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Design of Ergonomic Harmonica Wire Forming Tools to Increase Work Productivity of Harmonica Fence Craftsmen

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Abstract: A harmonica fence is a type of fence made of steel wire that is zigzaggingly assembled into a harmonica. Making harmonica fences requires appropriate wire forming tools so that the results can be more precise and consistent. Formation of harmonica wire using the bending method. Bending is a job by applying pressure to certain parts so that plastic deformation occurs in the pressurized part. Harmonica wire is often used for daily needs, such as house fences, land area fences, livestock fences (cattle, chickens, and goats). Making harmonica wire still uses manual methods and requires labor, patience and a long time. This research aims to develop an effective and efficient harmonica wire forming tool to increase the productivity of craftsmen. This research uses an experimental approach in the form of tool development which includes the stages of needs analysis, tool design, prototyping, trials, and evaluation. Workload is calculated based on the worker's pulse, production yield is measured based on the length of the harmonica wire produced, and work productivity is calculated based on the ratio between output (production output) and input (workload) multiplied by his working time. The results showed that there was a decrease in workload and a significant increase in production results and work productivity between using the old method manually and using a new way, namely using ergonomic chain wire forming tools. Workload decreased by 10.3%. Production output increased by 59.8%, while labor productivity increased by 78.7%. Therefore, it is recommended that harmonica wire craftsmen use ergonomic harmonica wire forming tools.

Keywords: Harmonica Wire Forming Tool, Ergonomic Work Tool, Craftsman Work Productivity

1. Introduction

Along with the times from the past until now, industrial machinery products show very rapid progress, both in terms of volume and diversity of products produced. The number of consumers and competitors continues to grow, this is due to the increasing need for the community for interior and security in the home environment, it requires the industry (workshop), most workshops are competing to produce their best work in order to be able to compete in the industrial world.

The uniformity of the types of work available on the market results in the growth of boredom and want to look different, so some workshop owners want to change the shape and design of production. The development of the workshop world today has become part of the needs of the community itself. The increasing need for markets or goods that are able to make the home page more beautiful and safe (changes in the shape of the frame and supporting components in accordance with the desired design), requires workshops to compete to display the best and interesting work with a more thorough level of workmanship and with various advantages of each workshop both in terms of design and construction made [1, 2].

Bending is a job by applying pressure to certain parts so that plastic deformation occurs in the pressurized part. One of the workpieces that can be bending is wire. Wire is a workpiece that can be used as a rope and also a fence that aims to make air circulation good and can help security and

barriers between places. Therefore, many home-based businesses use wire as the main medium for making zigzag wire or what can be known as harmonica wire. Harmonica wire is also often used for daily needs, such as use inside the house, property or such as land and is often used for livestock (cattle, chickens, and goats). Making harmonica wire still uses manual methods and requires labor, patience and a long time, thus making heavy workloads and optimal productivity. To provide solutions to workload and work productivity problems, intervention with an ergonomic approach and the use of appropriate technology tools is needed [3, 4].

The use of appropriate technology in the form of tools to speed up work is imperative in reducing workload and increasing the work productivity of artisans in small and medium industries [5-7]. In this study, the tool made was the design of ergonomic harmonica wire forming tools to increase the work productivity of harmonica fence craftsmen.

This research aims to develop an effective and efficient harmonica wire forming tool to increase the productivity of harmonica fence crafters. It is expected that the development of this appropriate harmonica wire forming device can increase the productivity of harmonica fence craftsmen, improve product quality, and increase the competitiveness of the harmonica fence industry in the market.

2. Research Methods

2.1. Design and Design

The design of this harmonica wire forming tool is designed to help chain wire-based fence business actors. The design design to be made can be seen in Figure 1.

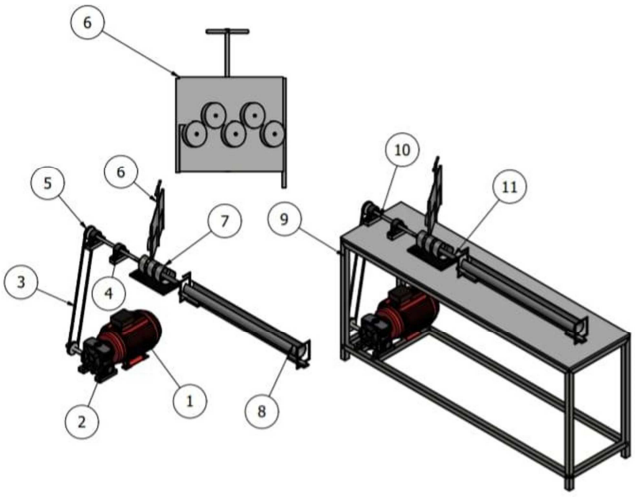

Figure 1. *Design Harmonica wire shaper design.*

Image Caption 1:
1. Electric motor
2. *Gearbox*
3. V-belt
4. *Pillow block*
5. *Pully*
6. Wire retaining graze
7. Harmonica wire mold
8. Weaving pipe
9. Skeleton
10. Shaft
11. Wire forming plate

2.2. Research Flow

The research flow is as follows.

