 6, 7, 8, 9]:

- mechanical stress (stretching, bending, compression, torsion, friction);

- abrasive wear from contact with rocks, soil, and equipment;
- climatic stress (low temperatures, precipitation, wind);
- moisture loads caused by rain, wet snow, and sweating;
- multiple loading cycles leading to fatigue failure of the fibers.

The combined effect of these factors creates a complex stress-strain state of the package materials and requires an integrated approach to assessing their wear resistance.

Research objects and methods

The research object is autumn clothing for

mountain tourism athletes used in the mountainous and foothill regions of the Republic of Kazakhstan.

Structure of material packages. The study examined typical material packages for tourist clothing, including:

- outer layer (dense woven and membrane synthetic materials);
- insulation layer (synthetic fiber fillers);
- lining layer (knitted and woven materials).

The formation of packages was carried out taking into account the technological compatibility of materials and their functional purpose. Table 1 shows the composition of the studied packages (fragment).

Table 1. Structure of the studied material packages

Package Number	The outer layer	Insulation layer	The lining layer
II1	Polyamide fabric with PU coating	Synthetic insulation (polyester)	Polyester knitwear
II2	Membrane fabric	Holofiber	Woven Polyester
II3	Thick synthetic fabric	Synthetic insulation	High-density knitwear

Methods for assessing wear resistance.

Standard methods according to GOST and ISO were used, as well as an experimental setup [10-12]. The wear resistance of the material packages was assessed using the following methods:

- abrasive and fatigue wear tests based on the number of cycles until surface failure;
- determination of the tensile strength of the package before and after exposure to wear factors;
- analysis of changes in the mass and structure of materials after testing;
- visual assessment of damage to fibers and interlayer bonds.

The tests were conducted on an experimental setup that simulates the conditions of clothing use in autumn mountain hikes. Unlike the standard Martindale abrasion methods, the setup used allows for the evaluation of the mechanism of fatigue wear under the volumetric stress state of the package. The degree of wear was assessed by the decrease in the breaking strength of the package of materials before and after the impact. At the same time, to quantify the wear resistance

of the packages of materials, the indicators of the coefficient of preservation of the strength of the package, the indicator of wear, which characterizes the relative decrease in strength and the integral indicator of wear resistance of the package were used.

The main criterion of wear resistance is adopted by the coefficient of preservation of the tensile strength of the package of materials:

$$K_{in} = \frac{P_{after}}{P_{before}}$$

where:

P_{before} — breaking force of the package before testing, H;

P_{after} — the breaking strength of the package after exposure to wear and tear factors, H.

According to the results of the experimental study, the coefficients of tensile strength preservation for the packages under consideration are as follows (Table 2).

Table 2. Tensile strength of bags before and after testing

Package Number	P_{before} , H	P_{after} , H	K_{in}
II1	820	710	0,87
II2	790	640	0,81
II3	860	770	0,89

When $K_{in} \geq 0.85$, the material package is considered wear-resistant [10].

The degree of degradation of the material package as a result of operational influences is characterized by the wear indicator. The wear indicator I reflects the relative decrease in durability and is determined as a percentage using

the following expression:

$$I = \frac{P_{\text{before}} - P_{\text{after}}}{P_{\text{before}}} \cdot 100 \%$$

The wear rate for the packers under consideration is shown in Table 3.

Table 3. Wear rates of material packages

Package	Reduced strength, %	Assessment of wear resistance
П1	13,4	high
П2	19,0	average
П3	10,5	high

An integral indicator was used for a comprehensive assessment of the multilayer structure:

$$W = \sum_{i=1}^n \alpha_i \cdot K_i$$

where:

K_i — the coefficient of preservation of the strength of the i -th layer;

α_i — layer weight ratio $\sum_{i=1}^n \alpha_i = 1$;

n — number of layers per package.

The most stable characteristic is demonstrated by package P1, which indicates an optimal distribution of stresses between the layers.

Results and discussion

The data obtained are consistent with the results of domestic and foreign studies [8, 9, 13, 14, 15]. The test results showed that the most wear-resistant materials are packages of materials with an outer layer based on dense synthetic fabrics with a protective coating. Such materials demonstrate high resistance to abrasive wear and maintain the integrity of the structure during repeated friction cycles.

Insulation layers based on synthetic fibers are characterized by satisfactory shape stability, but partial reduction of thermal insulation properties is observed at increased humidity, which is consistent with the results of previous studies.

Lining materials with increased surface density contribute to a more even distribution of loads and reduce the intensity of wear of the internal layers of the package. A comprehensive analysis has shown that the wear of one layer leads to accelerated destruction of the entire system of materials, which confirms the need for a systematic approach to the design of clothing packages.

Conclusion

The study allowed to establish the basic patterns of wear of packages of materials of autumn clothes of athletes of mountain tourism. The most

rational are packages that combine a wear-resistant outer layer, a moisture-resistant insulation and a durable lining material.

The obtained results can be used in the design and modernization of tourist clothing [16, 17], as well as in the development of recommendations for selecting materials in order to increase the reliability and durability of products.

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