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TECHNICAL CHARACTERISTICS OF INSOLES THAT AFFECT ERGONOMIC PROPERTIES OF FOOTWEAR

The aim of the work is to establish the technical characteristics of insoles and the methods for their measurement for subsequent analysis and comparison of the properties of insoles produced using various technologies and materials.

Relevance. Insoles are a crucial component of footwear as they significantly impact its comfort. Through the design of the insole and combinations of materials used, it is possible to reduce pressure on the arches and heel area, provide support for longitudinal or transverse arches of the foot, minimize the occurrence of calluses and corns, reduce foot fatigue, ensure proper weight distribution, correct walking biomechanics, and in some cases, even posture.

Many studies have been conducted in which insoles made from various materials or with the usage of different technologies (traditional method, subtractive method, or 3D FDM printing) are compared with the help of surveys and subjective analysis of sensations and comfort during wear. (Walker, Kyle & Przestrzelski, 2023; Ho M. & Nguyen J., 2022)

However, besides the subjective impressions of comfort and convenience reported by the wearer, it is also important to conduct laboratory research on the manufactured insoles. Obtaining such data will help form an objective quality characteristic of the product.

To determine the technical characteristics of insoles that affect the ergonomic properties of footwear, an analysis of recent research and experiments was conducted. A number of studies by European scientists over the past 5 years were analyzed. (Hermansson, E., & Marcus, E. 2019; Iacob, Mariana-Cristiana & Popescu, 2023; Miguel Davia-Aracil & Juan José Hinojo-Pérez, 2018).

Important mechanical properties and methods of their measurement are presented in Table 1.

Table 1. Mechanical properties of insoles and methods of their determination.

Property	**Impact on comfort**	**Definition of indicators, units of measurement**
1. Shock absorption	Absorption of impact force from the ground surface, ensuring uniform distribution of weight across the entire surface of the foot.	An impact testing machine or a shock absorption tester are used. These machines typically consist of a platform where the insole is placed and a mechanism to simulate impact or compression forces that mimic those experienced during walking or running.
2. Abrasion resistance	It affects the durability of the insole, determining how quickly it will thin out after prolonged wear.	It determines using a special device, such as a Martindale tester. A sample of the insole is placed under the levers and rubbed with an abrasive material with a certain force and speed for a certain number of cycles. After that material loss is measured.
3. Elasticity	It helps make walking in shoes more natural; however, a very flexible insole will not provide the arch support necessary for such conditions as flat feet and certain other deformities.	For example, SATRA STM 505 can be used. It can measure the bending angle and the force required for bending.
4. Shear stress	Loose footwear triggers a reaction of plantar thermal stress, which can result from the shift in the contact area between the footwear	Specialized equipment might include force sensors, pressure mapping systems, or shear stress sensors.

	and the foot. Shear stress increases the risk of developing calluses on the feet during walking.	
5. Material fatigue	This parameter also affects the durability of the insole. Load is applied to the construction over many cycles. Somewhere in the fatigue process, a microcrack appears. With prolonged loading, the microcrack grows until the structure fails.	An electromechanical fatigue tester includes a platform or mechanical structure on which insoles are placed for testing, a loading system that applies cyclic loading and a measurement system for data collection during testing (strain gauges, pressure sensors, or fatigue sensors).
6. Shore A hardness	This parameter also indicates the degree of support and fixation of the foot.	Shore durometer. Usually there are 30-50Sh according to person`s needs.
7. Residual deformation	Deformation of the insole material after prolonged wear.	The residual deformation (R) equals the final demention of thickness after loading (d) minus the initial dimention of thickness before loading (d_0) divided by the initial dimention of thickness and multiply by hundred percent. $$R = \left(\frac{d - d_0}{d_0}\right) * 100\%$$
8. Breathability	The energy required to evaporate a certain volume of water. The lower the value (i.e., the less energy required for evaporation), the more breathable the material, thus resulting in less sweating of the feet.	Breathability is measured using the Thermal Evaporative Resistance (RET) coefficient. The test method is defined by the ISO 11092 standard.
9. Moisture permeability	The ability of the insole to wick away sweat. The higher the moisture-wicking capability, the more hygienic the insole.	The test involves immersing test panels in water or other liquids, and measuring the rate of water vapor or gas transmission through the coating. Using the weight of the moisture that has passed through the sample and the time that has passed, the moisture permeability can be calculated, and is typically quantified as g h−1 m2.

10. Water absorption	Absorption of liquid (sweat) by the material. The more liquid absorption, the less comfortable and hygienic the insole.	The specimens are weighed. Then they are dried in an oven for a specified time and temperature and then placed in a desiccator to cool. Immediately upon cooling the specimens are weighed.

Conclusions. Using an analytical method, quality indicators for orthopedic insoles were established. Based on these indicators, a series of experiments is planned on samples of materials for the production of anatomical and orthopedic insoles. This will give an opportunity to select high quality technologies and materials for further implementing in production.

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