
The Effect of Phase on Paper Thickness Optimization in the Recycling Process Using Recycling Machine

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Abstract

Efforts to manage the recycling of paper waste into new paper have been carried out in recent times. It takes a tool or machine that is able to effectively and efficiently recycle used paper into new paper. There are several factors that affect the effectiveness of paper recycling machines, one of which is the paper thickness. One method that can be used to analyze the factors that influence paper thickness in the paper production process using a paper recycling machine is regression analysis. Regression analysis is data analysis techniques in statistics that is used to examine the relationship between several independent variables and dependent variable. However, if we want to examine the relationship or effect of two or more independent variables on a dependent variable, the regression model used is a multiple linear regression model. This study purposes are to analyze the factors that influence paper thickness using a paper recycling machine using multiple linear regression and to inform the modeling about that. The results showed that the factors that affect the paper thickness optimization are destruction and press phase.

Kata Kunci:: *Multiple linear regression analysis; Paper making phase; Paper recycling machine; Paper thickness*

Abstract

Upaya pengelolaan daur ulang sampah kertas menjadi kertas baru telah banyak dilakukan pada jaman sekarang. Dibutuhkan suatu alat atau mesin yang mampu secara efektif dan efisien dalam mendaur ulang kertas bekas menjadi kertas baru. Terdapat beberapa faktor yang mempengaruhi tingkat efektifitas mesin daur ulang kertas diantaranya adalah ketebalan kertas. Salah satu metode yang dapat digunakan untuk menganalisis faktor-faktor yang mempengaruhi ketebalan kertas pada proses produksi kertas menggunakan mesin daur ulang kertas adalah analisis regresi. Analisis regresi merupakan teknik analisis data dalam statistika yang digunakan untuk mengkaji hubungan antara beberapa variabel bebas dengan variabel tidak bebas. Namun, jika ingin mengkaji hubungan atau pengaruh dua atau lebih variabel bebas terhadap satu variabel tidak bebas, maka model regresi yang digunakan adalah model regresi linier berganda. Tujuan dalam penelitian ini yaitu menganalisis faktor-faktor yang mempengaruhi ketebalan kertas menggunakan mesin daur ulang kertas menggunakan regresi linier berganda serta memberikan informasi pemodelan mengenai hal tersebut. Hasil penelitian menunjukkan bahwa faktor yang mempengaruhi keoptimalan ketebalan kertas adalah fase penghancuran dan pemadatan kertas

Keywords: *Analisis regresi linier berganda; Fase pembuatan kertas; Ketebalan kertas; Mesin daur ulang kertas*

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INTRODUCTION

Manufacturing companies are companies engaged in processing raw materials by spending other costs into finished goods that are ready for sale. Manufacturing companies throughout the world are affected by globalization and are forced to become more competitive every day to maintain their profitability (Goddard, Tavakoli, & Wilson, 2005; Rahmasari, 2017). Some manufacturing companies are engaged in processing waste that no longer has the benefit of being a recycled product so that it can be reused and useful for life.

Lack of awareness from humans results in a lot of littering. It can cause some pollution. However, all can be overcome if we are creative in utilizing the garbage. Besides being able to preserve the environment, it can also increase our income. One of the waste utilization techniques is recycling by making various kinds of crafts and new products (Kementerian Keuangan Republik Indonesia, 2019).

The type of waste that is commonly found is paper waste. Paper waste as wasted goods can be used by recycling into unique and artistic paper or even becoming new paper for reuse. Through paper recycling, in addition to dealing with environmental problems, can also be used as an alternative in creating new job fields (Asmatulu & Asmatulu, 2011; Yafie, Kustiawan, & Seken, 2018; Zahra & Damanhuri, 2011). Efforts to manage the recycling of paper waste into new paper have been carried out in recent times. It takes a tool or machine that is able to effectively and efficiently recycle used paper into new paper. There are several factors that affect the effectiveness of paper recycling machines, one of which is the paper thickness. Therefore, it is necessary to do research on what factors influence the thickness of the paper in order to create optimal results in the production of paper on a paper recycling machine (Faraz, Biermann, & Weinert, 2009). One method that can be used to analyze the factors that influence paper thickness in the paper production process using a paper recycling machine is regression analysis.

