UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ERGONOMIC DEVELOPMENT OF SHOE SOLE DESIGN

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design)

by

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This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design). The member of the supervisory committee is as follow:

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ABSTRAK

Pilihan kasut sukan yang betul adalah penting untuk aktiviti-aktiviti yang berkaitan dengan sukan bagi memastikan prestasi olahraga bertambah baik. Masalah yang selalu berlaku adalah data ukuran kaki tidak mencukupi untuk penduduk dan kecederaan yang berlaku di kalangan atlet Malaysia. Oleh sebab itu, terdapat keperluan di dalam mempertimbangkan keperluan reka bentuk untuk sukan yang berbeza dan profil kaki yang berbeza. Objektif pembelajaran ini adalah untuk mendapatkan data antropometri untuk profil kaki pelajar UTeM, bagi membangunkan reka bentuk ergonomik tapak kasut untuk pelajar UTeM dan untuk menganalisis daya tekanan reka bentuk tapak kasut untuk ahli sukan UTeM. Skop di dalam kajian ini ialah mengumpul data antropometri menggunakan ukuran grafik visual. Berdasarkan data antropometri, reka bentuk dalam tapak kasut telah dilakukan pada tiga profil kaki normal, kaki lengkungan tinggi dan kaki rata. Kemudian, analisis daya tekanan dan anjakan telah dilakukan bagi membandingkan bahan, getah dengan ethylene vinyl acetate (EVA) dan tiga jenis profil kaki. Kajian ini mendapati, tapak kasut flat mencatatkan maksimum stress yang tertinggi (28,1301 MPa) dan displacement (664,639 mm) untuk menjalankan aktiviti-aktiviti sukan manakala bagi aktiviti sukan bola sepak, maksimum stress tertinggi tapak kasut lengkungan tinggi (572,294 MPa) dan maksimum displacement adalah tapak kasut normal (49.413,8 mm). Analisis juga mendapati bahawa, bahan getah mengakibatkan stress yang lebih rendah (27,889 MPa) dan maksimum displacement yang lebih besar (379,141 mm) berbanding dengan Ethylene Vinyl Acetate (EVA) material (28,077 MPa, 96,7997 mm). Kepentingan kajian ini adalah data antropometri kaki akan menjadi berguna untuk pengilang kasut untuk membangunkan reka bentuk kasut mereka untuk atlet Malaysia. Selain itu, reka bentuk baru tapak kasut dalam yang berguna untuk prestasi sukan yang lebih baik serta mengurangkan kecederaan kaki akibat aktiviti sukan.

ABSTRACT

Proper selection of athletic shoes is important for sports related activities to ensure improved athletic performance. The problem that always happened is inadequate data foot measurement for Malaysian population and injuries happened among the athletes. Therefore, there is the need to consider the design requirement for different sports and different foot profile. The objectives of this study are to obtain the anthropometry data of feet profiles for UTeM students, to develop an ergonomic design of shoe sole for UTeM students and to analyse the contact stress of the shoe sole design for UTeM sportsmen. The scope incorporated in this study is collecting anthropometry data using visual graphic measurement. Based on the anthropometry data, the design of inner shoe sole has been done for three foot profile which is normal, high- arch and flat foot print. Then, the analysis of stress distribution and displacement is done in comparing the material, rubber versus ethylene vinyl acetate (EVA) and three type of foot profile. This study found that, flat inner shoe sole recorded the highest maximum stress distribution (28.1301 MPa) and displacement (664.639 mm) for running sports activities whereas for soccer sports activities, the highest maximum stress distribution is high-arch inner shoe sole (572.294 MPa) and maximum displacement is normal inner shoe sole (49413.8 mm). The analysis also found that, rubber material resulted to lower stress distribution (27.889 MPa) and greater maximum displacement (379.141 mm) compared to ethylene vinyl acetate (EVA) material (28.077 MPa, 96.7997 mm). The significance of this study is the anthropometry data of foot will be useful for shoe manufacturers to develop their shoe design for Malaysian athletes. Besides that, the new designs of inner shoe sole are useful for an improved athletic performance as well as reduce injuries of foot due to sports activities.

DEDICATION

To my beloved parents and family members who really give me support and love that I really need to accomplish in this project study.

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I would like to offer my deepest gratitude to my supervisor, Miss Masni-Azian Binti Akiah from the bottom of my heart for all the support, encouragement and inspirations manage to obtain all the way through of this project study. The working relationship between my supervisor and me has provided a lot of knowledge and experience. The help from my supervisor is priceless for me. Last and not least, my highest thankfulness is dedicated to my beloved family members, friends and other parties whom helped me directly or indirectly.

