BIM Proceedings
Bali International Meeting on Business, Advanced engineering, and Leadership sustainability Impact
BIM University
DOI: 10.xxxxxxxxxxxxxxxxxxxx/

Design of a Clamping Device for Drilling Machine at the Work Systems and Manufacturing Laboratory, Muhammadiyah University of Surakarta

Ratnanto Fitriadi[1], Munajat Tri Nugroho[2], Bayu Ahmad Wicaksono[3], Aditya Panji[4]
1Department of Industrial Engineering, Faculty of Engineering, Muhammadiyah University of Surakarta,

e-mail: rf253@ums.ac.id

Abstract

The machining process is a crucial element in the manufacturing cycle; in an academic setting, it is implemented through laboratory practical sessions. Industrial Engineering Practicum (PTI) I at Universitas Muhammadiyah Surakarta is a capstone design course that integrates the product design process through to actual manufacturing. In its implementation, particularly in the production of toy car wheels, a challenge was identified in the form of low efficiency during the machine setup phase. This was caused by the suboptimal use of clamping aids, resulting in lengthy setup times and repetitive work. This study aims to design machining aids in the form of jigs and fixtures for a drilling machine to improve setup time efficiency, process time, and machining accuracy. The research was conducted by integrating design using SolidWorks CAD software and technical analysis covering clamping force calculations and the application of the 3-2-1 locator principle. Performance evaluation was conducted using the time study method to quantitatively measure cycle time and standard time. The research stages include a preliminary study, collection of machine specifications and actual operating times, design development, and the fabrication of tools using aluminum. The results of this research are expected to establish new standards for the machining process at the UMS Work Systems and Manufacturing Laboratory, which will not only shorten production times but also improve the precision of the products produced by students.

Keywords: *Clamping Tool, Drilling, Jig & Fixture,Machining Efficiency*

INTRODUCTION

Laboratories play an important role in education in the field of industrial engineering, especially in the field of Industrial Engineering, as a means of practical learning that supports the understanding of theoretical concepts. In UMS Industrial Engineering, Industrial Engineering Practicum (PTI) I integrates product design, manufacturing processes, and evaluation into a final project.

However, during the machining process, especially in drilling operations, it is observed that there is too long data during the machining process and the practitioner has difficulty holding the workpiece. The main problem lies in the suboptimal design of the clamping tool, which results in longer setup times and repetitive manual adjustments. Setup time has a direct impact on production efficiency; Longer setup duration leads to increased total processing time and decreased productivity.

Jigs and fixtures are essential tools in manufacturing systems to ensure workpiece stability, improve accuracy, and reduce set-up time [1]. However, the fixture system in the laboratory is

DOI: 10.xxxxxxxxxxxxxxxxxxxx/

currently not optimal, because in terms of placement, clamping and machining have not met good criteria.

An existing research entitled "Designing *Drilling Jig* with *Adjustable V-Block* for Stalk Drilling *Drill Chuck* The 22 STA Coordinate Drilling Machine" by Ilham Nazarudin Akmal et al. in 2022 focuses on designing jigs with the concept of adjustable V-blocks. The research gap in this study lies in the absence of a quantitative analysis of the efficiency of setup time and process time before and after the use of jigs [2]. Therefore, this study aims to fill these gaps by integrating fixture design, analytical calculations, and time study evaluation.

The aim of this study is to design better drilling fixtures to reduce set-up time, improve machining accuracy, and improve overall efficiency in the machining process in the laboratory.

METHOD

This research was conducted at the Industrial Engineering Laboratory of the University of Muhammadiyah Surakarta which is located at Building H 3rd floor west wing, Jl. A. Yani No. 157, Pabelan, Kartasura, Sukoharjo, Central Java 57162. The object that is the focus of this study is the setup and work process on *the drilling machine* which is considered less than optimal due to the limited gripper design. As well as the limitation of the problem, namely with the dimensions of the workpiece that can be cut, which is a minimum of 9 cm x 9 cm x 1 cm and a maximum width of 12 cm x 12 cm x 1 cm, then the material used is PVC FOAM. Figure 1 shows the flow chart of this research. The manufacture of the new gripper is divided into three stages, namely design, manufacture, and testing.

