OPTIMIZATION OF THE BALADO STICK POTATO CUTTING MACHINE

Khairil Fajar
Program Studi Teknik Mesin
Universitas Pembangunan Nasional "Veteran" Jakarta
Jakarta Selatan, Indonesia
khairilf6@gmail.com

M. Arifudin Lukmana
Program Studi Teknik Mesin
Universitas Pembangunan Nasional "Veteran" Jakarta
Jakarta Selatan, Indonesia
arifudin@upnvj.ac.id

Budhi Martana
Program Studi Teknik Mesin
Universitas Pembangunan Nasional "Veteran" Jakarta
Jakarta Selatan, Indonesia
budhi.martana@upnvj.ac.id

***Abstract*—Potato is an important crop in Indonesia utilized in various processed foods but there are still household industries that process potatoes using manual methods. Therefore, the writer researched the optimization of potato cutting tools using the frame static simulation method, variations of cutting trials with blade distances from 95 mm, 90 mm, 85 mm, and RULA (Rapid Upper Limb Assessment). The tool frame structure uses ASTM Steel A36 material. The results of the static simulation of the frame obtained the smallest factor of safety is 43. The optimization step that can be done is to change the frame dimensions to 20 x 20 x 3 mm and use SS 34 material. For the trial variation, the highest capacity and efficiency of cutting tools were obtained in trial variation 2 with a blade distance of 90 mm with a value of 98.5 kg/hour and 62.09%. The efficiency of the tool has met the efficiency standard with a result of 62.09% of the specified 60%-70% range. The application of RULA on the tool gets a final score of 3 so adjustments need to be made so that the worker's posture is comfortable.**

***Keywords*—Potato sticks, cutting machine, RULA**

I. Introduction

Potatoes are an important crop in Indonesia because they have high economic value, selling price, and demand. Therefore, potatoes are highly sought after and consumed as a substitute and ingredient in cooking in the community [1]. Home industry players generally process potatoes using the manual method. In the manual method, potatoes are cut using a knife so that they become the desired product and need skilled labor which makes this method time-consuming and labor-intensive [2]. During the design process, we often invent devices that did not exist before, or improve existing tools to make better devices to make work easier in society. Product design does not necessarily mean creating a completely new design, but it can further develop or modify an existing product design. Product design and development are always needed, because technology, consumer needs, and preferences continue to evolve as research progresses [3]. Based on observations made, ergonomics and product results from existing tools in the community are still not optimal. So, the author took the title "Optimization of Balado Potato Sticks Cutting Machine" which is expected to facilitate the producers of potato sticks balado on a household industry scale so that the cutting process and product results are more optimal in terms of quality and quantity.

Fig. 1. Roller Support

II. Literature Review

A. Optimization

Optimization comes from the English word optimization. Optimization is an effective and efficient decision-making process based on quantitative parameters [4]. Various topics of optimization problems can arise in many fields such as economics, biology, engineering, and others.

B. Support

A frame is a flat structure made of several rods that are connected to form a sturdy construction. Here are some placements of the pedestal, among others:

- Roller Support
- Pinned Support
- Fixed Support

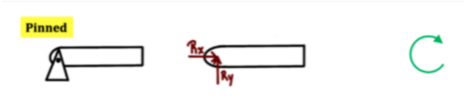

Fig. 2. Pinned Support

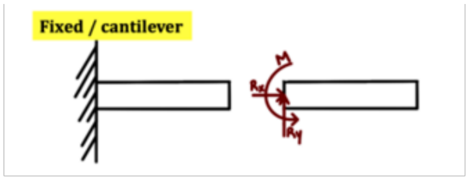

Fig. 3. Fixed Support

C. Ergonomics

Ergonomics comes from the Greek words ergos and nomos. Ergonomics is the study of how humans interact with machines and the variables that affect these relationships [5]. By increasing the interaction between humans and machines, the performance of the system can increase.

D. RULA (Rapid Upper Limb Assessment)

Rapid Upper Limb Assessment or RULA is an evaluation method used in ergonomic investigations of the workplace that affects upper limb disorders related to the work performed [6].

