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Literature Review of Concurrent Engineering in Kansei Engineering and Ergonomic

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ABSTRACT

This research aims to conduct a literature review on the application of the integration of Kansei engineering, ergonomics, and concurrent engineering methods in the context of product design. A systematic study of 8 scholarly journals related to the topic in the last decade indicates that combining these three methods has a positive impact on product performance and the efficiency of the development process. In conclusion, a multidisciplinary approach is highly recommended to produce innovative and highly competitive products through a faster and cost-effective process.
Keyword: Concurrent Engineering, Ergonomy, Literature Review, Kansei Engineering, Product Design

ABSTRAK

Penelitian ini bertujuan untuk melakukan tinjauan pustaka tentang penerapan integrasi kansei, ergonomi, dan *concurrent engineering* dalam konteks desain produk. Sebuah studi sistematis dari 8 jurnal ilmiah terkait topik dalam dekade terakhir menunjukkan bahwa menggabungkan tiga metode ini memiliki dampak positif pada kinerja produk dan efisiensi proses pengembangan. Secara keseluruhan, pendekatan lintas disiplin sangat disarankan untuk menghasilkan produk inovatif dan sangat kompetitif melalui proses yang lebih cepat dan hemat biaya.
Kata Kunci: Desain Produk, Ergonomi, Kansei Engineering, Rekayasa Serempak, Tinjauan Literatur

1. Introduction

The rapid growth in the industrial world has prompted the development of new methods and strategies to enhance the efficiency, quality, and competitiveness of products. One approach that has played a key role in this context is Concurrent Engineering (CE). Concurrent Engineering is a holistic approach that emphasizes collaboration and integration of various aspects of design and production from the early stages of product development. By assembling multidisciplinary teams, CE aims to reduce development time, costs, and enhance the overall quality of the product [1].

The definition of Concurrent Engineering encompasses a systematic approach to integrating design, production, and manufacturing aspects throughout the product lifecycle. This approach aims to minimize late design changes and enhance coordination between departments, thereby accelerating time to market and reducing production costs [2].

Subsequently, integrating Concurrent Engineering with leading methods becomes a key factor in enhancing its effectiveness. This method not only provides the foundation for more efficient product development but also supports the achievement of overall organizational goals. Furthermore, the introduction of Kansei Engineering becomes a crucial factor in enhancing emotional appeal and customer satisfaction with the product. Kansei Engineering is an approach that combines psychological and aesthetic elements in product design to achieve a positive emotional response from users. By understanding and incorporating these elements in the early stages of product development, companies can create products that better align with customer preferences and needs. Additionally, emphasis on ergonomic and anthropometric aspects in product design is becoming increasingly important. Ergonomics and anthropometrics address the relationship between humans and their devices or environment. Ergonomics helps ensure comfort and efficiency in product use, while anthropometrics considers variations in human body dimensions to optimize product design and usability [3].

Thus, the integration of Concurrent Engineering into Kansei Engineering and ergonomic/anthropometric aspects holds great potential for improving the efficiency and effectiveness of product development. This research will further explore the integration of these three methods, exploring potential synergies, and providing a foundation for achieving more innovative, appealing, and ergonomic products [4].

2. Concurrent Engineering

Concurrent Engineering (CE) is defined as a systematic approach in designing products and their manufacturing processes by integrating various disciplines from the early stages of the product development life cycle (Prasad, 1996). The primary goal of CE is to create high-quality products with more efficient time and cost management [3].

Representing a systematic approach to product development aimed at improving efficiency and effectiveness, Concurrent Engineering (CE) is defined as the integration of various disciplines from the early stages of the Product Development Life Cycle (PDLC). CE aims to create high-quality products with optimal time and cost. In this methodology, cross-disciplinary collaboration is at the core, where multidisciplinary teams work together, involving departments such as design, production, marketing, and maintenance. Fundamental principles such as parallel development, early involvement, iterative prototyping, risk management, and information sharing form the basis for implementing CE. The benefits include reduced development time, cost efficiency, improved product quality, flexibility, and increased customer satisfaction. By focusing on cross-disciplinary integration, CE provides organizations with the ability to accelerate innovation, reduce development costs, and enhance competitiveness in the market [5].

In the implementation of Concurrent Engineering (CE), the involvement of all relevant departments and functions becomes a crucial key from the product design stage. This includes marketing, design, manufacturing, and other departments working together to ensure that the needs and perspectives of each element are integrated holistically. Product design decisions are made collaboratively by considering input from various disciplines, ensuring that marketing, technical, and manufacturing aspects align to achieve desired goals [1].

Moreover, product design and production processes are no longer carried out sequentially but in parallel. This allows the team to work simultaneously on various aspects of product development, identifying and responding to issues promptly. This parallel process supports more adaptive decision-making and responsiveness to changes that may occur during the development cycle [5].