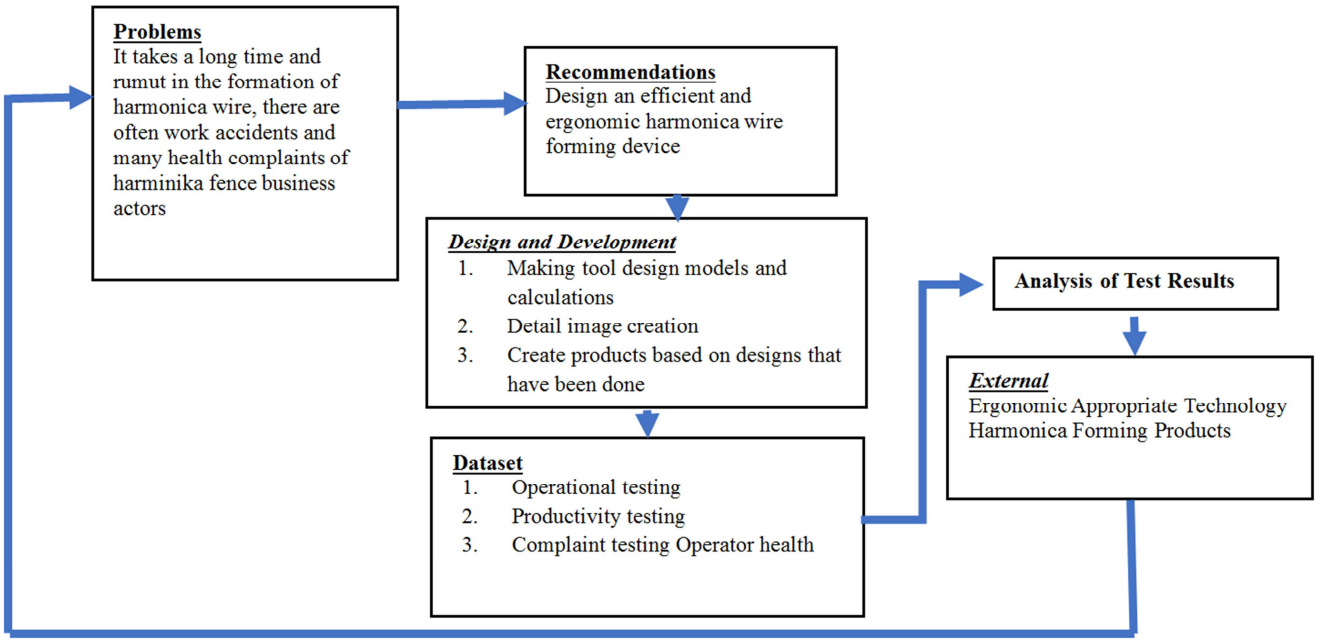

Figure 2. *Research flow.*

2.3. Data Retrieval and Data Analysis Techniques

Research data is production data from the design of appropriate technology for ergonomic harmonica wire forming. From the production data, the work productivity of business actors is calculated. Perpetrator productivity data is calculated according to the following formula: [6, 8].

$$P = \frac{\text{Output}}{Input\ x\ time} \quad (1)$$

P is the work productivity of business actors. Output is the amount of production produced by harmonica wire forming tools. Input is a workload calculated based on the work pulse of employees/business actors. Time is the working time of workers / business actors which is calculated based on working hours.

The data obtained were analyzed statistically, descriptively, and inferentially with an alpha error rate of 5% or 0.05.

3. Results and Discussion

3.1. Design Results

From The design made, then realized in the form of harmonica wire forming equipment products can be seen in figure 3.

The way this Harmonica Wire Forming Tool works is as follows: Galvanized wire used as the main material, the end of the wire will go to the wire retaining shame then the end of the wire that has entered the ragum will go to the spiral-shaped harmonica wire mold, then the wire that has entered the harmonica wire mold will be bent by the wire bending plate. The bending plate is driven by an electric motor, then press the *push button on* the power generated from the electric motor will be forwarded to *the gearbox using a fixed clutch, the power coming out of the* gearbox will rotate the pulley *and then the pulley will rotate the* V-bell. When the pedal is pressed it will pull the alternating towards the tensioner, then the tensioner will press the V-bell*, the* pressed V-bell *will rotate.*

Figure 3. *Harmonica Wire Forming Equipment Products.*

3.2. Workload Calculation

Workload is calculated based on the difference between the pulse rate after completion of work and the pulse before work. From the data obtained at the time of testing before using the tool and after using the tool can be seen in Table 1.

