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# Optimization of the cyclone separator performance using taguchi method and multi-response pcr-topsis

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ABSTRACT

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Pollutant control uses cyclone separators as pre-cleaners and is widely used in manufacturing and mining industries. Research on cyclone performance is carried out with changes in various variations that affect it, the problem that occurs is that multi-response can give results of different factors and levels as a result of equipment design cannot provide optimal results and research topics on inlet scroll types have not been widely carried out, this study aims to improve cyclone performance inlet scroll type separator with helical angle, experimental and development methods to get optimal performance where pressure drop and efficiency are indications of cyclone separator performance, to get optimal performance the use of Taguchi experimental design produces different factors and levels so that multi-response methods such as PCR and TOPSIS was used to produce the best combination of factors and levels, confirmation experiments and computational fluid dynamics (CFD) methods were carried out to ensure the validity of the study, the results showed that the scroll inlet prototype cyclone separator with a helical angle of $15^0$, inlet velocity of 10m/s, outlet diameter of 72 mm provides empirical values for pressure drop and the best particle separation efficiency for multi-parameter responses, further research can be done by modifying the shape and dimensions of the bottom outlet.



## INTRODUCTION

Cyclone separator is part of a pollution control system with extensive use, the increase in cyclone performance is influenced by particle cut diameter, pressure drop, and collection efficiency. This performance is influenced by dimensions, flow velocity, particle size, particle density, design, and cyclone type. Research that improving cyclone performance is generally carried out by changing the dimensions of certain parts [1], changing the number of inlets [2], changing the inlet slope [3], changing the length of the cyclone cone [4] [5], adding spray water [6], dust outlet geometry effect [7], comparing with stair and design [8], using statistical methods [9], artificial neural network [10], response surface [11], and Taguchi method [12]. Using the

Taguchi method, the optimal response is obtained according to the type of signal-to-noise ratio, so responses such as pressure drop and collecting efficiency produce different factor values and levels. To accommodate multiple responses of the Taguchi method in improving cyclone performance, the process capability ratio (PCR) [13] and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [14] [15] methods were employed. Therefore, the results obtained were a combination of factors and levels that represented many parameters.

Cyclone separator or turbo cyclone is part of the pre-cleaner, which separates the initial particles into relatively large sizes with a particle size range of 5 µm to 1000 µm [16]. These characteristics make cyclone separators widely used in various industrial fields such as food processing, mining materials, manufacturing, gas, and oil. The three main styles of cyclone separator performance parameters, namely cut diameter, pressure drop, and collection efficiency [17], became the focus of research in air pollution control and, therefore, the development of supporting equipment. This is often done due to the complexity of the parameters that affect the performance and requirements of particulate control equipment under specific conditions; thus, the design of the cyclone separator is always guided by the conditions under which will be used, such as particle size, working temperature, duration of operation, ease of maintenance, availability of energy and type of industry.

Various techniques and methods were administrated to improve the performance of cyclone separators, such as the Venkatesh study where the performance of multi Cyclone Separators with series and parallel installation using experimental methods and Computational Fluid Dynamics, the pressure drop predicted in the experimental and numerical analysis were 153 N/m$^2$ and 146.46 N/m$^2$ with good efficiency for a particle size of 7 µm in series and parallel [18].

The Taguchi method and Computational Fluid Mechanics (CFD) are used to optimizing the pressure drop by calculating the pressure drop in several variations of the Cyclone geometry dimension. It is as the basis for the experimental design to obtain the ratio of the dimensions of the Cyclone Separator. The results obtained are that the new design is better than the Stairmand model [12], the analysis of the separation structure was optimized by the Taguchi method. An orthogonal relationship is defined. The optimal solution is achieved by calculating the weight relationship. The calculated optimal structure is evaluated using Signal to noise (SNR). 2 responses in the form of speed and pressure have the same optimal combination, namely A2-B2-C2. The results show that the SNR value in the case is eligible. Research on separators shows benefits and an improved method for optimizing design parameters [9].

The Taguchi method was used to improve the efficiency of pressure drop and particle selection. Process parameters were analyzed on cone height with variations (300mm, 340mm, and 390 mm), inlet height (123mm, 153mm, and 173 mm), outlet height (80mm, 90mm, and 100 mm), and pipe length (450mm, 470mm, and 490mm). Taguchi orthogonal arrays and signal-to-noise ratio are used to find the optimal level and analyze the effect of design parameters on pressure drop and efficiency values. The combination of factors and optimal levels with multi-response[19] is obtained from the value of SNR large is better. SNR Smaller is better. The optimal combination shows the difference in the level of each completion factor is carried out using the Minitab software. The confirmation test with the optimal test parameters is carried out to verify the effectiveness. The results reveal that the main factors affecting pressure drop and efficiency are inlet height, followed by tube height, pipe length, and outlet height. The lowest pressure loss and highest efficiency are achieved according to cone height: 300 mm, inlet height: 153 mm, outlet height: 100, and pipe length: 490 mm [20].

Orthogonal L16 was used in the experiment. The Taguchi method integration with Gray Relational Analysis was used as a performance index in analyzing the response. The parameters used were vortex finder diameter (VFD) and spigot diameter (SPD). Three different SNR parameters were normalized by the gray-relational-analysis method so that can provide a new SNR response to determine the optimal value. The results of the analysis of the two confirmatory experiments carried out on the optimal combination of parameters confirm that performance can be effectively improved through this approach [21].


