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Design of work facilities in batik production using anthropometry and quality function deployment

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ABSTRACT

Batik is one of the creative economic sectors that plays an important role in supporting tourism and regional economic development in Yogyakarta City. One of the jumputan batik Small and Medium Enterprises (SMEs) located in Tahunan Village, Umbulharjo District, still relies on manual production processes with limited work facilities, resulting in musculoskeletal complaints caused by prolonged non-ergonomic working postures, particularly during the dyeing process. Preliminary studies and ergonomic risk assessments indicate that the dyeing process is classified as having a high risk of Musculoskeletal Disorders (MSDs) and therefore requires immediate improvement. This study aims to design an ergonomic worktable for the jumputan batik dyeing process to reduce the potential risk of MSDs based on user needs. The product design was conducted using the Quality Function Deployment (QFD) method to translate workers' needs into technical specifications, supported by anthropometric data to determine ergonomic dimensions. The results produced an integrated worktable design that accommodates the dyeing, draining, and rinsing processes with more ergonomic sitting and standing working postures. The proposed worktable has a width of 53 cm, a sitting height of 52.18 cm, and a standing height of 69.27 cm, and is equipped with basins, filters, water taps, and a personal protective equipment rack. This ergonomic worktable design is expected to improve working comfort, reduce non-neutral postural loads, and minimize the risk of MSDs among jumputan batik SMEs workers.

1. Introduction

The batik industry represents a vital component of the creative economy sector and serves as a strategic contributor to tourism attractiveness in Yogyakarta City [1]. One of the batik-producing Small and Medium Enterprises (SMEs) in Yogyakarta is in Tahunan Village, Umbulharjo District, specializing in jumputan batik. The production process consists of several stages, including motif creation, tie-dyeing, dye solution preparation, dyeing, and drying, which are predominantly carried out manually using limited and non-standardized equipment.

Despite its economic potential, the SME faces critical operational challenges, particularly related to non-ergonomic work facilities, repetitive manual activities, and the absence of integrated supporting tools. These conditions result in inefficient production processes characterized by high physical workload, excessive time consumption, and increased worker fatigue. In addition, field observations indicate that the existing work facilities are not systematically arranged due to limited supporting infrastructure. Such conditions pose significant risks to occupational health, especially those associated with awkward working postures, repetitive movements, and the use of inappropriate tools [2]. Previous studies have consistently demonstrated that workers in SMEs are highly susceptible to musculoskeletal disorders (MSDs), particularly lower back pain caused by prolonged non-ergonomic postures [3], [4].

These issues are also evident in the SME selected as the research object in Tahunan Village. Preliminary studies using the Nordic Body Map (NBM) questionnaire reveal that workers experience musculoskeletal discomfort in multiple body regions, including the lower neck, shoulders, back, waist, elbows, knees, and legs [5], [6]. Notably, the highest prevalence of complaints occurs in the lower neck (69%) and left knee (63%). These findings indicate a strong correlation between repetitive tasks, prolonged working duration, and non-neutral working postures.

Further observations during the jumputan batik dyeing process show that workers predominantly perform tasks in bending and squatting positions for extended periods (Fig. 1). Such postures are widely recognized as major ergonomic risk factors contributing to musculoskeletal disorders (MSDs) [7]. Moreover, the results of postural risk assessment confirm that the dyeing process falls into a high-risk category, thereby requiring immediate corrective action [6]. These findings highlight the urgency of ergonomic intervention, particularly in the dyeing stage, which represents the most physically demanding and risk-prone activity within the production process.


Fig. 1. Dyeing process work posture

To address these challenges, it is essential to develop an appropriate production support tool that can effectively minimize occupational risks while improving work efficiency. The development of such a tool is expected to reduce the potential for work-related health problems, enhance productivity, and decrease the likelihood of workplace accidents that may lead to financial, time, and labor losses for SMEs [8]. Therefore, a comprehensive design approach is required, not only focusing on functional performance but also integrating ergonomic principles and worker safety considerations.