Thank you.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

%	-	Percent
3D	-	Three Dimensional
NG	-	Not Good
FYP	-	Final Year Project
PSM	-	Projek Sarjana Muda
EVA	-	Ethylene Vinyl Acetate

CHAPTER 1

INTRODUCTION

1.1 Project Background

Proper selection of athletic shoes is important for sports related activities to ensure improved athletic performance. Good structural designs of athletic shoes are able to provide adequate support to the foot and prevent musculoskeletal injuries. The design of the shoe soles itself should be able to reduce stress and impact exerted onto the feet due to different sports activities. Repeated or continuous contact between the feet with the shoes will result to varying contact stress. Thus, different sports activity will exhibit different stress effect.

One of the main components of an ergonomic athletic shoe would be the shoe sole design. The design shall consider the anthropometry measurement for the selected population. This study will focus on the design and development of shoe sole for Malaysian sportsmen. The anthropometry data of feet for UTeM students is needed for this study as the design guidelines for the shoe sole. The anthropometric measures are usually expressed in 5^{th}, 50^{th}, and 95^{th} percentile measures. Gender and genetics influences the anthropometric measurement. Generally, the anthropometric measurements for men are larger than woman. On the other hand, genetics differences can be shown from the varying measurements between populations at different regions such as Europe and Asian populations. Current foot anthropometry data is not adequate for Malaysian population. Therefore, there is a need for the anthropometry data to be collected for the shoe sole design.

The anthropometry data collected in this study will be useful for shoe manufacturers to develop their shoe design for the Malaysian athletes. Further stress analysis can be simulated based on these data and the new designs are useful for an improved athletic performance as well as reduce injuries of foot due to sports activities.

1.2 Problem Statement

The problem that always happened in this shoe sole design is the inadequate data of foot measurement for Malaysian population. Inaccurate selection of shoes size will cause the foot to be injured. Among the foot related injuries due to inappropriate use of shoes will are blisters on the foot, calluses on the sole and ankle sprains (Saluta & Nunley, 2010; Dexter, 2004). Furthermore, inappropriate selection of shoe size will result to lack of stability and reduced athletic performance of the user. Other than that, it may also cause musculoskeletal disorder among the user which will affect the overall posture and performance of the athletes. In addition, different sports activities will cause different stress distribution with varying impact on the foot profile. Therefore, there is the need to consider different design requirement due to different foot profile such as flat, normal and high arched foot.

1.3 Objectives

Based from the problems highlighted above, the objectives of this study are:

(a) To obtain the anthropometry data of feet profiles for UTeM students.
(b) To develop an ergonomic design of inner shoe sole for UTeM students.
(c) To analyse the contact stress of inner shoe sole design for UTeM sportsmen.

1.4 Scope of Study

The scopes that are covered in this study are as below:

(a) The anthropometry data of feet collected focuses on UTeM students' adult age 18 to 30 years old.
(b) The inner shoe sole design and analysis focuses on running and soccer sports.

CHAPTER 2

LITERATURE REVIEW

2.1 Injuries Related to Foot during Sports Activities

Traumatic injuries frequently occur at foot and ankle in most sports activities. From the research in multispecialty sports clinic, 25% of 12,681 injuries are involving to foot and ankle during sports activities (Saluta & Nunley, 2010). According to Young et.al (2005), the foot and ankle are important as the main interface between the ground and body during walking and they are required to absorb impact loading forces, give efficient propulsion and adapt with the segregated ground which is consists 26 main bones in other to accomplish this task.

Soccer is the most popular sport in the world wide (Braver et.al, 2003). In addition, the most commonly injuries happened in soccer sports are ankle sprains (Manning et.al, 2006). The football player is also usually had their injuries related to mid-foot or Lisfranc sprains by a sudden rotation of a planted foot or an axial load on a plantar flexed foot (Saluta & Nunley, 2010).

The runners have high rates of running injuries between 30% and 75% per year for a distance running (Daoud et.al, 2012). According to Shorten & Ph (2000), runner experiences approximately 25,000 impacts of the ground during marathon. The repeated impact loading of the runner's body causes overuse injury. The impact also causes rapid joint motion, soft tissue stresses and high muscle forces.

On the other hand, the runners are exposed to stress fracture due to high repetition and low impact activities. These are caused by poorly cushioned shoes and stiff running surfaces (Saluta & Nunley, 2010).

Apart from that, calluses can form on soles of feet and palm as shown in Figure 2.1. Calluses at foot sole commonly form on the weight bearing areas and when it becomes too thick, it will cause discomfort to the individual. Apart from that, blisters also can form and occur on the soles because of the repeated friction as shown in Figure 2.2 which commonly happened when wearing a new pair of shoes (Dexter, 2004). Thus, the callus and blisters formation on the foot sole can be minimised with properly fitted shoes.

Figure 2.1.: Calluses on Foot Sole
(Dexter, 2004)

Figure 2.2: Blister on Foot Sole
(Dexter, 2004)

2.2 Sports Shoe Designs Consideration

For the soccer shoes, cleats provide an important role to give support in mid foot area and traction to the feet during playing. The cleats can give increased speed and manoeuvrability. The design for soccer cleat is important according to weather conditions, field types and skill levels (Caselli, 2006).