Regression analysis is data analysis techniques in statistics that is used to examine the relationship between several independent variables and dependent variable (Effendi, Mursilah, & Mujiono, 2018; Widiyawati & Setiawan, 2015). If we want to examine the relationship or effect of one independent variable, the regression model used is a simple

linear regression model. However, if we want to examine the relationship or effect of two or more independent variables on a dependent variable, the regression model used is a multiple linear regression model. Then to get a simple linear regression model and multiple linear regression models can be obtained by estimating its parameters using certain methods. The methods that can be used to estimate the parameters of a simple linear regression model or multiple linear regression model is ordinary least square (OLS) and maximum likelihood estimation (MLE) (Kutner, Nachtsheim, Neter, & Li, 2005).

This study purposes are to analyze the factors that influence paper thickness using a paper recycling machine using multiple linear regression and to inform the modeling about it to get the optimal paper thickness.

METHODOLOGY

Data Sources and Research Variables

In this study, the data used are secondary data obtained from the result of the study whose the observations were made in recycle paper mills. The data obtained are as follows:

Table 1. Observational data

No	Y	x_1	x_2	x_3	x_4	x_5	x_6
1	43	51	30	39	61	92	45
2	63	64	51	54	63	73	47
3	71	70	68	69	76	86	48
4	61	63	45	47	54	84	35
5	81	78	56	66	71	83	47
6	43	55	49	44	54	49	34
7	58	67	42	56	66	68	35
8	71	75	50	55	70	66	41
9	72	82	72	67	71	83	31
10	67	61	45	47	62	80	41
11	64	53	53	58	58	67	34
12	67	60	47	39	59	74	41
13	69	62	57	42	55	63	25
14	68	83	83	45	59	77	35
15	77	77	54	72	79	77	46
16	81	90	50	72	60	54	36
17	74	85	64	69	79	79	63
18	65	60	65	75	55	80	60
19	65	70	46	57	75	85	46
20	50	58	68	54	64	78	52
21	50	40	33	34	43	64	33

22	64	61	52	62	66	80	41
23	53	66	52	50	63	80	37
24	40	37	42	58	50	57	49
25	63	54	42	48	66	75	33
26	66	77	66	63	88	76	72
27	78	75	58	74	80	78	49
28	48	57	44	45	51	83	38
29	85	85	71	71	77	74	55
30	82	82	39	59	64	78	39

The variables used in the papermaking process are as follows:

The dependent variable used in this study is:

Y: Thickness (μm)

The independent variables used in this study are control factors, as follows (Djami, 2014):

x_1 : phase 1, destruction part

x_2 : phase 2, wire part

x_3 : phase 3, press part

x_4 : phase 4, drying part

x_5 : phase 5, callender part

x_6 : phase 6, heating water part

Research Methods

1. Multiple Linear Regression

The general form of multiple linear regression model with p -independent variable as in the following equation (Johnson & Bhattacharyya, 2010).

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots + \beta_{p-1} X_{ip-1} + \epsilon_i \quad (1)$$

with:

Y_i is dependent variable for i -observations, $i = 1, 2, \dots, n$.

$\beta_0, \beta_1, \beta_2, \dots, \beta_{p-1}$ are the parameters.

$X_{i1}, X_{i2}, \dots, X_{ip-1}$ are the independent variables.

ϵ_i are the error for i -observations that are assumed to be normally distributed that are independent and identical with the average of 0 (zero) and σ^2 variance.