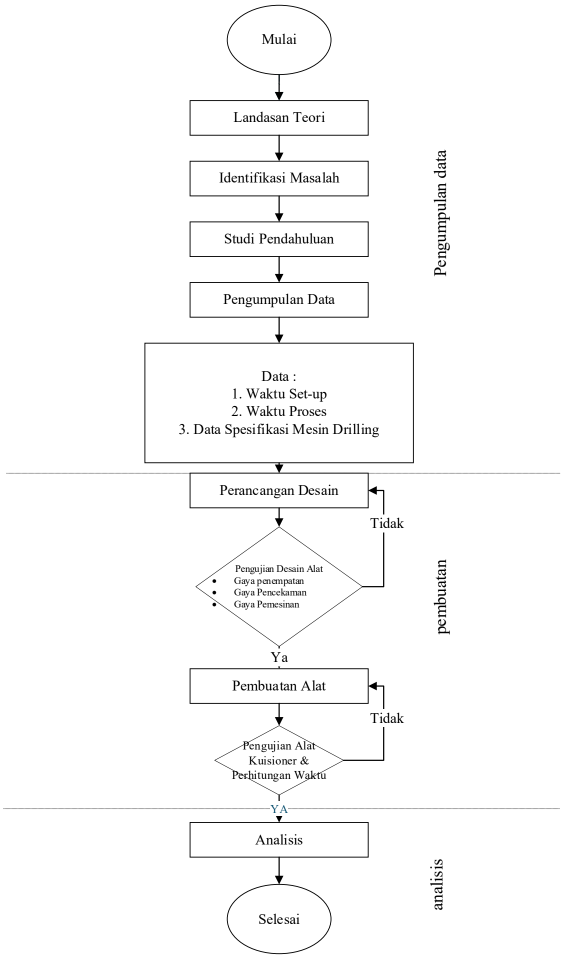


Figure 1. Research Flow

DOI: 10.xxxxxxxxxxxxxxxxxxxx/

Source: Author's own elaboration

A drilling machine is a type of machine whose movement rotates the cutting tool whose direction of feeding the drill bit is only on the axis of the machine (drilling work). While drilling is the operation of producing round-shaped holes in the worksheet by using a rotating cutter called a drill and has the function of making holes, making multi-level holes, enlarging holes and Chamfer [3]

Jig and Fixture is a term that refers to several types of equipment used in industry to facilitate production operations, especially those involving machinery[4]. *Fixture* defined as an aid that functions as a retaining or holding of the workpiece[5]. *Jig* is a tool that is specifically made to position and manipulate other tools. While *Fixture* is an aid or equipment that functions to help the production process used for the work of the same parts in mass production, so that it can reduce the time *setup* and increased productivity[6]

The clamping force is the force required to maintain the position of the workpiece during the machining process. The magnitude of the gripping force depends on the magnitude of the cutting force and the way the workpiece is placed relative to the chisel. This technique is important to ensure that the workpiece does not move and remains precise throughout the process.[7]

In determining the magnitude of the holding force in the machining process, it is based on the probability of the machining force that occurs during the process. The compression force can be calculated with the following equation:

$$Fc = \frac{6156{,}6576\ x\ fm\ x\ D}{SS}$$

Where:
Fc = Compressive force (Newton)
D = Diameter of feed bit (mm)
SS = Spindle speed (rpm)
fm = Feeding speed (cm/min)

In addition to the clamping force, there are two other types of forces that also play a role in the clamping system, namely placement force and machining force. The three forces interact with each other in determining the stability of the workpiece during the process.

In general, the machining process can be divided into three main stages, namely the placement stage, the clamping stage, and the machining stage. Each stage has different stylistic characteristics, so a special formulation is needed to analyze each of these conditions. The equations used in the three stages are explained as follows:

1. Placement Stage

At this stage, the force working is the placement force from the opposite direction to the direction of the locator force. The equation of placement style can be written as follows:

$$F_p = -{W_p}^{-1} . w_l . f_l$$

Description:
Fp = Matrix of forces on *locator*
Wp = Matrix of force direction on *locator*
Wl = Placement style directional matrix
Fl = Placement style matrix
[8]