As stated by Logan et al. (2010), fixation rotation can be reduced through design consideration of shoe cleats. It is proposed that height of cleat were to be minimized while maximizing the number of cleats and its diameter. Furthermore, the moulded rubber cleats as shown in Figure 2.3 are usually designed for shoes which are suitable for harder turf surface for better spring and traction effect. In addition, the number, shapes and placement of the studs on the bottom of cleats are also an important consideration in shoe design (Ozer & Barut, 2012). Thus, consider the athlete of foot types can reduce the frequency of injury and provide an improved performance.

Figure 2.3: Moulded Studs of Soccer Shoe (Caselli, 2006)

As stated by Caselli (2006), the runners will spend 800 times per mile during running and the force will be three times the weight of runner's body. There are five critical components that should be considered which are the last, outer sole, heel counter, midsole and upper. However, the scope of this project will focus more on the midsole and outer sole.

Current trends with athletic shoe design focuses on fitting of the shoe and force generation for an individual during sports activities. Generally, three characteristics are involved which is stability, cushioning and guidance. The sole provide cushioning and stability between the foot with the ground and plantar surface (Hilgers et al., 2009). It involves three component which is anterior sole, mid sole and outer sole. Lastly, there are design for straight, half bend or full bend. Those designs provide more comfort to the athletes during intense sports activities.

In addition, the important requirements for sport shoes including the design, cushioning, stability, grip, fitting, flexibility, weight, durability and air permeability. The mid sole and outer sole are commonly made of ethylene vinyl acetate (EVA) foam and rubber. From Figure 2.4, mid sole is categorized in three areas which are fore foot (zone 1 to 9), mid foot (zone 10) and rear foot (zone 11) (Shimoyama et al., 2010).

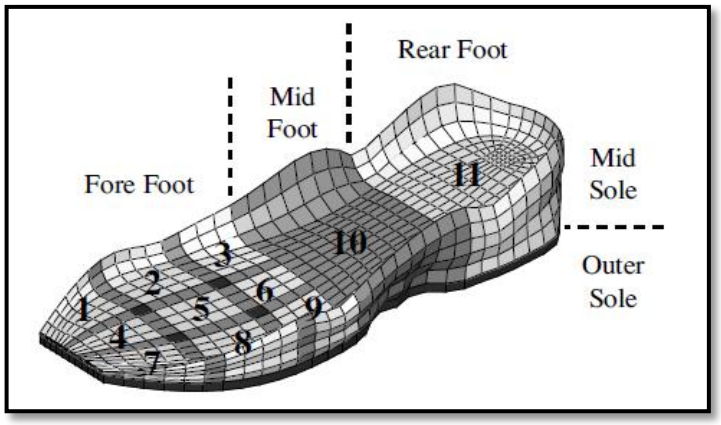

Figure 2.4: Sole Structure (Shimoyama et al., 2010)

According to Langone (2010), there are three classic types of foot profile which is, normal arch, rigid high arch foot and low arch flexible foot (Figure 2.5). The contact surface between different foot profiles can be measured using the wet paper test. The test exhibit minimal contact for high arch foot, moderate contact for normal arch and full contact for low arch. Thus, for improved performance, athletes with high arch foot prefer the cushioned shoes, normal arch may use stable shoes and low arch shall for more stable shoes than normal arch.

Figure 2.5: Rigid High Arch Foot, Normal Arch and Low Arch Flexible Foot
(Source: < http://www.edgeandwax.co.uk > 08 December 2012)

Harder soles offer less cushioning, wear longer and will be heavier (Caselli, 2006). For the soft soles, it wears out faster but provide more cushioning and have lighter weight. On the other hand, the midsole is also important because it can absorb shock, provide stability and flexes at toe-off as shown in Figure 2.6. Gel air, bags and other materials are used to increase the cushioning. However, when exposed to cold temperature, the material will lose its cushioning ability. Thus, running shoe can take consideration in cushioning, stability and motion control (Caselli, 2006).

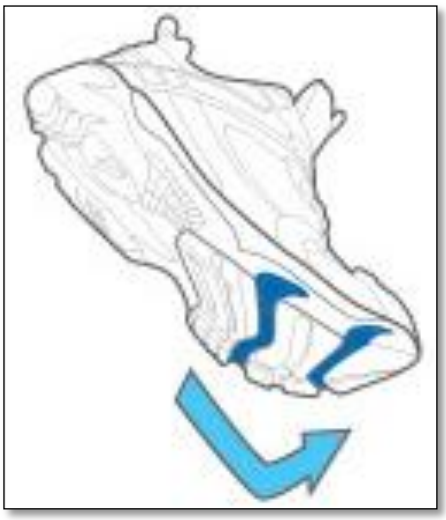

Figure 2.6: Example of Flexes at Toe-Off Shoe
(Source: < http://www.powerfootwear.com/athletic-footwear > 05 December 2012)