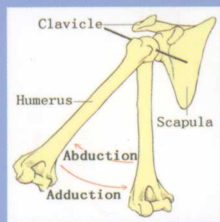
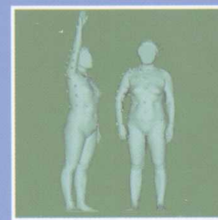
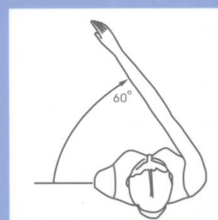
Engineering the Fit of Upper Body Clothing

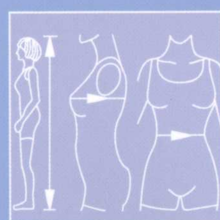


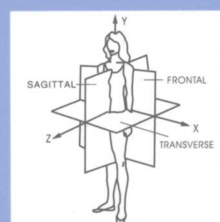


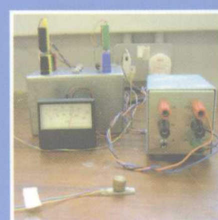
ENGINEERING THE FIT OF UPPER BODY CLOTHING

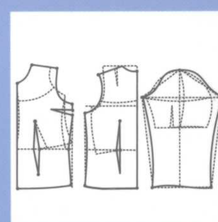
上装适体性研究











Written By LIU CHI

刘驰 著

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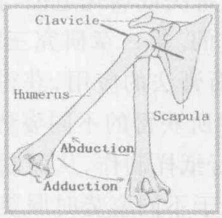

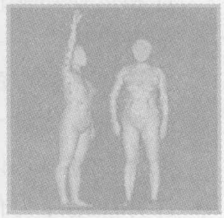

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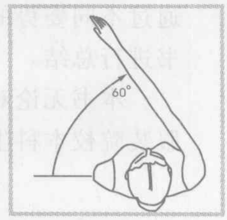

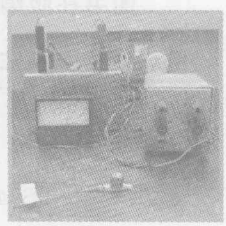

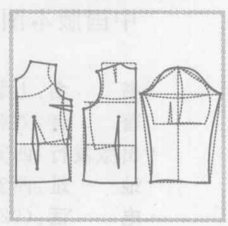

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内容提要

本书是作者在英国曼彻斯特大学攻读博士学位期间研究工作的结晶，亦是作者多年在服装工程领域教学与研究的经验总结。主要研究服装结构对于服装适体性和运动功能性的影响，并从结构上解决或弱化造型与运动功能性的矛盾。本书由七章组成。第一章介绍研究背景和目的。第二章研究三维人体扫描方法在人体非标准姿势测量中的应用。第三章通过石膏法的应用，获得不同姿势的人体原型，并精确测量人体尺寸。第四章以石膏法中所获得的不同姿势的原型为基础，利用服装软件“COAT4. 1”设计不同的放松量进行纸样制作，从而制作出实际的服装。第五章设计并应用压力传感器，测量当人体处于不同姿势时服装与人体之间的压力。第六章通过不同姿势的人体尺寸调查，对适体成衣中的放松量效果进行评价。第七章对全书进行总结。

本书无论对于企业生产，还是科研、教学工作都具有较强的指导作用，适用于服装院校本科生双语教学，也可作为服装工程专业研究生的参考书。

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Foreword

This book is based on Dr. LIU Chi's thesis submitted to The University of Manchester, Manchester, UK for the degree of doctor of philosophy in the Faculty of Engineering and Physical Sciences, School of Materials.

LIU Chi graduated in 1988 from the Northwest Institute of Textile Science and Technology, in Xi'an, China. She has also taken a Master degree in "Clothing Design and Engineering" at this institution and was awarded the highest grade of "Excellent Postgraduate". In October, 2001, LIU Chi registered with the Department of Textiles at UMIST, Manchester, UK to commence her studies into "Clothing Engineering" for the award of Doctor of Philosophy under my supervision. During her time in the department, she proved to be a mature, reliable and well-organised postgraduate student who related well to both academic staff and to her peers. Her communication in English was also very good, and she showed herself to be an extremely determined, industrious and resourceful research student. She delivered her PhD reports on time and finished her PhD studies in four years. Her PhD oral examination is memorable for the enthusiastic, lucid and coherent discussion of wide-ranging academic research findings; an outstanding achievement for any postgraduate student, but utterly exceptional for a viva involving an overseas research student.