E. Research Flowchart

see Fig. 5

F. Static Simulation of Frame Structure

The next step is to perform a static simulation on the frame. The input material is ASTM A36 Steel material. Here are the steps to perform simulations using CAD software:

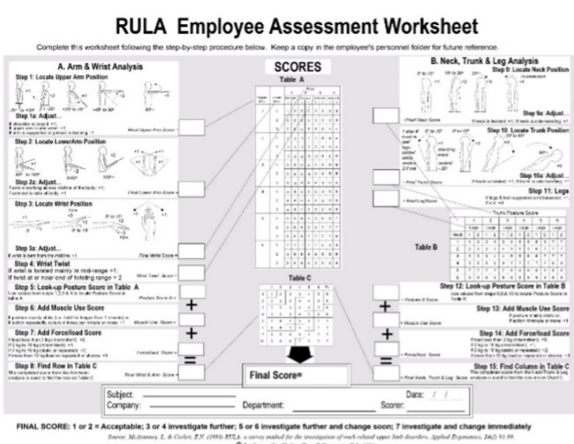

Fig. 4. RULA Employee Assessment Worksheet

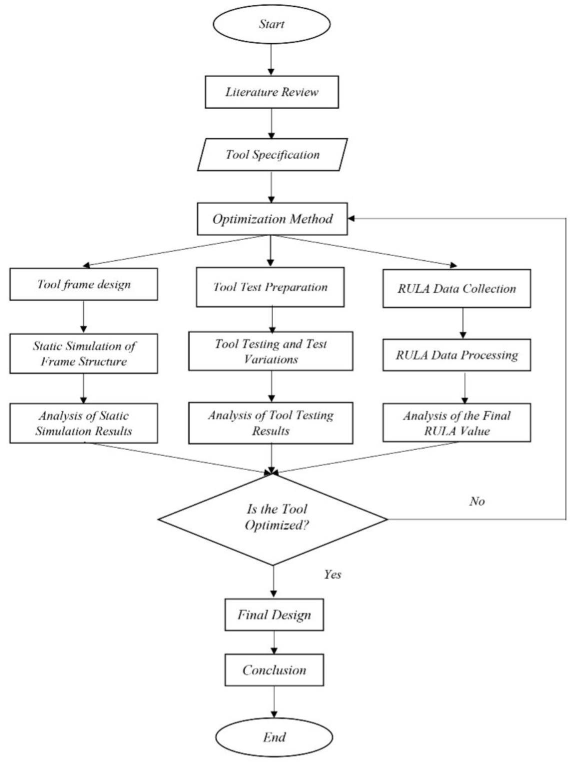

Fig. 5. Research Flowchart

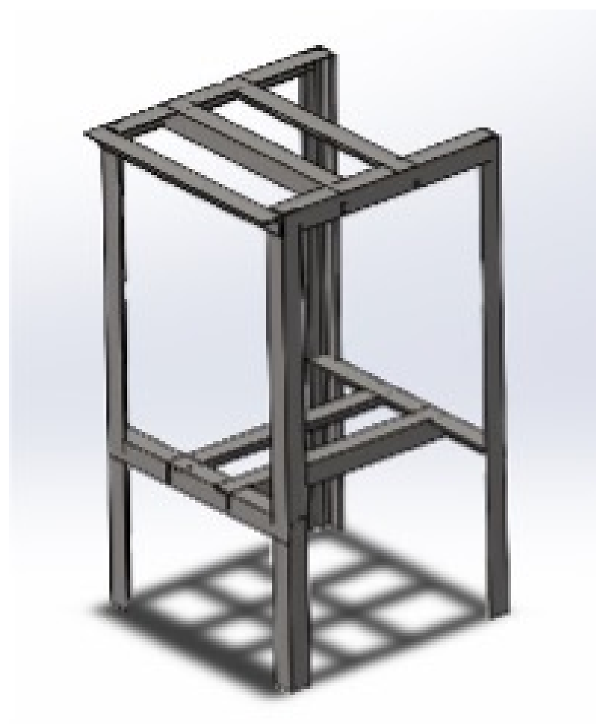

Fig. 6. Tool Frame Design

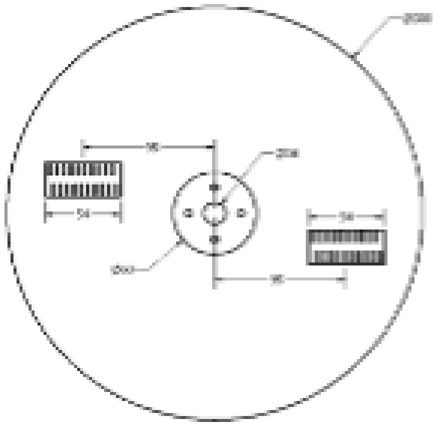

Fig. 7. Trial Variation 1

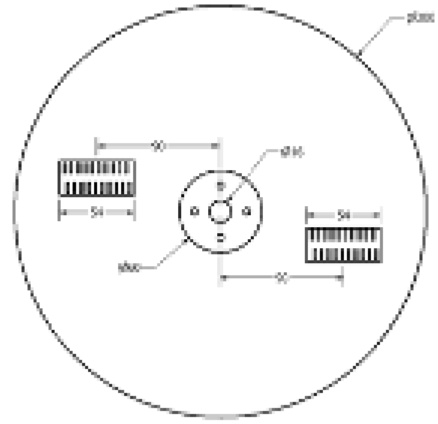

Fig. 8. Trial Variation 2

1) Open the CAD software and open the 3d model of the frame that will be static simulated.
2) Select the Simulation tab - select New Study
3) In the Study window, select Static and then Ok.
4) Input the type of material to be used in the frame.
5) Input the fixed geometry and reference geometry area by selecting the Fixtures icon and selecting Fixed Geometry.
6) For Load assignment, click the External Loads icon and then click the Force icon.
7) Perform meshing of the frame model, right-click on the mesh icon then create a mesh.
8) Run a static simulation on the frame, and click the Run This Study icon.