In this study, the design of batik production support tools is approached through the integration of ergonomic and functional aspects. The ergonomic aspect is addressed using anthropometric methods to ensure that the dimensions of the proposed tool are aligned with workers' body measurements, thereby promoting safer and more comfortable working postures [9]. Meanwhile, the functional aspect is addressed using the Quality Function Deployment (QFD) method, which systematically translates the voice of customer (VOC) into technical specifications, ensuring that the proposed design meets user needs and improves operational performance.

Several previous studies have explored the design of batik production tools using different approaches. For instance, study [10] proposed modifications to a pantograph and the development of an electric stove, while study [11]] designed a spanram for the dyeing process using the QFD method. Other studies include the development of mechanical dyeing tools without a structured design approach [12] and batik drying systems utilizing residual heat to improve efficiency [13]. However, these studies tend to focus on specific tools or processes without comprehensively integrating ergonomic considerations and user-centered design approaches.

Therefore, this study aims to develop an ergonomic and integrated work facility design that not only fulfills functional requirements but also enhances worker comfort and reduces the risk of musculoskeletal disorders. The proposed design is expected to provide both practical contributions for SMEs and theoretical contributions to the development of ergonomic product design methodologies.

2. Method

2.1 Research Subjects and Objects

This study was conducted in a Small and Medium Enterprise (SME) producing jumputan batik located in Tahunan Village, Umbulharjo District, which has been identified as experiencing significant ergonomic issues in its production process. The research subjects consisted of nine batik artisans aged between 38 and 62 years, representing the active workforce involved in the production activities. Notably, 88.9% of the respondents had more than nine years of working experience, indicating a high level of familiarity with the operational processes and associated work-related problems.

All respondents were directly involved in the entire production workflow, particularly in the dyeing process, which has been identified as the most ergonomically demanding stage. Therefore, they were considered capable of providing reliable and relevant input regarding user needs, work constraints, and ergonomic challenges. Given the relatively small population size, this study employed a total sampling approach, allowing all workers to be included as respondents. This approach ensures that the collected data comprehensively represents actual working conditions and strengthens the validity of the user-centered design process adopted in this study.

2.2 Preliminary Study

The preliminary study was conducted as an initial step to systematically identify the root causes of ergonomic problems and musculoskeletal complaints experienced by workers. This stage plays a critical role in ensuring that the proposed solution is grounded in real-world conditions and aligned with actual user needs. Data collection was carried out through direct field observations to capture working postures, task sequences, and workplace conditions, particularly during the dyeing process. In addition, semi-structured interviews and surveys were conducted to explore workers' perceptions, discomfort levels, and operational difficulties. Following problem identification, a comprehensive literature review was conducted to support problem formulation and to establish a theoretical foundation for ergonomic intervention. This integrated approach ensures that the research is both empirically grounded and theoretically supported.

2.3 Focus Group Discussion

To strengthen the validity of the user requirements and ensure alignment with real operational needs, Focus Group Discussions (FGDs) were conducted involving relevant stakeholders, including workers and researchers. The FGD process was carried out in three stages, each serving a specific purpose within the research framework.

The first FGD focused on the development and validation of research instruments to ensure their relevance and clarity. The second FGD was conducted to construct and validate the House of Quality (HOQ) matrix within the QFD framework, ensuring that the translation of user needs into technical requirements accurately reflects worker expectations. The third FGD supported the anthropometric measurement process to ensure that the selected body dimensions and design parameters are appropriate for the target users.

2.4 Quality Function Deployment (QFD)

In line with the user-centered design approach emphasized in this study, Quality Function Deployment (QFD) was employed as the primary method to systematically translate user needs into technical design specifications [14]. QFD enables the integration of the Voice of Customer (VOC) into the product development process, ensuring that the resulting design directly addresses identified ergonomic issues.