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Novelty opportunities in cyclone performance improvement research can be done by changing the design outlet dimensions, changing the shape of the tangential inlet to scroll inlet, by adding a helical angle to a specific value, changing the inlet flow velocity. Then, adding the Taguchi method with PCR [22] and TOPSIS [23], [24] is to complete multi-response collection efficiency and pressure drop. These changes were chosen to facilitate the experimental process based on orthogonal arrays.

## METHOD

Experimental and development methods were used to conduct this research (See Figure 1). The research was conducted at the Mechanical Engineering Laboratory of Hasanuddin University between September 2020 to February 2021. Digital manometers, anemometers, scales, vacuum pumps are the equipment used. The design and manufacture of cyclones are carried out according to the factors and levels. The Taguchi method was chosen to minimize the process with good results, combining PCR and TOPSIS to produce optimal values representing different SNR values. The cyclone design process uses several drawing software such as Autodesk Fusion 360, solid works, space clime, and Auto Cad. The cyclone is made separately to support the Taguchi method in getting the response value. It can be assembled and disassembled, and the 3D design results are made with detailed dimensions with the fabrication process.

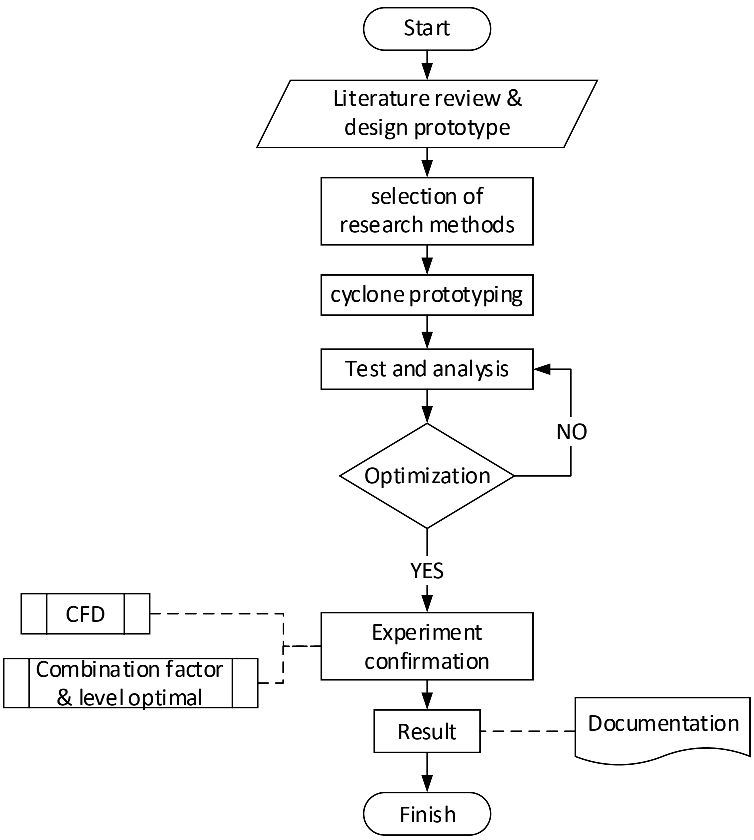


Figure 1. Flow chart research

### 1. Installation Experiment

The experimental installation is shown in Figure 2, where the process is carried out to obtain response data for each run according to the orthogonal array, the flow speed adjustment is carried out by adjusting the valve openings (V3) and Valve (V4), helical inlet angles of $5^0$,

$10^0$, and $15^0$ are obtained by replacing the primary cyclone, as well as the outlet diameters of 45 mm, 57 mm, and 72 mm, the anemometer measurement results in the measurement area are converted to determine the actual flow velocity at the inlet. The test particles used were corn cob powder with a mesh size of 18, particle weight measurements were carried out before and after the separation process in the cyclone, Eq.1 is used in determining efficiency.

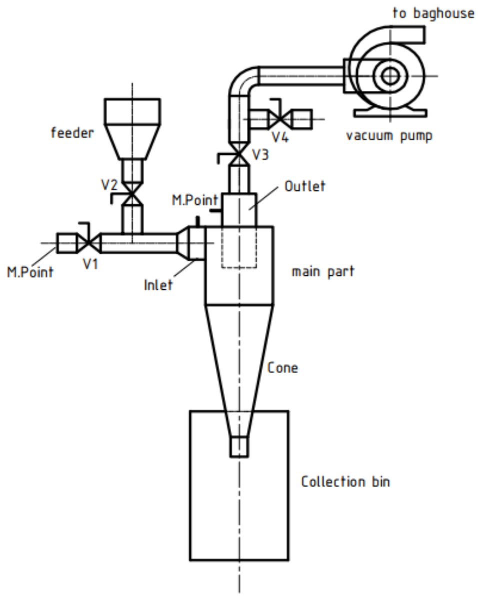


Figure 2. Installation of experiment

$$Efficiency = \frac{Trapped}{Tracked} \times 100\% \quad (1)$$

## 2. Design of Experiment

Design of experiment Taguchi uses the level and factor design orthogonal arrays as a guide for conducting experiments to maximize the process. Table 1 presents a combination of orthogonal array L9 (33) used to determine the effect of inlet flow velocity, outlet diameter, and the helical angle of the inlet channel on the cyclone separator. The factors and levels are set according to Table 2 by entering the factor values and levels in Table 1. The experimental response values will be analyzed using a signal-to-noise ratio. Large is better on response efficiency, and small is better on response pressure drop. Variance analysis is carried out to determine the effect of each factor in determining the optimal level by adding PCR and TOPSIS optimum value of factors and levels that can represent the two different SNR.