The incorporation of state-of-the-art technology such as Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), and Computer-Aided Engineering (CAE) is integral to CE. The use of this software aids in visualizing and simulating products, enabling the team to test concepts, identify potential issues, and make improvements before moving to the production stage. The utilization of this technology also facilitates more effective communication among the involved teams, ensuring that all stakeholders are connected and can contribute efficiently to product development [6].

Thus, Concurrent Engineering encompasses not only departmental integration, collaborative decision-making, and parallel processes but also involves leveraging cutting-edge technology to enhance effectiveness and efficiency throughout the entire product development cycle.

In its implementation, there are several challenges that often arise in applying the CE approach, such as resistance to change, a lack of comprehensive understanding of CE methodology, and the difficulty of coordinating collaboration between divisions. However, some studies have proven that with the right strategy, CE can improve product quality by up to 60 percent and reduce development time and costs by 70-80 percent [1].

The application of Concurrent Engineering (CE) involves a systematic approach to product development, and the process unfolds through several collaborative steps. Firstly, cross-functional teams, comprising members from departments like marketing, design, and manufacturing, engage early in the development cycle to establish targets and formulate plans for a new product. Subsequently, the conceptual design phase unfolds, where the initial design team collaborates, considering input from various departments, and conducts a comprehensive evaluation of the proposed concept [7].

As the process advances, detailed technical design development takes center stage, addressing aspects such as ergonomics, aesthetics, materials, and manufacturing processes. Simultaneously, the design undergoes rigorous validation through reviews conducted by all relevant departments, including production, marketing, and finance. This meticulous review ensures that the design is optimized before transitioning to mass production.

Parallel to the design phase, the planning and design of production processes occur, encompassing decisions related to material selection, equipment, methods, and production costs. Once these elements align seamlessly, the development and launch of the new product follow suit. This stage involves trial production and the official market launch of the product.

By following these steps in the CE methodology, the aim is to achieve efficiency in terms of both time and cost of product development without compromising quality. Research findings indicate that the implementation of CE can yield a substantial improvement in product quality (40-60%), a significant reduction in product development time (up to 70%), and a notable decrease in production costs (60-80%) [8]. In essence, Concurrent Engineering emerges as an effective and holistic approach, ensuring the creation of high-quality products efficiently in terms of both time and cost.

3. Kansei Engineering

The concept of Kansei Engineering was first introduced by Mitsuo Nagamachi in the 1970s as a method to translate consumer feelings and impressions (Kansei in Japanese) towards a product into the design parameters of that product [9]. Kansei is subjective and relates to user psychology and the emotions that arise during interactions with a product.

The primary goal of implementing Kansei Engineering in product design is to create new products that satisfy consumers' emotional preferences and aesthetic needs by considering users' feelings or responses to specific design attributes [10]. In other words, products are not only designed based on function and performance but also on Kansei aspects or the psychological impressions desired from the product.

3.1. Kansei Engineering Type I

This involves an ergonomic design system based on Kansei, utilizing multidimensional statistical techniques and computational intelligence. The goal is to translate consumer Kansei impressions of the product into quantitative product design parameters [11].

3.2. Kansei Engineering Type II

Aims to enhance the quality of a product by modifying existing product designs to meet user expectations and emotional impressions [12].

Commonly used methods in Kansei Engineering include affinity diagrams, Likert scales, semantic differentials (SD) scales, and multivariate analyses such as Quantification Theory Type I (Hayashi's QTT1) and Partial Least Square (PLS). These methods are employed to establish non-linear relationships between user emotion/Kansei dimensions and product design parameters that are considered to influence user emotions (Kansei words). The results from Kansei Engineering can be used as recommendations to produce or modify products to better align with user emotional preferences [13].

In practice, there are challenges in implementing Kansei Engineering [10], including identifying the right Kansei words that accurately represent consumer feelings about the product, dealing with varied expressions of Kansei among users, making categorization challenging, aligning manufacturers' aesthetic views with consumers' emotional desires.

Despite these challenges, research proves that the integration of Kansei Engineering into the product design process has successfully produced various products, ranging from vehicles and electronic devices to household appliances that evoke satisfaction and comfort for consumers [9]. Thus, Kansei Engineering can be an effective method for designing products based on psychological aspects and user emotions.

4. Anthropometry in Ergonomic

Ergonomics is defined as a scientific discipline that studies the interaction between humans and their work systems, focusing on optimizing health, safety, comfort, and human performance [14]. The main goal of applying ergonomic principles in product design is to adapt products and their work environments to fit the physical, cognitive, and psychological characteristics of users [15].

One crucial aspect of ergonomics is anthropometry, the study of human body measurements. Anthropometric data is highly valuable for product designers to determine the ergonomic and comfortable physical dimensions of products for specific user percentiles [16].

