

Clothing Classification Systems

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Prispjelo 20. 12. 2021.

UDC 687.006
Original scientific paper

The work deals with the systematic determination of clothing classification systems with corresponding definitions. This includes a general classification of clothing from an anthropological and engineering perspective. The anthropological aspect presents a classification based on fashion and anti-fashion, while the engineering aspect presents a classification based on functionality, which covers the logical types of fashion, functional clothing and high-tech clothing. This part contains both classifications and significant terminologies for individual types of clothing.

Keywords: Clothing, classification, fashion, anti-fashion, fashion seasonal clothing, functional clothing, uniforms, sportswear, medical clothing, protective clothing, high-tech clothing, intelligent clothing, clothing terminology.

1. Introduction

Clothing appears to be basic to civilisation [1]. It is a term referring to a covering that is worn to cover the body or to keep warm. It is an important interface between the human and the environment, and is exclusively a human characteristic, and is a feature of nearly all human societies.

Clothing is a form of communication and of visual language. In the history of clothing, this dress code held different connotations. It was an aesthetic pastime but it was also a mean to emphasize

social status and power as well as national identity [2]. Clothing has a double feature: it is a direct expression of the individual, but as part of a wider social framework, it necessarily adapts to the dictates imposed by society.

The kind and type of clothing worn depend on functional considerations (such as the need for warmth or protection from the sun, wind or rain, and/or from other environmental hazards) and social considerations. The functionality required of clothing can be very different depending on their end-use. Clothing functions are extremely diverse and depend on

the environmental condition of wear and the specifications for which they have been designed.

Clothing may be divided into many types displaying different styles and features. There is no set standard for their classification. Different classifications give rise to different names for clothing. However, in the second half of the 20th century and up to the present day, the terms of clothing terminology have expanded their meaning depending on the field of production. In art, clothing terminology refers to the conceptual meaning of the product, in industry it is subordinated to the functional

aspects of the product, while in theoretical and anthropological considerations the product is a material witness of personal and social habits. This contribution gives an overview of classification systems from an anthropological and engineering perspective, and a harmonized customs-based classification system with commonly used terminologies for individual clothing types, as well as clothing market segmentation.

2. Clothing classification from an anthropological perspective

Several authors have dealt with clothing classification in terms of anthropology, i.e., the study of culture and human societies. The classification of clothing can be done in many different ways. The historical study of clothing relates two levels of reality, that of dressing (habiliment), which Roland Barthes identifies with a speech in the Saussurian linguistic system [3] an individual act by which the individual adapts to himself what is proposed by the group, and that of clothing, seen from a sociological or historical standpoint as an element within a system which is formal, normative and sanctioned by society.

However, the time has come to subdivide the generic subject of clothing as adornment into two separate types: fashion and, on the other hand, anti-fashion. The essence of this differentiation can be found in Flügel's distinction between "modish" and "fixed" types of dress, in The Psychology of Clothes [4]:

The distinction here implied are not so much matters of race, sex, or cultural development, but depend rather on certain differences of social organisation. In their actual manifestations, the differences between two types become most clearly apparent in

the opposite relation which they have to space and time. 'Fixed' costume changes slowly in time, and its whole value depends, to some extent, upon its permanence; but it varies greatly in space, a special kind of dress tending to be associated with each locality and with each separate social body. 'Modish' costume, on another hand, changes very rapidly in time, this rapidity of change belonging to its very essence; but it varies comparatively little to space, tending to spread rapidly over all parts of the world which are subject to the same cultural influences and between which there exist adequate means of communication.

The term fashion and anti-fashion first appeared in a book in 1978, published by Polhemus. According to Ted Polhemus, fashion can be described as adornment, of which there are two types: fashion and anti-fashion [5]. Anti-fashion is fixed and changes little over time. Anti-fashion is different depending on the cultural or social group one is associated with or where one lives, but within that group or locality, the style changes little. Fashion is the exact opposite of anti-fashion. It is defined as "the cultural construction of the embodied identity." As such, it encompasses all forms of self-fashioning, including street styles, as well as so-called high fashion created by designers and couturiers [6]. Fashion changes very quickly and is not affiliated with one group or area of the world but is spread out throughout the world wherever people can communicate easily with each other. According to anthropologists Jane Richardson and Alfred L. Kroeber the fashion is not simply a change of styles of dress and adornment, but rather a systematic, structured and deliberate pattern of style change [7]. Fashion products are designed to meet the needs of consumers

that can be functional or intangible dimensions to highlight a social statue [8]. In addition, it should not be ignored the fact that the profitable strategy for fashion industry is in directing effort on "emphasizing the exclusivity" of their products [9]. Luxury fashion items are often result of emotional, psychological and social benefits arising from the purchase of high fashion products that represent status symbols of prestige, wealth and influence in society of its customers.

From the point of view of the segmentation frame aligned for the luxury fashion industry, which categorizes it into distinct segments according established criteria (e.g., brand loyalty, exclusivity), there are four specific areas within luxury fashion [10]:

- haut couture,
- prêt-à-porter,
- high-end, and
- premium.

