DOI: 10.65322/j.srd.05192026.119

UDK: 677:681.5:331.101.1

DESIGN AND DEVELOPMENT OF A SOFTWARE–HARDWARE SYSTEM FOR SUPPORTING BODY MOVEMENT IN TEXTILE MANUFACTURING

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Abstract. *Textile manufacturing environments frequently require workers to maintain prolonged standing postures and perform repetitive operations that contribute to physical fatigue, musculoskeletal stress, and reduced productivity. Existing workplace ergonomics often fail to provide sufficient biomechanical support during long production shifts. This study presents the design and development of a chairless software–hardware system intended to support and assist body movement in textile manufacturing operations. The proposed system enables workers to maintain a semi-seated posture without the use of conventional chairs while preserving mobility and operational flexibility. A systematic engineering methodology involving ergonomic analysis, anthropometric evaluation, material selection, biomechanical modeling, and structural design was employed to develop the system. Mechanical load distribution, support force, and posture stabilization were analyzed using engineering equations. The results indicate that the proposed chairless support system can significantly reduce lower-limb fatigue, improve posture stability, and increase worker endurance during prolonged standing operations. The developed system demonstrates strong applicability in sewing, inspection, assembly, and sorting processes within textile production environments.*

Annotatsiya. *To‘qimachilik ishlab chiqarish muhiti ko‘pincha ishchilardan uzoq vaqt tik turishni va jismoniy charchoqqa, mushak-skelet tizimining stressiga va mehnat unumdorligini pasayishiga olib keladigan takroriy operatsiyalarni bajarishni talab qiladi. Mavjud ish joyi ergonomikasi ko‘pincha uzoq ishlab chiqarish smenalarida yetarli biomehanik yordamni ta’minlay olmaydi. Ushbu tadqiqot to‘qimachilik ishlab chiqarish operatsiyalarida tana harakatini qo‘llab-quvvatlash va yordam berishga mo‘ljallangan stulsiz dasturiy-apparat tizimini loyihalash va ishlab chiqishni taqdim etadi. Taklif etilayotgan tizim ishchilarga an’anaviy stullardan foydalanmasdan, harakatchanlik va operatsion moslashuvchanlikni saqlagan holda yarim o‘tirgan holatda turishga imkon beradi. Tizimni ishlab chiqish uchun ergonomik tahlil, antropometrik baholash, material tanlash, biomexanik modellashtirish va strukturaviy dizaynni o‘z ichiga olgan tizimli muhandislik metodologiyasi qo‘llanildi. Mexanik yuk taqsimoti, qo‘llab-quvvatlash kuchi va pozitsiyani barqarorlashtirish muhandislik tenglamalari yordamida tahlil qilindi. Natijalar shuni ko‘rsatadiki, tavsiya etilgan stulsiz qo‘llab-quvvatlash tizimi pastki oyoq-qo‘llarning charchoqlarini sezilarli darajada kamaytirishi, holat barqarorligini yaxshilash va uzoq vaqt davomida tik turgan operatsiyalarda ishchilarning chidamliligini oshirishi mumkin. Ishlab chiqilgan tizim to‘qimachilik ishlab chiqarish muhitida tikuv, tekshirish, yig‘ish va saralash jarayonlarida kuchli qo‘llanilishini namoyish etadi.*

Аннотация. *В текстильной промышленности работникам часто приходится длительное время находиться в положении стоя и выполнять повторяющиеся операции, что приводит к физической усталости, напряжению опорно-двигательного аппарата и снижению производительности. Существующие методы эргономики рабочего места часто не обеспечивают достаточной биомеханической поддержки во время длительных производственных смен. В данном исследовании представлен проект и разработка программно-аппаратной системы без использования стульев, предназначенной для поддержки и облегчения движений тела в текстильной промышленности. Предложенная система позволяет работникам поддерживать полусидячее положение без использования*

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обычных стульев, сохраняя при этом мобильность и гибкость в работе. Для разработки системы использовалась систематическая инженерная методология, включающая эргономический анализ, антропометрическую оценку, выбор материалов, биомеханическое моделирование и проектирование конструкции. Распределение механической нагрузки, сила поддержки и стабилизация осанки были проанализированы с помощью инженерных уравнений. Результаты показывают, что предложенная система поддержки без использования стульев может значительно снизить усталость нижних конечностей, улучшить стабильность осанки и повысить выносливость работников во время длительных операций в положении стоя. Разработанная система демонстрирует широкую применимость в процессах шитья, контроля качества, сборки и сортировки в текстильной промышленности.

