Water absorption and dimensional stability of shoe insoles

Apsorpcija vode i dimenzijska stabilnost uložaka za obuću

Scientific paper / Znanstveni rad

Sashka Golomeova Longurova*, Sonja Jordeva, Silvana Zhezhova, Vangja Dimitriejva Kuzmanoska, Darko Andronikov

Faculty of Technology, University "Goce Delcev"

Krste Misirkov 10-A, Štip, Republic of North Macedonia

*saska.golomeova@ugd.edu.mk

Abstract

The aim of this research was to study water absorption and dimensional stability of shoe insoles. The dimensional stability was indicated by swelling, increase in size of the sample, and shrinkage. Tests were performed ac¬cording to the relevant ISO standards. Eight shoe insoles with different compositions were used in the experiment. The experimental results have shown that the water absorption ability of insoles is influenced by the composition and structure of insole components. The statistical analysis of the experimental results has shown a positive linear correlation between water absorption of insole and their swelling, and a negative linear correlation between swelling and increase in size of the samples. The shrinkage of all eight insoles was less than 1%.

Keywords: water absorption; dimensional stability; swelling; shrinkage

Sažetak

Cilj ovog istraživanja bio je ispitati apsorpciju vode i dimenzijsku stabilnost uložaka za cipele. Dimenzijska stabilnost je naznačena bubrenjem, povećanjem veličine uzorka i skupljanjem. Ispitivanja su provedena u skladu s relevantnim ISO standardima. U eksperimentu je korišteno osam uložaka za cipele različitog sastava. Eksperimentalni rezultati su pokazali da na sposobnost uložaka za apsorpciju vode utječe sastav i struktura sastavnih dijelova uložaka. Statistička analiza rezultata eksperimenta pokazala je pozitivnu linearnu korelaciju između apsorpcije vode uložaka i njihovog bubrenja, te negativnu linearnu korelaciju između bubrenja i povećanja veličine uzoraka. Skupljanje je kod svih osam uložaka bilo manje od 1%.

Ključne riječi: apsorpcija vode; dimenzijska stabilnost; bubrenje; skupljanje

1. Introduction

The insole is the inner part of the shoe that extends from the toes to the heel and provides support to the foot. They are usually easy to remove from shoes. Very often, people replace the original insoles with special insoles to make their shoes more comfortable, warmer, and to provide better foot support. Insoles are also used to adjust the size of the shoe to the size of the foot in cases where the shoe is a half-size larger. When the shoe fits the foot well, the friction between the shoe and the foot is less and the probability of foot injury and blisters is less [1].

The insoles can be used to improve posture. These types of insoles are custom made to provide appropriate treatment of a specific problem that affects standing, walking, and running by providing support to the arch of the foot [2]. Insole modifications could support more adaptive ankle angles, improve foot pressure distribution, absorb shock, and thus facilitate self-walking [3,4].

Various types of materials are used for insoles production, which have different advantages and disadvantages. These include foam, cork, non-woven materials, leather, etc. The most used material is foam. Foam is a natural shock absorber, firm and always reliable, but it can wear out quickly. Leather insoles are breathable, highly cushioned and provide strong feet support. Insoles made of cork are breathable, supportive and they tend to mold to the feet for a perfect fit. Non- woven insoles are good shock- absorbers, they have excellent elasticity, good hardness, they make shoes warmer, and are very cheap.

During the wearing of the shoes, the feet sweats; that sweat is absorbed by the insoles and they become wet [5]. Wet insoles are an ideal breeding ground for bacteria, which will emit unpleasant odor in shoes [6]. Most shoes are not machine washable, but shoe manufacturers' recommendations are to remove the insoles from the shoes and hand wash them, with water and soap [7,8]. During the washing process of the insoles, dimensional change may occur which will not only change the aesthetic appearance of the insoles, but also impair its functionality. The purpose of this paper is to examine the dimensional stability of several types of insoles recommended for hand washing by the manufacturer.