The QFD process was implemented through the development of the House of Quality (HOQ), which serves as a structured tool for linking customer requirements with technical responses. The implementation consisted of three main stages:

1) VOC data were collected through observations, interviews, surveys, and Focus Group Discussions (FGDs) to capture actual working conditions and identify key ergonomic problems contributing to musculoskeletal disorder (MSD) risks. The data collected were then systematically translated into customer requirement attributes, representing ergonomic needs, functional requirements, and operational efficiency as the basis for user-centered design.
2) The subsequent stage involved identifying technical requirements and systematically mapping the relationships between customer requirements and technical specifications using House of Quality (HOQ). In addition, correlations among technical parameters were evaluated, and target design specifications were determined. This process ensures that the proposed design directly addresses identified ergonomic risks while maintaining a structured and traceable decision-making process.
3) The final stage involved analyzing and interpreting the resulting design to ensure consistency between user needs and technical outputs, particularly in reducing non-neutral postures and minimizing MSD risk factors. Furthermore, the feasibility and effectiveness of the proposed solution were evaluated to ensure its practical applicability within SME working conditions.

2.5 Anthropometry

To ensure that the proposed work facility effectively addresses ergonomic risks, anthropometric analysis was applied as a key component in determining the design dimensions. This approach aligns with the objective of reducing musculoskeletal disorder (MSD) risks by promoting neutral and comfortable working postures. The anthropometric analysis began with the selection of relevant body dimensions corresponding to the identified work activities. The selected dimensions included Forward Reach Distance (FRD) for determining the width of the work facility, Popliteal Height (PH) and Thigh Thickness (TT) for determining the appropriate height for seated working positions during dyeing and draining, and Elbow Height (EH) for determining the optimal height for standing positions during rinsing activities. Appropriate percentile values were then determined to ensure that the designed facility accommodates many users while minimizing ergonomic risk. The anthropometric data were obtained from the Indonesian Anthropometric Database, ensuring contextual relevance to the target user population.

2.6 Product Design Visualization

As the final stage of the research, the proposed work facility design was visualized in the form of a three-dimensional (3D) model using SolidWorks software. This visualization serves not only as a representation of the design concept but also as a tool for evaluating the integration of functional and ergonomic aspects. The 3D model enables a clearer understanding of how the proposed design accommodates the dyeing, rinsing, and draining processes in an integrated and ergonomic manner. Furthermore, it provides a practical basis for future implementation and evaluation of the proposed work facility.

3. Results and Discussion

3.1 Production Process Stages

The jumputan batik production process consists of several main stages, including motif creation, fabric tying, dyeing, color fixing, drying, and ironing. Jumputan batik, also known as tie-dye batik, produces patterns through fabric binding techniques prior to the dyeing process [15]. In the SME located in Tahunan Village, Umbulharjo District, the techniques applied include tying and stitching methods.

Based on the findings from the preliminary study, the dyeing stage—comprising dyeing, rinsing, and draining processes—was identified as the most dominant stage involving manual activities with non-ergonomic working postures. These activities require workers to perform repetitive tasks under physically demanding conditions, particularly in bent and squatting positions. From an ergonomic perspective, this stage presents the highest risk of musculoskeletal disorders (MSDs) and has a direct impact on worker comfort and productivity. Therefore, the design of the proposed work facility in this study is specifically focused on the dyeing stage, as it represents the most critical point for ergonomic intervention and performance improvement within the production system.

3.2 Voice of Customer (VOC)

The results of the Voice of Customer (VOC) identification indicate that workers require work facilities and supporting tools that can improve the ergonomic quality and efficiency of the batik dyeing process. Currently, dyeing activities consisting of dyeing, rinsing, and draining are still performed manually without adequate supporting tools, forcing workers to adopt non-ergonomic working postures.

During rinsing and draining activities, workers frequently perform tasks in prolonged and repetitive squatting positions, leading to discomfort and fatigue. Such working postures have been widely associated with increased muscle stiffness and a higher risk of musculoskeletal disorders (MSDs) [16], [17]. This finding reinforces the need for an ergonomic intervention that can reduce postural load and improve working conditions. In addition, workers expressed the need for supporting tools that can reduce the physical workload on the upper body, particularly during the draining process. Manual draining activities require repetitive arm and shoulder movements over extended periods, resulting in pain and discomfort in these areas. These repetitive and non-ergonomic movements are also associated with the risk of Cumulative Trauma Disorders (CTDs) [18].

