OPTIMIZATION OF HARDENING AISI 1045 AS MATERIAL FOR CANE CUTTER BLADES USING THE TAGUCHI METHOD

Indra Gunawan[1)*], Fenoria Putri[1)], Soegeng Witjahjo[1)], Harry Mushafiqih[2)]
[1)] Mechanical Engineering Department, Politeknik Negeri Sriwijaya
[2)] Applied Graduate Student, Mechanical production and Maintenance study Program, Mechanical Engineering Department, Politeknik Negeri Sriwijaya
Jln.Srijaya Negara Bukit Besar Palembang 30139, Indonesia
[*] Corresponding: wawan.ig89@gmail.com

ARTICLE INFORMATION

Revised
13/09/2022

Accepted
10/10/2022

Online Publication
31/10/2022

doi:
http://doi.org/10.5281/zenodo.7265871

ABSTRACT

PT. X is a company that manufactures sugar. The situation of firm X cannot be described as ideal due to the need for extensive study, particularly on the cane cutter's blade. A common indication of cane cutters is a rapid rate of wear. In this study, researchers employed a qualitative technique based on the taguchi method. The taguchi approach is a modern engineering technique that strives to improve the quality of products and processes while reducing costs and maximizing resources. The taguchi experimental strategy is more effective because it permits research incorporating a large number of variables and numbers. Since a larger hardness response is preferable, the largest confirmation value is the ideal parameter value for the knife manufacturing process on the cane cutter. When measuring the hardness of the blade material on a cane cutter, temperature is a highly important component. According to the findings of the hardness test, the hardest material at a temperature of 750ºC and a cooling medium of NaCl solution with a hardness value of 12.4 HRC is, and the hardest material at a temperature of 800ºC and a cooling medium of NaOH solution with a hardness value of 59.7 HRC is.

***Keywords**: Hardening, Cane Cutter Blades, Taguchi method, AISI 1045, Rockwell*

1 INTRODUCTION

A cane cutter is a device used to reduce sugar cane to small pieces (Gandi, 2021), this tool is also in in the PT. X. The typical symptom of cane cutters is rapid wear; nonetheless, the company wants the cane cutter blades to last as long as possible because they must be replaced frequently during production. This has a significant impact on the manufacturing process, as the presence of impediments affects production time and production expenses, hence influencing production costs.

According to firm X's technicians, the problem with the *cane cutter*'s knife is caused by the hardness of sugar cane and the acidity (pH) of sugarcane juice, According to (Erwinda et al, 2014), the acidity of sugarcane juice has a pH ranging between 4.9 and 5.5. These variables contribute to the comparatively short blade life of the cane cutter. Along with the progression of time, people devised inventions to strengthen the resistance of a material by increasing its hardness in order to make the blade of the cane cutter resistant to wear (Pramudya et.al, 2022).

The objective of hardening is to increase the material's hardness through heat treatment (Darwis, 2020). The heating procedure is carried out until the austenization point, followed by a period of cooling (Husni, 2020). With comparatively inexpensive heat treatment, component service life will be extended (Karmin, 2009).

There are many researchers have applied the analysis using the Taguchi approach in there research namely Franando et al. (2020) in the 3D printing process, Wang et al (2019) and (2020) applied in the process manufacturing the plastic lens, and finally Arifin et al. 2012 applied Taguchi method in powder metallurgy of Aluminum.

So, the writer in this study want to applied the Taguchi method to increase hardness of the cane cutter.

