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Design of an Ergonomic Press Machine Work Aid to Increase Productivity in the Shoe Production Process (Case Study at SMEs One Maxx Mojokerto)

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ABSTRACT

UKM One Maxx Mojokerto is a small and medium-sized enterprise engaged in shoe production. The production process, particularly in the stage of attaching the upper to the sole, is still carried out manually using basic tools such as hammers, nails, and pliers. This method requires relatively long processing time, high physical effort, and potentially causes ergonomic complaints for workers. This study aims to design an ergonomic press machine as a work aid to improve productivity and operator comfort. The research method includes user needs analysis, anthropometric measurements for tool dimension determination, and work time analysis using the Maynard Operation Sequence Technique (MOST). The results indicate that the ergonomic press machine design is able to reduce production time compared to manual methods, increase work efficiency, and decrease workers' physical workload. The implementation of this work aid is expected to enhance production capacity while improving ergonomic working conditions for SMEs.

1. Introduction

One Maxx Shoes is a growing company specializing in the fashion shoe industry. The company's products include a variety of shoe styles, including men's loafers. One Maxx Shoes focuses on producing men's loafers. The company's sales system is made-to-order, operating both online and offline.

Small and medium enterprises (SMEs), including sandal SMEs, play a vital role in the national economy. One Maxx Shoes is a micro, small, and medium enterprise (MSME) sector specializing in sandal production. Sandal SMEs are spread across various regions in Indonesia and are capable of absorbing local labor while producing highly competitive products. However, many MSMEs still face productivity and efficiency challenges.

In addition to ergonomic issues, SMEs also face challenges due to inadequate equipment, such as the manual sole pressing process, which requires significant effort and time. This situation results in actual output not meeting targeted standards, resulting in low work efficiency.

Initial observations at the One Maxx SME indicate that the production process, particularly the shoe gluing process, is still carried out manually with simple equipment, resulting in inconsistent daily output and often falling short of production standards (STD). This productivity instability indicates the need for work process improvements. Furthermore, field observations indicate that operators often perform work in non-ergonomic postures, such as bending, prolonging their head, or using excessive hand strength. These conditions have the potential to cause musculoskeletal disorders (MSDs), which can lead to fatigue and reduce worker performance.

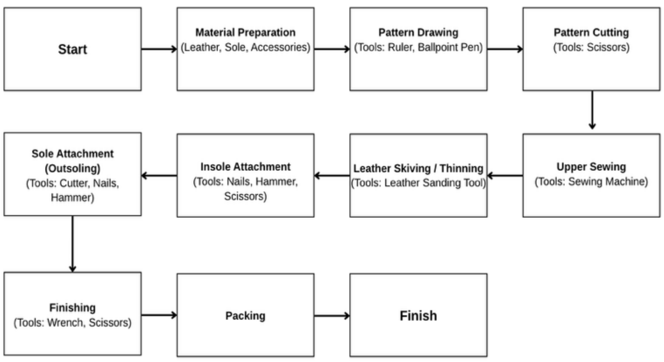

Figure 1 Loafer Shoe Production Process Flow

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Production productivity is influenced by three main aspects: working time, product quality, and operator conditions. In SMEs such as sandal/shoe SMEs, the gluing and component assembly processes are still performed manually. This manual activity takes longer, results in inconsistent adhesive quality, and causes operator fatigue. Facility layout significantly impacts the smoothness of production processes in SMEs such as shoe SMEs. Layout improvements impact throughput time, production delays, and labor productivity [1].

In modern production processes, machines function to support human labor by taking over heavy and repetitive tasks, thereby increasing efficiency and quality without completely replacing humans [2]. The advantages of using machines/tools include increased output and more consistent quality, shortened production cycle times, and reduced operator fatigue. Machines enable processes such as pressing, cutting, and bonding to be performed more quickly and precisely than manual methods, thereby lowering labor costs per unit and reducing product defects [2], [3]. This research focuses on the design of a work aid, a shoe press, for the gluing process, using ergonomic methods. This tool maximizes production productivity and increases profits for the One Maxx MSME.