The aim of her work was to improve the fit, appearance and comfort of ready-to-wear clothing. To this end, a 3D scanner was used to investigate alterations in body profile during the adoption of dynamic postures, and plaster casts were taken to explore these changes more thoroughly. Transducers were fitted between the clothes and the body to examine the fit in a number of dynamic postures. A survey was also conducted to investigate the relationship between ease and pattern design for different dynamic poses. In addition to this work, LIU Chi has also written five academic papers detailing her analysis of clothing design and geometry; two papers on clothing pattern design were published in the *Research Journal of Textile and Apparel* (Hong Kong); work on sleeve design was presented at the *2003 Autex International Conference* (Poland); a paper on body-scanning was published in the *International Journal of Clothing Science and Technology* (UK), and a paper on plaster method is in process of submission to *Journal of Textile Institute* (UK). Apart from these publications, she is an excellent researcher with a proven track record of published 11 papers and 5 textbooks before she came to England.

Although LIU Chi was awarded a bursary to cover her university fees, she had to find her own living expenses, and she supported herself in the UK by teaching clothing design to undergraduate students and by working outside the university. All of these activities absorbed her time, so it is of great credit to her that she has made good progress with her PhD studies and finished on time.

LIU Chi was also very active outside the university: having served as Secretary and Treasurer of the Chinese Textile and Apparel Society in the UK (CTAS-UK), she ultimately became Chairperson of the society. This involved organising academic conferences, research meetings and social events throughout the year. She also acted as interpreter for Chinese delegations visiting the university, and performed the duties of personal translator for the CEOs of Hangzhou Zhonghui Textiles Ltd., Hangzhou, Zhejiang, P. R. C.

LIU Chi's high level of academic achievement and her numerous publications taken together with her excellent performance in the UK, have resulted in original research of the highest calibre. I am pleased that her work is being developed into a book, and I very much look forward to reading it when it is published.

W. R. Kennon
Programme Director for Clothing Technology and Fashion Management
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Preface

Garments are usually created by three-dimensional or two-dimensional methods. The three-dimensional modelling approach (Haute Couture) involves draping fabric directly onto a human model. This gives the couturier and the tailor a feel for the way in which the fabric drapes and moves. The advantages of such an approach are that the garment is guaranteed to fit well, posture is taken into account and the properties of the primary material are used to best advantage. The drawbacks derive mainly from the time-consuming nature of the exercise.

The two-dimensional clothing pattern is a diagrammatic representation of the fabric panels, which may be consolidated into a garment and moulded around the contours of the three-dimensional human anatomy. When creating clothing patterns using a two-dimensional approach, the amount of ease to be included is determined from the estimations of static and dynamic freedom required to produce the desired fit and appearance of the clothing. The extent of ease that is necessary in various designs is difficult to determine theoretically, and is a serious concern for all pattern cutters. The resolution of this quandary is complex and involves many interrelated disciplines such as anatomy, ergonomics, anthropometry, morphology, aesthetics, physiology, psychology, and sociology.

The aim of this research is to produce a rule-based system for incorporating various levels of ease into pattern drafting for optimising the engineering of clothing. The objective of this work is thus to overcome problems with pattern drafting that leads to clothes exhibiting poor fit. Since little fundamental research has been performed in this area, it is important in both academic and industrial perspective, to bring together the literature, which is also currently scattered in different disciplines. This monograph is the first attempt to offer a comprehensive review and critical assessment of progress on the scientific understanding and technological innovations in the field of clothing engineering and the fit of high-performance garments.