2. Levels of Inhibition

At this stage the placement force is no longer working while the compression force is not working, so the equation is as follows:

$$F_p = -{W_p}^{-1} . w_a . f_a$$

Description:
Fp = Matrix of forces on *locator*
Wp = Matrix of force direction on

DOI: 10.xxxxxxxxxxxxxxxxxxxx/

Locator Does = Matrix of force on the
Time = Directional matrix of the gripper gripper
force

3. Machining Stage

At this stage, a test will be carried out on each *locator* to check if there is contact between the workpiece and the locator during the machining process. At this stage the cutting force and the clamping force work on the workpiece. The similarities of the styles at this stage are:

$$F_p = -W_p^{-1} . w_k . f_k$$

Description:

Fp = Matrix of forces on *locator*
Wp = Matrix of force direction on *locator*
Wk = Machining force direction matrix
Fk = Machining force matrix

The implementation of the new clamping aid was carried out by comparing its performance with the previously used clamps. The comparison was carried out using the *time study* to evaluate the time difference required in the setup process as well as the effectiveness of using the tool. Time Study is a systematic work measurement method that is carried out by recording and analyzing the duration it takes for a worker to complete a job [9]**.**

Locators are a key component in *Fixture* which determines the position and orientation of the workpiece. Proper lokator design and placement is essential to ensure accuracy and *repeatability* in the manufacturing process. Locators consist of 2 types, namely *Support* and *stopper. Support* is a rigid locator that functions to hold the workpiece, while *Stopper* is a locator that functions to generate a reference field on the side of the object [10].

Study Time is defined as a systematic method of work evaluation to establish a standard time. This standard is obtained by measuring the duration of work by an average capable operator working at a reasonable speed, under optimized working system conditions [11]**.** The time aspect includes a series of systematic procedures to establish a standard duration of work. This time study method is widely applied to evaluate the efficiency of manual (human), automation (machine), and the interaction between the two in an integrated production system [12]

The data uniformity test is an evaluation stage to validate whether all observation data is within the limits of statistical control [13]. By applying the Xand R control maps, we can detect data outside the control limits that are outside the upper and lower control limits

$$\text{BKA} = X + 2\delta x$$
$$\text{BKB} = X - 2\delta x$$

Ket:

BKA = Upper control limit
BKB = Lower control limit
δx = Standard deviation
X = average

The data adequacy test is used to find out whether the amount of cycle time taken is *representative* or not. The observation data can be said to be sufficient if (N'≤ N), but if the data is not enough (N' ≥ N), then the data can be measured again until the data is sufficient

$$N' = \left[\frac{{}^{k}/_{s}\sqrt{N(\sum xi2) - (\sum xi)2}}{(\sum xi)}\right]$$

Ket:

k = Trust level
s = Degree of precision
N = Number of observation data
N' = Quantity and theoretical
X = Time data

Cycle Time is the time needed to complete a production cycle or one unit on the production floor [14]. Before determining the standard time, it is necessary to determine the cycle time first.

$$\text{Ws} = \frac{\sum x}{n}$$

Ket:

DOI: 10.xxxxxxxxxxxxxxxxxxxx/

Ws= Cycle Time
n = Number of *subgroups*
x = Completion time i-i

Normal time is the working time that has taken into account the adjustment factor, i.e. the average time cycle multiplied by the adjustment factor [15]. Here, in fact, workers will often stop work and need special time for purposes such as *personal needs*, rest, and other reasons that are beyond his control

$$Wn = Ws \times P$$

Ket:
Wn = Normal Time
Ws = Cycle Time
P = Adjustment Factor

This standard time is used to determine the time for a complete cycle of a production process after the right adjustment factor and the relaxation factor are still within the control limit.

$$Wb = Wn \times \frac{100}{100 - allowance\ (\%)}$$

Ket:
Wb = Raw time
allowance = relaxation factor
Wn = Normal time

RESULTS AND DISCUSSION

1. Identify Needs

Based on observations on the machining process at the UMS Work and Manufacturing Systems Laboratory, several main problems were found in the use of compression aids, namely:

1. The setup time is relatively long because the workpiece placement process is done manually and repeatedly.
2. The absence of a fixed locator system means that the position of the workpiece changes frequently.
3. There is a shift in the workpiece during the drilling process.
4. Lack of consistency of position between users (students) thus affects the accuracy of the results.