Haute Couture is a French term (couture means dressmaking, while haute means high) that refers to the art of creating custom-fitted clothing. Haute couture pieces are unique and created for individual customers, such as royalty and wealthy [11]. Beginning in the mid-19th century, the Paris based haute couture created a unique fashion system that validated the couturier, a fashion designer, as an artist and established his or her "name" as an international authority for the design of luxurious, original clothing [6]. Each article of clothing is made with a single client in mind, and done in luxury high-quality materials, with an extreme attention to detail, and made by hand by the most experienced and skilled of all designers and tailors.

Prêt-à-porter is a French term for "ready-to-wear" that refers to the clothing lines as the first radical alternative to couture pieces when they hit boutiques in the 1960s.

The term describes factory-made clothing with added value of the concept of fashion, that is sold in finished condition and in standardized sizes [12]. The terms prêt-à-porter and ready-to-wear are comparatively new and describe a method of buying clothing whereby the customer no longer has to have clothing made to measure that time-consuming method that involves choosing a style, selecting a cloth, being measured, having a series of fittings [13]. Today prêt-à-porter is the dominant market segment in high fashion [14].

High-end fashion is fashion, which the goal was to produce beautiful garments that real people would wear. It refers to haute couture and contemporary fashion designs based on current fashion trends. According to a global market, high-end retailers have developed new functionalities, preserved existing methodology, and reconfigured new strategies of providing their customers with an experience richer than retail [15]. High-end is sustainable fashion brands whose design strategies include inter alia “vegan products, eco-friendly textiles, fair trade and artisanal craft.”

Premium fashion is an expensive variant of commodities in general. It is less ostentatious, more rational, accessible, modern, best in class, sleek design, and manufactured with precision. Premium is not luxury. They are two dissimilar categories catering to different market segments [16].

3. Clothing classification from an engineering perspective

Clothing and related products include all items of clothing and accessories worn by men, women, and children of all ages, with the exception of hosiery (stockings, socks, and tights) and over-

garments such as galoshes (waterproof shoes worn over conventional shoes), umbrellas, etc. Actually, there is no definite systematic classification of clothing, which are worn as ordinary clothing, or/and clothing providing additional value to the user by function, protection or virtue of innovative technologies. From the engineering standpoint, which treats the clothing in terms of the subject of interest, the encounters with fashion in everyday life, their functionality, intention of use, and specifications for which they have been designed, they can be divided into three different multifaceted groups:

- fashion seasonal clothing,
- functional clothing,
- high-tech clothing.

3.1 Classification of fashion seasonal clothing

Fashion seasonal clothing, also called everyday fashion clothing is the reflection of an interactive process through which the aspiring individuals of the society consciously distinctively project their bodily self in the form of clothing style. This distinctive manner of style is equally drawn from the fashion trends percolated through contemporary life, style conventions, fashion code concepts developed by the designers and forecasting service providers alike and street style fashion [17, 18]. From the point of view of many clothing manufacturers, regardless of the form of clothing style and fashion trends, there are five basic areas within clothing production:

- a) men's outerwear,
- b) women's outerwear,
- c) children's clothing,
- d) underwear,
- e) knitwear.

The kinds of fashion seasonal clothing according to the areas of production are shown in Tab.1.

Outerwear attire is worn over other garments and is generally designed to protect wearers from inclement weather or other adverse environmental conditions, although some outerwear is primarily ceremonial in function. Fashionable outerwear, however, does not include protective work clothing, so this entry focuses only on those outerwear styles worn with regular day or evening clothing [19].

Underwear is defined as the clothing worn next to the skin under outer clothing. The term underwear is used to describe items of clothing that act as a layer of insulation between the skin of the body and its outer garments [19].

Children's clothing as the smallest segment is delineated by age and size. They cover the children's outerwear and underwear. Children's outerwear is increasingly moving toward casual clothing that emphasize comfort and personal expression. Knitwear is a general term for clothing that is knitted or/and clothing made of knitted fabrics, and is often a prominent part of every collection. According to the performance of advanced knitted structures used that make knitwear desirable, the knitted clothing cover on a wide range of applications, from the area of underwear and outerwear, to the area in sport, protection, and medical applications.

