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TIME ANALYSIS OF THE MIXING PROCESS OF FIRE BRICK MATERIALS IN PT. BENTENG API TECHNIC GRESIK

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Abstract

PT. Benteng Api Technic is a leading refractory company in Indonesia with refractory bricks as one of its superior products. The process of making refractory bricks that will be observed in this study is the process of mixing materials and the molding process. In the mixing process, there are no tools in the form of time indicators to help operators make decisions about the mixing time of ingredients. This research aims to obtain the time for the mixing of materials with maximum mixing quality and to support the press process optimally. The research was conducted using a perfectly randomized experimental design in order to obtain different mixing results based on the nine selected mixing time treatments. Measurement of working time is carried out using the stopwatch time study method on press operators who are experienced in their fields. Calculations to align the two processes using a Gantt chart with idle time as an indicator. The experimental results revealed that the most optimal mixing with a mixing time of 12 minutes resulted in 7.2 kilograms of mass that did not pass through an 18 mesh sieve. Based on the results of the gantt chart, the use of 11 mixing time for material B resulted in the lowest idle time of 178 minutes. The processing time obtained is expected to be used as a guide in determining the time input on the time indicator tool in the process of mixing refractory bricks.

Keywords: *Mixing Materials, Stopwatch Time Study, Gantt Chart, Experimental Design, Idle Time*

1. INTRODUCTION

Brick is a common building material, however there is a specialized variety known as firebrick that has a strong resistance to flames (Khattab et al., 2021). As a barrier against high temperatures in the combustion chamber or between high temperature manufacturing machinery and the surrounding environment, refractory brick is utilized. Because refractory bricks play a crucial role in the high-temperature production process, the production process of refractory bricks must adhere to the proper procedure. Mixing is the random distribution of materials or particles under specific circumstances and time constraints (Febrianto, 2021). In this study, the author is primarily concerned in the dispersion of the material mixture. Because it is the beginning step in the production of refractory bricks, the even distribution of the mixture during the material mixing process is deemed essential. Two workers employ a mixer machine to combine the materials.

Standard operating procedures, or SOPs, for a firm's production will ensure that every production process runs smoothly if the company has regulated its execution (Rifka, 2017). Standard operating procedures must be explicit in order to give personnel with guidance for carrying out tasks or operating machines during the manufacturing process (Leonardi, 2011). The company has established a standard time of 15 minutes, while the graph below depicts the observation time.

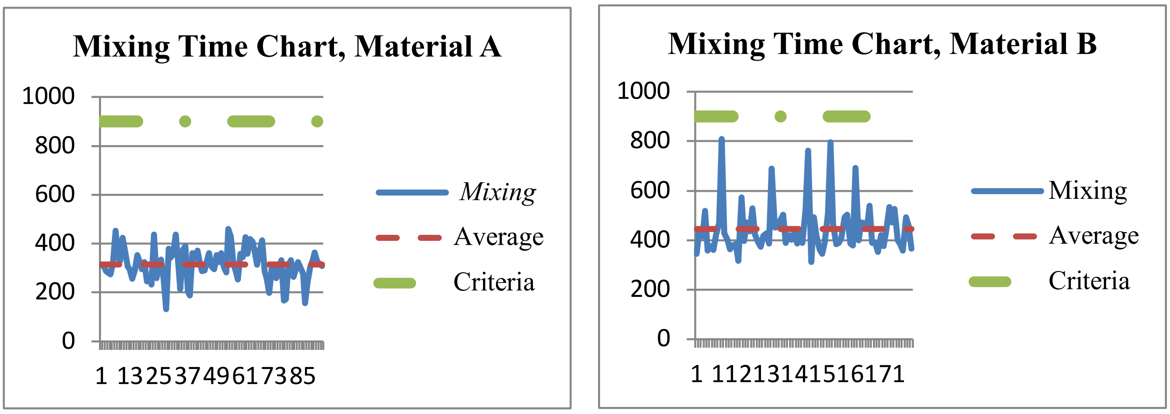

Figure 1 Chart of Mixing Time for Material A and Material B

Figure 2 Condition of Mixing Results of Material A (left) and Material B (right)

The impact of the time instability on the mixing process of ingredient A does not appear to have a certain effect, while in the process of mixing material B, lumps of material arise (Nguyen, 2009). After checking the humidity in the normal mass with the clotted mass, it was found that the clotted mass had higher humidity than the ordinary mass. The clumping mass has a humidity value of 70.4 RH while the ordinary mass has a humidity value of 61.3 RH.