2. MATERIALS AND METHODS

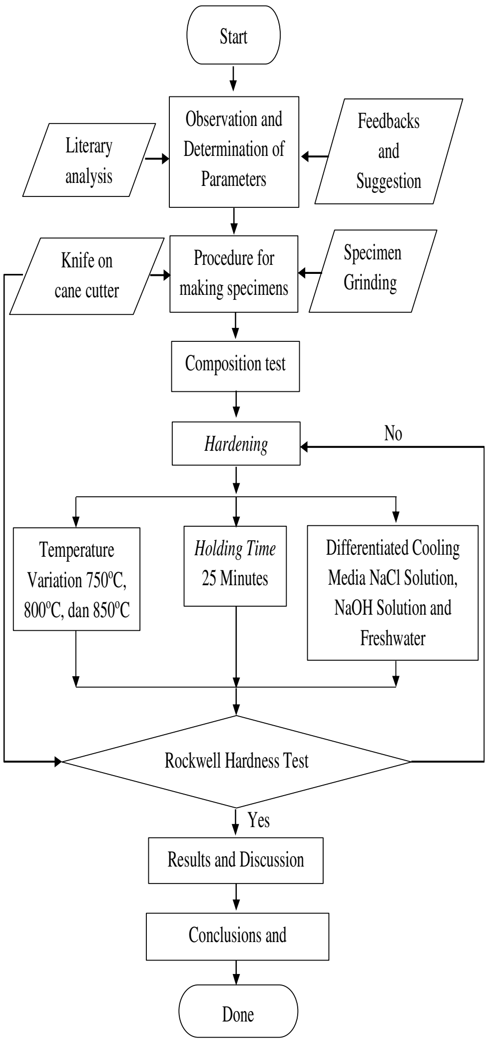

Figure 1. Research Flowchart

2.1 Research Tools

To conduct this research, research tools are needed, namely:

Table 1. Research Tools

No	Tool's name
1	Personal protective equipment
2	Furnace Nabertherm™ Chamber furnace N 321/13
3	Vernier calipers
4	Hand Grinder
5	Rockwell Hardness Tester Model HR-150A
6	Digital Termometer
7	Stopwatch
8	Polyspek Metal Scan

2.2 Research Material

The following research resources are required to complete this research:

Table 2. Research Material

No	Material Name
1	Specimen of AISI 1045 Steel
2	Solution NaCl
3	Solution NaOH
4	Freshwater
5	Wire
6	Blade Specimen On Cane Cutter

3. RESULTS AND DISCUSSION

3.1 Chemical Composition Test Results

The purpose of chemical composition testing is to determine the chemical constituents present in the item being examined (Pramono, 2011). After testing the knife material on the cane cutter, which is comprised of AISI 1045 steel with an average carbon content of 0.43 %, the material will be processed into specimens for rockwell hardness testing. The findings of testing the chemical composition listed in Table 3 are shown below.

Table 3. Chemical Composition Test Results

No	Name	Element	Percentage (%)
1	Iron	Fe	94.56
2	Carbon	C	0.430
3	Silicone	Si	0.671
4	Manganese	Mn	0.594
5	Phosphor	P	0.034
6	Sulfur	S	0.061
7	chrome	Cr	0.241
8	Molybdenum	Mo	0.395
9	Nickel	Ni	1.80
10	Aluminum	Al	0.143
11	Boron	B	0.011
12	Cobalt	Co	0.100
13	Copper	Cu	0.223
14	Niobium	Nb	0.262
15	Led	Sn	0.107
16	Tealium	Ti	0.067
17	Vanadium	V	0.105
18	Wolfram	W	0.090
19	calsium	Ca	0.004
20	Lead	Pb	<0.001

3.2 Hardness Test Results Rockwell

Testing the rockwell hardness of AISI 1045 steel before and after the hardening procedure at 750°C, 800°C, and 850°C for 25 minutes, followed by 15 minutes of cooling with NaCl solution media. A hardness value was determined by evaluating the surface of the test material using a 120° diamond indenter under a main load of 150 kg and NaOH solution. The results of Rockwell hardness tests are shown in the table below.

Table 4. Hardness Test Results Rockwell

Specimen	Temperature	Media Cooler	HRC
AISI 1045 without treatment	-	-	10,8
AISI 1045 hardening process	750°C	NaCl Solution	12,4
		NaOH Solution	15,9
		Freshwater	14,5
	800°C	NaCl Solution	48,5
		NaOH Solution	59,7
		Freshwater	52,9
	850°C	NaCl Solution	47,8
		NaOH Solution	54,5
		Freshwater	55,2

3.3 Taguchi Experiment Analysis Results

simultaneous examination of two or more elements (parameters) on their ability to influence the mean or standard deviation of particular product or process characteristics. (Zamheri et al, 2020). The processes involved in studying the taguchi experiment are as follows:

a. Establishing the level of each variable
   - Temperature
     The temperatures used in this study were 750°C, 800°C and 850°C.
   - Media Cooler
     Cooling media used in this study are NaCl solution, NaOH solution and fresh water.

b. Determine Matriks Orthogonal
   In order to select a suitable or adequate orthogonal matrix, an orthogonal matrix equation representing the number of components, the number of levels, and the number of observations to be collected is required (Apriansyah et al, 2020). L^9 is the degree of freedom for the orthogonal matrix during analysis (3^2).