3.2 Classification of functional clothing

Functional clothing is defined as a generic term that includes all such types of clothing or assemblies that are specifically designed and engineered to ensure predefined performance requirements and/or functionality for the user. It is clothing with achieves goals such as protecting the body, increasing health and safety, improving a

Tab.1 Areas of fashion seasonal clothing production

Area		Clothing type
Men's outerwear		• Men's suits • Jackets • Trousers • Coats • Raincoats • Sports clothing • Men's uniforms • Workwear, etc.
Women's outerwear		• Women's blouses and dresses • Women's costumes • Women's jackets • Women's slacks • Women's coats • Women's raincoats • Women's sports clothing • Women's uniforms • Women's workwear, etc.
Children's clothing		• Boys' suits, coats, jackets, trousers, shirts • Girl's dresses, coats, jackets, skirts, trousers, blouses • Children's blouses and dresses
Underwear	Men's underwear	Shirts, pyjamas, underpants, trunks, dressing gown, bathing wraps, etc.
	Women's underwear	Slips, corsets, bras, panties, bathing suits, pyjamas, nightgowns, housecoats, etc.
	Children's underwear	Undershirts, pyjamas, underpants, baby's underwear, bathing suits, bathing coats
	Bedlinen	Quilt cases, sheets, pillow cases, etc.
	Napery	Table cloths, serviettes, etc.
Knitted fabrics/ knitwear	Knitted underwear	• T-shirts, undershirts • Men's underpants • Women's panties • Slips • Trunks, bathing suits, bathing coats, etc.
	Knitted outerwear	• Cardigans • Pullovers • Jackets • Trouser, etc.

worker's efficiency on the job, or increasing body function. Moreover, it may include also protection under harsh environmental conditions during work or sporting activities and protection against extreme hazards and environments. It may also include clothing for use in monitoring and evaluating hazards in conditions under which conventional everyday seasonal clothing would not be adequate. The functionalities required of clothing can be very different, depending on the end-use.

Only a few examples of more widely used functional clothing are presented here, as the area is complex and broad. Functional

clothing may be classified according to the main application areas into the following groups:

- a) uniforms,
- b) sports-functional clothing,
- c) medical-functional clothing,
- d) protective clothing,
- e) clothing for special needs.

The performance of textile materials is frequently used in describing functional clothing. In the case of activity clothing, this user requirement is usually specific and complex. Some key areas for the application of functional clothing will be presented with regard to the above classification.

3.2.1 Uniforms

The term uniform is a word widely

used to refer to a vast range of garments employed by religious orders, the military, schools, professional groups, sports teams and others. The word uniform conveys a feeling of conformity, order and virtual absence of variability [20].

According to the Oxford English Dictionary the term is related to the distinctive clothing worn by members of the same organization or body or by children attending certain schools. Uniforms possess at least two functions [21]. First, they differentiate one class or group from another, and second, uniforms provide a common sense of identification for the group wearing them.

In view of these functions, uniforms may be divided into many types displaying different styles and features:

- a) diplomatic uniforms,
- b) military uniforms,
- c) authority uniforms,
- d) occupational uniforms,
- e) corporate uniforms,
- f) school uniforms,
- g) sports uniforms.

Classification of uniforms according to types and their functions is shown in Tab.2.

Diplomatic uniforms are civilian uniforms worn by ambassadorial and consular officers at public occasions. Diplomatic uniforms became part of general administrative reforms issued by most European countries around 1800 as a response to the French Revolution and the Napoleonic wars [19]. Diplomatic uniforms generally followed 19th-century court fashion and usually included a tailcoat with standing collar, breeches or pantaloons, a sword

and a two-cornered plumed hat known as “bicorné.” There were normally at least two versions, a dress uniform for ceremonial events and a simpler version for less formal occasions [22]. The diplomatic uniforms tended to keep their traditional design and vary by country (United Kingdom, Germany, Russia and the Soviet Union, United States, etc.).

The military uniform, which came into general use with the appearance of large national armies

Tab.2 Classification of uniforms

Area		Uniforms type
Uniform diplomatic		• Diplomatic consular uniforms • Diplomatic ambassadorial uniforms • European diplomatic uniforms • Diplomatic uniforms by country (Germany, United Kingdom, France, Russia and the Soviet Union, United States) • Uniforms of the Vatican’s Swiss Guard
Uniforms military	Uniforms regulation	• Marine corps uniforms • Army uniforms • Air force uniforms • Coast guard uniforms • Uniforms of the military orchestra, etc.
	Service uniforms	• Formal and dinner dress uniforms • Ceremonial uniforms • Parade uniforms • Service uniforms • Working uniforms • Combat uniforms, etc.
	Special uniform situations	• Camouflage uniforms • Flight clothing • Protective clothing for operators of vehicles other than automobiles • Submarine sweater
	Uniforms by country	• Uniforms of the British Armed Forces • Uniforms of German Army • French Army Uniform • Uniforms of the Canadian Armed Forces • Uniforms of the United States Armed Forces • Uniforms of the Russian Armed Forces, etc.
Uniforms authority		• Police uniforms • Parade uniforms, for example: the Royal Canadian Mounted police uniforms, Monaco’s police uniforms, etc.
Uniform Religious		• Nuns uniforms (uniforms of the Missionaries of Charity assemble at Saint Mary’s Church in Calcutta, uniforms of the Franciscan Sisters, etc.) • Monks uniforms, etc.
Uniform under authority		• Prison uniforms
Corporate uniforms		Airline Uniforms: • Air France’s uniforms, • Uniforms of German Airline Lufthansa, • Hainan Airlines uniforms Bank house’s uniforms: • London City banks uniforms • Uniforms of Barclays Bank London • AIB Bank uniform, etc.