Furthermore, the work time measurement process used in this study requires an approach capable of describing movement elements more accurately than conventional time measurements. The Maynard Operation Sequence Technique (MOST) method was chosen for its ability to map work activities into standardized movement categories, allowing for more objective and consistent time analysis. However, in the context of the shoe MSME, the application of MOST is still rare, especially for analyzing the gluing and sole pressing processes, which are repetitive and require a certain amount of pressure. The use of MOST in this study not only aims to obtain more precise cycle times but also validates the need for tool design that can eliminate ineffective work elements. MOST is a crucial component in addressing the research gap related to the integration of ergonomics, anthropometry, and motion analysis in the shoe production process.

Although previous studies have discussed the importance of ergonomic improvements and the use of assistive devices to increase productivity in small and medium-sized industries, most studies have focused on layout improvements, general workload reduction, or cycle time analysis without integrating the specific tool design needs of the repetitive, high-pressure shoe adhesive process. Furthermore, research on press tool design in the shoe MSME sector has generally not combined a comprehensive ergonomic approach based on anthropometric data with structured work analysis such as MOST. This results in limitations in ensuring that the tool design truly matches the operator's body characteristics while eliminating inefficient manual work elements. There is a research gap in the following The lack of a press tool design model that combines ergonomic, anthropometric, and motion analysis aspects in an integrated manner in the shoe gluing process in MSMEs, so that the effectiveness of increasing productivity and reducing physical load cannot be maximized.

2. Research methods

This research method falls into the applied research category, originating from a problem in the field. The research stages to be implemented include the following steps:

2.1 Field Study

At this stage, direct observation of the shoe production process at One Maxx was conducted. Activities included observing operator activities during the gluing and sole pressing process, identifying the equipment used, and recording working conditions related to body posture and physical load. Interviews were conducted with operators and division heads to obtain information regarding production constraints, output standards, and work procedures. This field study aimed to understand the real situation so that tool design requirements could be formulated accurately.

2.2 Literature Study

This stage is conducted to gather references related to ergonomics, anthropometry, work productivity, assistive device design, and time measurement methods such as the Maynard Operation Sequence Technique (MOST). The literature review aims to strengthen the theoretical foundation so that the analysis and design have a clear scientific basis. Furthermore, the literature review helps identify relevant previous research, thus mapping the research's scientific contribution.

2.3 Data Collection

Data collection was conducted quantitatively using observation checksheets to record process time, operator activity sequence, and work movement frequency. Operator anthropometric data was collected through direct measurements to determine the tool's design dimensions to suit the user's body characteristics. Additionally, operator activity was recorded using video to support motion analysis in the MOST method, allowing each movement element to be accurately classified.

2.4 Data Management

Data processing was carried out to systematically compile the results of the field study through mapping the operator's workflow, calculating anthropometric percentiles for ergonomic design, analyzing target capacity using bar charts, and measuring work time using the MOST method to obtain cycle time, normal time, standard time, and worker allowance. The Maynard Operation Sequence Technique (MOST) method was used to analyze work elements in a structured manner based on standard movement categories including General Move, Controlled Move, and Tool Use. Each category describes the operator's activity pattern The MOST method consists of movement sequences, movement distances, force usage, and interactions with work equipment. The purpose of this study was to identify inefficient movement elements during the gluing and pressing process of shoe soles.

Observations were conducted by recording the operator's movement sequence using the MOST sheet and visual recordings to ensure each movement element could be correctly classified. Observations were repeated several times for each operator to obtain a stable representation of working conditions. Validation was carried out in two stages: (1) verifying the conformity of movement categories by two independent observers to reduce subjective bias, and (2) checking the consistency of normal times by comparing calculation results between observations and between operators. This procedure ensures that the cycle time, normal time, and standard time calculations generated by the MOST have high reliability and can be used as a basis for designing effective ergonomic press tools.

