Parameter Optimization of Tray Dryer Machine Endless Chain Pressure (ECP) with Taguchi Method at PT PN VIII Purwakarta

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Keywords: Taguchi Method, Computational Fluid Dynamic, Static Structural, Tray, Stress's score

Abstract: PT. Perkebunan Nusantara is a company that produce black tea. One of the step to make black tea is the process of drying tea leaves to have a water content of 2.5% - 3%. The company use Endless Chain Pressure (ECP) type machine. Inside the ECP machine there is a tray where the tea will be dried. Tray that use today is often broken in certain location. This study goal is to look for factors that affect the broken tray with Taguchi Method. The factors are adjusted to the company’s standard operational procedure in order to maintain the product. The factors use are drying time, inlet temperature, and inlet velocity. Base on orthogonal array L₁₆(4³) so that the experiment was obtained 16 times. Each experiment was conducted twice, Computational Fluid Dynamic (CFD) and Static Structural. The experiment result be analyze using S/N Ratio smaller the better and ANOVA. It is known that the optimum factor for tea drying machine tray are time level 1 at 1200s; inlet temperature level 1 at 369.25K, and inlet velocity at 16m/s and 24m/s with stress's score 485.32 MPa. The ANOVA test results showed a significant factor in this study is inlet temperature with P-value close to zero but not zero.

Introduction

The process of making black tea at PT. PN VIII Purwakarta start from picking tea leaves, withering, grinding, enzymatic oxidation, drying, sorting, packing, and storing. To calculate production capacity, the indicator use is the output of tea drying machine. PT. PN VIII Purwakarta use Endless Chain Pressure ECP) type machine with actual capacity 200 – 250 kg/hour. Base on interview at tea drying work station the problem that often occurs is the broken tray. This case causes a bottleneck in the tea drying process. Bottleneck is obstructed tea to exit from ECP dryer machine. Broken tray cannot be separated by stress factors from the material used because it can change the micro arrangement of the tray geometry [6]. So this study will optimize the ECP drying machine parameters to maximize tray performance using Taguchi Method by analyzing the stress’s score.

Fig. 1 (a) Dryer Tray, (b) Broken Tray Dryer
Experimental Design Method

This research uses experiments to achieve the goal. The experimental process is done using simulation with computer-aided engineering (CAE) software, making it more effective and efficient. Experiment must be prepared well because results and conclusions very much depend on how data is collected [4].

Computational Fluid Dynamics (CFD)

Computational Fluid Dynamics (CFD) is a system analysis that involves fluid flow, heat transfer, and related phenomena such as chemical reactions through computer-based simulation [7]. This is chosen because in existing circumstances, a given air flow, certain temperature at the same time.

Static Structural

This simulation was conducted to find out and analyze the micro and macro structures of the geometry and tray material. Computer-aided design is very important for modern structural analysis [1].
Taguchi Method

The Taguchi method is an approach to product realization activities that focus on selecting the level of factors that can be controlled in a process or production to achieve two objectives, first to ensure that the average response output is at the desired level or target and the second is that variability around the target value is as small as possible [4].

Identification Factors and Levels

The number of levels for experiment is determined by the researcher. The more levels used, the more accurate the results of this study. This research user 3 factors and 4 levels on each factor.

| Factor   | Description          | Level 1 | Level 2 | Level 3 | Level 4 |
|----------|----------------------|---------|---------|---------|---------|
| A        | Time (s)             | 1200    | 1300    | 1400    | 1500    |
| B        | Inlet Temperature (K)| 369.25  | 373.85  | 378.55  | 383.15  |
| C        | Inlet Velocity (m/s) | 12      | 16      | 20      | 24      |

Orthogonal Array

Orthogonal array design determine after factors and levels are identified. The purpose of this design determines the number of experiment and scenario use in each experiment. With Taguchi Method obtained orthogonal array L16 (4^3) so, this study will be done after doing 16 times experiment.

| Experiment | Factor A | Factor B | Factor C |
|------------|----------|----------|----------|
| 1          | 1        | 1        | 1        |
| 2          | 1        | 2        | 2        |
| 3          | 1        | 3        | 3        |
| 4          | 1        | 4        | 4        |
| 5          | 2        | 1        | 2        |
| 6          | 2        | 2        | 1        |
| 7          | 2        | 3        | 4        |
| 8          | 2        | 4        | 3        |
| 9          | 3        | 1        | 3        |
| 10         | 3        | 2        | 4        |
| 11         | 3        | 3        | 1        |
| 12         | 3        | 4        | 2        |
| 13         | 4        | 1        | 4        |
| 14         | 4        | 2        | 3        |
| 15         | 4        | 3        | 2        |
| 16         | 4        | 4        | 1        |

Experiment Implementation

The number of experiments and input factors is obtained from the previous step in orthogonal array design, this study use tray as an object experiment.
The material used for this experiment is AISI 1045. Because the existing condition in PT.PN VIII use this material.