Tab.2 Classification of uniforms – continued

Area		Uniforms type
Uniforms occupational	Security	- Public security uniforms - Security service's uniforms - Firefighter uniforms, - Uniforms of civil protection, etc.
	Work	- Uniforms of postal workers - Postman's uniforms - Uniforms of railway workers - Pilot uniforms - Stewardesses' uniforms - Hotel uniforms - Hotel doorman's uniforms <i>Restaurant uniform</i> - Waiter uniforms - Food service's uniforms - Cookery uniforms - Mining uniforms - Chimney sweep, etc.
	Health care workers	- Healthcare uniforms - Nursing staff uniforms - Physical therapist's uniforms - Technician's uniforms - Occupational clothing for doctors - Occupational clothing for dentists - Veterinary surgeon uniforms - Ambulance staff uniforms
	Association	- Hunting uniforms - Hunting association uniforms - Scout's uniforms, etc.
Uniforms school		- Primary schools uniforms - Secondary schools uniforms - State schools uniforms - Private school uniforms - Catholic school uniforms, etc.
Uniforms sport		- Athletic team's uniforms - Football uniforms - Baseball uniform - Basketball uniforms - Handball uniforms - Volleyball uniforms - Cricket uniforms - Kit (association football) uniforms - Judo uniforms - Soccer uniforms - Uniforms of European Ryder Cup Team - Uniforms of American football, etc.

in the 17th century, had the primary function of identification. The belonging to a particular armed force distinguished the soldiers from their enemies and the military uniform had and has other welcomed functions such as promoting obedience, comradeship and a display of strength. International humanitarian law introduced to this identification

element another dimension, namely the cardinal principle of distinction between combatants and civilians [23]. Military regulations usually prescribe the appearance of uniforms and insignia and how they are to be properly worn by officers and enlisted personnel of the armed forces. Authority uniforms are non-military uniform

worn by persons or organization having political or administrative power and control. The uniforms promote discipline and pride in one's appearance. In addition, it is also necessary to mention religious uniforms, resp. religious vestments, which have historically served a dual purpose: to show the wearer's obeisance to a deity while also elevating the wearer

from the masses and emphasizing their religious authority or vocation [24].

Occupational uniforms are non-military civilian uniforms worn by members of certain professional groups during work or at official occasions. Specified and usually handed out by the employer, the uniform is designed in certain colours and carries signs and badges, which signal the employee's function and rank within a professional organization [19].

Since the second half of the 20th century, the character of occupational uniforms has changed significantly. Instead, professional uniforms have become part of modern concepts of corporate identity and corporate culture. Called corporate wear or corporate fashion, uniform dress at work is designed to communicate the philosophy of an organization or company and thereby is an increasingly important tool of marketing strategies [19]. Corporate uniforms as fashion clothing are based on a paradox: on one hand it relies on traditional values and conventions, thus having an antifashion feature, while on the other hand subjective desires of an individual should be fulfilled and adaptations to contemporaneous (modernised) business methods and fashion trend should be accomplished [25].

Contrary to occupational uniforms the school uniforms as understood in their modern sense are a particular manifestation of a more general uniformization of populations, as also a desire to minimize socioeconomic tensions between the "haves" and "have nots." As the U.S. Department of Education's Mantlal on School Uniforms notes, "Uniforms by themselves cannot solve all of the problems of school discipline, but they can be one positive

contributing factor to discipline and safety" [26].

Sports uniforms are uniforms, which wear sports teams, respectively, the members of sport club. They are made in the team's distinctive colours. Club uniforms were an integral part of a team's heritage and of heritage of the sport [27]. An important role in the field of sport uniforms possesses the Olympic uniforms of athletes who, on the one hand, bring together athletes of a particular nation, and on the other hand, the world as a whole, because nations differ especially in national colours. Olympic uniforms in the 21st century have also a greater impact on fashion due to the rising popularity of athleisure. Because of this, Team nation's ceremonial uniforms have become a bit more casual and sportier; however, imbue elements of national identity into their uniforms still.

3.2.2 Sports-functional clothing
Sports-functional clothing is clothing that is especially designed for sports and physical exercise. These sorts of clothing differ from casual clothing in that it often has features that enhance functionality. Sports clothing generally requires in addition to basic functions like comfort, protection, stretchability and lightweight, a high level of breathability and moisture/vapor transfer combined with heat insulation and/or wind-proofing, waterproofing, and UV protection. In many applications, the functionality must be considered in conjunction with interactions between bodily activity, clothing, and the environment.

Sports clothing is a general term and garments must meet specific functional requirements, which depend on the nature and duration of sports, amount of physical activity and its environment, as well as the construction, mechanical, physiological and/or

aerodynamic characteristics, and fitting of the clothing.

