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INNOVATION OF SPECIAL WORKWEAR DRIVEN BY SUSTAINABLE DESIGN: RESEARCH ON PRACTICAL PATHWAYS AND STRATEGIES

With the accelerated advancement of the industrial process and the continuous upgrading of industrial structures, human work categories and work fields are constantly expanding, and under the status quo of the improvement of practitioners' health awareness and operation efficiency requirements, the corresponding demand for professional special workwear is constantly increasing. At the same time, as the textile and apparel industry is the world's second-largest polluting industry, its sustainable development has become an important topic for all sectors of society. Therefore, this study focuses on the practical innovation design of contemporary special workwear, taking special workwear research as an example, explore the application pathways of sustainable design in the field of functional clothing design. Firstly, taking the classification and design element analysis of special workwear as the entry point, combining case analysis and literature research to systematically review the three major basic principles of sustainable clothing design: green ecological design, lifecycle design, and humanistic care design; then, on this basis, from the four aspects of zero-waste design, sustainable material design, silhouette structur design, and clothing lifecycle design, this study summarizes and proposes practical innovation design strategies for special workwear based on the concept of sustainable design. The strategies emphasize that special workwear design not only meets the wearing demands corresponding to user operations but also emphasizes the humanistic care and environmental friendliness of its design. By systematically integrating sustainable design concepts into the design practice of special workwear, this study aims to ensure better sustainability on the premise of guaranteeing its performance, providing certain theoretical support and design guidance for the sustainable design of modern workwear.

Key words: *sustainable design, special workwear, practical design, clothing design, green design, humanistic care.*

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ІННОВАЦІЇ СПЕЦІАЛЬНОГО РОБОЧОГО ОДЯГУ, ЗУМОВЛЕНІ СТАЛИМ ДИЗАЙНОМ: ДОСЛІДЖЕННЯ ПРАКТИЧНИХ ШЛЯХІВ ТА СТРАТЕГІЙ

З прискореним розвитком індустріального процесу та безперервною модернізацією промислових структур, категорії та сфери людської праці постійно розширюються, і в умовах підвищення обізнаності практикуючих фахівців про здоров'я та вимог до операційної ефективності, відповідний попит на професійний спеціальний робочий одяг невпинно зростає. Водночас, оскільки текстильна та швейна промисловість є другою за величиною

забруднюючою галуззю у світі, її сталий розвиток став важливою темою для всіх верств суспільства. Тому це дослідження зосереджується на практичному інноваційному дизайні сучасного спеціального робочого одягу, та, беручи за приклад дослідження спеціального робочого одягу, вивчає шляхи застосування сталого дизайну в галузі проектування функціонального одягу. По-перше, беручи за відправну точку класифікацію та аналіз елементів дизайну спеціального робочого одягу, поєднуючи аналіз кейсів та літературне дослідження для систематичного огляду трьох основних базових принципів сталого дизайну одягу: зеленого екологічного дизайну, дизайну життєвого циклу та дизайну гуманістичної турботи; потім, на цій основі, з чотирьох аспектів: безвідходного дизайну, дизайну зі сталих матеріалів, дизайну силуетної конструкції та дизайну життєвого циклу одягу, це дослідження узагальнює та пропонує стратегії практичного інноваційного дизайну для спеціального робочого одягу, що базуються на концепції сталого дизайну. Стратегії підкреслюють, що дизайн спеціального робочого одягу не лише задовольняє вимоги до носіння, що відповідають робочим операціям користувача, але й акцентує увагу на гуманістичній турботі та екологічності його дизайну. Шляхом систематичної інтеграції концепцій сталого дизайну в практику проектування спеціального робочого одягу, це дослідження має на меті забезпечити кращу сталість за умови гарантування його експлуатаційних характеристик, надаючи певну теоретичну підтримку та проектні настанови для сталого дизайну сучасного робочого одягу.