Table 2. *Analysis of Variance* (ANOVA) (Irianto, 2004)

Sources	Independent Level	Sum Square	Mean Square	F_{count}
Regression	p	SSR	$\frac{SSR}{k}$	$\frac{MSR}{MSE}$
Error Residuals	$n - p - 1$	SSE	$\frac{SSE}{(n - k - 1)}$	
Total	$n - 1$	SST		

2. Model Parameter Test

a. Simultaneous test

Simultaneous test is carried out to determine the significance of the model coefficient (Kusuma & Puspita, 2016).

- Hypothesis:

$$H_0: \beta_1 = \beta_2 = \dots = \beta_{p-1} = 0$$

$$H_1: \text{not all } \beta_k = 0, k = 1, 2, \dots, p - 1$$

- Testing statistics:

$$F_{count} = \frac{MSR}{MSE} \quad (2)$$

with:

MSR is average of regression square.

MSE is average of error square.

- Rejection criteria:

$$\text{Reject: } H_0 \text{ if } F_{count} > F_{table}; F_{table} = F_{(1-\alpha; p-1, n-p)}$$

b. Partial test

Partial test is used to see the effect of each predictor variable (Kusuma & Puspita, 2016).

- Hypothesis:

$$H_0: \beta_k = 0$$

$$H_1: \beta_k \neq 0, k = 1, 2, \dots, p - 1$$

- Testing statistics:

$$t_{count} = \frac{\beta_k}{s(\beta_k)} \quad (3)$$

with:

β_k is parameter estimated value.

$s(\beta_k)$ is deviation standard of β_k .

- Rejection criteria:

$$\text{Reject: } H_0 \text{ if } t_{count} > t_{table} \text{ or } t_{count} < -t_{table}; t_{table} = t_{(\frac{\alpha}{2}; n-p)}$$

c. Determination Coefficient (R^2)

Determination coefficient used to measure the goodness of the model. The model is said to be good if R^2 value is close to 1 (Soejanto, 2009). The formula used is:

$$R^2 = \frac{SSR}{SST} \times 100\% \quad (4)$$

3. Error Assumption Test

a. Error normality test

The testing of normal error assumption is carried out using *Kolmogorov-Smirnov* test (SATHEESH & EDWIN RAJA DHAS, 2013).

- Hypothesis:

$$H_0: \text{error spread normally.}$$

- H_1 : error does not spread normally.
- Rejection criteria:
Reject: H_0 if P-value > 0,05 at the real level 5%.
- b. Homogeneity test
The homogeneity test is using *Glejser* test (Setiawan & Kusriani, 2010).
- Hypothesis:
 H_0 : homogeneous error variance.
 H_1 : heterogeneous error variance.
 - Rejection criteria:
Reject: H_0 if P-value > 0,05 at the real level 5%.
- c. Detect of error independencies
The test used is Runs Test (Montgomery et al., 2012).
- Hypothesis:
 H_0 : independent mutual error.
 H_1 : dependent mutual error.
 - Rejection criteria:
Reject: H_0 if P-value > 0,05 at the real level 5%.
- d. Detect of multicollinearity
Multicollinearity detection for i -explanatory variables can use *VIF* test (Montgomery, Peck, & Vining, 2012), with the formula is:

$$VIF = \frac{1}{1 - R_i^2} \quad (5)$$

- Hypothesis:
 H_0 : there is no multicollinearity between independent variables ($VIF < 10$).
 H_1 : there is multicollinearity between independent variables ($VIF > 10$).
- Rejection criteria:
Reject: H_0 if $VIF > 10$.