Sports clothing design and its engineering modelling require detailed information on the materials (thermophysiological performance, mechanics, and surface physics of materials), and associated (mechanical, thermophysiological, and aerodynamic) behaviour during the sporting action. In the case of highly active sports, the main functional requirement of sportswear is sweat absorbing, fast drying and cooling [28]. High active sportswear should also have high stretch and elastic recovery to provide sufficient fit and freedom of movement to the wearer [29].

The required functionality may thus differ greatly and may be also based on the application of compression or the principles of aerodynamics to reduce wind or air drag during high-speed sports. In active sports like jumping or running compression is created by stretchable fabric to enhance the performance of an athlete. Compression clothing (e.g., clothing and stockings) includes elastic, body-moulded suits with an engineering compression gradient [30, 31]. Compression clothing provides the necessary compression and anatomic fit to an athlete. The function of aerodynamic clothing (i.e., garments for athletic or cycling wear) is to trap a thin layer of air next to the body [32, 33]. The aerodynamic clothing (i.e., ski jumping suits) requires besides the necessary anatomic fit to an athlete, first of all the necessary aerodynamic resistance and its associated energy loss during the sporting action, in which it plays an important role in the surface morphology of jumping suit, which affects the aerodynamic parameters (drag, lift and lift-to-drag ratio) [34, 35]. Both principles may be used in combi-

Tab.3 Classification of sports-functional clothing

The sports	Kind of clothing
Golf	Golf stylish clothing (allow also a casual or a formal look of clothing)
Tennis	- Short tennis skirts, t-shirts - Tennis dresses made out of a variety of high performance fabrics - Men shorts, t-shirts
Soccer	Soccer uniform
Basketball	Basketball wear
Baseball	Baseball uniform (sliding shorts and jerseys)
Football	- Football shirts, football shorts - Protective clothing - shin guards (EN 13061:2009)
Contact sports (like American football and ice hockey)	Adequate uniform as protective clothing with chest guard
Swimming	- Swimsuit, bathing suit - Swimming costume - Professionals skin-tight costumes - Bodysuits, called as dive skins
Diving	- Diving suit - Wetsuits
Running	- Women's running clothing (lightweight performance in an athletic design) - Men's running clothing (lightweight performance in an athletic design) - Skin-tight garment
Skiing	- Ski suit (one-piece ski suits), snowsuit - Jumpsuit (two-piece, in the form of a ski jacket and matching trousers) - Racing suit - Cross-country gear - Ski jacket
Ice skating	- Skating dress - Speed skating dress
Ice hockey	Hockey dress
Curling	Curling dress
Cycling	Cyclist wear
Motocross/motorcycle riding	Protective clothing for professional motorcycle riders (jackets, trousers, one piece or divided suits)
Aeronautics	One-piece flying suit
Fencing	Fencing clothes, jacket, knickers
Karate	Special karate clothing
Judo	Judo uniforms
Fitness clothing	- Men's T-shirts, tank tops, shorts, pants, - Ladies sports bras, workout pants or shorts,
Mountaineering / alpine climbing	- Mountaineering clothing - Climbing clothing, climbing breeches, snow shirt - Expeditionary clothing - Wanderer clothing - Running wear

nation or individually, according to the requirements.

Furthermore, the diving suit as a garment type for special purposes requires to satisfy high criteria of comfort, fit and functionality (performance characteristics include thickness, elasticity, bursting strength, hydrophobicity with very low surface energy, thermal resistance, and seal strength [36, 37].

Further classification of sports-functional clothing is given in Tab.3.

In addition, it should be emphasized that is noticeable increasing the number of individuals, which wear sports clothing as part of everyday life, what may have an impact on the development of a new type of consumer-oriented sportswear.

3.2.3 Medical-functional clothing

This category refers to functional clothing for healthcare. Characteristics typically include absorbency (wound-dressing), air permeability (surgeons' gowns, staff uniforms), and durability (pressure clothing). These types of functional clothing may be categorised into four separate and

Tab.4 Classification of medical-functional clothing

Areas of application	Kind of clothing
Healthcare/hygiene	• Healthcare uniform • Clothing for nursing staff, nurse's uniform • Clothing for patients, scrubs, patient wear • Medical coats, tabards • Medical protective clothing (in isolation wards and intensive care units) • Protective gown for dentist • Protective gown for veterinary
Surgery	• Surgical clothing • Surgeon's gowns, caps • Surgical cover cloths • Surgical hosiery • Surgical hosiery with graduated compression characteristics
Therapeutic clothing	• Pressure clothing • Bio-functional clothing for patients with atopic eczema • Clothing for protection against infectious agents (ISO 22609:2004) • Thermochromic clothing for early medical warning • Tubular elasticised net garment • Far infrared therapeutic clothing • Anti-microbial underwear • Anti-irritant's underwear [55]
Intelligent functional clothing	• Cardiopulmonary resuscitation vest • EKG Vest for heart patients • Intelligent biomedical clothing • Intelligent clothing's physiological monitoring • Intelligent clothing in prehospital emergency care • intelligent functional clothing for personal health records and medical information management • intelligent vest for fall-detection for the elderly

specialised areas of application, as follows:

- a) healthcare/hygiene clothing,
- b) surgical clothing,
- c) therapeutic clothing,
- d) intelligent functional clothing.