Ключові слова: *сталий дизайн, спеціальний робочий одяг, практичний дизайн, дизайн одягу, зелений дизайн, гуманістична турбота.*

Problem Statement. With the high-speed development of human society, problems such as the sharp increase in population quantity, the aggravation of environmental pollution, and the excessive consumption of resources are becoming more intense. This not only has an impact on human social life but also causes destruction to the natural ecological environment upon which humans rely for survival. In recent years, sustainable development has become a broad consensus of humanity, and the sustainable design concept is gradually being applied in various industries. As the world's second-largest polluting industry, the textile and apparel industry's attention to sustainable design has been increasing day by day in recent years (Ma, Rossonet al., 2020: 630–638), and it is gradually promoting a series of sustainability design researches to build a bridge effectively linking elements such as fashion, natural resources, and environmental protection (吴聪et al., 2023: 84–92). At the policy level, from the clear proposal of China's "Dual Carbon" goals and the successive issuance of the policy documents of the "14th Five-Year Plan for Industrial Green Development," to the EU "Circular Economy Action Plan" issued internationally, policy frameworks constantly construct clear guidance for the green, circular, and low-carbon development of the textile and apparel industry.

Analysis of research. Clothing, as one of the daily necessities of human life, causes resource waste and environmental pollution in its entire lifecycle of design, production, sales, use, and recycling. In recent years, numerous scholars in related disciplines have unfolded discussions and researches on the sustainable aspects of clothing from different perspectives, primarily divided into the following aspects: The first aspect, research on sustainable design strategies based on the clothing product itself. For example: (Lai, Chang, Lai, & Chang, 2021: 3686) investigated the influence of the colors of different shades of indigo dyed clothing on sustainable design through experiments and surveys; the research of (MacKinnon, Liu, & Becer, 2025) developed a heat-reversible adhesive formulation used for clothing assembly, aiming to promote automated production and the recycling and utilization of clothing fabrics; (Faysal et al., 2022) developed a zero-waste process scheme that converts leftover fabrics from the clothing industry into fibers and mixes them with virgin cotton in different proportions to produce sustainable yarns. The second aspect, research on clothing sustainable practice based on interdisciplinary intersection. For example: (Gurova, 2024: 289–307) explored the clothing consumption practices of Finland's Generation Z in following sustainable fashion in daily life, analyzing their patterns and the obstacles they face; (Pranta et al., 2025) explored effective merchandise recycling planning strategies in the Western clothing industry; (Kautish & Khare, 2022: 475–487) explored how to act on purchase behavior intentions and electronic word-of-mouth by influencing users' sustainable fashion cognition. The third aspect, research on trends related to clothing sustainable design, for example: (Jia, Yin, Chen, & Chen, 2020) reviewed the relationships among drivers, barriers, practices, and performance indicators for implementing the circular economy in the textile and apparel industry, and pointed out future research directions; (Chowdhury et al., 2022) summarized the sustainable practices implementable in the clothing industry and their driving factors to provide guidance for clothing enterprises.

Regarding the research on special workwear, it mainly concentrates on the design development, design optimization, and related basic support and application of the clothing itself. For example, (Pan, Wang et al., 2019) optimized the thickness design of each layer of high-temperature protective clothing based on heat

conduction theory to achieve the optimal human body external temperature distribution under specific environmental temperatures and working times; (Dąbrowska et al., 2024: 586) developed an active cooling clothing system integrating flexible thermoelectric modules for construction workers, and utilized AI technology combining environmental and physiological data to realize personalized intelligent regulation of cooling power.

According to literature analysis, it can be known that current clothing sustainability-related research mainly unfolds from aspects such as the design, material, manufacturing process, and lifecycle of clothing, as well as related interdisciplinary practices such as consumption scale, user intention, and education, and the sustainability-related design of clothing possesses broad research space. Furthermore, research regarding the sustainable design aspect of special workwear is relatively less. Therefore, this study starts from the analysis of design elements of special workwear, taking the sustainable design concept as guidance to explore the research of its practical innovation perspective. It aims to provide a theoretical basis for the sustainable design of the textile and apparel industry.