There are two approaches to applying anthropometric data: prescriptive and descriptive. The prescriptive approach establishes a set of product design dimensions based on average sizes or specific percentiles of the user population. For example, determining the width of a car seat based on the average shoulder width of adult men and women. Meanwhile, the descriptive approach provides variations in product sizes to accommodate the anthropometric range of a broad user population. For instance, producing car seats with multiple adjustment options to suit drivers of various body sizes [16].

The proper application of anthropometric data is crucial for producing ergonomic product designs. Products that do not align with user body dimensions can cause discomfort or even ergonomic injuries, such as carpal tunnel syndrome from using a computer mouse that is too small or lower back pain due to an ergonomic chair [17]. Therefore, the anthropometric approach should be undertaken from the early stages of product design, not just considered as a secondary consideration. Here is a more detailed explanation of the steps in anthropometry, including percentiles, validity and reliability testing, and measurement instruments:

1. Identification of relevant human body dimension characteristics for the product.

2. Selection of population and sample representing product users with age, gender, ethnic characteristics, etc.

3. Collection of anthropometric data using measuring instruments such as scales, calipers, measuring tapes, etc. Data recorded by trained enumerators.

4. Statistical analysis of data, including descriptive statistics such as mean and standard deviation. Percentiles, for example, 5th, 50th, and 95th percentiles, are determined.

5. Validation testing by comparing research data with other studies or reference anthropometric data. Reliability testing using test-retest or Cronbach's alpha.

6. Recommendations for product design dimensions based on specific percentiles, such as accommodating 90% of the population (5th to 95th percentiles).

This ensures that the resulting products have ergonomic dimensions within the anthropometric range of their users. Validation and reliability testing are crucial to ensure accurate and consistent data. This literature review provides insights into ergonomics and anthropometry in the context of product design [18].

5. Research Method

This research presents a highly intriguing focus on integrating Kansei Engineering, ergonomics, and Concurrent Engineering methods in product design. The systematic literature review process, concentrating on empirical studies in the last decade, is a commendable step toward gaining a profound understanding of this topic [19]. The strategy of searching reputable international journal databases such as ScienceDirect, SpringerLink, and Taylor & Francis Online using relevant keywords is also an effective approach to ensuring that the literature review encompasses recent and high-quality publications. The criteria for selecting articles, including being in English, conducting field studies (both quantitative and qualitative), focusing on physical/material products, investigating a minimum of two examined methods, and providing method implementation analysis, help ensure the selected articles possess the necessary relevance and quality [20].

A thorough analysis of the content and research findings from the selected articles will yield deeper insights into the effectiveness of integrating these methods in product design. The synthesis from this literature review is expected to generate new knowledge and possibly offer innovative perspectives regarding the impact of integrating Kansei Engineering, ergonomics, and Concurrent Engineering methods on design product performance.

In the subsequent steps, this research could make a significant contribution to the development of theory and practices for more effective and ergonomic product design. The conclusions drawn from this research may pave the way for further studies or even practical applications in the industry [21].

6. Research Results

This research aims to conduct a systematic literature review on the integrated application of Kansei Engineering, ergonomics, and Concurrent Engineering methods in the context of product design. A comprehensive review of eight scientific journals from the last decade indicates that the combination of these three methods has a positive impact on product performance and development process efficiency.

The study not only focuses on the application of Kansei Engineering, ergonomics, and Concurrent Engineering methods in product design but also aims to extend and correlate their integration. A detailed review of eight scientific journals from the last decade reveals that the integration of these three methods not only positively influences product performance and development process efficiency but also offers potential synergies that can be further expanded.

In "Design of ergonomic manufacturing equipment by a human-centered methodology" [18], this research incorporates ergonomic aspects into the design of manufacturing equipment with a focus on human involvement. What sets it apart is the effort to extend this approach by leveraging the Internet of Things (IoT). By incorporating IoT elements, this research addresses not only the physical comfort in equipment usage but also explores how technology can be used to monitor and enhance ergonomic performance in real-time. Thus, this research establishes a foundation for further integration between traditional ergonomic aspects and advanced technology to support the sustainability of method integration in manufacturing equipment design.

"Development of Natural Fibre-Reinforced Polymer Composites Ballistic Helmet Using Concurrent Engineering Approach" [22] highlights the importance of integration in the development of protective helmets using the Concurrent Engineering approach. Beyond considering ergonomics in helmet design, this research emphasizes the need to plan and unify design steps simultaneously. By involving various aspects, such as natural fiber-reinforced materials and the Concurrent Engineering approach, this research leads to more efficient and holistic results in the development of protective helmets, demonstrating that joint integration can have a positive impact on the end product.