Table 1. Orthogonal array $L_9$

| Run | A | B | C |
|---|---|---|---|
| **1** | 1 | 1 | 1 |
| **2** | 1 | 2 | 2 |
| **3** | 1 | 3 | 3 |
| **4** | 2 | 1 | 2 |
| **5** | 2 | 2 | 3 |
| **6** | 2 | 3 | 1 |
| **7** | 3 | 1 | 3 |
| **8** | 3 | 2 | 1 |
| **9** | 3 | 3 | 2 |

 10.12198/ijio.v3i1.4272

Table 2. Factor and level experiment

| No | Factor | Level | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1. | (A) Inlet velocity (m/s) | 10 | 13 | 16 |
| 2. | (B) Diameter Outlet Cyclone (mm) | 45 | 57 | 72 |
| 3. | (C) Helical angle | 5 | 10 | 15 |

The trial resulted in a response in pressure drop and collection efficiency with three replications each. The average replication was used to calculate the SNR value of large is better Eq. 2. Smaller is better Eq. 3, the average value of SNR Eq. 4, the standard deviation of Eq. 5, PCR value Eq. 6, the ideal positive solution Eq. 7, the ideal solution of negative Eq. 8, TOPSIS value Eq. 9, analysis of variance is used to determine the effect of each factor and level on the TOPSIS value.

$$\eta = -10\,log\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y^2}\right] \quad (2)$$

$$\eta = -10\,log\left[\frac{1}{n}\sum_{i=1}^{n}y^2\right] \quad (3)$$

$$\bar{X}_{\eta j} = \frac{\sum_{i=1}^{m}\eta_j^i}{m-1} \quad (4)$$

$$S_{nj} = \sqrt{\frac{\sum_{i=1}^{m}\left(\eta_j^i - \bar{X}_{\eta j}\right)^2}{m-1}} \quad (5)$$

$$C_j^i = \frac{\eta_j^i - \bar{X}_{\eta j}}{3S_{\eta j}} \quad (6)$$

$$d^{i+} = \sqrt{\sum_{j=1}^{n}\left(C_j^i - C_j^+\right)^2} \quad (7)$$

$$d^{i-} = \sqrt{\sum_{j=1}^{n}\left(C_j^i - C_j^-\right)^2} \quad (8)$$

$$S^i = \frac{d^{i-}}{d^{i+} + d^{i-}} \quad (9)$$

## RESULTS AND DISCUSSION

In this section, the initial process is carried out by designing a cyclone separator by changing the ratio on a standard cyclone or determining the dimensions directly. The barrel diameter dimension cyclone (Dc) is based on the calculation of the inlet cross-sectional area, and the velocity range of 6-20 m/s obtained a susceptible diameter of 0.333 m to 0.1 m, and a diameter of 150 mm was chosen as the Dc diameter. The design dimensions can be seen in

Figure 3 which the dimensions other than Dc are obtained from the modification ratio in Table 3 [25]. The process of making a cyclone with several different parts is carried out according to the factors and levels in the Taguchi method.