Purpose of the article. This study aims to take the sustainable design concept as the theoretical core and special workwear as the research object, to explore its practical innovation design pathway that possesses operational performance, humanistic care, and ecological friendliness simultaneously. Aiming at the development status of the textile and apparel field, conduct in-depth research on the premise of guaranteeing the core performance of special workwear, using design means to make it accurately adapt to user needs while possessing green design attributes to achieve the goal of ecological environmental protection. Through case analysis, dissect the product characteristics and design elements of special workwear, combining with the systematic review of sustainable design concepts and related design principles in the clothing field, to construct a sustainability-oriented innovation design method system for special workwear. Under the background of the industrial era, provide empirical and theoretical support for green design in the workwear field.

Research analysis. Special workwear refers to the clothing worn by staff when working in special work environments, and its design core is the protection of user life safety and the maintenance of operation efficiency under specific environments. Its design targets the protection against physical hazards, chemical hazards, biological hazards, etc., existing in the work environment, as well as the improvement of the work efficiency of operation personnel.

Regarding the design of special workwear, it mainly possesses characteristics in the following several aspects: The first aspect is functional-oriented design; the original intention of special workwear design is, through the forms of performance development and functional design, to serve as workwear that resists, isolates, and warns of specific dangers faced by wearers during the operation process and improves work efficiency; the second aspect is scenario limitation; the design of special workwear is conducted strictly according to specific operation scenarios and work operation processes, and possesses targeted functional and performance characteristics for different operation items; the third aspect is technical integration; in order to guarantee the professionalism of the clothing, special workwear integrates the research of multiple disciplines such as design studies, ergonomics, materials science, etc., and is a product of interdisciplinary research.

According to the core protection objects and the main hazard types dealt with by special workwear, it is classified into the following main categories (Tab. 1):

Table 1

Classification of Special Workwear

Classification Dimension	Main Category	Typical Application Scenarios	Design Objective
Flame Retardant and Heat Insulation Type	Flame Retardant and Heat Insulation Type	Firefighting, welding, metallurgical operations, etc.	Resist flames, high-temperature radiation, and contact heat
	Mechanical Protection Type	Machining, forestry, construction operations, etc.	Prevent mechanical cutting, impact, or puncture
	Anti-static Protection Type	Electronic industry operations, etc.	Eliminate static electricity accumulation
Biochemical Hazard Protection	Biochemical Protection Type	Chemical production, hazardous chemical disposal, epidemic prevention operations, etc.	Block toxic and harmful chemical substances, biological pathogens
	Particulate Protection Type	Mining, pharmaceutical, precision manufacturing operations, etc.	Prevent fine dust intrusion
Environment and Visibility Protection	High Visibility Warning Type	Road traffic, railway, emergency rescue operations, etc.	Enhance clothing visibility through high-contrast colors and reflective materials
	Climate Adaptability Type	Outdoor operations, cold storage, extreme weather environment operations, etc.	Maintain the heat-moisture balance and comfort of the human body under extreme climates

Through systematic research analysis, the research reviewed the main categories of special workwear as well as their application scenarios and design objectives. Under this background, it can be found that special workwear is applied in multiple scenarios with special work environments, its varieties are numerous and possess corresponding design objectives and performance requirements. Therefore, for the practical innovation design of special workwear, the integration of the sustainable design concept needs to be conducted from multiple dimensions and needs to conduct corresponding design according to category characteristics.