Table 5. Experiment Design and Test Results

Combination of Factors and Levels		Response (HRC)
Temperature	Media Cooler	
1	1	12,4
2	2	15,9
3	3	14,5
1	1	48,5
2	2	59,7
3	3	52,9
1	1	47,8
2	2	54,5
3	3	55,2

c. Ratio S/N
   The S/N ratio is designed so that the researcher can always select the largest factor level to optimize the experiment's quality attributes (Irwan, 2009). This study reacts to quality attributes with the maxim "more is better" because the largest confirmation value represents the ideal parameter value (Wang et al., 2019). Then apply the equation below:

$$\text{Ratio S/N} = -10 \text{ Log } [\frac{1}{n}\sum_{i=1}^{r}\frac{1}{Yi^2}]$$

which; Y_i = experimental value
n = number of repetitions

Table 4 displays the results of processing the Rockwell hardness test data. With a value of 12.4 for the hardness response variable in the first experiment, the SN Ratio is computed as follows

$$\text{Ratio S/N} = -10 \text{ Log } [\frac{1}{1}(\frac{1}{12{,}4^2})]$$
$$= 21{,}87$$

The outcomes of the whole SN Ratio calculation for the hardness response are displayed In Table 6.

Table 6. SN Ratio Hardness Value

Factors	A1	A2	A3	Amount
B1	21,87	33,71	33,59	89,17
B2	24,03	35,52	34,73	94,28
B3	23,23	34,47	34,84	92,54
Amount (∑)	69,13	103,7	103,16	275,99

The formula for calculating the variation in the S/N ratio of the hardness of AISI 1045 steel with a combination of each factor's values is shown below.

$\overline{A_1}$ = 1/3 (21,87 + 24,03 + 23,23)
= 23,04

$\overline{A_2}$ = 1/3 (33,71 + 35,52 + 34,47)
= 34,57

$\overline{A_3}$ = 1/3 (33,59 + 34,73 + 34,84)
= 34,39

The table below shows the results of calculating the mean value of each factor level:

Table 7. Average Value of Each Factor Level

Levels	Temperature	Media Cooler
1	23,04	29,72
2	34,57	31,43
3	34,39	30,85

Using the Minitab program 19, the examination of the *SN Ratio Taguchi* bigger is better yielded the following results:

Table 8. The Analysis of results *SN Ratio Taguchi Larger Is Better*

Levels	Temperatures	Media Cooler
1	23,04	29,72
2	34,57	31,43
3	34,39	30,85
Delta	11,53	1,70
Rank	1	2

A graph or plot is created to make it simpler to understand the best *Rockwell hardness* test findings after finishing the *Taguchi SN Ratio* analysis and receiving results that are consistent with Table 8.

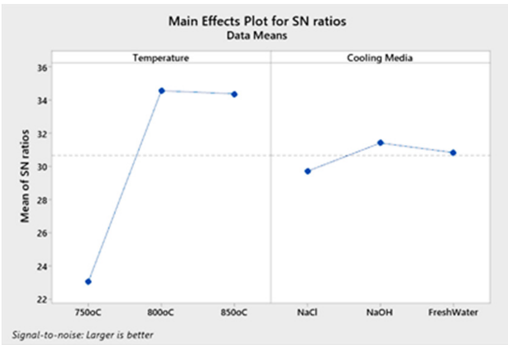

Figure 2. Main Effect Plot for SN Ratios

The graph or plot presented in Figure 4.1 is produced from the experimental findings of the Taguchi SN Ratio analysis of hardness. The best parameter value for the process of making a knife on a cane cutter is a temperature of 800°C with a value of 34.57 and a cooling medium of NaOH solution with a value of 31.43 because the more violent reaction, the better; therefore, the largest confirmation value is the optimal parameter value.

d. Conduct tests and use ANOVA to assess the outcomes

Calculations using analysis of variance (ANOVA) allow for a quantitative estimation of the contribution of each component to all response measures (Wang et al, 2019).