The design needs of the developed fixtures include:

1. Locator system based on the 3-2-1 principle to eliminate the degree of freedom of the workpiece
2. Strong and stable clamping system
3. Design that allows for faster setup
4. Drill bit-safe material

2. Design Design

The design of the clamping aids is carried out with a systematic approach using CAD software to produce a design that suits the needs of the machining process. The fixture design consists of several main components, namely the main body as the foundation, the stopper as the locator, and the clamp as the clamping mechanism. The main body is designed to provide a stable surface as well as be the mounting point for all fixture components. Stoppers are used as a fixed reference in determining the position of the workpiece, so that each setup process can be done faster and more consistently. Meanwhile, the clamp functions to provide a gripping force so that the workpiece stays in position during the drilling process.

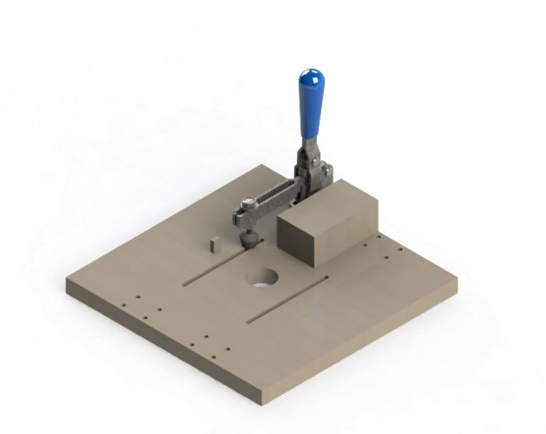


Figure 2. CAD Modeling
Source: Author's own elaboration

3. Tool Design Testing

Matrix calculations are used as an evaluation method to assess the quality of fixture design through the analysis of locator points. This approach aims to ensure that all the values of the resulting force are under a non-negative condition. This condition indicates that there is good contact between the workpiece and the locator, so that the clamping system is able to maintain stability during the machining process.

a) Placement Stage

At the placement stage, a force analysis is performed to evaluate the contact conditions between the workpiece and the locator using a matrix approach. The results of the reaction force (Fp) calculation are shown in Table 6.

Table 1. Fp Placement

		nx	The	mz	nz	mx	my
Fp	**f1**	0,00	0,00	0,00	0,10	0,10	0,10
	f2	0,00	0,00	0,00	0,10	0,10	0,10
	f3	0,00	0,00	0,00	0,19	0,19	0,19
	f4	0,00	0,50	0,50	0,00	0,50	0,00
	f5	0,00	0,50	0,50	0,00	0,50	0,00
	f6	1,00	0,00	1,00	0,00	0,00	1,00

A non-negative Fp value indicates that the entire locator is in contact with the workpiece, so that the system is in a stable state and able to hold the workpiece position well.

b) Levels of Inhibition

At the clamping stage, a force analysis is carried out to ensure that the clamping system is able to maintain the position of the workpiece during the process. The results of the reaction force (Fp) calculation are shown in the corresponding table.

Table 2. Fp2 Sting

DOI: 10.xxxxxxxxxxxxxxxxxxxx/

		nx	The	mz	nz	mx	my
Fp2	**f1**	0,00	0,00	0,00	53,40	53,40	53,40
	f2	0,00	0,00	0,00	1513,11	1513,11	1513,11
	f3	0,00	0,00	0,00	101,72	101,72	101,72
	f4	0,00	0,00	0,00	0,00	0,00	0,00
	f5	0,00	0,00	0,00	0,00	0,00	0,00
	f6	0,00	0,00	0,00	0,00	0,00	0,00

The resulting Fp value indicates a non-negative condition at all locator points, indicating that the entire locator remains in contact with the workpiece. Thus, the clamping system is able to effectively maintain the stability of the workpiece.

c) Machining Stage

At the machining stage, an evaluation is carried out on the effect of cutting force on the stability of the workpiece. The results of the reaction force (Fp) calculation are shown in the corresponding table.