At this time the target set by the company is 1000 bricks per machine, if one stone requires 3.9kg mase and there are 2 press machines, the mass required to meet the target is 7800kg mase. This need is fulfilled by mixing 26 times with a total time of 276.59 minutes or only using 65.8% of the available working time. Therefore, optimization can be done to get results according to production targets with minimal idle time (Asadi & Vahidi, 2010; Ghafoorpoor Yazdi et al., 2019; Montazeri-Gh et al., 2006; Shrouf & Miragliotta, 2015).

Based on the existing problems in the form of using working time that is not optimal and the emergence of lumps in material B, the research objective was set to get the process time for mixing material B with lumps that did not pass the minimum 18 mesh sieve and obtain a process that is in harmony between the mixing process and the press process. So that the research results can be used as a guide in planning and controlling the production of refractory bricks, especially in the process of mixing materials and the press process.

2. RESEARCH METHOD

A stopwatch is an instrument used to collect data on the cycle time of brick printing operators. The sieve is a piece of experimental equipment in the form of a wooden box with an 18-mesh hollow wire that is used to determine the number of lumps created during the treatment of mixing time. Observational data will be recorded and documented using stationary and mobile phones so that Excel can be used for data processing. The flow utilized in this study is as follows:

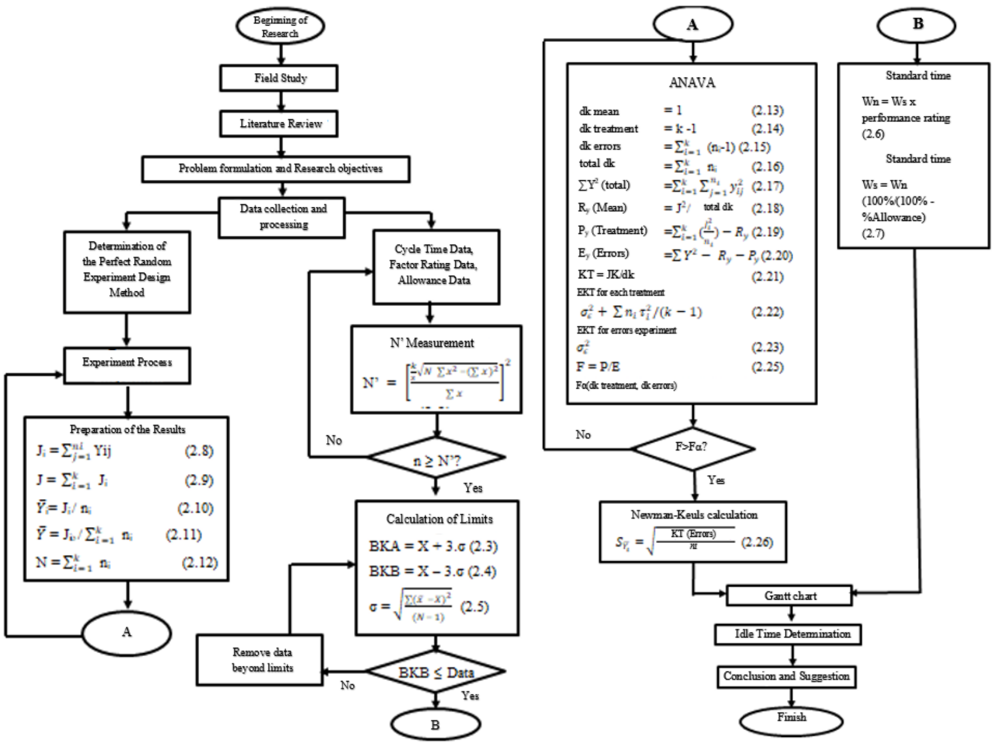

Figure 3 Research Flow

Research activities begin with field studies and literature review to determine appropriate steps to achieve research objectives. Using the stopwatch-time study method as an activity carried out to determine the standard time to complete the work, in which the measurement results will be used as a standard for completing the work ((Wignjosoebroto, 2000) in (Leonardi, 2011)). Using a perfectly randomized experimental design method to examine the impact of the treatment of 9 variations of mixing time on the number of agglomerates that pass through an 18 mesh sieve. Gantt charts are used to simulate the daily production process to determine the length of mixing time which creates the production process with the least idle time (Geraldi & Lechter, 2012; Kumar, 2005; Ong et al., 2016; Seymour & Hussein, 2014).