Another key finding from the VOC analysis highlights the need for integrated work facilities across different workstations. The current facility layout in the SME is not designed based on the interrelationship between workstations in the dyeing process, resulting in inefficient movement patterns and unnecessary time and energy expenditure [19]. This condition indicates the absence of a systematic and integrated work facility design. The QFD method was initiated by identifying VOC and user expectations regarding the proposed work facility design (Table 1). Data was collected through direct interviews with workers involved in the dyeing process. Based on the VOC identification, key user needs were identified and subsequently translated into user requirement attributes that serve as design parameters. Furthermore, the level of importance of each attribute was assessed using a Likert scale ranging from 1 (very unimportant) to 5 (very important), ensuring that the design prioritizes the most critical user needs (Table 2).

Table 1. VOC and User Requirements

No.	VOC	User Requirements
1.	The absence of supporting facilities in the dyeing process results in inefficient and fully manual operations.	Develop an integrated work system to support dyeing, rinsing, and draining processes.
2.	Prolonged squatting during rinsing and draining leads to discomfort and increased physical fatigue. performed in a squatting position.	Design work facilities that accommodate both seated and standing postures in accordance with task characteristics.
3.	Repetitive manual draining induces excessive load on the shoulders and arms.	Implement a draining mechanism to reduce manual handling and upper-body workload.
4.	Non-integrated workstations cause inefficient movement and workflow disruption.	Design an integrated workstation equipped with basins, water taps, draining units, and a PPE rack.

Table 2. User Requirement Attributes and Importance Level

No.	User Requirements	Attribute	Importance Level
1.	An integrated workstation that supports dyeing, rinsing, and draining operations.	Usability	5
2.	Work facilities that enable ergonomic seated and standing postures.	Comfort	5
3.	A draining system to minimize manual handling and repetitive motion.	Comfort	5
4.	A fully integrated workstation equipped with basins, water taps, draining units, and a PPE rack.	Completeness	4

3.3 Quality Function Deployment (QFD)

The identified Voice of Customer (VOC) was systematically translated into customer requirements through a classification process based on the similarity of user needs. As a result, the customer requirements were grouped into three main attributes, namely usability, comfort, and facility completeness. This classification ensures that the design process remains structured and aligned with the core ergonomic and functional issues identified in the preliminary study.

The usability attribute reflects the workers' need for a work facility that simplifies the dyeing, rinsing, and draining processes through ease of operation. The comfort attribute represents the need to improve working postures by promoting ergonomic positions, reducing manual workload, and adjusting the dimensions of the work facility according to user anthropometry. Meanwhile, the completeness attribute represents the need for an integrated work facility capable of accommodating all stages of the dyeing process within a single system.

These customer requirement attributes were subsequently translated into technical requirements using the Quality Function Deployment (QFD) method, as illustrated in Fig. 2. This transformation ensures that the proposed design directly addresses ergonomic risks, particularly those related to non-neutral postures and repetitive manual activities that contribute to musculoskeletal disorders (MSDs).

The usability attribute was translated into a technical requirement in the form of a worktable frame design consisting of four integrated basins made of 1 mm thick stainless steel, ensuring ease of operation, durability, and maintenance. The comfort attribute was translated into a work facility design that accommodates both sitting and standing working positions, with seated positions applied during dyeing and draining processes, and standing positions during rinsing activities. The dimensions of the worktable were determined based on anthropometric data to ensure ergonomic suitability and to minimize postural strain. In addition, the use of a durable plastic filter with a 4-mesh size was established as a technical requirement to reduce manual workload, particularly in the draining process.