In order to be able to integrate the sustainable design concept into the practical innovation design targeting multiple categories of special workwear, the basic principles of sustainable design for generalized clothing products are analyzed and reviewed, mainly summarized into the following three aspects:

The first aspect is possessing green ecological design. Green ecological nature refers to the principle starting from the perspective of maintaining the entire ecological environment, taking the decision-making direction of clothing material selection and production methods as the leading factor. In the product production link, choose more green clean energy and renewable natural resources; clothing materials first choose natural green materials, or use means such as reused materials to maintain the balanced development of the ecological environment. For example, the Chinese brand ICICLE is a case of the fusion of Eastern philosophy and sustainable design; this brand continuously explores and adopts environmentally friendly, renewable new materials, utilizes natural plant extracted dyes to replace chemical synthetic dyes containing heavy metals, and in the aspect of packaging adopts degradable, recyclable environmentally friendly packaging materials. Conduct green ecological type sustainable design exploration from multiple dimensions of material selection, dyeing, manufacturing, as well as packaging peripherals.

The second aspect is lifecycle design. The lifecycle design principle refers to starting from the usage duration of clothing, extending the lifecycle of clothing through means such as durability design and emotional design of clothing. Nowadays, the speed of update and iteration of clothing products increases sharply, making their lifecycle seriously shortened, and making the textile and apparel industry become a major polluting industry. Designers should take the sustainable development concept as guidance, use design means to fully extend the clothing lifecycle, conduct control in aspects of design conception and clothing material selection, and reduce the update speed of clothing products. For example, the outdoor clothing brand Arc'teryx uses high weather-resistant materials such as GORE-TEX and launches the ReBIRD service, aiming to establish a complete ecological closed loop with durability as the core. When the product is damaged, ReBIRD provides cleaning and functional repair services such as re-taping and replacing zippers through the brand's unique professional processes. In this form, extend the service life of clothing and equipment, reduce the discard and waste caused by equipment damage, and reduce resource consumption from the root source.

The third aspect is humanistic care design. Humanistic care refers to the principle that starts from the perspective of being people-oriented and the harmonious coexistence of humans and nature, paying attention to the physical and mental health of clothing wearers while conducting green design of products and protecting the ecological environment. When designing products, clothing designers should start from clean energy and natural raw materials, actively adopt environmentally friendly materials, and through design means make the products reduce the emission of toxic and harmful waste during the processes of processing, use, discarding, recovery, and recycling, making the products serve humans while protecting the environment, and promoting the harmonious getting along of humans and nature. For example, regarding the decision to fully switch to organic cotton implemented by the outdoor clothing brand Patagonia in 1996, although facing cost increases, Patagonia still decided to use certified organic cotton in all sportswear series. This decision is a responsibility for user health and also an indirect protection for operation personnel at the production end, profoundly constructing the sustainable design concept system of humanistic care.

Based on the above analysis, this study constructs a practical innovation design method for special workwear based on the sustainable design concept, including 4 design principles, elaborating on the sustainable design development strategies of special workwear from multiple angles.

Presentation of the main material. After clarifying the design characteristics and category analysis of special workwear, summarizing and reviewing the three major clothing sustainable design principles of green ecological design, durability design, and humanistic care design, aiming at the design of special workwear with diverse categories, this study constructed practical innovation design strategies for special workwear based on the sustainable design concept. Specific design strategies are as follows:

(1) Zero-waste design strategy.

Production and manufacturing are the starting links of the lifecycle of special workwear and the pri-

mary links for realizing the principle of green ecological nature, and the zero-waste design strategy plays an important role in enhancing its sustainability. The goal of this strategy is to minimize the negative impact on the environment and society, taking maximizing resource utilization and environmental protection as the principle. In the production and manufacturing of special workwear, it means through reducing the consumption of materials as much as possible, which is mainly realized through cutting and forming technologies in the design practice of special workwear.

