State and Trends of Test Technology on Hygienic Properties for Leather Shoes

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Abstract: Hygiene properties of leather shoes, which has great influence on health and comfort, mainly contains air permeability, water vapor permeability, hygroscopicity, heat preservation and antimicrobial ability. The developing situation of test technology on hygiene properties of leather shoes is summarized. Natural leather has excellent hygiene properties for its collagen fibers, each hygiene property is not isolated and there are complex relationships between them. But the properties are studied separately basically. It is necessary to launch an overall point of analyzing and testing hygiene properties of leather shoes. Grey system theory is introduced to determine the weightiness of each factor of hygiene properties, and decide which factor should be improved and which ignored. The prospect of analyzing the hygiene properties using gray system theory and establishing a testing standard of hygiene properties of leather shoes are forecast.

Key Words: leather shoes, hygiene property, test

1 Introduction

A pair of shoes with good hygiene properties is important to the health of feet and the whole body. With growing concern on health, better hygiene properties of shoes are expected. Hygiene properties of leather shoes mainly contain air permeability, water vapor permeability, hygroscopicity, heat preservation and antimicrobial ability[1]. At present, air permeability and water vapor permeability are the items that must be tested to measure leather's hygiene properties, and some industry standards or national standards have been established. But there is no uniform standard in leather properties of moisture absorption, heat preservation and antimicrobial ability[2], and the hygiene properties of shoe material are used to measure those of entire shoe directly. In this paper, research state of leather shoes test technology is presented, and its developing trends are forecast, with a view to provide a theoretical basis for improving shoes' comfort and products' value-added.

2 State of hygiene property test technology for leather shoes

2.1 Air permeability

The ability of shoes that air can go through their upper or sole is called air permeability. Since there are many gaps between the collagen fibers and fiber itself, natural leather has excellent air permeability performance. Air permeability in general is measured by air volume through leather of unit area in unit time, its unit is $ml \cdot h^{-1} \cdot cm^{-2}$, and the main test instrument is H • C Fedorov detector of leather air permeability[3].

Tang Ke-yong et al[4] studied the mass transfer properties of leather and influencing factors via air permeability. Shoe ventilation was the process that air transferred inside and outside under pressure. Shoes' air permeability had a good linear relationship with air pressure. Material and energy exchanged between interior and outside of shoes, and gave people the feeling of comfort. John Arthur Wilson et al[5]

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studied the impact of leather chemical composition to footwear comfort. Research showed that leather's air permeability, moisture absorption and water vapor permeability contributed a lot to comfort of shoes, and these properties of leather were different in different temperature and different relative humidity. Ding Shao-lan et al[2] studied air permeability of monolayer of different shoe upper and lining leather, and composite samples. These experiments confirmed that leather's air permeability was reduced by finishing and film, and found that air permeability of leather was different in opposite directions, air permeability of composite samples was mainly influenced by single-layer's air permeability, their combination orders and methods were secondary factors, and there was a certain randomness in leather's air permeability.

Seen from above, air permeability of leather formed when air transfers through leather between inside and outside under pressure. Air permeability of shoes could be improved by reducing coating and film, ameliorating air permeability of finishing agent, or minimizing combination of shoe material. Air permeability of shoes is mainly measured by that of shoe material. Actually, shoe structure and processing technology also affect shoes' air permeability. Different material, different structure and different processing technology make different air permeability of shoes. Du Shao-xun[6] designed an air permeability tester of whole shoes, having simulation foot, opening sealed device and high-precision electronic air measurement equipment, which specified a certain direction and method for more accurate quantitative study of whole shoes' air permeability.

2.2 Water vapor permeability

Water vapor permeability is the ability of leather shoes allowing water vapour to transfer through from higher humid air to lower humid air. Water vapor permeability is defined as the volume of permeating water vapour in unit time and unit area, its unit is $mg/10cm^2 \cdot 24h$. There are two commonly used test methods, dynamic and static, to test water vapor permeability of leather.

Tang Ke-yong et al[7] studied mechanism of water vapor permeability and the mass transfer properties of un-finished leather, PU-finished leather, filmed leather and synthetic leather. For un-finished leather, water molecules migrated along leather pore, and were transmitted by hydrophilic group of collagen. For finished leather, filmed leather and synthetic leather, water molecules only migrated along leather pore under steam pressure. Ding Shao-lan et al[1] studied water vapor permeability of monolayer of different shoe upper and lining leather, and composite samples. These experiments found that water vapor permeability of leather was different in opposite directions, water vapor permeability of composite samples was mainly influenced by single-layer's air permeability, porosity, hydrophilicity, surface state and their combination methods.

Based on above, leather coating thickness should be minimized, materials with much different water vapour permeability should be avoided in shoe upper combination for good water vapour performance of shoes. Shoes cannot show natural leather's outstanding performance, if upper uses natural leather upper, while lining uses synthetic leather.