The completeness attribute was translated into several supporting technical features, including the installation of stainless-steel water taps in each dyeing and rinsing basin connected through PVC piping, the use of 27-liter plastic basins, and the addition of a Personal Protective Equipment (PPE) rack as part of an integrated work facility. These features are intended to enhance workflow efficiency, reduce unnecessary movement, and support a safer and more organized working environment.

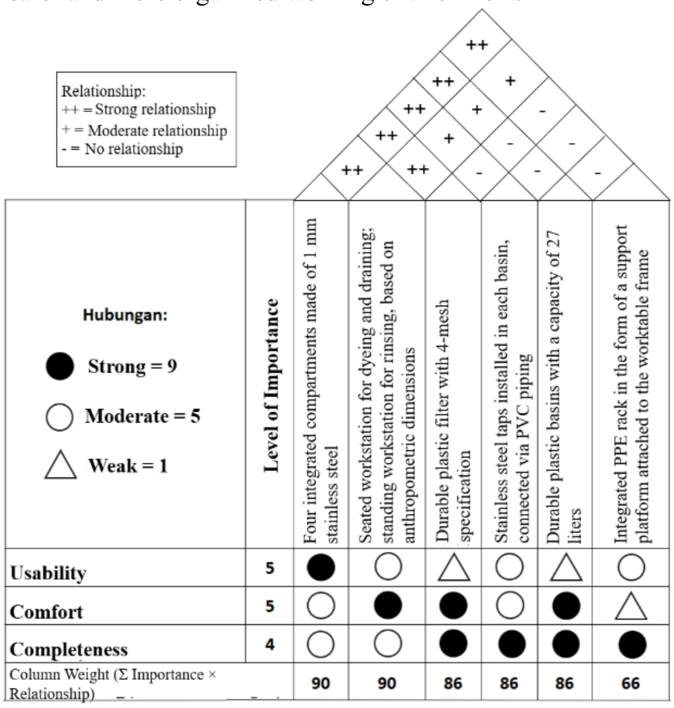

Fig. 2. House of Quality (HOQ) result

3.4 Anthropometric Analysis

Based on the technical requirements identified through the Quality Function Deployment (QFD) process, it is necessary to determine the dimensions of the proposed work facility to fulfill the usability and comfort attributes. Therefore, anthropometric data was employed as the primary basis for defining the shape and dimensions of the designed worktable. This approach ensures that the proposed design is ergonomically aligned with user characteristics and capable of reducing musculoskeletal disorder (MSD) risks associated with non-neutral working postures.

The determination of work facility dimensions was based on four key body dimensions, namely Forward Reach Distance (FRD), Popliteal Height (PH), Thigh Thickness (TT), and Elbow Height (EH). The FRD dimension was used to determine the width of the worktable, while PH and TT were used to define the table height for seated working positions during the dyeing and draining processes. Meanwhile, EH was used to determine the table height for standing positions during the rinsing process. The anthropometric data used in this study were obtained from the Indonesian Anthropometric Database, with adjustments made to reflect the characteristics of jumputan batik workers.

The selection of anthropometric data was tailored to the primary users of the work facility, namely female batik artisans aged 38 years and above. All dimensions were determined using the 50th percentile (P50), considering that the user population is relatively homogeneous and the facility is intended for general use. The use of the 50th percentile aims to produce dimensions that accommodate the majority of users while minimizing discomfort for the dominant user group, as recommended in ergonomic literature [20]. The results of the dimensional calculations based on anthropometric data are presented in Table 3.

The determination of worktable dimensions based on the selected body measurements is described as follows:

1) The Forward Reach Distance (FRD) was not directly derived from anthropometric percentile data; instead, the worktable width was adjusted to the diameter of the container used in the dyeing process, resulting in an approximate width of 53 cm. This adjustment ensures functional compatibility with existing operational tools.
2) The worktable height for seated positions was determined by combining the Popliteal Height (PH) and Thigh Thickness (TT) using the 50th percentile, resulting in a height of 53.18 cm. This dimension is intended to support a neutral and comfortable sitting posture during dyeing and draining activities.
3) The worktable height for standing positions was determined based on the Elbow Height (EH) using the 50th percentile, resulting in a height of 69.27 cm. This dimension is designed to minimize bending posture and reduce upper body strain during rinsing activities.