2.5 Tool Design Stage

The tool design stage is carried out by referring to the production process requirements obtained from field studies and data analysis. The design process begins by determining the functional specifications of the press tool, such as the required pressing force, structural stability, ease of operation, and safety during use. Ergonomic principles are applied through the use of operator anthropometric data to determine the tool dimensions, working position, work surface height, and hand reach so that the tool can be used comfortably and minimize the risk of fatigue. After the initial concept is formulated, materials and components are selected based on strength, durability, and production costs. This stage produces the tool design in the form of technical drawings and design models as a basis for the manufacturing process.

2.6 Trial

The trial phase was conducted to evaluate the performance of the designed and built press. Testing was conducted directly during the production process, involving operators who typically work on gluing and sole pressing. During the trial, work time, ease of use, tool stability, and potential ergonomic risks were recorded. Comparisons between conditions before and after use were analyzed using the MOST method to determine whether inefficient movement elements were successfully reduced. If deficiencies were found, design improvements were made, such as adjusting dimensions, adding structural reinforcement, or modifying the press mechanism. This phase ensures the tool meets functional, ergonomic, and usability requirements before being fully implemented in SMEs.

3. Results and Discussion

From the data collection, it was found that before the repair, the process of gluing the sole and upper of the shoe still had a relatively long and unstable working time. This instability was caused by the high proportion of manual activities, especially at the stage of pressing the sole to the upper which relied on the strength and accuracy of the operator. It was necessary to design a press aid that could reduce the burden of manual movements and reduce working time. The design of this tool was carried out by referring to the MOST method to analyze time-consuming movement elements, as well as worker anthropometric data to ensure the tool design was ergonomic and in accordance with the body dimensions of the majority of operators [4], [5]. Anthropometric parameters ensure that the tool can be used by the majority of operators without causing the risk of fatigue, discomfort, or potential injury.

3.1 MOST Calculation Observation

3.1.1 Normal Time

Prior to the system improvements, normal time measurements were conducted to determine the actual condition of the sole and upper bonding process, which still uses manual methods. These measurements aimed to identify the work elements that required the most time and serve as a basis for comparison against the improvement results. A summary of the normal time measurements before the improvements is shown in Table 1.

Table 1
Normal Time Calculation Results Before

No	Manual Press Operator	Wn
1.	Operator 1	44,41 second
2.	Operator 2	43,47 second
3.	Operator 3	46,67 second
4.	Operator 4	44,96 second

The results of the normal time output calculation for the pre-condition condition were 507 pairs of shoes per 7-hour work shift, with an average normal time of 44.48 seconds. After the implementation of the ergonomic press, normal time measurements were conducted again to evaluate the impact of the improvements on operator efficiency. This data was used to compare changes in cycle time and productivity before and after the use of the tool. The results of the normal time calculations after the improvements are presented in Table 2.

Table 2
Results of Normal Time Calculation After

No	Manual Press Operator	Wn
1.	Operator 1	34,97 second
2.	Operator 2	33,90 second
3.	Operator 3	34,71 second
4.	Operator 4	35,31 second

The results of the normal time output calculation for the following conditions are 725 pairs of shoes/7-hour work shift with an average normal time of 34.72 seconds.

3.1.2 Standard Time

To obtain standard time, adjustments are made to normal time, taking into account factors such as allowances and operator performance variability. This measurement is essential for establishing realistic work standards before making improvements. Table 3 displays the results of standard time calculations under initial manual work process conditions.

This value indicates inefficient work movements, resulting in longer cycle times and lower productivity. After the ergonomic press was implemented, standard times were recalculated to more comprehensively assess efficiency improvements. This data provides a clear picture of the extent of cycle time reduction and productivity gains achieved by the press. The results of the standard time calculations after improvements can be seen in Table 4.