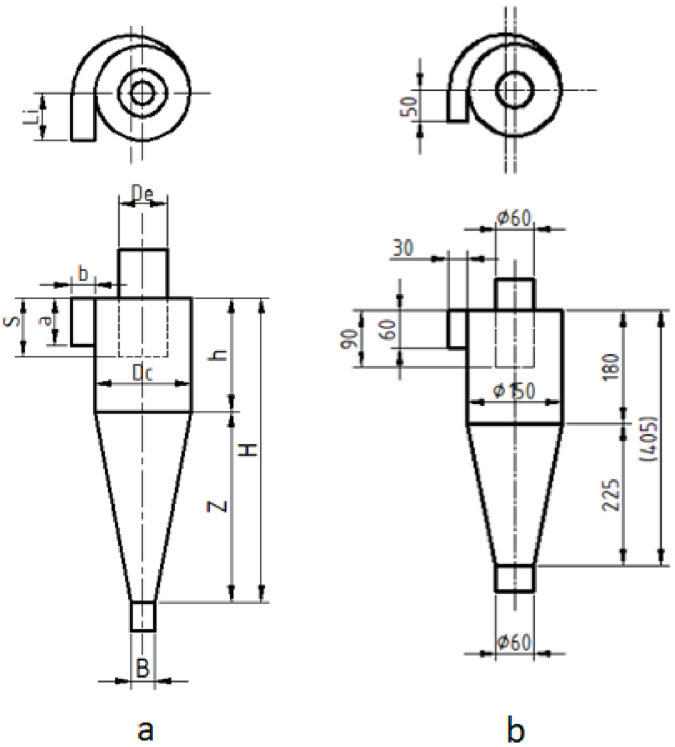


Figure 3. Cyclone separator: a) standard symbol and b) modified cyclone

Table 3. Standard dimension and modification

| Family | Lapple (1951) | Swift (1969) | Stairmand (1951) | Swift (1969) | Stairmand (1951) | Swift (1969) | Modify |
|---|---|---|---|---|---|---|---|
| **Use** | **General-purpose** | **General-purpose** | **High Efficiency** | **High Efficiency** | **High flow rate** | **High flow rate** | **ratio** |
| **Dimension** | **1** | **2** | **3** | **4** | **5** | **6** | |
| *a/Dc* | 0.5 | 0.5 | 0.5 | 0.44 | 0.75 | 0.8 | 0.4 |
| *b/Dc* | 0.25 | 0.25 | 0.2 | 0.21 | 0.375 | 0.35 | 0.2 |
| *H/Dc* | 4.0 | 3.75 | 4.0 | 3.9 | 4.0 | 3.7 | 2.7 |
| *h/Dc* | 2.0 | 1.75 | 1.5 | 1.4 | 1.5 | 1.7 | 1.2 |
| *De/Dc* | 0.5 | 0.5 | 0.5 | 0.4 | 0.75 | 0.75 | 0.4 |
| *B/Dc* | 0.25 | 0.4 | 0.375 | 0.4 | 0.375 | 0.4 | 0.4 |
| *S/Dc* | 0.625 | 0.6 | 0.5 | 0.5 | 0.875 | 0.85 | 0.6 |
| *ΔH* | 8.0 | 7.6 | 6.4 | 9.2 | 7.2 | 7.0 | - |
| *Z/Dc* | 2 | 2 | 2.5 | 2.5 | 2.5 | 2 | 1.5 |

## 1. Optimization by Taguchi Method

The optimization process is a step to improve quality according to certain specifications. The Taguchi method is carried out starting from the planning process by involving a minimum of resources, setting the variation of factors, determining the level to get a response as an ingredient in determining the optimal combination [26].


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## 2. Experiment Response

Retrieval of response data according to the combination in Table 4 by adding a response column, then the results of the pressure drop measurement (response 1) and efficiency measurement (response 2) obtained from particle weight measurements and calculations with Eq. 1, the response value can be seen in Table 4 below.

Table 4. Experiment response

| Run | Factor | | | Response 1 (mbar) | | | | Response 2 (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | 1 | 2 | 3 | Avg. | 1 | 2 | 3 | Avg. |
| 1 | 10 | 45 | 5 | 0.4 | 0.6 | 0.6 | 0.5 | 99.71 | 99.43 | 99.86 | 99.67 |
| 2 | 10 | 57 | 10 | 0.7 | 0.6 | 0.6 | 0.6 | 99.86 | 99.86 | 99.86 | 99.86 |
| 3 | 10 | 72 | 15 | 0.8 | 0.6 | 0.6 | 0.7 | 99.86 | 99.86 | 99.71 | 99.81 |
| 4 | 13 | 45 | 10 | 0.5 | 0.4 | 0.5 | 0.5 | 99.00 | 99.43 | 99.00 | 99.14 |
| 5 | 13 | 57 | 15 | 0.7 | 0.8 | 0.9 | 0.8 | 99.86 | 99.86 | 99.86 | 99.86 |
| 6 | 13 | 72 | 5 | 0.3 | 0.3 | 0.3 | 0.3 | 99.14 | 98.86 | 98.86 | 98.95 |
| 7 | 16 | 45 | 15 | 0.9 | 0.8 | 0.9 | 0.9 | 99.86 | 99.86 | 98.86 | 99.52 |
| 8 | 16 | 57 | 5 | 0.3 | 0.4 | 0.3 | 0.3 | 99.71 | 99.86 | 98.86 | 99.48 |
| 9 | 16 | 72 | 10 | 0.3 | 0.3 | 0.3 | 0.3 | 99.43 | 99.86 | 98.86 | 99.38 |

## 3. Signal to Noise Ratio

The value of SNR can be obtained using Eq. 2 and 3 as shown in Table 5 and all calculations of SNR can be seen in Table 6.

Table 5. The example of calculation of SNR value

| SNR response 1 on run 1 | SNR response 2 on run 1 |
|---|---|
| Smaller is better: | Large is better |
| $\eta = -10log\left[\frac{1}{n}\sum_{i=1}^{n} y^2\right]$ | $\eta = -10log\left[\frac{1}{n}\sum_{i=1}^{n} \frac{1}{y^2}\right]$ |
| $\eta = -10log\left[\frac{1}{3}(0{,}4^2 + 0{,}6^2 + 0{,}6^2)\right]$ | $\eta = -10log\left[\frac{1}{3}\left(\frac{1}{99{,}71^2}\right) + \left(\frac{1}{99{,}43^2}\right) + \left(\frac{1}{99{,}86^2}\right)\right]$ |
| $\eta = 5.326$ | $\eta = 39{,}97$ |

The factor and level values in the equation above are obtained from the average combination of each factor and level according to Table 6. The smaller is better SNR or pressure drop produces the optimal combination of A3-B3-C1 (150-72mm-10m/s). In comparison, the large SNR is better. The optimal combination is A1-B2-C3 (50-57mm-16m/s). This can also be seen in Figure 4 and Table 7, with the difference required combining methods with PCR and TOPSIS.