B.O.Bitlisi et al[8] tested water vapour permeability and static water absorption of upper leather, inner sole and lining of shoes. Test results of upper leather and lining were generally satisfactory, but absorbent and moisture liberation quality of inner sole material were very poor, which impeded the absorption of moisture inside and moisture transfer outside, and had a negative impact on foot comfort. SATRA testing laboratories developed an absorbent and moisture liberation tester of shoes, which could simulate shoes' micro-environment (temperature and relative humidity in shoe cavity).

Zhong An-hua et al[9] made a vapor permeability testing equipment of leather, and analyzed environmental factors' influences on natural leather's water vapor permeability. A temperature regulator device was installed in Hand Po (about 500g) to control stability of temperature, which simulated human body's temperature (36.7 ℃ ~ 37.6 ℃). This method may be used to test water vapour permeability of shoes. Netherlands Institute of Leather and Shoes developed a TNO Comfort Tester which could test absorbent and moisture liberation of shoes.

2.3 Hygroscopicity

Hygroscopicity is the ability of leather shoes to accommodate moisture, especially sweat. Hygroscopicity is usually tested through the moisture regain balance rates of materials. Firstly materials are baked to completely dry under certain temperature, then placed in a certain temperature and humidity to absorb moisture and weighed in time interval. Moisture regain balance rate = (weight of balance under standard atmospheric conditions – weight after drying) / weight after drying × 100%. The more the regain balance, the stronger the hygroscopicity is.

Wang Ni et al[10] studied moisture absorbent and liberation properties of military shoe material. Samples were put in the oven with 8 baskets, baked to completely dry under temperature of (105 ± 2) ℃, then tested in water vapor permeability tester (38 ℃, 90% RH), weighed in appropriate time interval until moisture balance to get hygroscopicity. Hygroscopicity of shoe material reflects the situation of the entire shoe to a certain extent, but is also impacted by shoe's structure and manufacturing process. Ed H. M. Schols et al[11] developed artificial perspiring foot to detect moisture absorbent and liberation properties of entire shoes. Sweating foot was made of sock that water vapor could go through but water impermeable. It was placed into testing shoe after filled with water, hygroscopicity was indicated by increasing quality of the shoe, moisture permeability by decreasing quality of the shoe and the foot before and after the test.

2.4 Heat preservation ability

Heat preservation ability is the ability of leather shoes to maintain the temperature of foot. People will feel uncomfortable if feet are below or above body temperature. Heat preservation property mainly depends on the content and state of still air in material. The more the content of air, the better the heat preservation is[12].

Heat preservation property of shoes can be enhanced by improving the material's. Wang Gai-zhi et al[13-14] analyzed heat preservation application technology of leather goods by applying the far infrared material and phase change materials in leather. Acrylic resin and polyurethane, modified by far infrared material, were used as leather finish. Finishes and far infrared material achieved effective integration in the interface and modified, then thermal insulation was achieved. The phase-change material microcapsules, applied to the leather, could also increase the warmth of leather products.

Tang Yun-qi et al[15] tested thermal property of different upper materials, 3M-B shoe materials and composite samples and analyzed the influences of different upper materials and different combination ways on composite samples' thermal property. Yan Zi-li[16] proposed the use of ultra-fine fiber synthetic leather, down floc blanket, flexible PTFE laminated fabric, carpet and staple down floc foam material for shoes of cold resistance.

Liu Guang-ming et al[17] put forward a method of thermal performance evaluation of cold shoes. He made a copper foot model according to the principle of transient heat conduction. The temperature gap between solid copper foot and ambient temperature was dropping in an exponential law with time. The CLO value was calculated from the data of temperature and time.

2.5 Antimicrobial ability

Antimicrobial ability is the ability of shoes inhibiting bacterial growth in shoe cavity. There are lots of bacteria, skin mentagrophytes, viruses which can cause disease and odor in footwear. The most representative species of bacteria are Staphylococcus aureus, Escherichia coli and Bacillus subtilis, and the common epiphyte species are white fungus Candida and Trichophyton rubrum[18].

Gu Hai-bin et al [19] developed anti-bacterial paper for leather products using a new type of anti –bacterial and anti-mildew agent CCBMP by impregnation method. He evaluated the anti-bacterial paper's inhibitory effect on Streptomyces, bacteria and yeast separated from shoes using antibacterial inhibition zone method and Bacteriostasis method. Gong Tai-sheng studied anti-bacteria shoe material using a combination of inorganic and organic material, carried out a series of anti-bacterial effect assessment, and tried to apply in large-scale production manufacturing. Xu De-jia[20] introduced methods of anti-bacterial rubber shoes making and the main methods to evaluate their antimicrobial properties and expounded test methods of agar plate method.