RESULTS AND DISCUSSIONS

Data Exploration

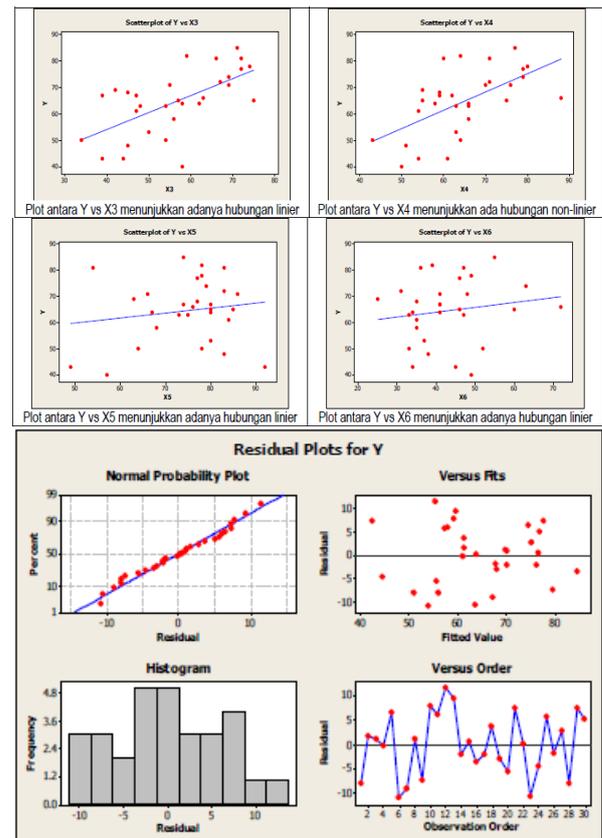
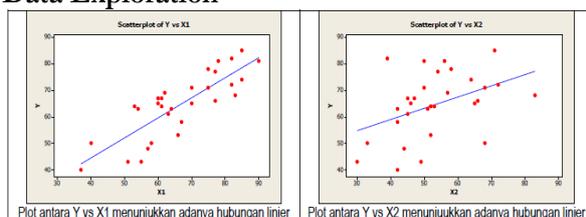


Figure 1. Results of data exploration

The normal QQ plot shows a normal spread error, this is seen from the points that are around the line. Error plot vs fitted value shows a homogeneous errors range, it can be seen from the absence of patterns formed and the same bandwidth. Error plot vs order shown no pattern, so it can be concluded that the errors are mutually independent.

Result of Multiple Regression Analysis

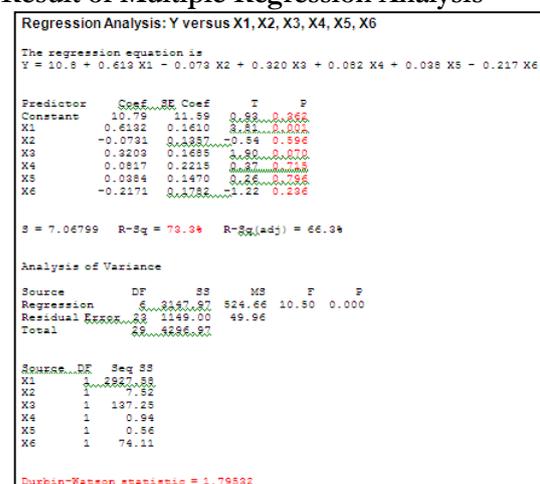


Figure 2. Result of Regression Analysis

Interpretation:

The results of regression analysis for Y with x_1 to x_6 produced significant F test (P -value < 0.05), so there is sufficient evidence to state that there is at least one explanatory variable affecting Y . The t-test on each explanatory variable concluded that the x_1 and x_6 had P -value < 0.05 , it means that there is sufficient evidence to state that both variables affect Y at the real level 5%, while the other explanatory variables do not affecting Y . The result of R^2 value is 73.3%, it means that the variance of Y that can be explained by x_1 to x_6 is 73.3%, while the remaining 26.7% is explained by variables outside the model. This R^2 value is relatively small, so it can be concluded if the model formed is not good enough, this is also supported by the R^2_{pred} value = 54.7% which is relatively low. From this regression analysis, no outliers or observations were found to be influential.