The first aspect is zero-waste cutting design. Zero-waste cutting refers to planning out the shape and distribution position of each clothing cutting piece from the clothing design development stage; these cutting pieces combine into a complete piece of fabric, and after cutting and making, produce no textile waste, maximizing the fabric utilization rate. Nowadays, the design methods of zero-waste cutting mainly include the tessellation method, one-piece cutting, geometric cutting method, as well as laser cutting seam allowance technology, etc.; designers select corresponding cutting methods according to different fabrics and style designs. In addition, besides conducting complete zero-waste cutting, it also derives the remnant reuse strategy of utilizing cutting remnants to conduct the making of clothing accessories, parts, etc. Zero-waste cutting design innovates traditional cutting methods, improves the utilization rate of making materials in the way of reducing discarded remnants, and promotes the sustainable development of the textile and apparel industry.

The second aspect is integrated molding design. Integrated molding design is also called whole-garment design, which is clothing formed by using technical means to make clothing use no or a small amount of stitching and cutting; because omitting the cutting and stitching steps in production will reduce the generation of leftovers and remnants, to achieve the goal of zero waste of raw materials. At the same time, reducing stitching lines not only means saving cutting work, but more importantly, it reduces the structural weaknesses at the seams of special workwear, and is able to enhance the airtightness of clothing such as the biochemical hazard protection type.

(2) Sustainable material design strategy.

Material as one of the three elements of clothing, its environmental performance directly affects the degree of sustainability of clothing. The sustainable material design strategy means starting from the perspective of materials, on the basis of designers considering the performance and balancing the cost of special workwear, the design focus should shift towards ecologically compatible materials to fit the principles of humanistic care and green ecological nature. In the design practice in special workwear, it mainly manifests in two aspects: the application of natural environmentally friendly materials and new environmentally friendly materials.

The first aspect is the application of natural environmentally friendly materials. Natural environmentally friendly materials refer to clothing materials produced from renewable resources such as cotton, linen, silk, and wool; this kind of material possesses the characteristics of low pollution to the environment during production, non-toxic and harmless to human health during wearing, and renewable and easy to degrade during recycling. The application of this type of fabric is able to protect the health of wearers while guaranteeing ecological balance, possessing both the safety and green ecological nature of clothing sustainable design; in addition, designers can also take the color and texture of natural materials as design highlights to guide users to choose clothing of sustainable design and protect the natural environment.

The second aspect is the application of new environmentally friendly materials. Aiming at the high strength and high barrier performance requirements of chemical protective clothing or particulate protective clothing, relying solely on natural fibers is often difficult to satisfy. New environmentally friendly fabrics refer to degradable environmentally friendly fabrics synthesized by extracting fibers from plants or recycled materials, and are a kind of fabric that is low pollution, non-toxic and harmless, degradable, and renewable and recyclable. With the development of technology, new environmentally friendly materials have been able to develop rapidly, and this provides more choices and guarantees for realizing the sustainable development of the clothing industry. This type of material not only retains the excellent physical and mechanical properties of synthetic fibers but also possesses low carbon emission and controllable degradation characteristics. It provides a green transition pathway for those high-performance protective equipment that must rely on chemical synthetic materials.

(3) Silhouette Structure Design.

Regarding the structure design of special workwear, it not only concerns the performance and appearance of the clothing but is also an important link for using design means to enhance its sustainability. Designers, through consideration and optimization of the structural level of special workwear, can realize the maximization of clothing functions targeting its specific wearing scenarios and the substantial improvement of its sustainability. In the design practice in special workwear, it can be manifested in two aspects: minimalist design and one-garment-multiple-wears design.

The first aspect is minimalist design. Applying minimalist design to special workwear design needs to take user actual needs as the center, emphasizing the structural design of clothing to let design return to the essence of functional attributes (谢勤, 2022: 93–95). The implantation of the minimalist design concept can effectively enhance the sustainability level of special workwear design, focusing on the specific operation scenarios of the clothing to excavate user actual needs, rather than blindly piling up functions and structural elements. It is able to avoid resource waste caused by the excessive piling up of unnecessary cumbersome structures in special workwear design, at the same time preventing clothing function redundancy, avoiding invalid designs where the design fails to produce positive gain to user operation efficiency and wearing experience.