Table 3
Standard Time Calculation Results Before

No	Operator	Wb
1.	Operator 1	49,17 second
2.	Operator 2	48,12 second
3.	Operator 3	51,67 second
4.	Operator 4	49,78 second

Table 4
Results of Normal Time Calculation After

No	Operator	Wb
1.	Operator 1	38,71 second
2.	Operator 2	37,53 second
3.	Operator 3	38,42 second
4.	Operator 4	39,09 second

This reduction in time indicates that the press is able to eliminate unnecessary manual movements, reduce the physical burden on the operator, and speed up the gluing process.

3.2 *Anthropometry*

Anthropometric data of employees' bodies at the One Maxx Shoes UMKM was collected through direct measurements of four workers involved in the shoe production process (Table 5).

Table 5
Employee Anthropometric Data

Data	Khoirul	Rozak	Andi	Kamto
TB	165	169	174	176
TD	89	91	93	94
TSD	63	65	67	68
TP	43	45	47	47
PL	58	60	62	63
JH	72	74	77	78
LB	44	45	47	47
PT	19	20	21	22
G	38	39	41	42

3.3 *Standard Deviation Calculation*

In the anthropometric data analysis stage, calculating the standard deviation is a crucial step in understanding the extent of body size variation among respondents. Standard deviation is used to assess the degree of dispersion of data relative to the mean, thus determining whether the collected data is relatively uniform or shows significant differences in size.

Table 6
Standard Deviation Calculation Results

No	Nama	TB	TD	TSD	TP	PL	JH	LB	PT	G
1	Koirul	165	89	63	43	58	72	44	19	38
2	Rozak	169	91	65	45	60	74	45	20	39
3	Andi	174	93	67	47	62	77	47	21	41
4	Kamto	176	94	68	47	63	78	47	22	42
Average		171	91.75	65.75	45.5	60.75	75.25	45.75	20.5	40
Standard Deviation		4.96655	2.21736	2.21736	1.91485	2.21736	2.75379	1.50000	1.29099	1.82574
$\sum XI$		684	367	263	182	243	301	183	82	160
$(\sum XI)^2$		467856	134689	69169	33124	59049	90601	33489	6724	25600
$\sum XI^2$		117038	33687	17307	8292	14777	22673	8379	1686	6410

The results of the standard deviation calculations for each parameter show relatively small variations in body size between operators, indicating that the data is uniform and can be used as a basis for designing work tools [6]. A low standard deviation value indicates a stable data distribution, so this anthropometric data is valid and representative for use in designing ergonomic press tools.

Table 7
Percentile Selection

No	**Antrophometri**	**1^{th}**	**$2{,}5^{th}$**	**5^{th}**	**10^{th}**	**50^{th}**	**90^{th}**	**95^{th}**	**$97{,}5^{th}$**	**99^{th}**
1	TB	159.4528	161.2656	162.8300	164.6428	171	177.3572	179.1700	180.7344	182.5472
2	TD	86.5946	87.4040	88.1024	88.9118	91.75	94.5882	95.3976	96.0960	96.9054
3	TSD	60.5946	61.4040	62.1024	62.9118	65.75	68.5882	69.3976	70.0960	70.9054
4	TP	41.0480	41.7469	42.3501	43.0490	45.5	47.9510	48.6499	49.2531	49.9520
5	PL	55.5946	56.4040	57.1024	57.9118	60.75	63.5882	64.3976	65.0960	65.9054
6	JH	68.8474	69.8526	70.7200	71.7252	75.25	78.7748	79.7800	80.6474	81.6526
7	LB	42.2625	42.8100	43.2825	43.8300	45.75	47.6700	48.2175	48.6900	49.2375
8	PT	17.4984	17.9697	18.3763	18.8475	20.5	22.1525	22.6237	23.0303	23.5016
9	G	35.7552	36.4215	36.9967	37.6631	40	42.3369	43.0033	43.5785	44.2448

The 50th percentile, or median, was chosen for anthropometric data selection because it represents the middle value of the distribution, reflecting the characteristics of the majority of the population without being affected by extreme values. In the context of ergonomic design, such as elbow height, hand reach, and knee height, the use of the median allows for more inclusive tool design that fits the posture of the majority of users [7], [8]. This is crucial for ensuring comfort and work efficiency, particularly in shoe press machine design.