At present, there is no uniform testing standards for footwear anti-bacterial ability evaluation. Proper and accurate evaluation would be established on choosing main pathogenicity bacteria of foot and appropriate testing methods. Anti-bacterial performance parameters of shoes should include toxicological analysis of antibacterial agents, anti-bacterial effect, scope and durability of anti-bacterial strain.

3 The relationships between shoe hygiene indicators

The hygiene properties of shoes are not isolated, but have some relationship between each other. It is necessary to analyze and test hygiene properties of leather shoes in overall point.

3.1 Air permeability and water vapor permeability of leather shoes

Air permeability refers to the ability of air going through leather shoes, while water vapor permeability the ability of water vapor going through leather shoes. Both air and water vapor are gas, so there are some similarity and also difference between them. Under normal circumstances, water vapor permeability of leather shoes has a positive correlation relationship with air permeability of leather shoes, but the change trends are inconsistent.

Ding Shao-lan et al[21] researched air permeability and water vapor permeability of shoe upper materials, lining materials and their composite samples, and found their change trends were not inconsistent. Mechanism of air permeability can be understood as: air molecules passed through the gap of the material, which was just a physical process. The process of water vapor permeability was not just a simple physical process. Water molecules were polar, and would react chemically with hydrophilic materials to form hydrogen bonds. Therefore, the water vapor permeability was a combination of physics process and chemistry process.

3.2 Heat preservation, air permeability and water vapor permeability of leather shoes

There are some relationships among heat preservation ability and air and vapor permeability of leather shoes. Warm-kept material has heat preservation ability because it contains a certain amount of air inside, which doesn't form air convection. The structure of warm-kept material has disadvantage on its air and water vapor permeability. On the one hand, composite-based insulation material (coating or film) makes gaps blocked, water vapor cannot pass through fabric easily; On the other hand, composite base separated the fiber on two sides, so water vapor cannot go through by fiber transmission. Heat preservation ability has a negative relationship with water vapor and air permeability. Heat preservation ability of shoes can be enhanced by materials combination, and air and water vapor permeability can be increased by changing inner and outer material and their combination methods[12]. Antimicrobial ability of leather shoes also has some relationships with air and water vapor permeability, heat preservation, etc. because certain bacteria and fungi grew well in a certain temperature and humidity conditions, while other temperature and humidity are not conducive to their reproduction.

3.3 Establishment of grey system for shoes hygiene properties

Hygiene property of leather shoes mainly contains air permeability, water vapor permeability, hygroscopicity, heat preservation, and antimicrobial ability. Each property characterizes one aspect of shoe's hygiene properties, and they interact each other. The hygiene properties of leather shoes are very complex, and it's difficult to establish a uniform standard. Liu Jing-Long et al [22] used the gray system to study the nature of leather, which brought inspiration for research of shoes hygiene properties.

Gray system uses shade of color to describe the degree of information definition, that is, "black" means information unknown, "white" means the information is completely clear, and "gray" means some information is clear, while some information is not clear. System in which some information is clear and some information is not clear is defined as gray system. The goal of gray system modeling is to transform gray system to a white system in structure, in model and in relationship. Its main contents include the theory system based on gray twilight set, the analysis system based on gray relational space, the method system based on gray sequences, the model system based on gray modeling, and technical system based on system analysis, evaluation, modeling, forecasting, decision-making, control and optimization.

Liu Jing-long et al[23] first introduced the gray system theory to study moisture permeability behavior of leather and the influencing factors. The system formed by parameters of the structural characteristics of leather, parameters of the material characteristics and moisture permeability rate was considered as a gray system. Moisture permeability rate would be forecast according to the white information in system quickly, easily and effectively. This method had great significance for studying the moisture permeability of leather and ameliorating process technology to improve moisture permeable performance of leather.

Because there are many factors that impact hygiene properties of shoes, complex and uncertain, gray system theory has its advantages to analyze this. Firstly, determine every factor's weightiness in hygiene property. Then, according to their weightiness, strengthen some factors, and neglect others. Gray relational analysis method can be used to resolve and establish the test technology on hygiene property for leather shoes.

4 Trends of test technology on hygiene property for leather shoes

At present, test items of shoes hygiene properties mainly refer to air and water vapor permeability and test material or samples from entire shoes, which not only break the integrity of shoes, but its credibility is obviously inferior to a direct test of shoes. Actually, there are many factors impacting on hygiene properties of leather shoes. Hygiene performance index of leather shoes will be useful to form a testing standard of hygiene property of leather shoes. We can range all the factors according to their contribution rate using grey system theory, identify the key factors and calculate their corresponding weight values, multiply value of each factor by its weight value, add all the values and get hygiene performance index of leather shoes. More items will be incorporated into hygiene properties testing, direct test on entire shoes, forming a testing standards, are important trends of test technology on hygiene property for leather shoes.

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