The second aspect is one-garment-multiple-wears design. One-garment-multiple-wears in the special operation field manifests as the modular and adaptive design of equipment, making the clothing possess disassembly and combination functions through clothing structures such as zippers and buckles, making it able to satisfy different wearing demands to apply to multiple wearing scenarios (余越 et al., 2025: 147–155). In special workwear of the environment and visibility protection category, it can obtain more application, conducting the transformation of corresponding work scenarios and work environments through disassembling and combining clothing structures and parts. This strategy breaks the limitation of the single function of clothing, endowing the single piece of clothing with use value for multiple scenarios. It effectively replaces the repeated procurement of multi-category clothing, enhancing sustainability from the perspective of enhancing resource utilization rate.

(4) Clothing Lifecycle Design.

Regarding special workwear, due to the particularity of its usage scenarios and the height of performance requirements, it often gradually ends its lifecycle with the increase of user work and wearing duration, having a relatively large consumption quantity. The important goal of special workwear sustainable design is to enhance its durability to delay the time of entering the disposal process, and clothing lifecycle design is an important means to actually complete the goal. In the design practice in special workwear, it can be manifested in two aspects: clothing durability design and emotional design.

The first aspect is clothing durability design. Clothing durability design is a design method based on material, extending the lifecycle of clothing by improving the durability degree of special workwear thereby realizing its sustainable design. Starting from the durability of materials and processes, select materials with relatively high oxidation resistance, corrosion resistance, abrasion resistance, and even stain resistance, and adopt sturdy processes to conduct making and conduct thickening and reinforcement treatments on easily damaged parts. This strategy, while enhancing clothing protective performance, also directly reduces its replacement and discard frequency through the way of extending clothing service life, especially targeting special workwear for physical hazard protection and environmental hazard protection. While protecting wearer safety, it reduces resource waste and environmental pressure produced due to the frequent scrapping of clothing.

The second aspect is emotional design. Regarding the lifecycle of special workwear, besides physical life, user psychological life is equally critical. In special workwear design, this strategy manifests as respect for the professional dignity of operation personnel as well as care for limb comfort during operation. Through ways such as the emotional expression of materials, the adaptability of design, letting users participate in design, and providing detailed custom designs such as adding name tags, to realize the generation of emotional resonance between users and clothing. When users obtain positive perception intentions such as sense of security and professional identity during wearing, they will spontaneously produce cherishing and maintenance behaviors, thereby indirectly extending the usage cycle of the product. In addition, emotional design can also add special emotional elements in clothing design to guide users to produce sustainable awareness and environmental protection awareness (唐颖, et al., 2020: 503–506).

Conclusion. This study starts from the status quo of typical serious pollution in the development of the textile and apparel industry, re-examining these problems taking the sustainable design theory as the core perspective. Taking special workwear as the research object, through the macro-classification and characteristic analysis based on its protection essence, it demonstrated the possibility of realizing the maximization of ecological benefits and user humanistic care on the premise of guaranteeing the core design requirements and clothing performance of special workwear. On this basis, propose practical innovation design strategies from four aspects: zero-waste design, sustainable material design, silhouette structure design, and lifecycle design, converting sustainable concepts into specific design frameworks. The research provides a theoretical basis for conducting sustainable design thinking to break the inherent design patterns of traditional special environment operation equipment.

This study only uses conceptual analysis as design-oriented research results; the current focus lies in constructing its universal design methodology based on the sustainable design concept taking special workwear as the research object. It has not yet conducted targeted in-depth research and quantitative evaluation targeting clothing for a single operation. In the future research process, it is possible to conduct development targeting clothing for specific operation environments based on the design strategy framework proposed in this study and estimate its sustainability and practical value by quantitative means.

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