Table 9. *Analysis of Varian's*

Analysis of Varian's					
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Temperature	2	3018,22	1509,11	244,74	0,000
Cooling media	2	78,60	39,30	6,37	0,057
Error	4	24,66	6,17	-	-
Total	8	3121,48	-	-	-

The significance level is 5% or 0.05 when using a P-value with a significance value since the confidence level is 95%. So set:

- Temperature has a substantial impact on hardness when the P-value is less than 0.05.
- If the cooling media's P-value is more than 0.05, then the factor has no bearing on hardness.

e. Confirmation

The highest value, which is the parameter value used for experiment confirmation, is discovered after data analysis.

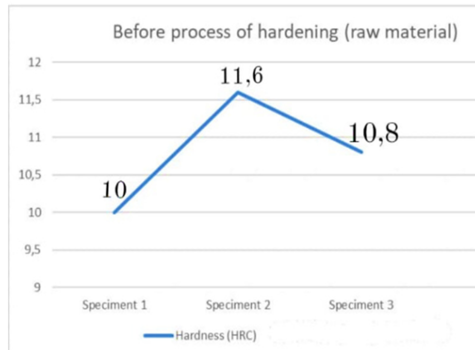

Figure 3. Before process of hardening

A graph of the outcomes of the knife hardness test on the cane cutter before it was hardened with a hardness value of 10, is shown in figure 3. For the initial. The second specimen had an HRC of 11.6 whereas the third had an HRC of 10.8. In addition, the image below shows the outcomes of the hardness test after hardening:

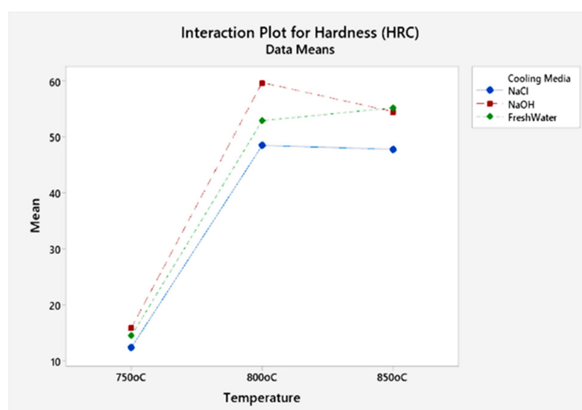

Figure 4. Interaction Plot for Hardness (HRC)

The graph or plot in Figure 4 was created using the experimental results of the Taguchi analysis of the hardness test. The optimum temperature for the knife-making process on the cane cutter is 800°C, and the best cooling medium is NaOH solution with a hardness value of 59.7 HRC. This is because the response to hardness is larger is better, and the largest confirmation value is the optimal parameter value.

Temperature is a highly important aspect in hardness testing, according to (Windarto, 2020). Low temperatures result in suboptimal variations in hardness. In this research, temperature plays an important role in the hardening process and assessment of hardness.

Table 10. The confirmation of analysis Taguchi

Responses	*Optimum Levels*	*Hardness* (HRC)
Hardness	A_2B_2	59,7

4. CONCLUSION

These inferences can be made in light of the outcomes of the study and data analysis that was done:

According to the results of the hardness test, the lowest hardness value was obtained at a temperature of 750℃ and the cooling medium used was NaCl solution, which had a hardness value of 12.4 HRC. The highest hardness values were obtained at temperatures of 800℃ and the cooling medium used was NaOH solution, which had a hardness value of 59.7 HRC. The Taguchi approach can be utilized to optimize the multiresponse situation of knife products on cane cutters. According to the results of the Taguchi method analysis, temperature was determined to be the most influential element in determining the value of hardness.

REFERENCES

Apriansyah I, Zamheri A and Arifin F. 2020. Peningkatan Akurasi Dimensi Dan Tingkat Kekerasan Pada *Fillamen Esteel* Dengan Pendekatan Metode *Taguchi*. *Machinery* Jurnal Teknologi Terapan Vol.2 No.1, February 2021 ISSN: 2776-673X (Online). https://doi.org/10.5281/zenodo.4748423

Arifin, F, Iskandar, Azharuddin, 2012, Taguchi Method Approach to Optimize Manufacturing Process Parameters of Aluminum-5 % Fly Ash Alloy Using Powder Metallurgy, Advanced Materials Research, ISSN: 1662-8985, Vol. 576, pp 284-288, doi:10.4028/www.scientific.net/AMR.576.284.