2. Experimental part

2.1. Materials and methods

In this study, eight shoe insoles were used for water absorption and dimensional stability examination. The characteristics of tested insoles are shown in Table 1.

DOI: 10.34187/ko.72.1.1

Table 1. Characteristics of the tested insoles

Sample	Layers		Composition of layers		Thickness (mm)	Cross-section of the insole sample
	First	Second	First	Second		
PPC	Foam	Plain fabric	PU*	Cotton	2.05	
MPP	Foam	Mesh fabric	PU	PES*	3	
MEP	Foam	Mesh fabric	EVA*	PES	3.3	
NEP3	Foam	Non-woven fabric	EVA	PES	3.69	
NEP2	Foam	Non-woven fabric	EVA	PES	2.95	
NEP6	Foam	Non-woven fabric	EVA	PES	6.85	
LEP	Foam	Artificial Leather	EVA	PVC*	2.31	
KEP	Foam	Knitted fabric	EVA	PES	3.15	

*PU- Polyurethane, EVA- Ethylene-Vinyl Acetate, PES - Polyester, PVC - Polyvinyl chloride

The determination of water absorption and desorption of insoles was carried out according to the standard EN ISO 22649: 2016, method A [9]. From each insole, three samples with dimensions (50 ± 1) mm × (50 ± 1) mm were weighed, then submerged into distilled water at 20±2 ˚C for 6 hours. Afterwards, the samples were taken out with the removal of remaining drops of water on the surface and weighed again. Water absorption was calculated based on the weight gains, expressed in g/m2. For determining water desorption, the samples were dried for 16h in standardized conditions according to the standard EN ISO 18454: 2018, and then reweighed. Water desorption was calculated based on the percentage loss in mass of the sample, expressed in terms of the mass of water absorbed. The results for water absorption and desorption were calculated as average values from the three tested samples and based on that, standard deviation was calculated, too.

The dimensional stability test was carried out according to the standard ISO 22651: 2000 [10]. Two samples were cut from the shoes' insoles with the dimensions (50 ± 1) mm × (50 ± 1) mm, one to determine the swelling and increase in size and the other to determine the shrinkage. Both samples were marked as in Fig. 1. The distances were measured between the points A-B, C-D (length of the sample), A-C, B-D (width of the sample) and the thickness at the points E, F, G, H, and I. Then, initial values for the length, width and thickness of the sample were calculated as the average values of the specified measurements. For the swelling and increase in size tests, one of the samples was submerged into distilled water at 20 ± 2 ˚C for 6 hours. Afterwards, the sample was taken out with the removal of remaining drops of water on the surface and the distances between the marked point and thickness were measured, and the average values were calculated. Swelling was calculated based on the percentage gain in thickness, expressed in terms of the initial thickness. Increase in size was calculated based on the percentage increase in length and in width, expressed in terms of the initial values of length and width.

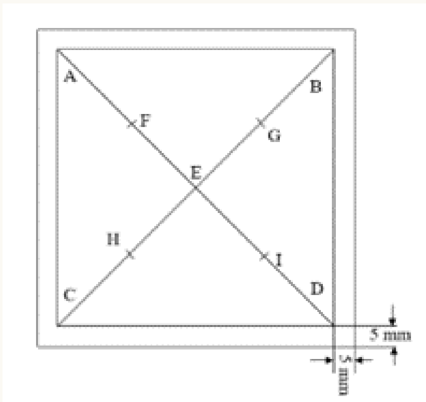


Fig. 1 Marking of the sample

To test the shrinkage rate, the sample was dried at 35˚C in an oven for 24h. After the cooling down, the distances were measured between the marked points at the sample. The shrinkage was calculated based on the percentage reduction in length and width, expressed in terms of the initial values of length and width. The final shrinkage value was expressed as one average value from the calculated length and width shrinkage.

In both tests, water absorption and desorption and dimensional stability, the samples preparation was done according to the standard EN ISO 17709: 2018 [11]. Prior to the tests, the samples were conditioned according to the standard ISO 18454:2018 for 24h [12].