Table 3. Anthropometric Measurement Result

No.	Body Dimension	Product Dimension	Measure (cm)
1.	FRD	Table Width	53
2.	PH	Table Height (Seated)	53,18
3.	TT	Table Height (Seated)	
4.	EH	Table Height (Standing)	69,27

3.5 Worktable Design for the Dyeing Process

Based on the classification of production stages in the jumputan batik dyeing process, as illustrated in Figure 2, the worktable design was specifically developed to accommodate dyeing, rinsing, and draining activities in an integrated manner. Each of these stages involves distinct technical requirements; therefore, the worktable was designed as a multi-component system in which each component supports the functional needs of the respective production stage. The final design of the worktable is presented in Fig. 3, demonstrating a comprehensive solution that aligns with the technical specifications derived from the QFD analysis and anthropometric considerations.

The worktable frame serves as the primary structural component that supports all elements of the facility and ensures overall stability during operation. It was designed to withstand continuous use under wet and repetitive working conditions, thereby maintaining both durability and ergonomic reliability.

The basins function as the main containers for dyeing and rinsing processes. Their number and arrangement were configured based on the production workflow to facilitate smooth and sequential operation. This configuration minimizes unnecessary movement and enhances process efficiency.

The filter component was designed to support the draining process after dyeing. Its implementation aims to reduce manual handling activities, particularly repetitive upper-body movements, thereby lowering the risk of musculoskeletal disorders (MSDs) and improving overall work efficiency.

The water taps were incorporated to provide controlled water flow during the rinsing process, enabling more efficient and consistent operations. In addition, a Personal Protective Equipment (PPE) rack was integrated into the worktable design to support workplace organization and ensure the accessibility of safety equipment. This feature contributes to a safer and more structured working environment.

Overall, the proposed worktable design represents an integrated ergonomic intervention that not only improves workflow efficiency but also addresses key risk factors associated with non-neutral postures and repetitive manual activities identified in the earlier stages of this study.

3.6 Discussion

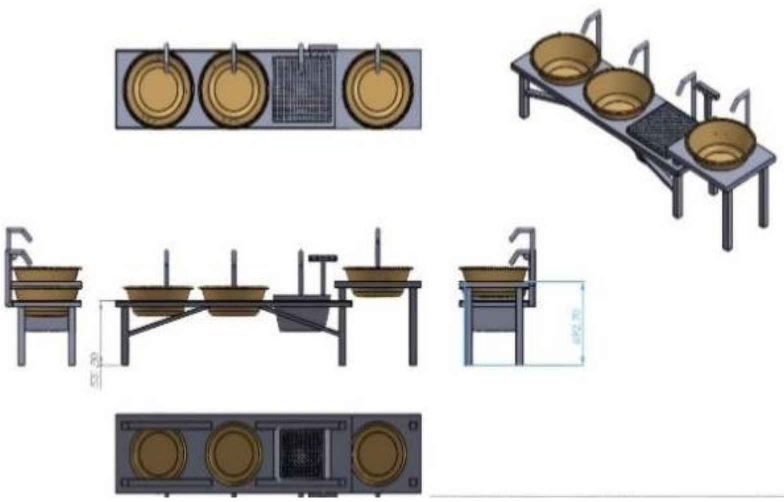

Fig. 3. Design of the work facility for the Jumputan Batik

The design of the work facility for the dyeing process was developed based on the identified problem of non-ergonomic working postures during the fabric immersion stage. In this process, the primary activity involves soaking the fabric while workers maintain a squatting posture for prolonged and repetitive durations. Based on preliminary studies conducted at the same research location [6], workers reported significant discomfort, particularly in the lower neck and left knee areas. These conditions indicate a high potential risk for musculoskeletal disorders (MSDs) as well as cumulative trauma disorders (CTDs) if no appropriate intervention is implemented.