9) Finish.

G. Tool Testing and Test Variation

At this stage, several operations are carried out on the machine to see the performance of the machine. The trial variation is done by changing the distance of the knife on the knife disk as shown in the following figure:

1) Trial Variation 1 with a blade distance of 95 mm from the shaft axis.
2) Trial Variation 2 with a blade distance of 90 mm from the shaft axis.
3) Trial Variation 1 with a blade distance of 85 mm from the shaft axis.

H. RULA Data Processing

RULA Data Processing on the balado stick potato cutting machine is carried out with the following steps:

- Observe the testers who are operating the cutting machine.
- Determine the critical posture position during the cutting machine trial as shown below.
- Conduct assessment for arm and wrist posture.
- Conduct assessment for neck, torso and leg postures.

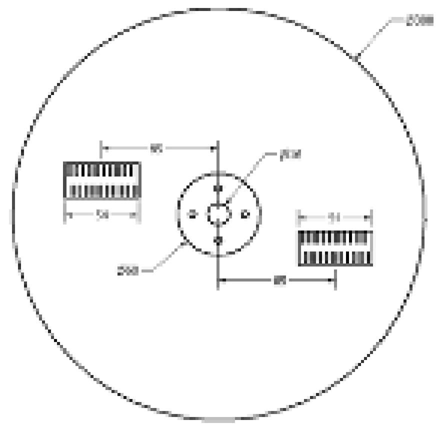

Fig. 9. Trial Variation 3

- Assess the final RULA result.

III. Result

A. Static Simulation Results of The Frame Structure

1) Results of Static Simulation of the Frame Structures Stress (von Misses): (see Fig. 11) The results