Table 6. SNR 1 and SNR 2

| Run | Factor | | | Response 1 | | Response 2 | |
|---|---|---|---|---|---|---|---|
| | A | B | C | Avg. | SNR1 | Avg. | SNR2 |
| 1 | 10 | 45 | 5 | 0.5 | 5.33 | 99.67 | 39.97 |
| 2 | 10 | 57 | 10 | 0.6 | 3.94 | 99.86 | 39.99 |
| 3 | 10 | 72 | 15 | 0.7 | 3.44 | 99.81 | 39.98 |
| 4 | 13 | 45 | 10 | 0.5 | 6.58 | 99.14 | 39.93 |
| 5 | 13 | 57 | 15 | 0.8 | 1.89 | 99.86 | 39.99 |

| Run | Factor | | | Response 1 | | Response 2 | |
|---|---|---|---|---|---|---|---|
| | A | B | C | Avg. | SNR1 | Avg. | SNR2 |
| 6 | 13 | 72 | 5 | 0.3 | 10.46 | 98.95 | 39.91 |
| 7 | 16 | 45 | 15 | 0.9 | 1.23 | 99.52 | 39.96 |
| 8 | 16 | 57 | 5 | 0.3 | 9.46 | 99.48 | 39.95 |
| 9 | 16 | 72 | 10 | 0.3 | 10.46 | 99.38 | 39.95 |

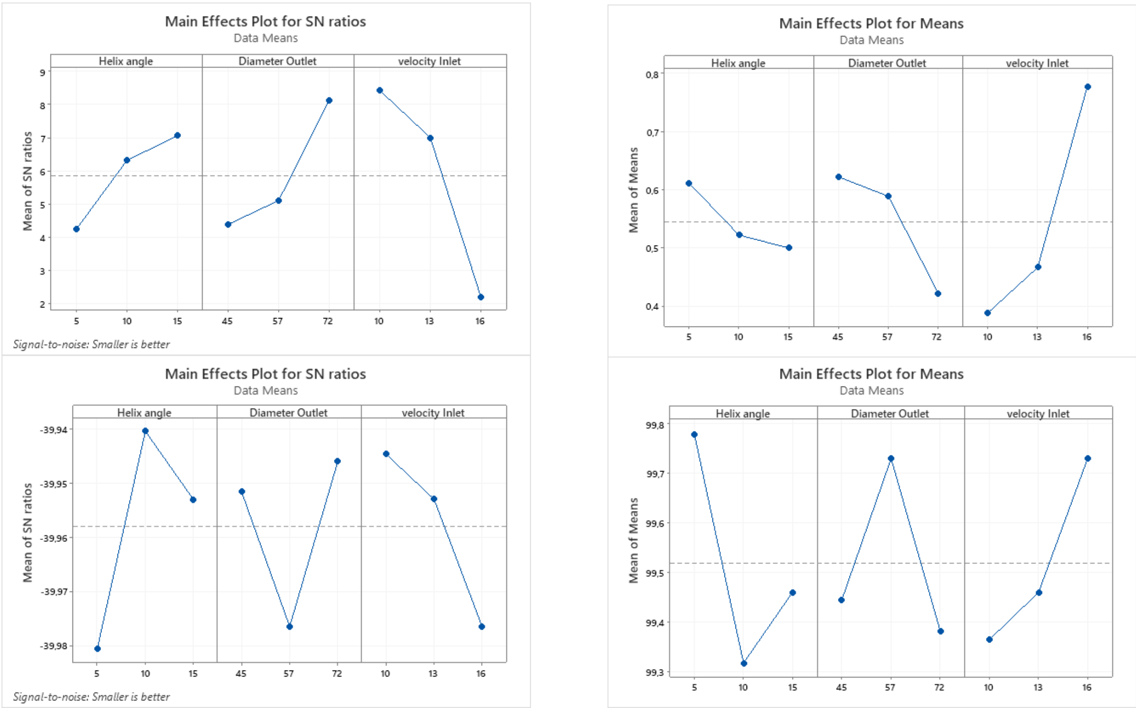


Figure 4. SNR and means response graph (smaller the better and larger the better)

Table 7. Response table for the signal-noise ratio and response table for means

Smaller is better

| Level | Helix angle | Diameter Outlet | Velocity Inlet | Level | Helix angle | Diameter Outlet | Velocity Inlet |
|---|---|---|---|---|---|---|---|
| 1 | 4.235 | 4.377 | 8.413 | 1 | 0.6111 | 0.6222 | 0.3889 |
| 2 | 6.309 | 5.098 | 6.992 | 2 | 0.5222 | 0.5889 | 0.4667 |
| 3 | 7.048 | 8.117 | 2.186 | 3 | 0.5000 | 0.4222 | 0.7778 |
| Delta | 2.813 | 3.740 | 6.227 | Delta | 0.1111 | 0.2000 | 0.3889 |
| Rank | 3 | 2 | 1 | Rank | 3 | 2 | 1 |

Larger is better

| Level | Helix angle | Diameter Outlet | Velocity Inlet | Level | Helix angle | Diameter Outlet | Velocity Inlet |
|---|---|---|---|---|---|---|---|
| 1 | 39.98 | 39.95 | 39.94 | 1 | 99.78 | 99.44 | 99.37 |
| 2 | 39.94 | 39.98 | 39.95 | 2 | 99.32 | 99.73 | 99.46 |
| 3 | 39.95 | 39.95 | 39.98 | 3 | 99.46 | 99.38 | 99.73 |
| Delta | 0.04 | 0.03 | 0.03 | Delta | 0.46 | 0.35 | 0.37 |
| Rank | 1 | 3 | 2 | Rank | 1 | 3 | 2 |

## 4. PCR and TOPSIS Method

Changes in SNR (SNR 1 and SNR2) to PCR-SNR are carried out by calculating using Eq. 4, 5, and 6. Table 8 shows the results of calculating these changes, while the calculation of

 10.12198/ijio.v3i1.4272

TOPSIS values uses Eq. 7, 8, and 9. Then, Table 9 presents the results of the calculations. PCR-TOPSIS values represent both SNR.