Darwis. 2020. Pengaruh Variasi Suhu Pada Proses *Tempering* dan *Hardening* Dengan Media Pendingin Oli Terhadap Kekuatan Tarik As Baja dan Kuningan. Vol 2 No 1 (2020): Celebes Engineering Journal. https://journal.lldikti9.go.id/CEJ/article/view/428

Erwinda M D and Susanto W H. 2014. Pengaruh pH Nira Tebu *(Saccharum Officinarum)* Dan Konsentrasi Penambahan Kapur Terhadap Kualitas Gula Merah. Jurnal Pangan dan Agroindustri Universitas Brawijaya Malang Vol. 2No. 3 (2014). https://jpa.ub.ac.id/index.php/jpa/article/view/52

Franando, Zamheri A and Arifin A. 2020. Studi Pembuatan Bagian Alat Rehabilitasi Penderita Stroke Dengan Pendekatan Metode *Taguchi*. *Machinery* Jurnal Teknologi Terapan Vol.1 No.1,August 2020 p-ISSN : 2723-3359. https://doi.org/10.5281/zenodo.4540849

Hanggara, Gandi. 2021. Proses Penggantian Pisau Pada Mesin *Cane Cutter* di PT. Buma Cima Nusantara Unit Cinta Manis. Politeknik Negeri Sriwijaya.

Karmin. 2009. Pengendalian Proses Pengerasan Baja Dengan Metoda *Quenching*. Jurnal Austenit Volume 1, No. 2 october 2009. https://doi.org/10.5281/zenodo.4542646

Pramono, Agus. 2011. Karakterisrik Mekanik Proses *Hardening* Baja AISI 1045 Media *Quenching* Untuk Aplikasi *Sprochet* Rantai. Jurnal Ilmiah Teknik Mesin Vol. 5 No.1. April 2011 (32-38). https://ojs.unud.ac.id/index.php/jem/article/view/2346

Pramudya B.I, Ariyanto and Husman. 2022. Analisis Pengaruh Temperatur dan Media Pendingin Terhadap Sifat Kekerasan Dan Ketangguhan Baja S45c Pada Pisau Crusher. Vol. 2 No. 01 (2022): Seminar Nasional Inovasi Teknologi Terapan (SNITT). https://snitt.polmanbabel.ac.id/index.php/snitt/article/view/185

Soejanto, Irwan. 2009. Desain Eksperimen Dengan Metode *Taguchi*. Graha Ilmu. Yogyakarta.

Wang M-W, Arifin F and Huynh T T-N. 2019. *Optimization of Molding Parameters for a Micro Gear with Taguchi Method. Journal of Physics: Conference Series*. https://iopscience.iop.org/article/10.1088/1742-6596/1167/1/012001

Wang M-W, Arifin F and Kuo H-L. 2019. *Study on micromoulding of a high viewing angle LED lens*. Macromolecular Engineering. https://www.tandfonline.com/doi/abs/10.1080/14658011.2019.1685803

Wang M-W, Arifin F, Kuo J-W and Dzwo T H. 2020. *Optimal Design of Plasticizing Screw Using Artificial. Journal of Physics: Conference Series.* 1500 (2020) 012022 doi:10.1088/17426596/1500/1/01202

Windarto W, Mahfud M.I and Wibowo S. 2020. Pengaruh Variasi Temperatur *Hardening* Terhadap *Mechnical Properties* Pada Baja S45C Untuk Komponen *Griper*. Vol 8 No 1 (2020): Jurnal Ilmiah Teknik Mesin. https://doi.org/10.33558/jitm.v8i1.1999

Zamheri A, Syahputra A.P and Arifin A. 2020. Studi Penyusutan Pembuatan Gigi Palsu Dengan 3d Printing Fdm Pendekatan Metode Taguchi. Jurnal Austenit Vol.12 No.2, October 2020 ISSN: 2085-1286 E-ISSN : 2622-7649. https://doi.org/10.5281/zenodo.4547840