3. Results and discussion

The obtained results of water absorption and desorption test are listed in Table 2 and the results from the dimensional stability test are shown in Fig. 2.

DOI: 10.34187/ko.72.1.1

Table 2. Water absorption and desorption of the shoe insoles

	PPC	MPP	MEP	NEP3	NEP2	NEP6	LEP	KEP
Water absorption, WA(g/m2)	2962 (1.69) *	2779 (4.04)	308 (1)	132 (0.76)	150 (0.64)	3897 (4.51)	82 (2.52)	100 (0.76)
Water desorption, WD (%)	95 (1.76)	100 (0)	100 (0)	99 (0.88)	99 (0.76)	85 (1.06)	99 (0.61)	99 (0.23)

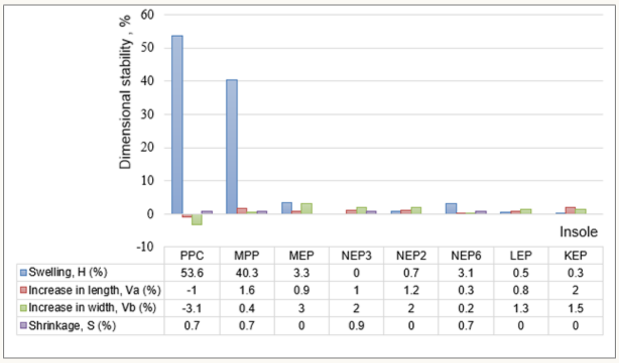
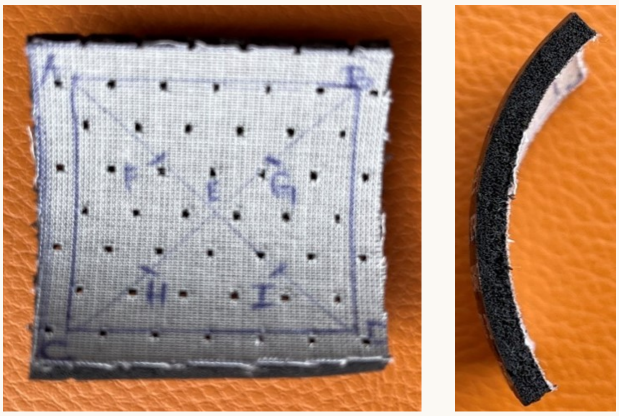


Fig.2 Dimensional stability of shoe insoles

After being submersed in water for 6 hours, the insole PPC absorbs 2962 g/m2 of water, swells 53.6%, and in this type of insole there was a decrease in size of the wet sample resulting with deformation of the sample, Fig.3. This type of insole is composed of PU foam and cotton plain fabric, Tab.1. Both components have high water absorption ability. PU foam has a spongy porous structure, which has high permeability and high-water absorption characteristics [13]. Cotton has a good absorption property too. In water, its transverse diameter swelling is up to 20%, and its axial swelling is around 0.1% [14]. As a result of the predominant transverse swelling, the dimensions of the cotton material may decrease; it means that shrinkage occurs. This explains the decrease in size and the deformation of the sample from insole PPC. The length of the sample is decreased by 1%, and the width by 3.1%. After 16h of drying in normal conditions, the desorption of the PPC insole is 95%.



a) Whole sample b) Cross-section of sample

Fig. 3 Deformed sample of insole PPC

The insole MPP absorbs 2779 g/m2 of water, with the percentage of swelling 40.3%, increase in length by 1.6%, and increase in width by 0.4%. In this insole, the ability to absorb 2779 g/m2 amount of water is due to the PU foam, which has a good ability to absorb water. The other component, PES mesh fabric, is a porous, highly breathable fabric, with a noticeable ability to wick moisture and low ability to absorb water. After 16h of drying, the desorption of the insole MPP is 100%, due to the properties of the PES mesh fabric.

The insole MEP absorbs 308 g/m2 of water, swells 3,3%, and the increase in length and in width is 0.9% and 3%, respectively. This insole is composed of EVA foam and PES mesh fabric, both components with low-water absorption. The desorption of the insole MEP is 100%.