Table 1. *Pulse Before and After Using the Device.*

Variable	Using old tools		Using new tools		t	P
	Mean (bpm)	SD	Mean (bpm)	SD		
Resting pulse	72,19	3,15	71,93	3,47	4,134	0,102
Work pulse	125,16	4,21	112,32	4,32	2,221	0,001

Description: bpm = beats per minute

Table 1 shows that the resting pulse obtained an insignificant difference ($p>0.05$), indicating that the initial workload conditions of the artisans were the same. While the working pulse obtained a significant difference ($p < 0.05$), this shows that there is a significant difference in the work pulse between working using the old way and using the new way (harmonica wire bending tool). Judging from the average working pulse, when using the old tool, a workload of 125.16 beats per minute was obtained, including heavy workloads [3, 5], while when using the new tool, a working pulstabe of 112.32 beats per minute was obtained, including a moderate workload. There was a 10.3% decrease in workload from the old way to the new way.

Ergonomic intervention in work problems is imperative to increase work productivity and worker welfare [9, 10]. In this study, the use of work aids was proven to reduce the workload of harmonica wire craftsmen.

3.3. Work Productivity

Machine productivity is the ratio of the output of harmonica wire forming products during the normal period of time to the input of harmonica wire forming products in the period of time needed to form harmonica wire with the output period obtained. In the process of testing the productivity of this harmonica wire forming tool, it was tried to be tested using tools and with manual methods (the old way) with the same operator and this operator was already accustomed to using the manual way. Samples were taken in periods of 10 minutes, 20 minutes and 30 minutes. From that time it is sought how long the harmonica wire can be formed by the operator manually and by using tools. The test result data is shown in Table 2 and Table 3.

Table 2. *Data on the results of harmonica wire formation testing by manual means.*

process	Testing	specified time (minutes)	The result of the formation of a harmonica wire length with a width of 125 cm (cm)
Making harmonica fences by manual means	1	10 Minutes	63 cm
	2	20 Minutes	114 cm
	3	30 Minutes	177 cm
Average		20 Minutes	118 cm

Table 3. *Data from the test results of harmonica wire formation by using design tools.*

process	Testing	specified time (minutes)	The result of the formation of a harmonica wire length with a width of 125 cm (cm)
Making harmonica fences using tools	1	10 Minutes	90 cm
	2	20 Minutes	195 cm
	3	30 Minutes	281 cm
Average		20 Minutes	188.6 cm

From the test result data shows within 20 minutes The length of the harmonica wire that can be formed by the manual method and the method using the tool shows different results, with the method using a tool designed to get a longer formed wire length compared to the manual method. This shows that the new way provides greater production results and is certainly neater and more accurate.

While the results of the calculation of the work productivity of artisans are as follows.

Table 4. *Work productivity of harmonica wire artisans.*

Variable	Using old tools		Using new tools (multifunctional contractors)		t	P
	Average	SD	Average	SD		
Total Production (pc/hour)	565,8	12,39	354,1	15,18	3,612	0,000
Work productivity	0,94	0,13	1,68	0,19	0,691	0,000

Based on the results of the calculation above, it was obtained that the production and work productivity of harmonica wire craftsmen experienced a significant increase ($p < 0.05$). Production output increased from 354.0 to 565.8 or an increase of 59.8%. Meanwhile, the work productivity of artisans increased from 0.94 to 1.68 or an increase of 78.7%.

Work productivity is an important thing that needs to be improved in small and medium industries [11-13]. This work productivity is related to worker welfare, worker income, and company profits [14-16]. This research proves that ergonomic interventions can provide benefits in the form of reduced workload and significantly increased production output and productivity of artisans. Therefore, it is recommended that harmonica wire craftsmen use this ergonomic harmonica wire forming tool.

4. Conclusion

From the research that has been done, it can be concluded as follows.

a. The harmonica wire forming tool designed can speed up the harmonica wire forming process compared to the harmonica wire forming by the manual method.
b. There was a significant decrease in workload between using the old method manually and using the new way, namely using ergonomic chain link forming tools by 10.3%.
c. The design of the Ergonomic Harmonica Wire Forming Tool also increased production output by 59.8% and increased work productivity by 78.7%.

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