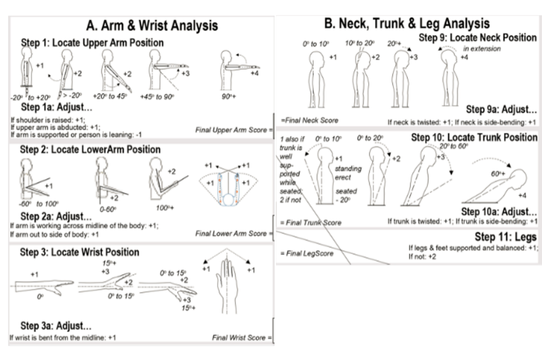

Fig. 10. RULA Assessment Step

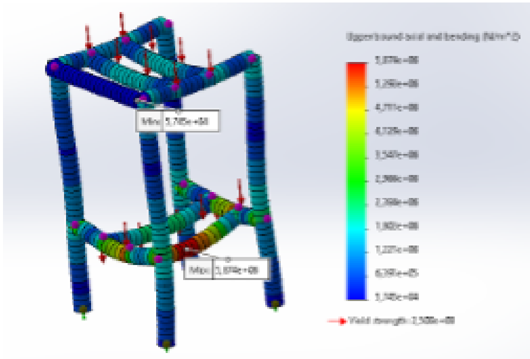

Fig. 11. Stress simulation data results

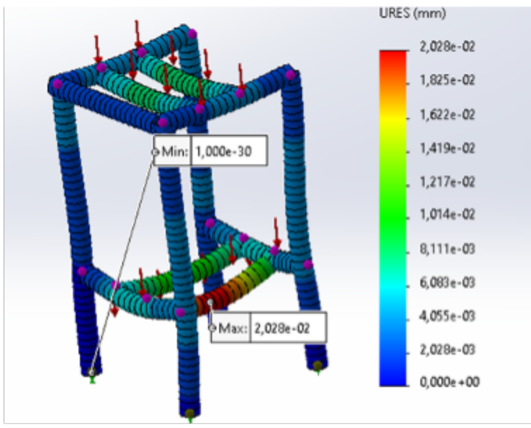

Fig. 12. Displacement simulation data results

of the stress simulation (von misses) with the highest value are found in the middle of the frame marked in red at $5.874\text{x}10^6 N/m^2$. While the smallest value is marked in dark blue with a stress value (von misses) of $5.745\text{x}104 N/m^2$.

2) Results of Static Simulation of the Frame Structures Displacement: (see Fig. 12)

3) Results of Static Simulation of the Frame Structures Factor of Safety: (see Fig. 13)

B. Results of Tool Testing Data and Trial Variations

1) Test data results Variety Trial 1 (see Table 1)
2) Test data results Variety Trial 2 (see Table 2)

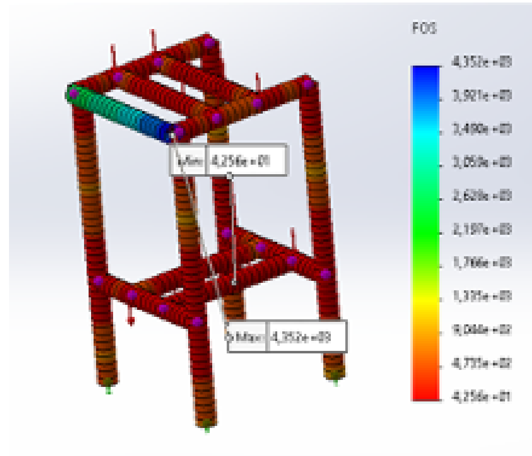

Fig. 13. Factor of Safety simulation data results

TABLE 2
DATA RESULT OF TRAL VARIATION 2

No	Massa Bahan (Kg)	Massa Produk Terpotong (gr)	Massa Produk Terpotong Hancur (gr)	Massa Produk Tidak Terpotong (gr)	Waktu Pemotongan (s)
1	0,5	460	10	20	18,35
2	0,5	450	20	25	17,26
3	0,5	455	25	20	19,21
∑	1,5	1365	55	65	54,82
X̄	0,5	455	18,33	21,67	18,27

3) Test data results Variety Trial 3 (see Table 3)

C. Implementation of RULA on The Tool

The final RULA score for Posture A is 3, so it is at action level 2 which indicates that further examination or changes need to be made.

IV. DISCUSSION

A. Analysis of Static Simulation Results of Frame Structure

From table 5 above, it is known that the static simulation of the frame structure in CAD software using ASTM A36 Steel L profile material measuring 40 x 40 x 3 mm, the value of stress (von mises), displacement and factor

TABLE 1
DATA RESULT OF TRAL VARIATION 1

No	Massa Bahan (Kg)	Massa Produk Terpotong (gr)	Massa Produk Terpotong Hancur (gr)	Massa Produk Tidak Terpotong (gr)	Waktu Pemotongan (s)
1	0,5	440	20	20	19,45
2	0,5	425	50	25	17,4
3	0,5	420	25	20	18,6
∑	1,5	1285	95	65	55,45
X̄	0,5	428,33	31,67	21,67	18,48

TABLE 3
DATA RESULT OF TRAL VARIATION 3

No	Massa Bahan (Kg)	Massa Produk Terpotong (gr)	Massa Produk Terpotong Hancur (gr)	Massa Produk Tidak Terpotong (gr)	Waktu Pemotongan (s)
1	0,5	450	15	20	18,65
2	0,5	440	20	20	19,31
3	0,5	445	25	25	18,56
∑	1,5	1335	60	65	56,52
X̄	0,5	445	20	21,67	18,84