Results of Error Assumption Test

1. Result of error normality test

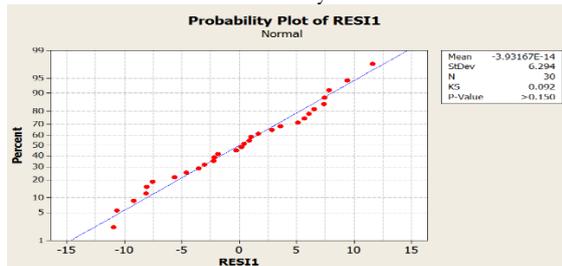


Figure 3. Result of of error normality test using Kolmogorov-Smirnov test

Interpretation:

Hypothesis:

H_0 : error spread normally

H_1 : error does not spread normally

Conclusion:

Normality test using Kolmogorov-Smirnov produced P -value > 0.150 , so there is sufficient evidence to state that H_0 does not rejected at the real level 5%, it means there is no violation of the normality assumption error.

2. Result of homogeneity test

Analysis of Variance					
Source	DF	SS	MS	F	P
Regression	6	101.22	16.87	1.60	0.193
Residual Error	23	243.12	10.57		
Total	29	344.35			

Figure 4. Result of homogeneity test using Glejser test

Interpretation:

Hypothesis:

H_0 : homogeneous error variance

H_1 : heterogeneous error variance

Conclusion:

Glejser test produced P -value = 0.193, so there is sufficient evidence to state that the error variance is heterogenic at the real level 5%, in other words, the assumption of homogeneous error variance is fulfilled.

3. Result of detect of error independencies

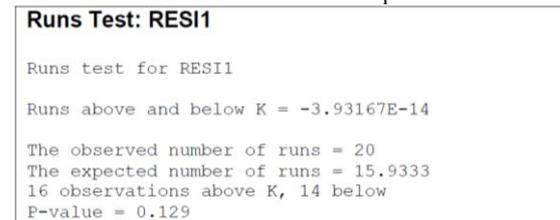


Figure 5. Result of detect of error independencies Runs Test

Interpretation:

Hypothesis:

H_0 : independent mutual error

H_1 : dependent mutual error

Conclusion:

Runs Test produced P -value = 0.129, is means there is not sufficient evidence yet to state that the error not mutually independent at the real level 5%, so the assumption of error independencies is fulfilled.

4. Result of detect of multicollinearity

Predictor	Coef	SE Coef	T	P	VIF
Constant	10.79	11.59	0.93	0.362	
X1	0.6132	0.1610	3.81	0.001	2.667
X2	-0.0731	0.1357	-0.54	0.596	1.601
X3	0.3203	0.1685	1.90	0.070	2.271
X4	0.0817	0.2215	0.37	0.715	3.078
X5	0.0384	0.1470	0.26	0.796	1.228
X6	-0.2171	0.1782	-1.22	0.236	1.952

Figure 6. Result of detect of multicollinearity

Interpretation:

The assumption of multicollinearity can be seen through the VIF value on each independent variable. It can be seen that there is no VIF value greater than 9, so it can be concluded that there is no multicollinearity. So this assumption is fulfilled.

Regression analysis Y with x_1 to x_6 produce R^2 value is 73.3% and there is no violation of

assumption. Although the model formed is good enough, but not all variables are significant, so it is necessary to create a new model that can explain Y to be better. Some ways are used best subset and stepwise regression. The results of best subset and stepwise regression are as follows:

Best Subset						
Response is Y						
Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	1	2 3 4 5 6
1	68.1	67.0	1.4	6.9933	X	X X X X X
1	38.9	36.7	26.6	9.6835		X
2	70.8	68.6	1.1	6.8168	X	X
2	68.4	66.0	3.2	7.0927	X	X
3	72.6	69.4	1.6	6.7343	X	X X
3	71.5	68.2	2.5	6.8630	X	X X
4	72.9	68.6	3.3	6.8206	X	X X X
4	72.9	68.5	3.4	6.8310	X	X X X
5	73.2	67.6	5.1	6.9294	X	X X X X
5	73.1	67.5	5.1	6.9396	X	X X X X
6	73.3	66.3	7.0	7.0680	X	X X X X X X

Figure 7. Result of best subset

Interpretation:

The result of best subset concluded that the variables x_1 and x_3 were included into the model. When x_1 and x_3 are included, the result of R^2 value model is quiet large compared to the other models, which is 70.8%. Cp Mallow value of 1.1 can also be said to be good because it approaches the number of explanatory variables included into the model that is 2. The S value of 6.8268 is relatively low when compared by the other models.