Table 8. PCR-SNR Transform

| Run | Factor | | | Pressure drops | Efficiency | PCR-SNR | |
|---|---|---|---|---|---|---|---|
| | A | B | C | SNR1 | SNR2 | PCR-SNR1 | PCR-SNR2 |
| 1 | 5 | 45 | 10 | 5.33 | 39.97 | -0.115 | -0.314 |
| 2 | 5 | 57 | 13 | 3.94 | 39.99 | -0.242 | -0.312 |
| 3 | 5 | 72 | 16 | 3.44 | 39.98 | -0.287 | -0.313 |
| 4 | 10 | 45 | 13 | 6.58 | 39.93 | -0.002 | -0.316 |
| 5 | 10 | 57 | 16 | 1.89 | 39.99 | -0.428 | -0.312 |
| 6 | 10 | 72 | 10 | 10.46 | 39.91 | 0.351 | -0.317 |
| 7 | 15 | 45 | 16 | 1.23 | 39.96 | -0.488 | -0.314 |
| 8 | 15 | 57 | 10 | 9.46 | 39.95 | 0.260 | -0.315 |
| 9 | 15 | 72 | 13 | 10.46 | 39.95 | 0.351 | -0.315 |

Table 9. PCR- TOPSIS

| PCR-SNR | | di+ | di- | PCR-TOPSIS (Si) |
|---|---|---|---|---|
| PCR-SNR1 | PCR-SNR2 | | | |
| **-0.115** | -0.314 | 0.466 | 0.373 | 0.444 |
| **-0.242** | -0.312 | 0.592 | 0.246 | 0.294 |
| **-0.287** | -0.313 | 0.638 | 0.201 | 0.239 |
| **-0.002** | -0.316 | 0.353 | 0.486 | 0.580 |
| **-0.428** | -0.312 | 0.779 | 0.060 | 0.072 |
| **0.351** | -0.317 | 0.005 | 0.839 | 0.994 |
| **-0.488** | -0.314 | 0.839 | 0.003 | 0.004 |
| **0.260** | -0.315 | 0.091 | 0.748 | 0.892 |
| **0.351** | -0.315 | 0.003 | 0.839 | 0.997 |

The contribution of each factor is based on the PCR-TOPSIS calculation, then an analysis of variance (ANOVA) was carried out as shown in Table 10. This analysis also determines the interaction of factors on the PCR-TOPSIS response. The results of the ANOVA analysis can be seen in Table 10, at the value of = 0.05, the inlet flow velocity factor has a significant effect <0.05 while the Outlet diameter and the effect of helical angle with a value of > 0.05 then the two factors are not significant, percent contribution of each helical angle factor = 12.51%, outlet diameter = 22.78%, inlet velocity = 62.26%

Table 10. Anova response PCR-TOPSIS

| Source | DF | Adj SS | Adj MS | F-Value | P-Value | Contribution (%) |
|---|---|---|---|---|---|---|
| Helix angle | 2 | 0.14939 | 0.07470 | 5.09 | 0.164 | 12.51% |
| Diameter Outlet | 2 | 0.27194 | 0.13597 | 9.27 | 0.097 | 22.78% |
| Velocity inlet | 2 | 0.74335 | 0.37167 | 25.34 | 0.038 | 62.26% |
| Error | 2 | 0.02933 | 0.01467 | | | 2.46% |
| Total | 8 | 1.19401 | | | | |

Table 11 shows the recapitulation of the PCR-TOPSIS calculation results. The value of the combination of factors and the optimum level can be known by calculating the average value of each factor and the level based on the PCR-TOPSIS value. Average value of factor A level 1 and C level 3 as below.

$$A1 = \frac{(0{,}444 + 0{,}294 + 0{,}239)}{3} = 0{,}326$$
$$C3 = \frac{(0{,}239 + 0{,}072 + 0{,}004)}{3} = 0{,}105$$

Table 11. Recapitulation PCR-TOPSIS

| Run | Factor | | | PCR-SNR | | di+ | di- | PCR-TOPSIS (Si) |
|---|---|---|---|---|---|---|---|---|
| | Helix angle | Diameter Outlet | Velocity inlet | PCR-SNR1 | PCR-SNR2 | | | |
| 1 | 5 | 45 | 10 | -0.115 | -0.314 | 0.466 | 0.373 | 0.444 |
| 2 | 5 | 57 | 13 | -0.242 | -0.312 | 0.592 | 0.246 | 0.294 |
| 3 | 5 | 72 | 16 | -0.287 | -0.313 | 0.638 | 0.201 | 0.239 |
| 4 | 10 | 45 | 13 | -0.002 | -0.316 | 0.353 | 0.486 | 0.580 |
| 5 | 10 | 57 | 16 | -0.428 | -0.312 | 0.779 | 0.060 | 0.072 |
| 6 | 10 | 72 | 10 | 0.351 | -0.317 | 0.005 | 0.839 | 0.994 |
| 7 | 15 | 45 | 16 | -0.488 | -0.314 | 0.839 | 0.003 | 0.004 |
| 8 | 15 | 57 | 10 | 0.260 | -0.315 | 0.091 | 0.748 | 0.892 |
| 9 | 15 | 72 | 13 | 0.351 | -0.315 | 0.003 | 0.839 | 0.997 |

The value of each factor and level can be seen in Table 12, the average value of the PCR-TOPSIS response. The selected factor is the level that gives the highest average value of PCR-TOPSIS. Based on the table and graph of the mean response in Figure 5 of PCR-TOPSIS, Optimal factors and levels are A3 – B3 – C1, where the level is determined according to the highest value, factor C (velocity inlet) is the most influential factor in achieving optimal conditions. The setting factor and optimal level of PCR-TOPSIS for pressure drop quality and efficiency can be achieved with a helical angle factor of $15^0$, a Cyclone Outlet diameter of 72 mm, and a flow velocity of 10 m/s.