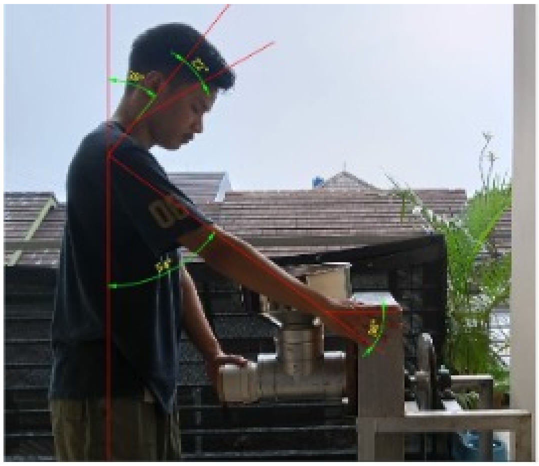

Fig. 14. Worker A's Posture

TABLE 4
FINAL RULA SCORE

Tabel C		Nilai dari Tabel B						
		1	2	3	4	5	6	7+
Nilai dari Tabel A	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8+	5	5	6	7	7	7	7

Fig. 15. Worker B's Posture

TABLE 5
FINAL RULA SCORE

Tabel C		Nilai dari Tabel B						
		1	2	3	4	5	6	7+
Nilai dari Tabel A	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8+	5	5	6	7	7	7	7

TABLE 6
STATIC SIMULATION RESULT DATA OF FRAME STRUCTURE

No	Jenis Simulasi	Nilai Terbesar	Nilai Terkecil	*Yield Strength*
1	*Stress (Von mises)*	5,874 x 106 N/m2	5,745 x 104 N/m2	2,5 x 10^{8} N/m^{2}
2	*Displacement*	2,028 x 10-2 mm	1 x 10^{-30} mm	-
3	*Factor of Safety*	4,352 x 103	43	-

of safety with the smallest value is 5.745 x 104 N/m2, 1 x 10-30 mm and 43. So, optimization that can be done to the frame structure of this balado stick potato cutting machine is by changing the thickness of the frame or frame dimensions and choosing alternative materials to be used in the frame.

B. Frame Optimization

After re-running the static simulation of the frame structure by changing the dimensions of the L profile steel, the stress (von mises), displacement and factor of safety data obtained can be seen in the table below:

In the static simulation of the frame structure by changing the dimensions to 25 x 25 x 4 mm and 20 x 20 x 3 mm, the same stress (von mises) simulation results were obtained, namely 1.363 x 107 N/m2 for the highest value and the lowest value of 3.678 x 105 N/m2. Meanwhile, the displacement simulation results and factor of safety are different. For static simulation of frame structures using SS 34 and SS 41 materials, the same stress (von mises), displacement simulation results are obtained. While for the simulation results the factor of safety is different. So, optimization can be applied to the frame structure of this tool, namely by using a 20 x 20 x 3 mm frame and SS 34 material.

C. Analysis of Tool Testing Data Results and Trial Variations

1) Data result analysis percentage damage result: In this study, the percentage value of damage to the results from the highest value to the lowest value is in trial variation 1 with a value of 10.67%, then in trial variation

TABLE 7
STATIC SIMULATION OPTIMIZATION RESULTS BY CHANGING THE DIMENSIONS OF THE L PROFILE STEEL IRON

Dimensi	Jenis Simulasi	Nilai Terbesar	Nilai Terkecil	*Yield Strength*
25 x 25 x 4 mm	*Stress (Von mises)*	1,363 x 10^7 N/m^2	3,678 x 10^5 N/m^2	2,5 x 10^8 N/m^2
	Displacement	6,286 x 10^{-2} mm	1 x 10^{-30} mm	-
	Factor of Safety	6,797 x 10^2	18	-
20 x 20 x 3 mm	*Stress (Von mises)*	1,363 x 10^7 N/m^2	3,678 x 10^5 N/m^2	2,5 x 10^8 N/m^2
	Displacement	1,741 x 10^{-1} mm	1 x 10^{-30} mm	-
	Factor of Safety	4,546 x 10^2	8,37	-

TABLE 8
STATIC SIMULATION OPTIMIZATION RESULTS BY CHANGING THE L PROFILE STEEL MATERIAL

Material	Jenis Simulasi	Nilai Terbesar	Nilai Terkecil	*Yield Strength*
SS 34	*Stress (Von mises)*	5,872 x 10^6 N/m^2	5,774 x 10^4 N/m^2	2,5 x 10^8 N/m^2
	Displacement	2,026 x 10^{-2} mm	1 x 10^{-30} mm	-
	Factor of Safety	3,637 x 10^3	36	-
SS 41	*Stress (Von mises)*	5,872 x 10^6 N/m^2	5,774 x 10^4 N/m^2	2,5 x 10^8 N/m^2
	Displacement	2,026 x 10^{-2} mm	1 x 10^{-30} mm	-
	Factor of Safety	4,329 x 10^3	43	-