The book comprises seven chapters related to my PhD research of engineering the fit of upper body clothing for non-standard applications. The background and aims of the research is introduced in Chapter 1 of the book. In the quest to develop a system for obtaining accurate measurements of the human body, investigations will be made into the capabilities of the 3D body scanner and a plaster cast method will be applied, which is considered and discussed in Chapter 2 and Chapter 3. It is intended to use a pattern drafting system to design garments and to test the approach by constructing garments with different levels of ease. It is further intended to test the ease by examining the freedom of movement available to the upper limbs when the garment is being worn, which is explored in Chapter 4. This will be effected through the use of small pressure transducers applied between the garments and the body concentrating particularly around the shoulder girdle, which is devoted in Chapter 5. Chapter 6 is planned to explore the universal application of different degrees of incorporated ease into the construction of commercial clothing by an adaptation of the survey technique which will allow assessment of a wide cross-section of ready-made garments. And Chapter 7 sums up the conclusions and describes the future work for clothing engineering.

Although this book is principally a research monograph under the supervision of Dr. W. R. Kennon, programme director for Fashion Management in the University of Manchester, UK, it is expected that this work will provide the basis for changes in the design and in the sizing of ready-to-wear clothing, and as such it should interest catalogue companies, retail chain stores and manufacturers of military uniforms. It is useful not only for academia but also provides a sound theoretical basis and practical reference for technologists, designers and engineers in the industry in their future development and innovation.

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CONTENTS

1. Introduction

It has been said for centuries that whilst man makes the clothes "clothes make the man". In China, there is an old saying: "clothing, food, shelter and transportation are the four basic necessities that are essential for the human being to survive". Clothing is an integral part of human life, and civilized people are, under ordinary conditions of life, protected by clothing from the cradle to the grave [Renbourn E. T., 1972]. Clothing has become the crucial product that is used everyday to obtain physiological and psychological comfort. It not only has fundamental implications for the survival of human beings, but also improves the quality of life.

1.1 Garment-Making Systems

Garments are usually created using one of three fundamental approaches. Each method has its strengths and weaknesses and the system which is ultimately selected depends predominantly upon the circumstances and cost.

1.1.1 Haute Couture

The three-dimensional (Haute Couture) modelling approach involves draping fabric directly onto a human model. This gives the couturier and the tailor a feel for the way in which the fabric drapes and moves. An intermediate stage is commonly introduced by employing an inexpensive, but dimensionally-stable material (usually calico, or muslin), which is pinned or sewn around the body or onto an adjustable mannequin, to form a toile. This toile is then marked with panel boundaries and is cut off the mannequin. This "sacrificial" fabric may then have ease and seam allowances added before being used as a pattern for cutting the primary fabric from which the garment is to be created. The advantages of such an approach are that the garment is guaranteed to fit well, posture is taken into account and the properties of the primary material are used to best advantage. The drawbacks derive mainly from the time-consuming nature of the exercise.

1.1.2 Block Patterns

The use of block patterns derives from the Haute Couture approach and is intended to simplify the process by starting from the toile stage. Instead of making a fabric toile and an individual pattern for each client, a series of blocks is first created, usually in cardboard. Each block contains a set of pattern pieces that encompasses the graded measurements required for a single standard size; so several graded blocks are required for each garment. These block patterns incorporate ease and may include seam allowances. An item of clothing made from a block pattern will exactly fit a customer who has a perfect "average" figure in one of the standard sizes. The appropriate pattern block is selected by chest or waist measurement, depending on the type of garment being created. As the majority of customers do not have a perfect average figure, it is necessary for the tailor to customise the garment "on the fabric", and adjustments are made to accommodate specific arm or leg lengths as the chalk is drawn around the block on to the fabric. Allowances may also be made for unusual posture and shape. The advantages of such an approach are the speed and efficiency compared with Haute Couture. The drawbacks revolve mainly around the fact that only an experienced tailor is capable of modifying the design on the fabric, and the necessity for customer fittings that are required to adjust the fit, particularly at the crown of the sleeves and the nape of the neck. The fabric is not draped on to a model, so there is no opportunity to observe its dynamic behaviour. The final appearance of the garment depends largely on the skill and judgement of the tailor.