Table 3. Material Properties AISI 1045 [2]

| No. | Property                                           | Value        | Unit  |
|-----|---------------------------------------------------|--------------|-------|
| 1   | Density                                           | 7.850        | Kgm-3 |
| 2   | Isotopic Instantaneous Coefficient of Thermal Expansion | 1.15E-05     | C^-1  |
| 3   | Young’s Modulus                                   | 2.05E+05     | Mpa   |
| 4   | Poisson’s Ratio                                   | 0.29         |       |
| 5   | Bulk Modulus                                      | 1.627E+05    | MPa   |
| 6   | Shear Modulus                                     | 7.9457E+04   | MPa   |
| 7   | Specific Heat                                     | 470          | J/Kg-K|
| 8   | Thermal Conductivity                              | 51           | W/m-K |

The implementation of this experiment uses 2 simulations in the CAE software. First step is Computational fluid dynamic to input the factor time, inlet temperature, and outlet temperature, second step is structural statistic to find out how stress’s score is receive by tray on the treatment that has been determined according to the scenario.

![Fig. 5 Experiment flow](image)

**S/N Ratios**

In this study the quality characteristics use is “smaller is the best” because, the better quality of the tray can get

\[
S/N \text{ Ratio Smaller the Better} = -10 \log_{10} \left( \frac{\sum_{i=1}^{n} x_i(j)^2}{n} \right) \hspace{1cm} (1)
\]

Eq. 1 S/N Ratio Smaller the Better [3]

**Result and Discussion**

**Simulation Result**

Experimental results were obtained from the CAE simulation process CFD and structural statistic according to the scenario that has been designed in an orthogonal array. The output for this experiment is stress’s score when tray is use.
| Experiment | Maximum Stress (MPa) |
|------------|---------------------|
| 1          | 485.32              |
| 2          | 503.19              |
| 3          | 546.23              |
| 4          | 562.65              |
| 5          | 485.32              |
| 6          | 515.44              |
| 7          | 546.23              |
| 8          | 576.35              |
| 9          | 485.32              |
| 10         | 515.44              |
| 11         | 546.23              |
| 12         | 576.35              |
| 13         | 485.32              |
| 14         | 515.44              |
| 15         | 546.23              |
| 16         | 576.35              |

**S/N Ratio Stress Respond for Influence Factor**

This step to determine the optimum value of each tray factors use during the experiment.

| Level | Time  | Inlet Temperature | Inlet Velocity |
|-------|-------|-------------------|----------------|
| 1     | -54,38| -53,72            | -54,48         |
| 2     | -54,48| -54,19            | -54,43         |
| 3     | -54,48| -54,75            | -54,48         |
| 4     | -54,48| -55,16            | -54,43         |

Delta |Δ| 0,10 | 1,44 | 0,05

Rank 2 1 3
In this graph the optimum factor is indicated by the highest point on each factor [5], therefore it can be concluded that the optimum factor for time level 1 with equal to 1200s, inlet temperature level 1 equal to 369.25K and inlet velocity level 2 and level 4 equal to 16m/s and 24m/s.

Analysis of Variances (ANOVA)

ANOVA test use to find out the significant factors in this study.

| Table. 6. ANOVA          |
|-------------------------|
| Faktor                 | DF | F-Value | P-Value |
| Time                   | 3  | 1.67    | 0.271   |
| Inlet Temperature      | 3  | 72.79   | 0.000   |
| Inlet Velocity         | 3  | 1.38    | 0.336   |

it is known that factor time and inlet velocity sequentially have P-Value 0.271 and 0.336 because P-Value more than 0.05 so, these two factors have not a significant effect on this research. While inlet temperature factor has P-Value close to zero but not zero, because P-Value less than 0.05 this factor is significant effect against the stress’s score.

Conclusion

Based on the results of data processing and analysis above, so the conclusion of this study is optimum factor setting tray tea drying machine for time level 1 at 1200s; inlet temperature level 1 at 369.25K and inlet velocity level 2 and level 4 equal to 16m/s and 24m/s. Inlet temperature factor have P-
Value 0.000, because P-Value less than 0.05 this factor is significant effect against the stress’s score. Optimum settings can be used as a consideration for the process of setting in tea drying machine to get long life time product.

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