Table 3. Fp3 Machining

		nx	The	mz	nz	mx	my
Fp3	**f1**	0,00	0,00	0,00	427,23	427,23	427,23
	f2	0,00	0,00	0,00	427,23	427,23	427,23
	f3	0,00	0,00	0,00	813,77	813,77	813,77
	f4	0,00	834,12	834,12	0,00	0,00	0,00
	f5	0,00	834,12	834,12	0,00	0,00	0,00
	f6	1668,23	0,00	1668,23	0,00	0,00	1668,23

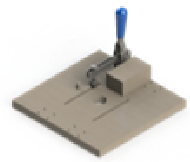
A non-negative Fp value indicates that the entire locator is still functioning properly and that no loss of contact occurred during the machining process. This indicates that the system is able to maintain the stability of the workpiece during the machining process.

4. Tool Manufacturing

The process of making tools is carried out based on the results of the design that have been validated through matrix analysis. This stage includes the process of cutting materials, drilling, assembling components, and finishing. The main material used is aluminum, which was chosen because it is lightweight, easy to work with, and strong enough to withstand the workload during the machining process.

Table 4. Process Plan Sheet

DOI: 10.xxxxxxxxxxxxxxxxxxxx/

PP-01	LEMBAR RENCANA PROSES			
Nama : Clamping	Halaman Ke-		: 01/01	File Gambar: 
No. Part : 01	Material		: HMR	
Nama Part : Base Body	Ukuran	Panjang	: 300 mm	
Dibuat Oleh : Bayu Ahmad		Lebar	: 300 mm	
Tanggal : 1 April 2026		Tinggi	: 40 mm	

No.	Uraian Operasi	Stasiun Kerja	Set up		Feed Rate (mm)	Spindle speed (rpm)	Waktu set up (m)	Waktu proses (m)	Waktu total (m)
			Alat bantu	Tools					
1	Membuat marking awal bahan dengan ukuran 300 mm x 300 mm	Kerja Bangku	Mistar	Pensil	-	-	0,67	5,8	6,47
2	Menjepit PVC menggunakan clamp dan masukan kode G yang diperoleh dari fitur cam serta melakukan pemotongan dengan CNC	CNC	Clamp	Flat Mill 6 mm	480	2400	1,3	7,5	8,8
3	Menghaluskan part yang sudah jadi dan melakukan pemeriksaan	Kerja Bangku	-	Amplas, Cutter	-	-	0,6	3,6	4,2
	Waktu Total Pembuatan (m)								19,47

Table 5. Bill Of Material

Part Number	Description	Decision	Quantity
A	Clamping	DIRAKIT	1
A1	Base	DIBUAT	1
A2	Stopwatch	DIBUAT	1
A3	Screw	PURCHASED	8
A4	Toogle Clamp	PURCHASED	2

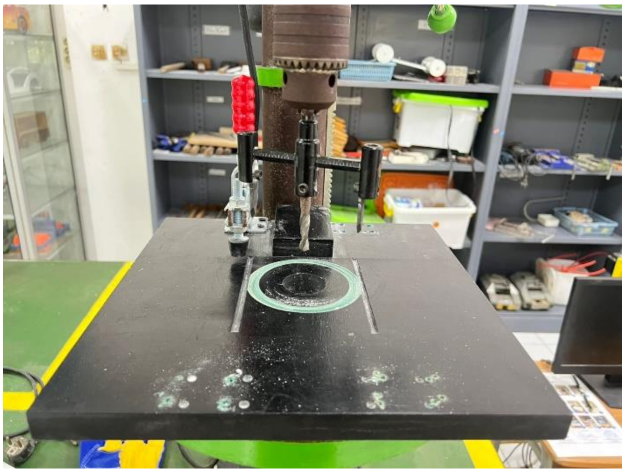


Figure 3. Finished Product

Source: Author’s own elaboration

5. Implementation

The implementation and testing of the tool is carried out by comparing set-up time data between the old and new handlers. After the time data is obtained, then analysis is carried out using the time study method

From the calculation, the results of LCL = 16.20 and UCL = 27.04 were obtained and the figure below shows the results of the graph from the calculation of the data uniformity test.