Table 12. Averages value response PCR-TOPSIS

| Level | Factor | | |
|---|---|---|---|
| | **A** | **B** | **C** |
| **1** | 0.326 | 0.343 | 0.777 |
| **2** | 0.548 | 0.419 | 0.623 |
| **3** | 0.631 | 0.744 | 0.105 |
| **Dev** | 0.305 | 0.401 | 0.672 |
| **Rank** | 3 | 2 | 1 |

## 5. Validation and Simulation

The confirmation experiment was carried out according to the combination of the optimal level of PCR-TOPSIS. The purpose of the confirmation experiment was to test the predicted value of the level setting (optimal) so that the effectiveness of the optimization could be known. The confirmation experiment was carried out using ten samples based on the optimal level setting (A3-B3-C1), namely the helix angle $15^0$, outlet diameter 72 mm, Velocity inlet 10 m/s, Table 13 show the confirmation test result data.

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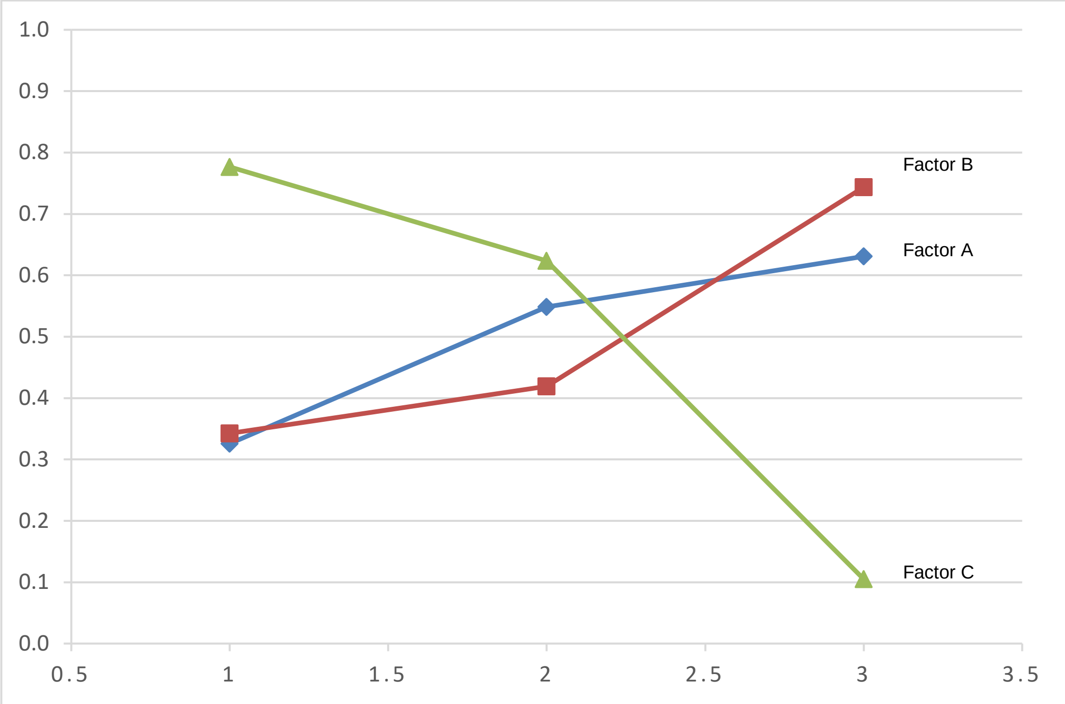


Figure 5 Means response graph PCR-TOPSIS

The simulation process using CFD software begins with the geometry step by drawing according to Figure 6, then the mesh settings are done by generating mesh, selecting the mesh method to be used, giving names to certain surfaces such as inlet, outlet, walls, outlet trap, setting up is done by value the y-axis gravity value = -9.81 m/s, viscous model k-epsilon (2eqn), k-epsilon model RNG, DPM iteration 10, tracking parameters 50000, step length factor 5, release from surface = surface, inert = inlet, z-velocity (m/s) -10, diameter (m) 1e-3, total flow rate (kg/s) 0.0023333, DPM inlet = reflect, DPM outlet = escape, DPM outlet_bin = trap, solution initialization pressure velocity = simple, pressure = second order, momentum = second order upwind, turbulent kinetic energy = second order upwind, turbulent dissipation rate = second order upwind, compute from inlet, run calculation with number of iteration 500, velocity magnitude=10m/s, simulation result in the form of value number tracked=36, escape =3, aborted=0, trapped=29, so the efficiency value based on Eq. 1 is 80,55%, pressure walls max=86,6545 bar, min=-9,29746bar, inlet pressure max=0,118435 bar, min=0,0967764 bar, outlet pressure max=0,00099645, min=-0,00202641 bar, the particle path in Figure 7 shows a total of 35 paths, b, and c 10 paths, indicating the flow in the cyclone wall is swirl.