The insoles NEP3 and NEP2 absorb 132 g/m2 and 150 g/m2 of water, respectively. Both insoles are composed of EVA foam and PES non-woven fabric, components with a low absorption ability. The insole NEP3 does not swell, it only increases in size, in length by 1% and in width by 2%. In the insole NEP2, the swelling rate is 0.7%, increase in length by 1.2%, and in width by 2%. After 16h of drying, the desorption of both insoles NEP3 and NEP2 is 99%.

The insole NEP6 absorbs the largest amount of water, 3897 g/m2, swells 3.1% and the increase in length and in width is less than 1%. Compared to the rest of insoles samples tested, this insole has the highest absorption, but not the degree of swelling and the increase in size. The insole NEP6 is composed of two materials that have a low water absorption ability, EVA foam and PES non-woven fabric (Table 1), which is the reason for low percentages of swelling and increase in size. In this type of insole, water absorption occurs in the structure of the non-woven fabric, in the void spaces between the fibers oriented in various directions. From the cross-section of the insole NEP6 shown in Tab. 1, it is noticeable that this insole has a thicker layer of non-woven fabric compared with the other non-woven insoles NEP3 and NEP2, in which water penetrates, and is retained in the spaces between the fibers. After 16h of drying in normal conditions, the desorption of the NEP6 insole is 85%.

The insole LEP has the lowest ability to absorb water; it absorbs 82 g/m2 of water, swells 0.5% and increases in length by 0.8% and in width by 1.3%. These results are due to the composition of the insole, which is EVA foam and artificial leather; both are low-water absorption materials. The desorption of the insole LEP is 99%.

The insole KEP has water absorption of 100 g/m2, it swells 0.3%, increases in length and width by 2 % and 1.5%, respectively. This insole is composed of EVA foam and PES knitted fabric, both components with low-water absorption. The desorption of the insole KEP is 99%.

After 24h in a drying oven at 35˚C, the shrinkage of all tested insoles is less than 1%.

From the discussion of the obtained results, it is noted that the insoles with a higher ability of water absorption have a higher percentage of swelling. This correlation is statistically confirmed with the linear correlation coefficient R= 0.62 (Fig. 4).

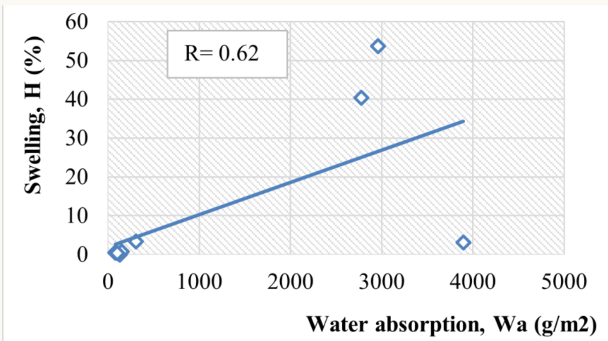
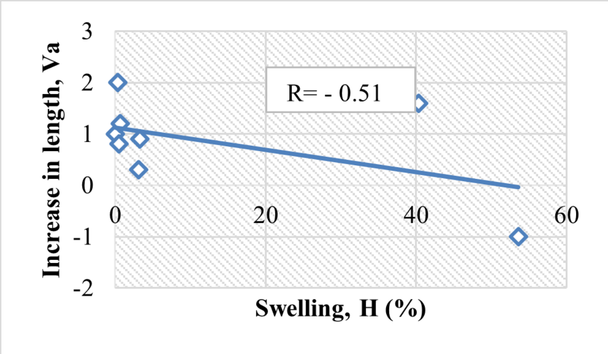