The range of medical clothing described according to functional requirements or in protecting against potential health hazards is illustrated in Tab.4.

Healthcare/hygiene and surgical clothing are important sectors in the fields of medicine and surgery, and includes all the essential disposable medical clothing required the meet an infection control standard, and includes aprons, gowns, gloves, surgical masks, theatre caps and overshoes. They may be used in operating theatre's and on hospital wards for the care, hygiene, and safety of staff and patients [38, 39]. Surgical gowns as medical-functional clothing has to fulfil the basic demands stipulated in the

European standard series EN 13795 [40]. Their relevant properties, such as a barrier effect, purity, low particle release rates and strength are stipulated in EN 13795-1 (2019) [41], and the requirements and test methods in EN 13795-2 (2019) [42]. For various types of operations, two different product performance classes are defined: (a) high performance, for operations with a high risk of infection and penetration by liquids and (b) standard performance, for operations where these risks are lower. Therapeutic clothing is by definition user-requirement specific and designed or engineered to meet the therapeutic performance requirements of the user. Therapeutic clothing includes pressure clothing and clothing designed specifically to aid in reducing the risk of infection and/or for sensory stimulation. Pressure therapy imparted through

compression garments is a well-established method of treatment for hypertrophic scars, burn injuries, venous and lymphatic disorders [43, 44]. In addition, it is necessary to mention therapeutic clothing for the relief of eczema symptoms [45], and/or therapeutic clothing for sensory stimulation of children with psychomotor delay [46], as well as application of pressure therapy in rehabilitation clothing. This type of clothing is based on a combination of the science of proprioception and targeted skeletal support technology. The rapid development of science and technology enables also the use of intelligent functional clothing, which as high-tech products possess an important role in medicine and health care. Intelligent clothing integrates functional clothing design and wearable technology and can be regarded as one of the functional clothing in which technological

functions are automatically activated and deactivated. They are garments used to monitor health or help with treatment that could reduce reliance on costly equipment and a heavily burdened healthcare system.

3.2.4 Protective clothing

According to the Standard ISO 13688 (2013) [47], protective clothing can be defined as clothing including those protectors which cover or replace personal clothing and which are designed to protect against one or more hazards. Particular clothing may be designed to protect against hazards encountered during specific types of work. Examples include garments providing protection against cuts, abrasion, ballistic and other types of severe impact, including stab-wounds and explosions, fire and extreme heat, hazardous dust and particles, nuclear, biological and chemical hazards, high-voltages, static electricity and extreme cold. High-visibility wear also comes into this category.

Under the strict regulations placed upon employers by the introduction of legislation such as the Personal Protective Equipment (PPE) at Work Regulation (European Union), it is necessary to ensure that protective clothing is adequate for meeting anticipated hazards and is used effectively. The clothing must be well designed and comfortable to wear. Protective clothing, considered as an integral part of PPE, is covered by the Regulation (EU) 2016/425 on Personal Protective Equipment [48], and is divided into three categories of risk against which PPE is intended to protect users:

Category I — This covers exclusively PPE intended to protect the wearer against the following minimal risks:

a) superficial mechanical injury;

- b) contact with cleaning materials of weak action or prolonged contact with water;
- c) contact with hot surfaces not exceeding 50°C;
- d) damage to the eyes due to exposure to sunlight (other than during observation of the sun);
- e) atmospheric conditions that are not of an extreme nature.

Category II includes risks other than those listed in categories I and III.

Category III includes exclusively the risks that may cause very serious consequences such as death or irreversible damage to health relating to the following:

- a) substances and mixtures which are hazardous to health;
- b) atmospheres with oxygen deficiency;
- c) harmful biological agents;
- d) ionizing radiation;
- e) high-temperature environments the effects of which are comparable to those of an air temperature of at least 100°C;
- f) low-temperature environments the effects of which are comparable to those of an air temperature of -50°C or less;
- g) falling from a height;
- h) electric shock and live working;
- i) drowning;
- j) cuts by hand-held chainsaws;
- k) high-pressure jets;
- l) bullet wounds or knife stabs;
- m) harmful noise.

Classification covering types of protective clothing according to the Personal Protective Equipment (Regulation (EU) 2016/425), is given in Tab.5. The classification is based on the need for adequate standards of protection and does not cover military clothing or clothing ensembles.

3.2.5 Clothing for special needs

This category of clothing is concerned with improving the quality of life for people with

special needs or disabilities. This includes wheelchair users, stroke victims, arthritis sufferers, and people with physical disabilities, and those with restricted movement. Clothing for special needs or the so-called adaptive clothing are garments, designed with medical function in mind for post-surgery patients, the disabled, elderly, rehabilitation patients, special needs children and adults, people with arthritis, stroke victims, etc. [49]. Special needs clothing for disabled people are garments made to measure for individual comfort. This includes clothing with modifications for paraplegics, the elderly and handicapped, hypo-allergenic garments, clothing for Alzheimer's sufferers, arthritis patients, incontinence sufferers, jumpsuits, sensory-perceptive children's clothing and clothing for those with other disabilities, for example adaptive bra [50] or adaptive clothing for amputees [51]. The needs of each group are distinct. It is therefore necessary for the clothing to be engineered to specific requirements. Design considerations include changes in body shape, limitation of mobility, ergonomic and physiological requirements and psychological and social needs.