Table 13. Confirmation experiment

| Sample | Pressure drop (mbar) | Efficiency (%) |
|---|---|---|
| 1 | 0,3 | 99,57 |
| 2 | 0,3 | 99,57 |
| 3 | 0,4 | 99,71 |
| 4 | 0,3 | 98,57 |
| 5 | 0,4 | 99,86 |
| 6 | 0,3 | 99,57 |
| 7 | 0,4 | 99,00 |
| 8 | 0,3 | 99,86 |
| 9 | 0,4 | 99,71 |
| 10 | 0,3 | 99,57 |
| Average | 0,34 | 99,50 |

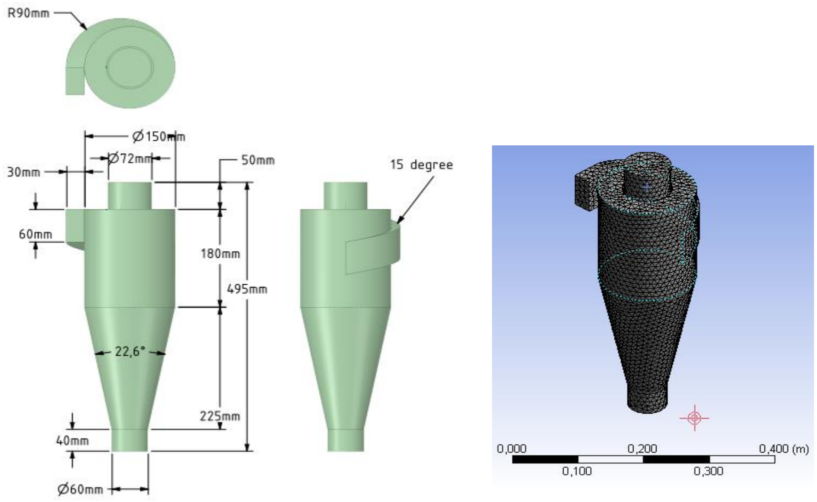


Figure 6. Model cyclone separator and mesh

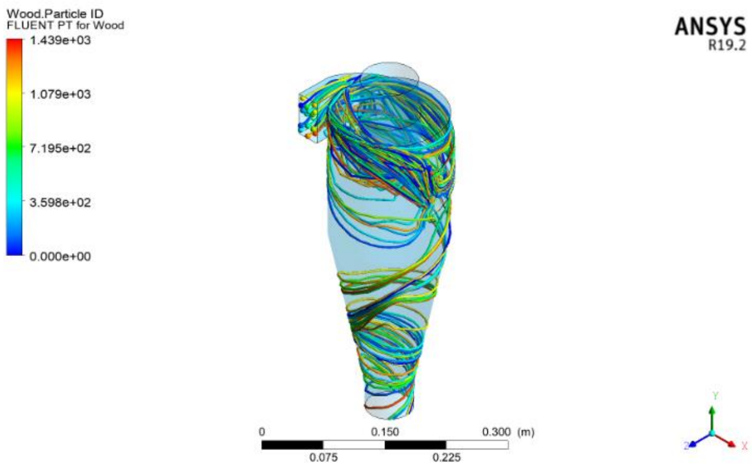


Figure 7. Particle trace

This shows that the PCR-TOPSIS method can accommodate both performances. The simulation values are different with experimental confirmation of 18.97% due to specific parameters not by actual conditions such as air humidity and particle size, whose size can vary with use during the experiment. Significant results were obtained by utilizing the multi-response method, where based on confirmation testing, an efficiency value of 99.5% was obtained in particle separation. Developments that can be carried out in this study are the design of the lower outlet where this section greatly influences the reverse direction of the vortex flow by providing several variations in shape, size, and testing on various types of particles that affect the overall performance of the cyclone.

## CONCLUSION

Research with the topic of optimizing performance on a scroll inlet cyclone separator prototype by paying attention to the most influential parameters in performance can give better results where the factor value and optimal level of the scroll inlet cyclone separator using the Taguchi method are following the pressure difference response, the inlet helix angle of $15^0$, outlet diameter 72 mm, inlet speed 10 m/s and efficiency response, inlet helix angle $5^0$, outlet diameter 57 mm, inlet speed 16 m/s, this is due to differences in Signal to noise ratio categories. Meanwhile, according to the Taguchi multi-response PCR-TOPSIS method, it produces a


10.12198/ijio.v3i1.4272

combination of pressure difference and efficiency with a combination of factors and degrees of inlet helical angle of $15^0$, outlet diameter of 72 mm, and inlet velocity of 10 m/S. Confirmation experiments showed an efficiency value of 99.5%. They decreased pressure of 0.34 mbar, the average value of the Taguchi experiment for pressure drop performance of 0.544 mbar and efficiency of 99.5%, based on simulation efficiency of 80.55%. This shows that the PCR-TOPSIS method can accommodate both performances. The simulation values are different with experimental confirmation of 18.97% due to specific parameters not by actual conditions such as air humidity and particle size, whose size can vary with use during the experiment. Significant results were obtained by utilizing the multi-response method, where based on confirmation testing, an efficiency value of 99.5% was obtained in particle separation. Developments that can be carried out in this study are the design of the lower outlet where this section greatly influences the reverse direction of the vortex flow by providing several variations in shape, size, and testing on various types of particles that affect the overall performance of the cyclone.

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