"Digital twins to enhance the integration of ergonomics in workplace design" [23] presents the integration of ergonomics in workplace design through the digital twins approach. Here, the concept of a digital representation reflecting the physical conditions of the workspace provides a foundation for improving ergonomics. This research highlights how digital twins enable real-time modeling of working conditions, allowing designers to identify and address potential ergonomic issues over time. Thus, the integration of digital twins brings a time dimension and continuous monitoring into ergonomic planning.

In "From Design for Assembly to Design for Collaborative Assembly - Product Design Principles for Enhancing Safety, Ergonomics, and Efficiency in Human-Robot Collaboration" [24], the research expands the scope of integration by incorporating safety and efficiency aspects in the context of human-robot collaboration. Besides considering traditional ergonomic aspects, this research proposes product design principles that encompass collaborative aspects, making safety and efficiency primary goals. This integration demonstrates how product design can be more holistic by considering a broader scope of product development factors involving human-robot interaction.

"Application Of Concurrent Engineering Method Supported By Virtual Prototyping Based Cad And Cae" [25] involves the concurrent engineering method supported by virtual prototypes for product design and ergonomic analysis. In this context, not only is the prominence of concurrent engineering methods highlighted, but also how advanced technologies like virtual prototypes, Computer-Aided Design (CAD), and Computer-

Aided Engineering (CAE) can be used to support and enrich the integration process. This integration creates a close framework between concurrent engineering methods and advanced technology, resulting in a more effective and efficient design approach.

The seventh journal, titled "Kansei Engineering over Multiple Product Evolution Cycles: An Integrated Approach" [26], provides an in-depth view of integrating Kansei Engineering into a product development strategy involving multiple product evolution cycles. In this study, emphasis is placed on how Kansei Engineering aspects can be synergistically integrated throughout various product evolution cycles, unlocking the potential for continuous updates based on user feedback and market developments.

The eighth journal, titled "Implementing Kansei Engineering and Quality Function Deployment Method in Designing Shoes" [27], explores the application of Kansei Engineering, particularly in shoe design. In this research, the authors use the Kansei Engineering method along with Quality Function Deployment (QFD) to ensure that shoe design not only meets ergonomic aspects but also considers consumer preferences and perceptions holistically. The integration of QFD provides a systematic framework for linking customer preferences with measurable design attributes, supporting a more directed design process.

This research presents a highly intriguing focus on integrating Kansei Engineering, ergonomics, and Concurrent Engineering methods in product design. The systematic literature review process, concentrating on empirical studies in the last decade, is a commendable step toward gaining a profound understanding of this topic [19]. The strategy of searching reputable international journal databases such as ScienceDirect, SpringerLink, and Taylor & Francis Online using relevant keywords is also an effective approach to ensuring that the literature review encompasses recent and high-quality publications. The criteria for selecting articles, including being in English, conducting field studies (both quantitative and qualitative), focusing on physical/material products, investigating a minimum of two examined methods, and providing method implementation analysis, help ensure the selected articles possess the necessary relevance and quality [20].

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In the subsequent steps, this research could make a significant contribution to the development of theory and practices for more effective and ergonomic product design. The conclusions drawn from this research may pave the way for further studies or even practical applications in the industry [21].

Table 1. Tabulation of Literature Review

No.	Research	Concurrent Engineering	Kansei Engineering	Ergonomic & Anthropometry
1	"Design of ergonomic manufacturing equipment by a human-centered methodology" [18]	✔		✔
2	"Development of Natural Fibre-Reinforced Polymer Composites Ballistic Helmet Using Concurrent Engineering Approach" [22]	✔		
3	"Digital twins to enhance the integration of ergonomics in the workplace design" [23]	✔		✔
4	"From Design for Assembly to Design for Collaborative Assembly - Product Design Principles for Enhancing Safety, Ergonomics and Efficiency in Human-Robot Collaboration" [24]	✔		✔

No.	Research	Concurrent Engineering	Kansei Engineering	Ergonomic & Anthropometry
5	"Penerapan Kansei Engineering dalam Perbandingan Desain Aplikasi Mobile Marketplace di Indonesia" [28]	✔	✔	
6	"The Application Of Concurrent Engineering Method Supported By Virtual Prototyping Based Cad And Cae" [25]	✔		✔
7	"Kansei Engineering over Multiple Product Evolution Cycles: An Integrated Approach" [26]	✔	✔	
8	"Implementing Kansei Engineering and Quality Function Deployment Method in Designing Shoes" [27]	✔	✔	

7. Conclusion

Based on a comprehensive literature review of 8 empirical studies conducted in the last 10 years, it can be concluded that the integration of Kansei Engineering, ergonomics, and Concurrent Engineering methods has proven to yield more innovative and competitive products with more efficient development costs and time. Therefore, it is highly recommended for manufacturing industries and product design to adopt this multidisciplinary approach to enhance the competitiveness of their products.

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