Adaptive clothing should promote harmony between functionality and aesthetics. The quality aesthetic approach in the design of adaptive clothing can accentuate positive attributes of the body while distracting from negative attributes, such as disability [52].

3.3 Classification of high-tech clothing

The 21st century can be marked as a turning point in the development of new high-tech materials. A new generation of materials, called intelligent materials, is developed. The concept intelligent materials were for the first time defined at

Table 1.5 Classification of protective clothing

The need of protection	Kind of protective clothing
Protection against mechanical impact	Special workwear, which must be sufficiently shock-absorbent to prevent injury resulting, in particular, from the crushing, etc., at last up an impact-energy level. Motorcyclists' protective clothing (EN 1621-1, 2013; EN 1621-2, 2014) [56, 57] • Protective clothing for horse riders (protective jackets, body and shoulder protectors) (EN 13158, 2018) [58] • Protective clothing for professional motorcycle riders (EN 17092-1, 2020, which replaced EN 13595-1, 2002; EN 13595-2, 2002; EN 13595-3, 2002; and EN 13595-4, 2002) [59-63] • Protective clothing for motorcycle riders (EN 17092, 2020 Part 1-6; Part 1 describes the test methods, while parts 2 to 6 detail the requirements for garments in classes 'AAA', 'AA', 'A', 'B' and 'C' (EN 17092-1, 2020; EN 17092-2, 2020; EN 17092-3, 2020; EN 17092-4, 2020; EN 17092-5, 2020; and EN 17092-6, 2020) [59,64-68]
Protection against physical injury (abrasion, perforation, cuts, bites)	Protective clothing against abrasion, protective clothing against perforation, cut resistant protective clothing. Aprons, trousers and vest protecting against cuts and stabs by hand knives (ISO 13998, 2003) [69] Protective clothing for abrasive blasting operations using granular abrasives (ISO 14877, 2002) [70] Protective clothing for users of hand-held chainsaws—resistance to cutting by a chainsaw (EN ISO 11393-1, 2018) [71]
Protection of drowning	• Lifejackets, lifesaving suit • Buoyancy aids clothing which will ensure an effective degree of buoyancy
Protection against heat and/or fire	• Protective clothing for protection against heat and flame (ISO 11612, 2015; ISO 14116, 2015) [72, 73] • Protective clothing for fire-fighters (EN 469,2020; ISO 15384, 2018) [74,75] • Protective clothing for use in welding and allied processes (ISO 11611, 2015) [76] • Protective clothing for workers exposed to heat (excluding fire-fighters' and welders' clothing) (ISO 11612, 2015) [72] • Protective clothing against the thermal hazards of an electric arc (IEC 61482-2, 2009, ASTM F1506-17be1, 2017) [77, 78] • Protective clothing with electrostatic resistance - when the worker is exposed to environments where a spark could cause explosions or ignite fires, e.g. petrol stations, petrol tanker drivers, flour mills, clean rooms etc. Protective clothing can be classified according to the type of fabric used: clothing with surface conducting fabrics, resp., fabrics for which the electrostatic dissipative behaviour is based on surface conductivity (EN 1149-1, 2006) [79], and clothing with core conductive fabrics (for which the electrostatic dissipative behaviour is based on core conducting fibres) (EN 1149-5, 2018) [80]. • Protective clothing for automobile racing drivers (ISO 14460, 1999) [81].
Protection against cold	Protective clothing against cold (EN 342, 2017) [82]
Protection against rain	Protective clothing for protection against rain (EN 343, 2019; EN 14360, 2004) [83, 84]
Protection against electric shock	Protective clothing against electric shock • Electrical insulating protective clothing for low-voltage installation (EN 50286, 1999) [85]. • Conductive clothing for live working at a nominal voltage (EN 60895, 2003) [86]. • Protective shielding clothing for live working [87].
Protection against radiation	Protective clothing against radioactive contamination (EN 1073-1, 2016; EN 1073-1:2016+A1:2018, 2018; ISO 8194, 1987) [88-90] • Protective clothing against radioactive particulate matter
Protection against pesticides	• Protective clothing worn by operators applying pesticides and for re-entry workers (ISO 27065, 2017; ASTM F2669-12, 2018) [100, 97]
Protection against invisibility	• High-visibility warning clothing for professional use (ISO 20471, 2013) [101] • Visibility clothing for non-professional use (EN 17353, 2020) [102]