In addition to anthropometric analysis, press machine design also requires technical specifications to ensure that the device meets mechanical standards, safety standards, and the pressure requirements for the shoe gluing process [9], [10]. Based on observations of the manual process, the average operator must apply a pressure of 25–35 kgf to ensure proper adhesion of the sole and upper. Therefore, the press machine is designed to produce a minimum pressure of 40 kgf as a safety margin to maintain consistent adhesion. This pressing force is achieved through a lever mechanism with a lever-to-press arm ratio of 1:4, allowing the operator to exert only 10 kgf of force to produce a 40 kgf of pressure output at the working point.

Structurally, the main frame of the tool uses ASTM A36 mild steel, which has a tensile strength of 400–550 MPa, is malleable, and offers high durability for repetitive use in MSME environments. The hinge components utilize high-strength alloy steel to withstand cyclic loads without deformation. The surface of the press base is coated with a heat-resistant rubber sheet to maintain the quality of the shoe sole and increase friction so the shoe does not shift when pressed. The tool dimensions are determined based on the 50th percentile of the operator's anthropometry, such as a workbench height of 75 cm, a lever handle height of 95 cm, and an effective reach of 45–50 cm to allow use without excessive bending or shrugging.

The tool's working mechanism utilizes a vertical lever system with a single fulcrum and a linkage [11]. When the operator pulls the lever down, the force is amplified through the mechanics of the lever and transmitted to the vertically moving pressure plate. This system was chosen for its easy maintenance, minimal moving parts, and good compressive force stability. For operator safety, the tool is equipped with a mechanical stopper to prevent the lever from excessively hitting the bottom point, as well as a spring return that returns the lever to its original position after use. Surfaces that could potentially cause injury, such as the lever tip and hinge, are equipped with protective covers to prevent the operator from being pinched during operation.

The safety analysis was conducted using a failure mode observation approach, which included identifying potential risks such as hand trapping, structural instability, and excessive compressive loads. The evaluation results showed that the use of frame reinforcements, movement restraints, and hinge guards significantly reduced potential hazards.