From an occupational safety perspective, the design of work facilities represents a preventive approach within the engineering control level of the hierarchy of controls, achieved through modifications of facilities, equipment, and work processes [21]. Therefore, this study proposes an ergonomic work facility capable of accommodating all stages of the batik dyeing process in a more integrated and user-centered manner. The Quality Function Deployment (QFD) method was applied to ensure that the design is systematically developed based on user needs (voice of customer).

The results of the VOC analysis indicate that workers require a worktable that facilitates dyeing, rinsing, and draining processes in an integrated manner, reduces manual activities, and supports ergonomic working positions in both sitting and standing postures. These user needs were subsequently translated into technical requirements through the House of Quality (HOQ), including the integration of multiple work basins, controlled water flow systems, draining media, and supporting facilities such as a Personal Protective Equipment (PPE) rack.

Based on the HOQ analysis, the primary technical requirement identified is the design of an ergonomic and integrated worktable frame. The usability attribute was fulfilled through a design consisting of four main sections that accommodate the first dyeing process, second dyeing process, draining, and rinsing. Considering that the process involves water and chemical substances, stainless steel was selected as the primary material due to its corrosion resistance, with a thickness of 1 mm, which is consistent with standard worktable specifications.

The comfort attribute was addressed by implementing a combination of sitting and standing in working positions. Sitting positions are applied during dyeing and draining processes, while standing positions are applied during rinsing activities. This configuration is intended to reduce excessive bending postures and distribute physical load more evenly across the body. The draining media utilizes a plastic filter to prevent corrosion and maintain fabric quality, while the use of a 4-mesh size ensures adequate support for the fabric while allowing efficient water drainage.

The completeness attribute was addressed by integrating additional supporting components, including stainless steel water taps connected via PVC pipes, selected for their lightweight properties, corrosion resistance, and chemical stability. Plastic basins were used to maintain fabric quality, while the PPE rack was integrated into the worktable structure and positioned centrally to ensure accessibility and improve workplace organization.

The HOQ matrix evaluation further indicates that the ergonomic worktable frame based on anthropometric considerations has the highest level of importance among all technical requirements. This is because the frame serves as the primary supporting structure that integrates all functional components, as illustrated in Fig. 2, and has strong interrelationships with other technical elements.

Based on anthropometric measurements, the final worktable dimensions were determined as follows: a width of 53 cm based on forward reach distance, a seated height of 53.18 cm, and a standing height of 69.27 cm. The table width was determined using the 5th percentile to ensure that users with smaller body dimensions can comfortably reach the entire work area, while the height dimensions were determined using the 50th percentile to accommodate many users. Overall, the proposed worktable design for the jumputan batik dyeing process was developed as an integrated ergonomic solution aimed at improving working conditions, reducing excessive manual activities, and minimizing the risk of musculoskeletal disorders (MSDs) previously experienced by workers.

4. Conclusion

The design of a production support tool for the jumputan batik process—specifically in the dyeing, draining, and rinsing stages—was developed to minimize the risk of musculoskeletal disorders (MSDs) caused by non-ergonomic working postures. The proposed worktable was designed based on key user-centered attributes, namely usability, comfort, and facility completeness, ensuring alignment with the ergonomic and operational needs identified in this study.

The resulting worktable dimensions include a width of 53 cm, a seated height of 53.18 cm, and a standing height of 69.27 cm, which were determined based on anthropometric data of the target users. These dimensions are intended to support neutral working postures and reduce physical strain during repetitive activities. In addition, the worktable is equipped with integrated components, including a filter, water taps, basins, and a Personal Protective Equipment (PPE) rack, to support a more efficient and ergonomically integrated dyeing process. Overall, the proposed design provides a practical ergonomic solution that not only improves working conditions but also reduces excessive manual workload and potential MSD risks among workers. For future research, it is recommended to conduct feasibility testing and ergonomic evaluations to assess the effectiveness and real-world applicability of the proposed design.

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