1.1.3 Pattern Drafting

To make garments, it is also possible to first draft a pattern onto paper, using body measurements in conjunction with geometrical construction. The aim of such an approach is to create a pattern, which is similar to a tailor's block pattern, except that it has been synthesised from first principles. Ease and seam allowances may be included with such an approach, so the finished pattern is ready to be used by a relatively inexperienced technician. Bespoke patterns can be fabricated by using one particular customer's measurements, or mass-produced clothes can be designed by using "average" measurements for each individual standard size. The advantages of pattern drafting include the replacement of judgement with scientific pattern synthesis. Such a rule-based approach is well suited to computerisation that has inevitably led to an increasing take-up of this system in recent years. Once a pattern has been stored in electronic form, minor modifications may be inserted without difficulty and most importantly, the information may be transmitted directly to remotely-situated marker making and fabric-cutting machines. Disadvantages stem from the fact that complex geometrical synthesis is being used to try and re-create a two-dimensional pattern block, which is itself an attempt to replicate the three-dimensional shape of the human body. In addition to the increasing remoteness of the pattern from the customer when drafting is employed, measurements of the human body rarely yield information about posture; pattern synthesis thus tends to produce clothes which offer a relatively inexact fit. However, when used for mass-produced clothing, such distance from the client is inevitable, and the resulting fit is acceptable.

1.2 Background of the Research

The two-dimensional clothing pattern is a diagrammatic representation of the fabric panels, which may be consolidated into a garment and moulded around the contours of the three-dimensional human anatomy. Such patterns may be used as a basis for creating mass-produced garments that provide something approaching a good fit. Ready-to-wear clothing has been available for over two hundred years [Cooklin G., 1999], and the quality of fit has improved significantly over this period of time. The undertaking of national sizing surveys [BS5511: 1977, BS3666: 1982] has supported this development, as these surveys have been used to assist the categorisation of people into a range of standard sizes and shapes. Following on from this, garments have been manufactured to correspond with standard sizes, and these are generally assumed to provide a sufficiently wide range of shapes and sizes for garments to be available to fit the wearer reasonably well. However, this situation is not universally true, partly because body shape is evolving faster than data collection. The evaluation of UK standards BS3666: 1982 is no longer fully representative of today's female population, thus the validity of manufacturing women's apparel to outdated sizes and body form classification methods must be questioned [Gray D., 2002]. Problems resulting from the imperfect figures derived from sizing surveys are compounded by the flaws in the pattern drafting systems which are now commonly used to create ranges of clothes in various sizes for ready-to-wear fashion collections. These geometrically-based drafting methods were originally developed by mathematicians in an attempt to mechanise pattern creation, but contain standard curve forms which have been rendered imperfect by the evolution of the human body in these days of over-nutrition.

Similarly, A 1996 Textile/Clothing Technology Corporation (TC^2) study revealed that half of all American consumers were unable to find ready-made garments that fitted them properly; during the study, 67% of subjects indicated that the outlet "didn't have my size". A 1993 article in Bobbin, claimed that an estimated 70–80% of garments on the rack did not correspond to reported size, forcing consumers to contend with a wide variation in fit and mail order houses to experience a 30% return rate due to poor fit [Pechoux B. L., 2002].

In direct contrast, the cost of clothing in the ready-to-wear market has little effect on the fit except considering the factors of fashion trends and aesthetic concepts. The fit and comfort are controlled to a significant extent by the drafting system used to create the pattern. Consequently, any problems associated with the drafting system will degrade the fit and comfort of the resulting garment. Similarly, the way that body measurements are categorised within the sizing system will also affect both the fit and the level of comfort experienced by the wearer. It is the pattern and the sizing system that are largely responsible for clothes not fitting the body in the static and dynamic states.

In order to accurately convert a specific fashion style into a precisely-fitting flat pattern, the most important aspect of the pattern-making exercise is the incorporation of ease, as clothing made from normal woven fabric draped onto the body has to be designed with a degree of looseness, or ease, in various areas so that the body can move freely when the clothing is being worn. However, at the moment, there is no reliable means of assessing the amount of ease necessary to be included in different areas for particular styles of clothing. Hence, during the process of pattern design, if the pattern is to provide sufficient freedom of movement for the body, the pattern designer must rely on experience for the determination of how loose or how tight the clothing must be, and this decision will ultimately establish the dimensions of the two-dimensional pattern.