3. RESULT AND DISCUSSION

3.1. Material A Mixing Process Time

Table 1 Processing Time for Mixing of Material A (seconds)

Observation of-	Pouring ingredients (seconds)	Mixing (second)	Transfer Result (seconds)	Observation of-	Pouring ingredients (seconds)	Mixing (second)	Transfer Result (seconds)
1	150	345	35	30	128	454	42
2	143	438	56	31	134	482	39
3	122	416	37	32	123	503	31
4	230	519	42	33	162	389	50
5	164	358	37	34	137	420	39
6	147	377	38	35	200	401	49
7	252	361	50	36	189	428	52
8	104	421	54	37	137	386	34
9	129	469	48	38	141	430	31
10	162	809	39	39	147	389	35
11	158	427	51	40	132	524	37
12	142	402	32	41	159	762	45
13	169	363	39	42	128	312	39
14	138	379	49	43	151	493	36
15	230	384	57	44	149	418	31
16	126	316	38	45	122	362	29
17	137	572	46	46	127	346	46
18	165	398	41	47	139	392	37
19	170	472	37	48	152	507	36
20	224	435	42	49	196	796	42
21	153	528	32	50	178	463	37
22	126	423	32	51	135	383	45
23	120	392	38	52	138	390	41
24	143	374	35	53	125	410	38
25	169	418	31	54	122	492	57
26	161	429	39	55	128	503	31
27	241	387	41	56	200	386	36
28	205	689	37	57	174	378	30
29	145	451	46	58	152	692	32
59	149	400	42	69	127	439	28
60	132	472	35	70	148	533	41
61	147	469	39	71	154	472	44
62	167	451	31	72	112	526	36
63	124	539	42	73	245	400	40
64	183	389	31	74	123	385	35
65	152	389	35	75	133	359	32
66	149	352	30	76	100	493	45
67	142	421	37	77	210	460	43
68	141	376	32	78	135	365	27

Based on the time of the mixing process for material A, the cycle time of each element is obtained. Cycle time is determined by calculating the average of each work element as follows:

$$\text{Ws} = \frac{\sum xi}{N}$$

Table 2 Mixing Process Cycle Time Material A

Work Element	Cycle Time (seconds)
1	132.4
2	455.3
3	39.1
Total	626.8

After statistical tests were carried out in the form of data adequacy tests and data uniformity tests, there was a change in the cycle time of the mixing process for material A as follows:

Table 3 Cycle Time After Statistical Test of Mixing Process of Material A (seconds)

No.	Work Element	Cycle Time (seconds)	N	N'	BKA	BKB
1	Pouring Ingredients	132.4	78	18.08	174.61	90.16
2	Mixing	425	73	51.4	596.36	254.20
3	Transfer Results	39	78	51.3	60.13	18,10
Total		618				

The calculation of the performance rating and the allowance factor is only used for work elements that involve humans in most processes. Where in the process of mixing material b which is subject to performance rating and the allowance factor is work element 1, namely pouring material. The following is the performance rating table along with the allowance factor:

Table 4 Adjustment Factor

Work Element	Performance Rating	Allowance (%)
1. Pouring Ingredients	+0.11	14.5

The calculation is continued by determining the normal time and standard time for all work elements as follows:

a. Normal Time

$$Wn = Ws \text{ x performance rating}$$

Table 5 Standard Time for Material A Mixing Process

Work Element	Normal Time (seconds)
1	146.94
2	425
3	39
Total	610.94

b. Standard Time

$$Ws = Wn\ (100\% / (100\% - \%Allowance)$$

Table 6 Material A Mixing Process Standard Time

Work Element	Standard Time (seconds)
1	171
2	425
3	39
Total	635

Table 7 Local Work Map of Material A Mixing Process Workers and Machines

Map of Workers and Machinery	
Work	: Mixing Material B
Machine name	: Mixer Machine
Map Number	: 01
Operator Name	: Operator 1, Operator 2
Mapped By	: Andika
Mapping Date	:

Operator 1	Time (Second)		Operator 2	Time (Second)		Machine	Time Seconds	
	Operation	Symbol		Operation	Symbol		Operation	Symbol
Pouring Ingredients	170.5		Pouring Ingredients	170.5		Waiting	170.5	
Wait	425		Waiting	425		Mixing	425	
Open the valve	39		Keeping Control	39		Transfer Results	39	

Time	Work (seconds)	Percentage (%)	idle time (second)	Percentage (%)
Operator 1	209.5	33.06	425	66.94
Operator 2	209.5	33.06	425	66.94
Machine	464	73.08	170.5	26.98

3.2. Material B Press Process Time

Observation of-	Weighing Materials (seconds)	Press (second)	Result Setting (seconds)	Observation of-	Weighing Materials (seconds)	Press (second)	Result Setting (seconds)
1	3.57	15.06	2.56	11	3.31	15.50	3.16
2	3.65	16.02	2.74	12	3.66	14.80	3.25
3	3.12	13.52	3.02	13	3.60	16.22	2.98
4	3.59	15.52	3.1	14	3.91	15.02	3.19
5	3.64	15.36	2.53	15	3.27	16.76	2.32
6	3.25	18.76	2.78	16	4.02	15,10	2.89
7	3.39	15.41	2.43	17	3.92	15.26	2.67
8	3.98	15.52	2.8	18	3.41	15.36	2.35
9	3.26	15,10	2.86	19	3.59	14.58	2.94
10	3.40	15.57	2.99	20	3.67	14.26	3.02

Based on the processing time of press material B, the cycle time of each element is obtained. Cycle time is determined by calculating the average of each work element as follows:

$$Ws = \frac{\sum xi}{N}$$

Table 8 Material B Press Process Cycle Time

Work Element	Cycle Time (seconds)
1	3.56
2	15.44
3	2.83
Total	21.83

After statistical tests were carried out in the form of data adequacy tests and data uniformity tests, there was a change in the cycle time of the press process for material B as follows:

Table 9 Cycle Time After Material B Brick Press Process Statistical Test

No.	Work Element	Cycle Time (seconds)	N	N'	BKA	BKB
1	Weighing Ingredients	3.56	20	8.10	4.32	2.8
2	Press	15.26	19	3.23	17.32	13.2
3	Result Setting	2.83	20	14.75	3.64	2.01
Total		21.65				

Determination of the performance rating and leeway factor for all elements of work as follows:

Table 10 Material B Press Process Adjustment Factor

Work Element	Performance Rating	Allowance (%)
1. Weighing Ingredients	+0.16	10.5
2. Press	+0.09	9.5
3. Result Setting	+0.09	8.5

The calculation is continued by determining the normal time and standard time for all work elements as follows:

a. Normal Time

Wn = Ws x performance rating

Table 11 Normal Time for Pressing Material B

Work Element	Normal Time (seconds)
1	4.12
2	16.63
3	3.01
Total	23.76

b. Standard Time

Work Element 1

Ws = Wn(100% /(100% - %Allowance)

Table 12 Material B Press Process Standard Time

Work Element	Standard Time (seconds)
1	4.61
2	18.46
3	3.28
Total	26.35

Table 13 Local Work Map of Workers and Machines 2 Times Press Process

Map of Workers and Machinery	
Work	: Press
Machine name	: Press machine
Map Number	: 03
Operator Name	: Operator 1, Operator 2, Operator 3
Mapped By	: Andika
Mapping Date	:

<table>
<tr><th rowspan="2">Operator 1</th><th colspan="2">Time (Second)</th><th rowspan="2">Operator 2</th><th colspan="2">Time (Second)</th><th rowspan="2">Operators 3</th><th colspan="2">Time (Second)</th><th rowspan="2">Press machine</th><th colspan="2">Time Seconds</th></tr>
<tr><th>Operation</th><th>Symbol</th><th>Operation</th><th>Symbol</th><th>Operation</th><th>Symbol</th><th>Operation</th><th>Symbol</th></tr>
<tr><td>Weighing</td><td>4.61</td><td></td><td>Waiting</td><td>4.61</td><td></td><td>Waiting</td><td>4.61</td><td></td><td>Wait</td><td>4.61</td><td></td></tr>
<tr><td>Waiting</td><td>2</td><td></td><td rowspan="3">Press</td><td rowspan="3">18.46</td><td rowspan="3">44.81</td><td>Giving paper</td><td>2</td><td></td><td rowspan="3">Press</td><td rowspan="3">18.46</td><td rowspan="3"></td></tr>
<tr><td>Weighing</td><td>4.61</td><td></td><td rowspan="2">Waiting</td><td rowspan="2">16.46</td><td rowspan="2"></td></tr>
<tr><td>Waiting</td><td>11.85</td><td></td></tr>
<tr><td rowspan="3">Waiting</td><td rowspan="3">21.74</td><td rowspan="3"></td><td rowspan="2">Press</td><td rowspan="2">18.46</td><td rowspan="2"></td><td>Result Setting</td><td>3.28</td><td></td><td rowspan="2">Press</td><td rowspan="2">18.46</td><td rowspan="2"></td></tr>
<tr><td>Waiting</td><td>15.18</td><td></td></tr>
<tr><td>Waiting</td><td>3.28</td><td></td><td>Result Setting</td><td>3.28</td><td></td><td>Wait</td><td>3.28</td><td></td></tr>
</table>

Time	Work (seconds)	Percentage (%)	idle time (second)	Percentage (%)
Operator 1	9.22	20.58	35.59	79.42
Operator 2	36.92	82.39	7.89	17.61
Operators 3	8.56	19.11	36.25	80.89
Machine	31.84	82.39	7.89	17.61

3.3. Experiment Results

Table 14 Experimental Results of Many Clumps in the Results of Mixing B Material

	Treatment (minutes)									Amount
	7	8	9	10	11	12	13	14	15	
Observation Data (kg)	15.1	12.6	11	9.6	8.4	7.4	6.1	6.3	6.1	
	14.2	13.2	10	9	7.9	7	6.2	5.9	5.5	
	13.9	12	10.2	9.2	8	7.2	5.9	6	6.4	
Amount	43.2	37.8	31.2	27.8	24.3	21.6	18.2	18.2	18	240.3
Many Observations	3	3	3	3	3	3	3	3	3	27
Mean	14.4	12.6	10.4	9.3	8.1	7.2	6.1	6.1	6	8.9

Observational data will be analyzed for variance and Student Newmans Keuls test to determine the differences caused by each treatment.

3.3.1. ANOVA Test

Table 15 Analysis of Variance of Experimental Results

Source of Variation	dk	JK	KT	EKT	F
Average	1	2138.7	2318.7	–	116.113
Treatment	8	222.96	27.87	$\sigma_\epsilon^2 + \sum n_i \tau_i^2/(k-1)$	
Experiment Error	18	3.02	0.168	σ_ϵ^2	
Amount	27	2364.5	_	_	_

Fα(8,18)= 2,51
F > Fα
116.13 > 2.51

Based on the ANOVA calculation, it can be seen that F > Fα, it is concluded that there is a significant difference caused by the difference in treatment in the experiment. Furthermore, the range test was carried out with the Newman Keuls test.

3.3.2. Newman Keuls Test

Follow-up testing to determine the significance of the difference between treatments using the average of each treatment. The average of each treatment is arranged sequentially from the largest average as follows:

Table 16 The Average Arrangement of Each Treatment

Treatment of	1	2	3	4	5	6	7	8	9
Mixing Time	7	8	9	10	11	12	13	14	15
Average	14.4	12.6	10.4	9.3	8.1	7.2	6.1	6.1	6

Calculation of the average standard error for each treatment:

$$S_{\overline{Y_i}} = \sqrt{\frac{KT\ (Errors)}{ni}}$$
$$= \sqrt{\frac{0{,}168}{3}}$$
$$= \sqrt{0{,}056}$$
$$= 0.24$$

Retrieval of grades from the student range table with
level of significance (α) = 0.05
v = dk error
p = 2,3,... k
k = number of treatments

The range value obtained must be multiplied by the average standard error value for each treatment so that the smallest significant range table is obtained as follows:

Table 17 Smallest Significant Range Arrangement

P	2	3	4	5	6	7	8	9
v	18	18	18	18	18	18	18	18
Range value	3	3.6	3.9	4.3	4.5	4.7	4.8	5
RST	0.72	0.86	0.94	1.03	1.08	1.13	1.15	1.2

The optimal experimental result in this experiment is the last treatment that gets a difference > RST when compared to the smallest average. In the comparison table what is meant is the comparison of numbers. The last comparison that gets a meaningful difference predicate.