DOI: 10.xxxxxxxxxxxxxxxxxxxx/

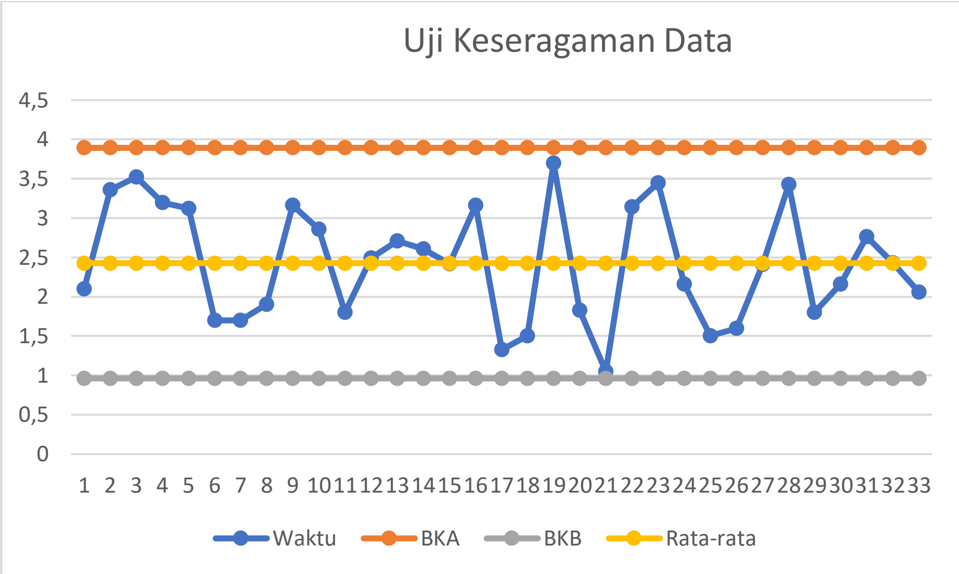


Figure 6. Control Chart

Source: Author's own elaboration

Table 6. Data Adequacy Test

Remarks	Value
∑X	70,71
∑X^2	4999,90
(∑X)2	141,42
N	33
N'	0,38

Based on the results of the calculation of data adequacy in Table 4, the values of N' < N, it can be concluded that the data is sufficient. Where N' < N are the data considered feasible. In addition, the results of the data adequacy test showed that the value of N' was smaller than N, so the amount of data collected was sufficient to represent the actual condition. Thus, the results of the analysis can be considered valid and can be used as a basis in evaluating the performance of the tool.

Overall, the implementation of the new clamping tool shows improved setup time efficiency as well as consistency in the machining process.

To evaluate the performance improvement resulting from the use of new recording aids, standard time analysis was carried out as the main indicator of work efficiency. A standard time is used to describe the time required by an operator to complete a work cycle taking into account adjustment and allowance factors.

Measurements were taken under two conditions, namely before the use of the clamping device (initial condition) and after the use of the new clamping device (the proposed condition). The cycle time data obtained is then processed into normal time and subsequently converted into standard time.

Table 7. Setup Time Before

Groups	Time (m)	Groups	Time (m)	Groups	Time (m)
1	2,1	13	2,71	25	2,16
2	3,36	14	2,61	26	1,5
3	3,52	15	2,42	27	1,6

DOI: 10.xxxxxxxxxxxxxxxxxxxx/

4	3,2	16	3,16	28	2,41
5	3,12	17	1,33	29	3,43
6	1,7	18	1,5	30	1,8
7	1,7	19	3,7	31	2,16
8	1,9	20	1,83	32	2,76
9	3,16	21	1,05	33	2,43
10	2,86	22	3,14	34	2,06
11	1,8	23	3,45		
12	2,49	24	2,71		

Table 8. Setup Time After

Groups	Time (m)	Groups	Time (m)	Groups	Time (m)
1	0,2	14	0,5	26	0,09
2	0,6	15	0,13	27	0,16
3	0,3	16	0,4	28	0,2
4	0,56	17	0,3	29	0,28
5	0,4	18	0,13	30	0,4
6	0,5	19	0,4	31	0,3
7	0,13	20	0,4	32	0,2
8	0,4	21	0,6	33	0,21
9	0,2	22	0,6	34	0,16
10	0,5	23	0,64		
11	0,2	24	0,27		
13	0,26	25	0,09		

Based on the results of the time calculation shown in Table 6 and Table 7, the average setup time before using the interception aid was 21.62 seconds, while after the use of the new interception aid decreased to 6.71 seconds.