When creating clothing patterns using a two-dimensional approach, the amount of ease to be included is determined from the estimations of static and dynamic freedom required to produce the desired fit and appearance of the clothing. The extent of ease that is necessary in various designs is difficult to determine theoretically, and is a serious concern for all pattern cutters. The resolution of this quandary is complex and involves many interrelated disciplines such as anatomy, ergonomics, anthropometry, morphology, aesthetics, physiology, psychology, and sociology. It is therefore very difficult to establish suitable systems capable of indicating the appropriate levels of ease required to provide a high level of comfort combined with a good fit, indeed, it is demanding even to assess a single aspect of the subject. A possible approach is to isolate one specific area of the body and examine this element in those postures or positional states which most affect comfort and fit, and then examine in detail the relationships between ease and fit in this area.

Research has shown that a significant, though complex, aspect of fit and comfort in clothing is where seams are made between the major sub-assemblies of a garment. These joints occur, for example, where the head and other extremities connect to the trunk. In a study of overalls worn for asbestos removal work, 80 per cent of the subjects indicated that the crotch area was prone to ripping [Huck J., 1997]. When considering the upper body, the key areas in terms of stress are the segment parts where the upper limbs join the torso. These areas are termed the "shoulder girdle", which comprises predominantly the structure of the shoulder and arm, but also includes the structures of the front and back.

Accordingly, clothing design for the shoulder girdle is the key to upper garment structural design and is particularly pertinent to obtaining an acceptable fit that can still support all required articulations. The addition of extra fabric to provide higher levels of garment ease in the shoulder junction area could possibly help reduce tearing of the garment, however too much ease may hamper certain extreme movements (e. g. arm extension). Meanwhile, including differing amounts of ease into clothes may make them too tight or too loose in some parts of the body, and produce problems in regard to obtaining an acceptable fit, not only in terms of comfort, but also from the aesthetic point of view, and in respect of facilitating movement. Therefore, the state of the shoulder girdle, and the mobility of the scapula and clavicle form the fundamental basis for shoulder, sleeve, and front-back design. This is particularly the case as when it is being worn, upper body clothing hangs from the shoulder girdle. The shape it assumes depends largely upon the way it drapes from the shoulder structure under its own mass. The shoulder girdle and the necessary movement of the shoulder joint also constrain the style of clothing that may be formed. With movement of the shoulder girdle, the form of the shoulder and therefore the shape of a whole garment can change. It is therefore not easy to provide a good fit for the wearer and let him or her feel completely comfortable in the area of the shoulder girdle, especially when articulating this joint; this is what makes the engineering of the shoulder girdle of an upper body garment so fundamental to its structural design.

1.3 Proposed Solution

Computer technology has for many years been used in the determination of garment fit. The main applications used in such work include the 3D body scanner [Gray S., 1992, 1993, 1998; Heyd J. L, 2003; Ashdown S. P., 2004], and simulation of the human body and clothing [Kang T. J., 2000; Claudia M. E., 2000; Chiricota Y., 2001; Inui S., 2001; Baraff D., 1998; Volino P., 1995; Hodgins J. K., 1995], and the use of three-dimensional apparel CAD and CAM systems [Gray S., 1998; Kang T. J., 2000; Claudia M. E., 2000; Slavenka P., 2001; Gong D. X., 2001; Kang T. J., 2000; Woods G. P., 1989; Hhidehiko O., 1992; Heyd J. L., 2003] . Digital technology has been successfully applied to clothing pattern design, grading and marker making which have advanced rapidly over recent years. In fact, the purpose of most of this research and software development has been to help the clothing industry manufacture products that are comfortable and attractive, as well as facilitating an acceptable fit for a wider range of body shapes. Such work has also been aimed at reducing industrial costs and promoting quick market response. It has also made the mass production of clothing more efficient so that manufacturers and retailers can derive the greatest commercial benefit providing that suitable anthropometric data is available.

The 3D body scanner embodies some of the most advanced technology currently in use for measuring the human body. It has many advantages such as speed of measurement, absence of physical contact, and off-line measurement analysis that can be managed without the presence of the subjects. 3D body scanning is playing a gradually increasing role in pattern design, a trend that should accelerate as the technology improves. In this research it is planned to use one of the most advanced scanners, the Vitus 3D body scanner, to obtain measurements in both static and dynamic postures.

Publications by researchers working in the area of clothing pattern design and construction [Zhang W. B., 1990; Nakazawa S., 2000] have indicated that plaster casts taken of the human arm and leg can prove to be of assistance in the determination of the