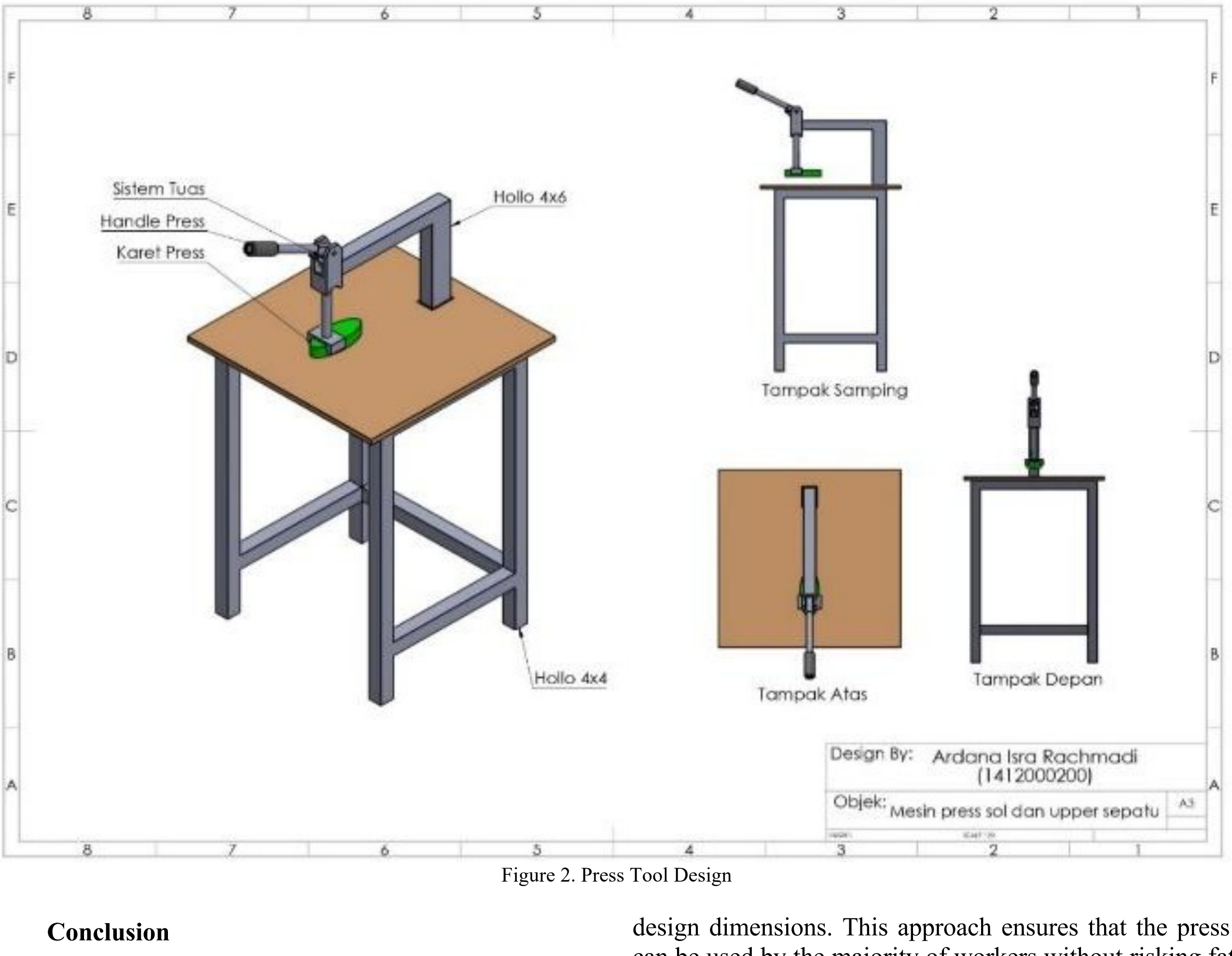

Figure 2. Press Tool Design

4. Conclusion

This research resulted in the design of an ergonomic press tool adapted to the operator's body characteristics by utilizing anthropometric data that has been tested for adequacy and uniformity, and selecting the 50th percentile as the basis for design dimensions. This approach ensures that the press tool can be used by the majority of workers without risking fatigue or excessive physical strain. The integration of motion analysis using the Maynard Operation Sequence Technique (MOST) method provides a more accurate picture of inefficient work elements and serves as the basis for structured process improvements. In terms of technical performance, the designed press tool has mechanical specifications capable of producing consistent pressing force according to the gluing process requirements, with a stable lever mechanism, a low-carbon steel frame structure, and safety features such as stoppers and hinge covers. This design meets engineering-grade standards for repetitive use in an MSME environment.

Results of work time measurements indicate that before the improvements, the average normal time was 44.88 seconds with an output of 507 pairs per shift. After the implementation of the ergonomic press tool, the normal time decreased to 34.72 seconds and output increased to 725 pairs per shift. Thus, the designed tool can increase productivity by 218 pairs per shift or approximately 43%, while reducing the manual burden on operators and significantly improving work comfort. Overall, this study proves that the application of ergonomic principles, MOST structured motion analysis, and appropriate mechanical design can produce work aids that are not only efficient but also safe and feasible for implementation in MSMEs. Further research can develop pneumatic or hydraulic-based press systems, conduct long-term operator fatigue analysis, and test the sustainability of the tool's use on a larger production scale.

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