Table 7. Process Time Before

Groups	Time (m)	Groups	Time (m)	Groups	Time (m)
1	2,1	13	2,71	25	2,16
2	3,36	14	2,61	26	1,5
3	3,52	15	2,42	27	1,6
4	3,2	16	3,16	28	2,41
5	3,12	17	1,33	29	3,43
6	1,7	18	1,5	30	1,8
7	1,7	19	3,7	31	2,16
8	1,9	20	1,83	32	2,76
9	3,16	21	1,05	33	2,43
10	2,86	22	3,14	34	2,06
11	1,8	23	3,45		
12	2,49	24	2,71		

Table 8. Process Time After

DOI: 10.xxxxxxxxxxxxxxxxxxxx/

Groups	Time (m)	Groups	Time (m)	Groups	Time (m)
1	0,2	14	0,5	26	0,09
2	0,6	15	0,13	27	0,16
3	0,3	16	0,4	28	0,2
4	0,56	17	0,3	29	0,28
5	0,4	18	0,13	30	0,4
6	0,5	19	0,4	31	0,3
7	0,13	20	0,4	32	0,2
8	0,4	21	0,6	33	0,21
9	0,2	22	0,6	34	0,16
10	0,5	23	0,64		
11	0,2	24	0,27		
13	0,26	25	0,09		

This decrease in the average value of time indicates a significant increase in efficiency in the setup and machining processes. This is due to the use of fixtures that are able to simplify the process of placing and holding the workpiece, thus reducing the time of manual adjustment that previously occurred frequently.

To find out if there is a significant difference between the processing time before and after the use of the new fixture, statistical testing was performed using *the paired sample t-test* method. This test is used because the data being compared comes from two paired conditions, namely the measurement of the process time on the same object before and after the treatment is given.

Table 9. Time After

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Waktu_Lama - Waktu_Baru	2.10355	.77695	.13954	1.81856	2.38854	15.074	30	.000

Based on the results of the *paired sample t-test* output obtained, the significance value was 0.000 ($p < 0.05$), so it can be concluded that H_0 was rejected. This indicates that there is a significant difference between the processing time before and after the use of the recording aid.

The average value of the time difference of 2.10355 indicates that the use of a new fixture is able to significantly reduce the process time. Thus, the implementation of the designed clamping aids has proven to be effective in improving the efficiency of the machining process in the laboratory.

Thus, it can be concluded that the application of the new clamping aids not only improves the stability of the workpiece, but also has a direct impact on increasing process productivity through an overall reduction in working time.

CONCLUSION

Based on the results of the research that has been carried out, it can be concluded that the design of a gripping device (fixture) for drilling machines has succeeded in improving the

DOI: 10.xxxxxxxxxxxxxxxxxxx/

efficiency of the machining process at the Laboratory of Work and Manufacturing Systems of the University of Muhammadiyah Surakarta. The main problems that previously occurred, namely the length of setup time, workpiece instability, and low position consistency, can be overcome through the application of a fixture design based on the 3-2-1 locator principle.

The results of the analysis using the matrix method showed that all force values at each stage, namely placement, clamping, and machining, were in a non-negative condition. This indicates that the locator and clamping systems are able to maintain good contact with the workpiece thus ensuring stability during the process.

In addition, the test results using the time study method show that the use of new fixtures is able to increase the efficiency of setup time and produce stable and statistically sufficient data. Thus, the research goal of improving the efficiency, accuracy, and stability of the machining process has been achieved.

This research makes a practical contribution to the development of production aids in the laboratory environment and can be used as a reference for the development of fixtures in other manufacturing processes. For further research, it is recommended to develop a more flexible design for a wide variety of workpieces as well as conduct further analysis of the influence of dynamic forces during the machining process.

REFERENCES

[1] I. Setiawan *et al.*, “Penerapan Jig & Fixture pada Produksi Massal di Industri Manufaktur,” *J. Media Tek. dan Sist. Ind.*, vol. 7, no. 2, hal. 104, 2023, doi: 10.35194/jmtsi.v7i2.3165.

[2] I. N. Akmal dan D. Yuhas, “Jurnal Mekanik Terapan Perancangan Drilling Jig dengan Adjustable V-Block untuk Pengeboran Tangkai Drill Chuck Mesin Bor Koordinat 22 STA,” vol. 03, no. 01, hal. 26–33, 2022, doi: 10.32722/jmt.v3i1.4546.