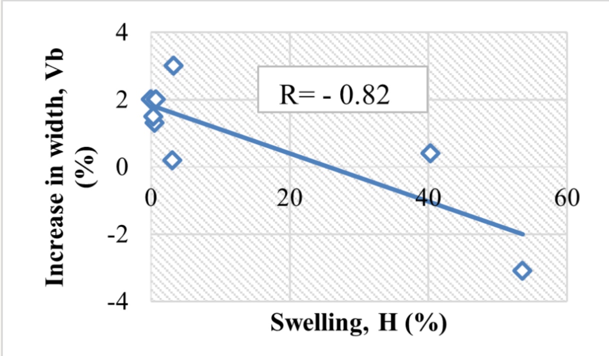
Fig. 4 Linear correlation between water absorption and swelling of the insoles

DOI: 10.34187/ko.72.1.1

The statistical analysis of the experimental results has shown that swelling is in the negative linear correlation with increasing in size. The correlation diagrams are shown in Fig. 5.



a)



b)

Fig. 5 Linear correlation between: a) swelling and length increasing b) swelling and width increasing

4. Conclusions

The aim of this paper was to examine the water absorption and dimensional stability of shoe insoles. Eight insoles were tested, and the obtained results have shown that the water absorption ability of insoles is influenced by the composition and structure of insole components. The PU foam insoles have higher water absorption than EVA foam insoles. The thickest insole, which has the thickest layer of non-woven fabric, absorbs the largest amount of water. The percentage of swelling of insoles with EVA foam is in ranges from 0- 3.3%, while PU insoles swell over 40%. There is a positive linear correlation between water absorption of insole and insoles' swelling, which is confirmed with the coefficient of linear correlation R = 0.62. Insoles that have high swelling rates have low percentages of increase in size. This is statistically confirmed with the coefficients of linear correlation R = -0.51 between swelling and increase in length and the coefficient of linear correlation R = -0.82 between swelling and increase in width.

The insoles that have mesh fabric in their structure have 100% desorption after 16h of drying. The shrinkage values of all tested insoles are less than 1%, which would not impair the functionality of insoles.

References

[1] https://www.shoezone.com/Blog/all-about-insoles. Accessed 20.02.2023.

[2] Chuter V., Spink M., Searle A., Ho A.: The effectiveness of shoe insoles for the prevention and treatment of low back pain: a systematic review and meta-analysis of randomized controlled trials, BMC Musculoskelet Disord, 2014, Apr 29;15;140.

[3] Nagano H., Begg R. K.: Shoe-Insole Technology for Injury Prevention in Walking, Sensors (Basel). 2018 May 8; 18 (5): 1468.

[4] Anderson J., Williams E.A., Nester C. : Development and evaluation of a dual density insole for people standing for long periods of time at work, Journal of Foot and Ankle Research, 2020, 13:42.

[5] Irzmańska E., Dutkiewicz J. : Preliminary Evaluation of Airlaid Nonwovens with Superabsorbent for Use in Protective Footwear: Tests Involving a Thermal Foot Model and Climatic Chamber, FIBRES & TEXTILES in Eastern Europe 2015; 23, 6(114): 138-142.

[6] Irzmańska E., Footwear Use at Workplace and Recommendations for the Improvement of its Functionality and Hygiene, Autex Research Journal, 2014,14: 2.

[7] https://www.nike.com/a/how-to-clean-shoes. Accessed 22.02.2023.

[8] https://www.adidas.com/us/how-to-clean-shoes. Accessed 22.02.2023.

[9] EN ISO 22649: 2016 Footwear – Test methods for insoles and insocks – Water absorption and desorption.

[10] ISO 22651: 2000 Footwear – Test methods for insoles- Dimensional stability.

[11] EN ISO 17709: 2018 Footwear – Sampling location, preparation, and duration of conditioning of samples and test pieces.

[12] ISO 18454:2018 Footwear – Standard atmospheres for conditioning and testing of footwear and components for footwear.

[13] http://www.insolewholesale.com/what-are-the-advantages-of-pu-foam-insole.html. Accessed 02.03.2023.

[14] https://textiletuts.com/swelling-textile-fibres/. Accessed 03.03.2023.

DOI: 10.34187/ko.72.1.1