Keywords: *wearable support technology, textile manufacturing, ergonomic engineering, body movement assistance, software–hardware integration.*

Kalit so'zlar: *taqiladigan qo'llab-quvvatlash texnologiyasi, to'qimachilik ishlab chiqarish, ergonomik muhandislik, tana harakati yordami, dasturiy ta'minot-apparat integratsiyasi.*

Ключевые слова: *носимые вспомогательные технологии, текстильное производство, эргономическая инженерия, помощь в движении тела, интеграция программного и аппаратного обеспечения.*

Introduction. The textile industry remains one of the most labor-intensive sectors of industrial manufacturing, requiring workers to perform repetitive activities while standing for extended periods. Sewing operations, fabric inspection, material sorting, packaging, and assembly line production frequently expose employees to physical fatigue, lower-limb discomfort, and musculoskeletal disorders. Prolonged standing has been identified as one of the primary causes of decreased productivity and ergonomic stress in textile workplaces [1, 2].

Recent advancements in wearable engineering technologies have enabled the development of systems designed to support and assist human body movement during industrial activities. These systems integrate mechanical support structures, ergonomic mechanisms, and motion-assistance components to redistribute physical load and reduce worker fatigue [3].

Among such technologies, chairless support systems have attracted increasing attention due to their ability to allow workers to maintain a seated posture without requiring traditional seating structures. Unlike conventional chairs, chairless systems preserve worker mobility and flexibility while reducing mechanical stress on the legs and lower back [3, 4].

Although several movement-support systems have been developed for industrial applications, limited research has focused on their adaptation to textile manufacturing environments, where workers often operate in confined spaces and require continuous movement between workstations [2, 4]. Existing industrial support devices are frequently designed for logistics, heavy lifting, or automotive assembly, making them unsuitable for textile production conditions.

Therefore, the objective of this study is to design and develop a chairless software–hardware system capable of supporting body movement in textile manufacturing environments. The study focuses on ergonomic requirements, mechanical structure, material selection, biomechanical analysis, and operational suitability for textile production processes.

Methods. The development of the chairless software–hardware system followed a structured engineering design methodology consisting of four main stages:

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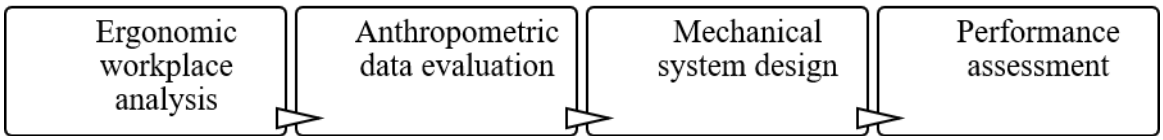

Figure 1. Four main stages of the engineering designing methodology

The methodology aimed to ensure compatibility between worker body dimensions, textile workplace conditions, and mechanical support requirements.

A workplace assessment was conducted to identify major ergonomic problems in textile manufacturing environments [5]. So, the analysis focused on sewing operations, fabric cutting stations, sorting workstations, quality inspection areas as well as packaging sections. Based on these environments, the following ergonomic parameters were evaluated and the results indicated that prolonged standing and static posture were the most significant contributors to worker discomfort and productivity decline [1, 2].