[3] A. Waskito, M. Fitra Dana, M. M. Hariadi, dan S. Lubis, “Analisa Optimasi Pemesinan Pada Mesin Bor Breda Tipe R-35 Dan Mesin Bubut Tipe M-300 Horizon Dengan Metode Algoritma Genetika,” *J. Therm. Sci. Technol.*, vol. 12, no. 14, hal. 111–122, 2019.

[4] B. C. Tjiptady, R. Z. Rahman, R. F. Meditama, dan G. Widayana, “Jig and Fixture Redesign for Making Reamer on Head Cylinder,” *J. Pendidik. Tek. Mesin Undiksha*, vol. 9, no. 1, hal. 32–41, 2021, doi: 10.23887/jptm.v9i1.32597.

[5] M. P. Indrayati, R. Djoenaidi, dan A. Setiawan, “JIG AND FIXTURE PENGELASAN SUDUT SIKU UKURAN LEBAR PROFIL (3 - 60 mm) DI JURUSAN TEKNIK MESIN POLITEKNIK NEGERI MALANG,” *J. Energi dan Teknol. Manufaktur*, vol. 4, no. 02, hal. 17–20, 2021, doi: 10.33795/jetm.v4i02.81.

[6] A. B. Widiyanti, D. Z. Wati, dan F. V. Sitanggang, “Rancangan Alat Bantu Proses Welding Produk Rangka H (Studi Kasus : Lab Perencanaan dan Perancangan Produk FT UNS),” hal. 1–9, 2022.

[7] F. Rachmat Ramdhan *et al.*, “Optimalisasi Perancangan Fixture Permesinan Komponen Utama Bantalan Sling menggunakan Pneumatic System,” hal. 1–10, 2023, doi: 10.51132/teknologika.v13i1.273.

[8] M. A. Rozaq dan R. Fitriadi, “PERANCANGAN ALAT BANTU PENCEKAMAN UNTUK MESIN CNC ROUTER 3 AXIS DI LABORATORIUM TEKNIK INDUSTRI UNIVERSITAS MUHAMMADIYAH SURAKARTA,” 2025.

[9] R. Dohar dan Q. Qawariri, “Analisis Pengukuran Waktu Dengan Metode Time Study (Studi Kasus Pada Proses Produksi UD Zahira Shoes),” vol. 20, hal. 93–100, 2025.

[10] N. C. Rizani *et al.*, “Analisa proses produksi jig untuk perakitan pintu depan mobil x,” vol. 23, no. 2, 2021.

[11] N. Mayselah *et al.*, “Optimalisasi Produktivitas dengan Metode Time and Motion Study di PT . XYZ,” hal. 1–12, 2023.

[12] A. Purbasari, E. Sumarya, dan R. Mardhiyah, “PENERAPAN METODE STUDI WAKTU DAN GERAK PADA PROSES PACKING DI PT . ABC,” vol. 6, no. 2, hal. 290–299,

DOI: 10.xxxxxxxxxxxxxxxxxxxx/

2023, doi: 10.33373/sigmateknika.v6i2.5633.

[13] S. I. Chasanah, D. Ganesha, dan E. Apriani, “Perancangan sistem kerja dan ergonomi beban kerja mental pada apoteker dan asisten apoteker,” no. 2, hal. 123–131, 2025.

[14] N. P. Utomo, R. D. Febriansyah, M. Agus, dan K. Pramudianto, “Analisis Pengukuran Kerja untuk Menentukan Waktu Baku dalam Peningkatan Produktivitas Produksi Tube Underfloor di PT . UVW Indonesia,” vol. 5, hal. 10330–10342, 2025, doi: 10.31004/innovative.v5i4.20770.

[15] N. P. D. Arwini, Y. E. Ate, dan M. Winda, “ANALISIS PERHITUNGAN WAKTU SIKLUS , WAKTU NORMAL DAN WAKTU BAKU DENGAN MENGGUNAKAN METODE JAM HENTI,” vol. 9, no. 1, hal. 19–23, 2026, doi: 10.47532/vastuwidya.v9i1.478.