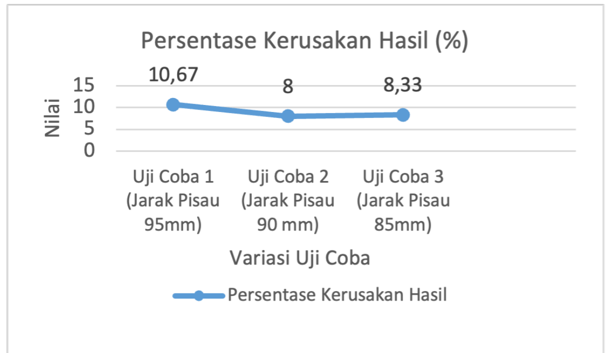

Fig. 16. Graph of Percentage of Damage Result

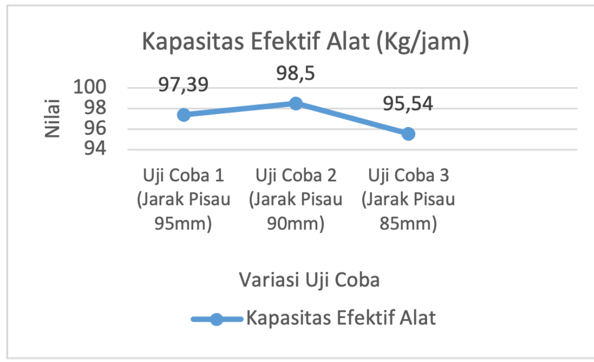

Fig. 17. Graph of Tool Effective Capacity

3 with a value of 8.33% and trial 2 with a value of 8%. To reduce the percentage of damage to the results during cutting can be done by adjusting the distance between the knife disk and the hooper so that the material can be cut evenly.

2) Data Result Analysis of Tool Effective Capacity: The data results from the research that has been done obtained the effective capacity of the tool from the highest value to the lowest value, namely in trial 2 with a value of 98.5 Kg /hour, then trial 1 with a value of 97.39 Kg/hour and trial 3 with a value of 95.54 Kg/hour. To increase or decrease the effective capacity of this tool can be done by adjusting the number of blades, cutting speed or changing the thickness of the product pieces.

3) Data Result Analysis of Tool Cutting Efficiency: The data results from the research conducted obtained data on the efficiency of cutting tools from the highest value to the lowest value, namely trial variation 2 with a value of 62.09%, then trial variation 1 with a value of 61.4% and trial 3 with a value of 60.22%. Based on industrial energy efficiency guidelines in Asia, a machine or tool can be declared feasible or not for use if the efficiency value of the tool is in the range of 60-70% or a higher value. So, this balado stick potato cutting tool can be declared feasible for use in the community.

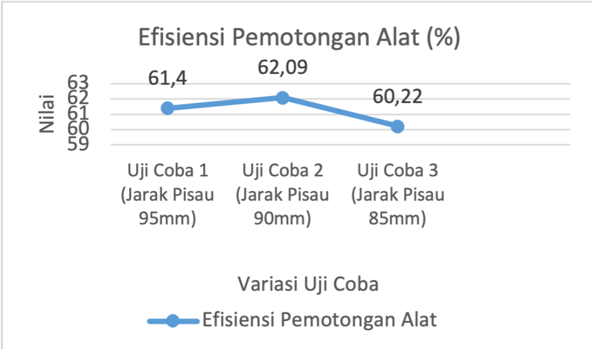

Fig. 18. Graph of Percentage of Tool Cutting Efficiency

V. Conclusions

Based on the research that has been conducted, the following conclusions can be drawn:

1) The results of static simulations of the frame using ASTM A36 Steel material obtained a factor of safety with the smallest value of 43. Optimization can be done by changing the frame dimensions to 20 x 20 x 3 mm and using SS 34 material.
2) The results of optimizing the knife with a variety of trials, namely the results of tool efficiency of 62.09% and based on references are feasible to use.
3) RULA assessment for postures A and B with differences in height get the final value of the RULA score of 3 and action level 2. So, further examination or changes are needed if needed.

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