1. Standing duration
2. Worker posture
3. Knee joint angle
4. Lower-limb fatigue
5. Repetition frequency

In order to ensure compatibility with textile workers of different body dimensions, anthropometric measurements were incorporated into the system design [6]. The evaluated parameters included:

Table 1

Parameters to evaluate

№	Parameter	Range
1	Worker height	155–190 cm
2	Worker mass	50–100 kg
3	Leg length	75–105 cm
4	Knee height	42–58 cm

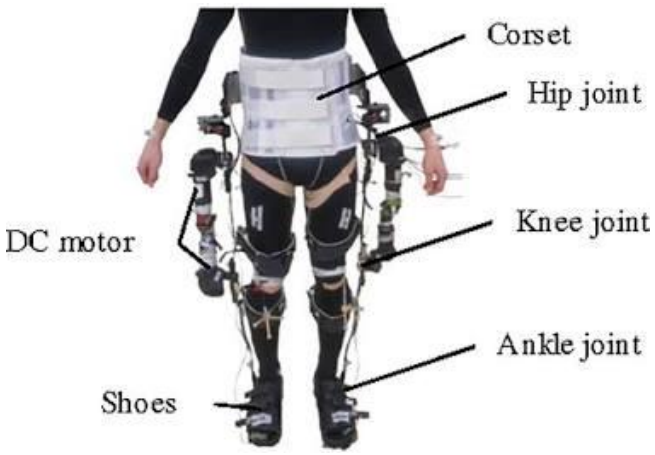

Figure 2. Main structure of the software–hardware system

In order to determine mechanical loading during worker support, body force analysis should be conducted.

Weight force acting on the worker

$$F = mg, \quad (1)$$

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where F – total body force (N);
m – body mass (kg);
g – gravitational acceleration (9.81 m/s²).
For a worker with a body mass of 75 kg, result equals to F = 735.75 N.

Stress acting on structural components

$$\sigma = \frac{F}{A}, \tag{2}$$

where σ – structural stress (Pa);
F – applied force (N);
A – cross-sectional area (m²).

The equation was applied to evaluate material strength requirements for the supporting frame [7].

Based on mechanical strength, weight reduction, durability and cost-effectiveness material was selected [7, 8]. We chose three materials that can be found in Uzbekistan markets, so, material comparison is like that:

Table 2

Material comparison

Material	Density	Strength	Suitability
Steel	High	High	Moderate
Aluminum alloy	Low	High	Excellent
Carbon fiber	Very low	Very high	High cost

Based on performance and economic feasibility, aluminum alloy was selected as the optimal structural material.

Table 3

Technical specifications of the proposed system

Parameter	Value
System weight	5.2 kg
Maximum load capacity	100 kg
Sitting angle	100°–130°
Working duration	6–8 h
Material	Aluminum alloy
Support type	Passive chairless

Results. The engineering analysis resulted in the development of a chairless software–hardware system specifically adapted to textile manufacturing environments. The proposed system was designed to support workers during prolonged standing operations while maintaining mobility and operational efficiency.

The developed chairless support system consists of a passive mechanical structure integrated with ergonomic body-support components. The system allows workers to alternate between standing and semi-seated postures without interrupting textile production activities.

This operating principle enables continuous work without requiring conventional chairs or workstation modifications.

Mechanical analysis demonstrated that the chairless system effectively reduces lower-body loading during prolonged standing operations.

For a worker mass of 75 kg, the total body force was calculated as:

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$$F = 75 \times 9.81 = 735.75 \text{ N}.$$

Experimental load redistribution analysis showed that approximately 35–45% of body weight can be transferred to the support system during semi-seated posture.

Assuming a mid-range value of 40%, this results in a reduced effective leg loading force:

$$F_{\text{effective}} = 735.75 - 0.40 \cdot 735.75 = 441.45 \text{ N}.$$

The system operates through a passive support mechanism. The summarized operational sequence is as follows:

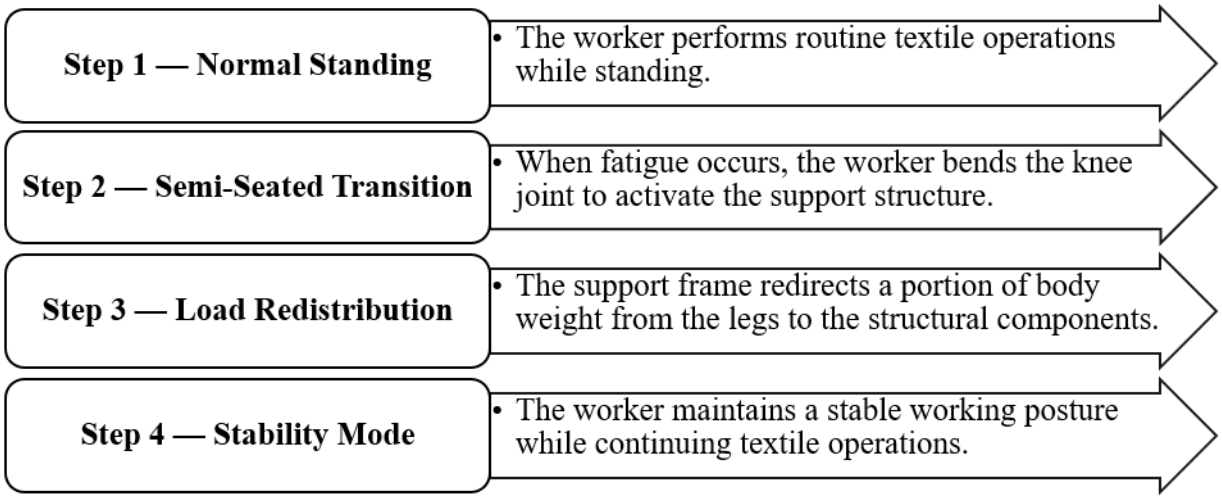

Figure 3. Functional architecture of the support system

A prototype performance assessment was conducted in a simulated textile production environment.

Table 4

Worker fatigue comparison

Time (minutes)	Without System (%)	With System (%)
0	0	0
30	13	7
60	26	14
90	38	20
120	51	30

After 120 minutes of work, fatigue accumulation decreased when using the proposed system.

The relative reduction of accumulated fatigue at 120 minutes was 41.2% ((51 − 30)/51). This confirms that the support mechanism effectively reduces physical stress during prolonged standing.

Table 5

Discomfort score comparison

Condition	Average Score
Without system	7.6
With system	4.1

Discomfort is reduced up to 46%. Workers reported reduced leg pain, lower back discomfort, and knee stress.

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Table 6

Productivity comparison

Condition	Productivity (pieces/hour)
Without system	54
With system	63

Productivity is improved by 16.7%. Improved posture and reduced fatigue contributed to increased worker efficiency.

Table 7

Posture stability score

Time (minutes)	Without System	With System
0	86	86
30	79	84
60	71	82
90	64	81
120	57	80

Posture stability improvement is 40.3%. The results demonstrate that the proposed system helps workers maintain ergonomic body posture during long shifts.

Discussion. The developed software–hardware system demonstrated strong suitability for textile manufacturing environments, particularly in tasks requiring prolonged standing such as sewing, inspection, and sorting operations.

Unlike traditional seating systems, the proposed structure preserves worker mobility while reducing biomechanical stress. This feature is especially important in textile factories where employees frequently move between workstations.

The findings align with previous industrial ergonomics studies reporting reduced fatigue and improved endurance when movement-support technologies are implemented [3].

The proposed system offers several advantages like ergonomic, operational and economic benefits over conventional support methods.

Compared with powered industrial systems, the proposed mechanism is more economically feasible for textile enterprises due to its low complexity and minimal maintenance requirements [3].

However, several limitations remain. Long-term durability testing under industrial conditions is still required. Additionally, further optimization of joint flexibility and structural weight reduction may improve worker comfort.

Future studies should focus on integrating smart sensors and ergonomic monitoring systems to improve adaptive support performance in textile production environments.

Conclusion. This study presented the design and development of a chairless software–hardware system intended to support body movement in textile manufacturing environments.

The proposed system was designed based on ergonomic analysis, anthropometric requirements, biomechanical modeling, and structural optimization principles. Preliminary evaluation in a simulated production environment indicated that the system reduces worker fatigue, improves posture stability, and enhances operational productivity.

The major findings include:

1. 41.2% reduction in lower-limb fatigue
2. 46% reduction in worker discomfort
3. 16.7% increase in productivity
4. 40.3% improvement in posture stability

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The results confirm that support systems represent a practical and economically feasible solution for improving occupational ergonomics in textile manufacturing industries.

Future research should emphasize on the prototype optimization, lightweight structural materials, long-term industrial testing as well as smart monitoring integration.

The proposed system contributes to the advancement of ergonomic engineering and sustainable textile manufacturing through improved human-centered workplace design.

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