Stepwise Regression		
Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15		
Response is Y on 6 predictors, with N = 30		
Step	1	2
Constant	14.376	9.871
X1	0.755	0.644
T-Value	7.74	5.43
P-Value	0.000	0.000
X3		0.21
T-Value		1.57
P-Value		0.128
S	6.99	6.82
R-Sq	68.13	70.80
R-Sq(adj)	66.99	68.64
Mallows Cp	1.4	1.1

Figure 8. Result of stepwise regression

Interpretation:

Stepwise regression suggested that the variables x_1 and x_3 were included into the model.

Base on the results of best subset and stepwise regression, it can be decided to use variables x_1 and x_3 into the model. And the result of regression analysis Y with x_1 and x_3 as follows:

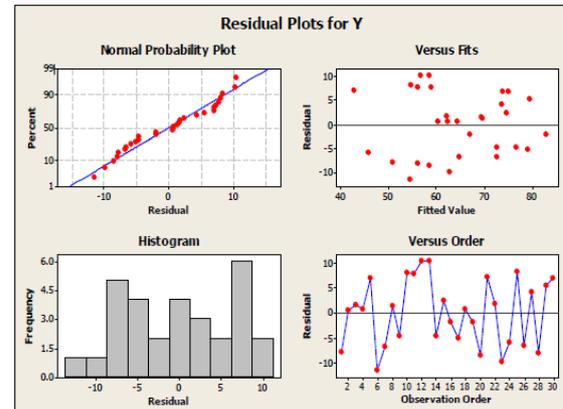


Figure 9. Result of data exploration after best subset and stepwise regression

Interpretation:

The normal QQ plot shows a normal spread error. Error plot vs fitted value shows a homogeneous errors range, it can be seen from the absence of patterns formed and the same bandwidth. Error plot vs order shown no pattern, so it can be concluded that the errors are mutually independent.

Regression Analysis: Y versus X1, X3						
The regression equation is						
$Y = 9.87 + 0.644 X1 + 0.211 X3$						
Predictor	Coef	SE Coef	T	P	VIF	
Constant	9.871	7.061	1.40	0.174		
X1	0.6435	0.1185	5.43	0.000	1.553	
X3	0.2112	0.1344	1.57	0.128	1.553	
S = 6.81678 R-Sq = 70.8% R-Sq(adj) = 68.6%						
PRESS = 1545.97 R-Sq(pred) = 64.02%						
Analysis of Variance						
Source	DF	SS	MS	F	P	
Regression	2	3042.3	1521.2	32.74	0.000	
Residual Error	27	1254.6	46.5			
Total	29	4297.0				
Source	DF	Seq SS				
X1	1	2927.6				
X3	1	114.7				
Unusual Observations						
Obs	X1	Y	Fit	SE Fit	Residual	St Resid
24	37.0	40.00	45.93	3.65	-5.93	-1.05 X
X denotes an observation whose X value gives it large leverage.						
Durbin-Watson statistic = 1.95818						

Figure 10. Result of regression analysis after best subset and stepwise regression

Interpretation:

The result of regression analysis produces the formula:

$$Y = 9.87 + 0.644x_1 + 0.211x_2 \quad (6)$$

F test produced the testing statistics of 32.74 and P-value = 0.000, so it can be concluded there is sufficient evidence to state that there is at least one explanatory variable that affect Y at the real level 5%. Following the F test, the test of each explanatory variable using t test produced P-value = 0.000 and 0.128 for variables x_1 and x_3 , so it can be concluded there is sufficient evidence to state that x_1 affects Y while x_3 does not affect Y at the real level 5%. The result of R^2 value is 70.8%, it means that the variance of Y that can be explained by model is 70.8%, while the remaining 29.2% is explained by variables outside the model. R^2 and R^2_{pred} values on this model are larger than previous model, in other word this model is better. Regression analysis also shows the observed effect on the data, namely the 24th observation. Because this observation is influential, this observation is not removed from the data. Although x_3 is not significant, but this model is better than when Y is only regressed by x_1 (it can be seen from best subset).

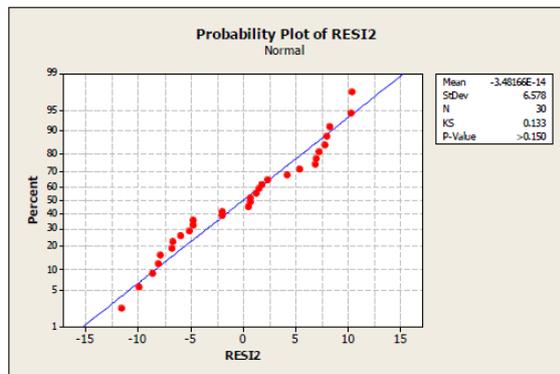


Figure 11. Result of error normality test using Kolmogorov-Smirnov test after best subset and stepwise regression

Interpretation:

Hypothesis:

H_0 : error spread normally

H_1 : error does not spread normally

Conclusion:

P-value > 0.150 for Kolmogorov-Smirnov test conclude that error spread normally at the real level 5%, so this assumption is fulfilled.

Analysis of Variance					
Source	DF	SS	MS	F	P
Regression	1	36.850	36.850	3.78	0.062
Residual Error	28	273.033	9.751		
Total	29	309.884			

Figure 12. Result of homogeneity using Glejser test after best subset and stepwise regression

Interpretation:

Hypothesis:

H_0 : homogeneous error variance

H_1 : heterogeneous error variance

Conclusion:

P-value = 0.062 for Glejser test concluded that homogeneous error variance at the real level 5%.

Runs Test: RESI2	
Runs test for RESI2	
Runs above and below K = -3.48166E-14	
The observed number of runs = 18	
The expected number of runs = 15.7333	
17 observations above K, 13 below	
P-value = 0.391	

Figure 13. Result of detect of error independencies using Runs Test after Best Subset and Stepwise Regression

Interpretation:

Hypothesis:

H_0 : independent mutual error

H_1 : dependent mutual error

Conclusion:

P-value = 0.391 for Runs Test concluded that between errors does not correlated at the real level 5%.

Predictor	Coef	SE Coef	T	P	VIF
Constant	9.871	7.061	1.40	0.174	
X1	0.6435	0.1185	5.43	0.000	1.553
X3	0.2112	0.1344	1.57	0.128	1.553

Figure 14. Result of detect of multicollinearity after Best Subset and Stepwise Regression

Interpretation:

VIF value on the variables x_1 and x_3 are 1.553 and 1.553 indicate that there is no correlation between explanatory variables, so the assumption of the absence of multicollinearity is fulfilled.

Analysis Result

Based on the results of multiple linear regression analysis and after proven by the error assumption test, obtained the most optimal model in producing paper thickness in the recycling process using paper recycling machine is

$$Y = 9.87 + 0.644x_1 + 0.211x_3 \quad (7)$$

From the model above, it can be seen that the phases that most influence the paper thickness are first phase (x_1) namely destruction phase and (x_3) namely press phase.

CONCLUSION

The phases that influence the paper thickness on the recycling process using paper recycling machine are first phase (x_1) namely destruction phase and third phase (x_3) namely press phase. This is reinforced by the data obtained that has fulfilled the error assumption test. So that in producing optimal recycled paper thickness, the phase that needs attention are destruction phase and press phase.

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