Table 1.5 Classification of protective clothing - continued

The need of protection	Kind of protective clothing
Protection against dangerous substances and infective agents	Clothing for protection against penetration or skin contact with hazardous chemicals, toxic gases, body fluids: • Protective clothing for protection against chemicals (ISO 16602, 2007; ISO 16602:2007/AMD 1:2012, 2012) [91, 92] • Clothing for protection against liquid chemicals (ISO 13994,2005) [93] • Chemical protective clothing for use against solid particulates (ISO 13982-1, 2004) [94] • Clothing for protection against infectious agents (ISO 22609, 2004) [95]
Protection against blood, body fluids, and other potentially infectious materials	Medical protective clothing for protection against contact with blood and body fluids, which serve as a barrier to blood, body fluids, and other potentially infectious materials. • Clothing for protection against contact with blood and body fluids (ISO 16603, 2004) [96] • Protective clothing, which is resistant to penetration by blood-borne pathogens (ASTM F1671/F1671M-13, 2013; ISO 16604, 2004) [97, 98] • Surgical Gowns Intended for use in healthcare facilities (ASTM F2407–20, 2018) [99]
Protection against solar ultraviolet radiation exposure	Sun-protective clothing (EN 13758-1:2001+A1:2006, 2006; EN 13758-2:2003+A1:2007, 2007) [103-104]

International Workshop on Intelligent Materials in Japan in 1989 [53]. Based on a concept that differs greatly from that of the so-called structural and functional materials. According to T. Takagi, the intelligent materials may be defined as “materials which respond to environmental changes at the most optimum conditions and manifest their own functions according to the changes” [53].

High-tech clothing is a generic term referring to clothing, which are a result of integration of advances in science and technology, and have the capability to interact with their user or environment, including tracking and communicating data about their wearer or environment.

High-tech clothing as a new generation of the “high technology” product (high-tech is an acronym for “high technology”) can be classified according to their technological level of integration of science, technology and engineering, and their capability to interact with their user or environment, into three groups, in accordance with Takagi’ concept of intelligent materials [53], and Tao’ classification [54] of smart textiles:

- passive high-tech clothing, that sense environmental stimuli,
- active high-tech clothing, called smart clothing, that sense and react to the environmental condition or stimuli, and
- very active high-tech clothing, which has a character of an intelligent clothing that able to sense, react and adapt their behaviour to the given circumstances.

The intensive development of this kind of clothing has led to different definitions and classifications of high-tech clothing. From degree of technology integration and their functionality point of view, high-tech clothing can be divided into three subgroups:

- a) e-clothing,
- b) smart clothing,
- c) intelligent clothing.

E-clothing as first generation of high-tech clothing belongs to the technology of garment. It is the combination of integrated electronic devices, such as mobile phone and an MP3 player. Furthermore, e-clothing contains batteries, simpler electronic devices, sensors, keyboards, etc.

Such garments are not considered smart clothing, especially if the wearer only controls the electronic equipment to realise some functions of the clothing.

Smart clothing as active high-tech clothing comprise both sensors and actuators. According to Tao (2001) smart clothing is defined as a new clothing feature which can provide interactive reactions by sending signals, processing information, and actuating the response [54].

Intelligent clothing as the third generation of high-tech clothing is much more advanced. They cannot only sense disparate data types but also interacts with wearer, capable of sensing, feedback and response. According to Tao, three components may be present in such clothing: sensors, actuators and controlling units. The sensors provide a nerve system to detect signals. The actuators act upon the detected signal either directly or from a central control unit; together with the sensors, they are the essential element for active smart materials/clothing. The third unit is essential, which works like the brain, with cognition, reasoning and activating capacities [54].

The degree of integration is highly dependent on the expressiveness and functionality of intelligent clothing. In general, the intelligent systems embedded into intelligent clothing consist of three units:

- a) sensor group for measurement and input of information,
- b) processing unit for interpretation of input information and decision making (microcomputers, microprocessors or microcontrollers with associated programs), and
- c) output device (actuator unit) that performs the adjustment of the garment and gives output information.

Intelligent clothing occupies today a wide field of use that extends from the military field, medical field, sports, safety protection and positioning, entertainment and leisure to the beauty of decoration. From the technological standpoint, which show the constant breakthroughs in technology, it is expected more and more complete and systematic development of intelligent clothing.

4. Conclusions

Although there have recently been major developments in new materials and clothing products (e.g., wearable electronics), their classifications have not yet been systematically defined. It is necessary to establish a coherent and universally acceptable description and classification for such clothing. The classification systems presented here are for the purposes of general knowledge and the understanding of clothing requirements, while the market segmentation presented are the basis for understanding the profile of the actual target customers, and for designing consumer-oriented clothing. In recent years customer segmentation has become a more difficult concept to operationalize in dynamic market contexts as

consumer lifestyles have fragmented traditional markets. Both, classification systems and market segmentation also contribute to the development of terminology in the field of clothing engineering. There are also important linguistic and cultural perceptions as to what constitutes clothing across a range from fashion, fashion seasonal clothing, and functional clothing to high-tech clothing.

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