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Porous Lattice Structure Optimization in 3D Printed Insole Design

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Abstract

This work realises the total parametric design of the insole through the topological structural design of the lattice units, which helps to meet the pressure requirements of different locations and increase the comfort and personalisation of insoles. Prior research has primarily concentrated on creating planar porous structures and basic geometric insole structures; intricate three-dimensional lattice structure optimisation has been systematically neglected. To close this gap, the research examines three common porous lattice structural units for analysis: equilateral triangular, square, and hexagonal units. It does this by using 3D printing technology to produce customised insoles. In addition, variance analysis is carried out, and the orthogonal experimental design method is used to examine the significant impact of structural design factors on the compressive performance of the porous lattice structure. The lattice's structural neutral size, unit size, and rod diameter are chosen to influence the elastic modulus. With a 22% reduction in maximum plantar pressure and an 18% reduction in average pressure compared to the uniform solid structure, research reveals a considerable improvement in plantar pressure distribution with the lattice insole structure created in this study. In the meantime, the porous lattice structure's overall weight is 15% less than that of the solid structure, which successfully reduces the insole's burden while still fulfilling the standards for mechanical performance. This study offers a fresh technological perspective on creating customised, comfortable insoles.

Keywords: Personalized Insoles; Lattice Structure; Plantar Pressure; 3D Printing

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1 Introduction

Wearing comfort and foot health are greatly impacted by insoles, which serve as a vital interface between the human body and footwear [1]. Reasonably designed insole constructions can reduce fatigue, pain, and other foot discomfort, enhance plantar pressure distribution, and guard against foot injuries and associated illnesses [2]. Plantar pressure distribution is a crucial metric for assessing how comfortable insoles are. Personalised footbed design is becoming a significant area of research because it is challenging to fully suit the needs of every individual due to the wide variations in foot form and pressure distribution. True customisation is impossible with the intricate, inefficient manufacturing methods of creating traditional bespoke insoles. Recent developments in CAD, 3D printing, and 3D scanning provide fresh methods for creating customised insoles. 3D scanning can collect foot data individually. Parametric design can be aided by computer-aided design (CAD), and complicated insoles can be effectively manufactured with 3D printing [4].

This work investigates insole parametric design using a topological lattice structure. Orthogonal experiment analysis examines the impact of key lattice characteristics on compressive performance, such as neutral size, unit size, and rod diameter. This offers a conceptual framework for later customised insole design. Wearing comfort and foot health are greatly impacted by insoles, which serve as the vital interface between the human body and footwear and are of utmost importance to the textile and clothing industries [1]. In a market where demand for personalised and customised goods is rising, insole design and production have emerged as key areas of study.

Rationally designed footbed constructions can reduce tiredness, pain, and other foot discomfort, enhance plantar pressure distribution, and guard against foot injuries and associated illnesses [2]. Plantar pressure distribution is a crucial metric for assessing how comfortable insoles are. Personalised insole design is becoming a significant research topic in the textile and apparel sector, as it is challenging to fully suit the needs of every individual because of the wide variations in foot form and pressure distribution.

The growing demand for personalised and comfortable footwear is predicted to propel the global 3D printed insole market, which is projected to expand at a Compound Annual Growth Rate (CAGR) of 20.4% between 2022 and 2030, according to a recent industry analysis [3, 4]. True customisation cannot be achieved with the intricate, inefficient manufacturing techniques of creating traditional bespoke insoles. New methods for custom insole design in the textile and clothing industries are made possible by recent developments in 3D scanning, CAD, and 3D printing. 3D scanning can collect foot data individually. Parametric design can be aided by computer-aided design (CAD), and complicated insoles can be effectively manufactured with 3D printing [5].

This offers a theoretical foundation for designing and producing individualized insoles utilizing 3D printing technology. The parametric design of insoles through topological lattice structure is explored in this study, which is a promising approach for personalised insole development in the textile and apparel industry, in contrast to previous studies that have primarily focused on planar porous structures and simple geometric insole designs. The impact of key lattice factors on compressive performance is examined through orthogonal experiment analysis, including rod diameter, neutral size, and unit size. This offers a theoretical foundation for the design and production of individualised insoles utilising 3D printing technology.