3.4. Gantt Chart

The simulation of the working process time between the mixing process and the press process is displayed in the form of a gantt chart to determine which mixing process time should be selected using variations of mixing time (Seymour & Hussein, 2014). The gantt chart is made with the following process requirements:

1) The mixing process time is the time to process 2 times until the mass container box with the mass of material B 600kg
2) Time The mixing process can be separated according to the constituent elements of time if needed.
3) The Processing Time of Press 1 and Press 2 is the same
4) The press processing time is the time to complete 1 box of mase container with a mass of material B 600kg using only 2 work elements.
5) There are 3 preparation times, namely, initial machine preparation for 10 minutes, machine preparation after a break for 5 minutes, preparation for ending production for 15 minutes.

6) There are no production activities at the time of preparation except for the completion of the process at the time of preparation for ending production.
7) The press process can only be started after the mixing process except at the beginning of the production it will be started by using the existing safety stock on the previous day.

The variation of the mixing process time used for material B is the treatment variation listed in the experimental results table, namely 7 minutes, 8 minutes, 9 minutes, 10 minutes, 11 minutes, 12 minutes, and 13 minutes, 14 minutes and 15 minutes.

The recapitulation of mixing time for material B and press time for material B with 9 variations of mixing time used in making the gantt chart is as follows:

Table 18 Processing Time Recapitulation (minutes)

Mixing Time	7	8	9	10	11	12	13	14	15
Material B Mixing Time	21	23	25	27	29	31	32	34	35
Material B Press Time	47	47	47	47	47	47	47	47	47

After making a gantt chart using 9 variations of mixing time, the results obtained in the form of total daily production and total idle time generated for each use of mixing time.

Table 19 Total Results

Mixing Time	**Mixing Process Result (kg**	**First Press Process Results (pcs bricks)**	**Second Press Process Results (pcs bricks)**	**Total Press Process Results (pcs bricks)**
7 minutes	7800	1000	1000	2000
8 minutes	7800	1000	1000	2000
9 minutes	7800	1000	1000	2000
10 minutes	7800	1000	1000	2000
11 minutes	7800	1000	1000	2000
12 minutes	7500	994	918	1912
13 minutes	6900	841	918	1759
14 minutes	6600	805	878	1683
15 minutes	6300	841	765	1606

It can be seen that the total results from the press process cannot meet the press target of 1000 bricks/machine or 2000 bricks for 2 machines if the mixing time exceeds 11 minutes.

Table 20 Total Idle Time

Mixing Time	**idle time Mixing Process (minutes)**	**idle time Process Press 1 (minutes)**	**idle time Process Press 2 (minutes)**	**Total Idle time of Press Process (minutes)**
7 minutes	112	83	83	166
8 minutes	91	83	83	166
9 minutes	60	83	83	166
10 minutes	38.5	83	83	166
11 minutes	12.5	78	87.5	165.5
12 minutes	7	86	108	194
13 minutes	0	131	108	239
14 minutes	0	148	120	268
15 minutes	0	131	155	286

The minimum total idle time when using a mixing time of 11 minutes, the lowest idle time of the press process when using a mixing time of 11 minutes.

4. CONCLUSION

Based on the analysis, it can be concluded as follows:

1. Time changing mixing showed a significant difference in the results of the mixing that did not pass through the 18 mesh sieve. Based on the Newman Keuls test, the mixing time of 12 minutes has a maximum yield of 7.2 kilograms and has a significant difference with the smallest average yield of 6 kilograms.
2. There is a use of time mixing which produces the least idle time in the experiment using 9 variations of mixing time for material B. The use of mixing time of 11 minutes for the mixing process for material B produces the least idle time, which is 178 minutes overall. Mixing time of 11 minutes is the longest mixing time that can produce 2000 units of B bricks.

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