Application study of evolutionary operation methods in optimization of process parameters for mosquito coils industry

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Abstract: Evolutionary Operation Methods (EVOP) is a method that is designed used in the process of running or operating routinely in the company to enables high productivity. Quality is one of the critical factors for a company to win the competition. Because of these conditions, the research for products quality has been done by gathering the production data of the company and make a direct observation to the factory floor especially the drying department to identify the problem which is the high water content in the mosquito incense coil. PT.X which is producing mosquito coils attempted to reduce product defects caused by the inaccuracy of operating conditions. One of the parameters of good quality insect repellent that is water content, that if the moisture content is too high then the product easy to mold and broken, and vice versa if it is too low the products are easily broken and burn shorter hours. Three factors that affect the value of the optimal water content, the stirring time, drying temperature and drying time. To obtain the required conditions Evolutionary Operation (EVOP) methods is used. Evolutionary Operation (EVOP) is used as an efficient technique for optimization of two or three variable experimental parameters using two-level factorial designs with center point. Optimal operating conditions in the experiment are stirring time performed for 20 minutes, drying temperature at 65°C, and drying time for 130 minutes. The results of the analysis based on the method of Evolutionary Operation (EVOP) value is the optimum water content of 6.90%, which indicates the value has approached the optimal in a production plant that is 7%.

1. Introduction
The EVOP method [1] was introduced in the late 1950s as a field application technique for improving existing industrial processes. It was to be applied to an existing manufacturing process that was currently producing acceptable product. By exploring small incremental changes in an existing set of process conditions, the process could be improved and moved in the direction of some process optimum [2]. There are other advanced statistical methods, such as Artificial Neural Network. [3] simplex optimization [4, 5] response surface methodology, [6] and advanced factorial design but they are more complex and require a great deal of training for reliable application and interpretation. Most of the methods deal with an intial strategy of experimentation when formulating a set of bench-scale experimental runs.[7]

Evolutionary Operation Methods (EVOP) is designed to use in the process of running or operating routinely in the company to enables high productivity [8]. This method embedded in the activities carried out by employees with minimum assistance from the research or development of the company.
PT.X is one of the private companies engaged in manufacturing, which produces anti-mosquito drugs in big quantities and has cooperated with many other similar companies to producing anti-mosquito drugs in various brands. In carrying out its production activities, the company faces a problem with a water content of products produced mosquito repellent. With the operating conditions in the drying section that runs the company today is stirring time 15 minutes, drying temperature 65°C, and the drying time for 120 minutes produces water content approximately 7.4% - 7.6%, while the optimum value is 7%, this leads to around 8% (10-20 pieces) broken products, where the mosquito coils produces is 240 pieces in one drying. To overcome this problem researchers has been trying to reduce the value of the water content by testing it in a laboratory to determine the better-operating conditions and to apply it in the production floor. Therefore a way to get information on how to process improvement so that the product is better than the current conditions Improving quality and productivity will be effective if it is an integral part of the product development cycle and production processes. The Design of experiments on line can be used for this purpose, because the experimental design online application used in manufacturing processes to identify the relationship between the variables in a process. One method of design of experiments on line that can be used to obtain the desired operating condition information is Evolutionary Operation Method (EVOP).

This paper describes the application of Evolutionary Operation Method to research the impact of water content towards mosquito coils product quality.

2. Methodology
Since EVOP’s introduction in the late 1950’s, many books and journal articles have been published discussing the method. This article is not intended as a survey review of EVOP; the reader is invited to consult the original publication or other excellent discussions [9-12].

2.1. Evolutionary Operation Method and Design of Experiment
In EVOP method, there are stages of planning which are done, where the definition of planning is the process, how, or plan, organize, and outlines the steps the implementation of activity. Planning stages to begin the implementation of EVOP is:
1. Select two, at most three variables of the process and select a level for each process variable.
2. Select the suitable criteria for testing / treatment combination.
3. Estimate the number of cycles required to obtain a significant change in the process.

EVOP worksheets consist of five parts, each of which requires calculation. The sections are: Average calculation, Effects calculation, Standard deviation calculation, Error limit calculation and Decision Making Procedure.

2.2. Methods of Evolutionary Operation (EVOP) for Three Variables
Design of experiments performed or information obtained from the production of the three variables that influence, Va, Vb, and Vc. Then the effects were calculated using an EVOP three variables worksheet. The position 0,1,2,3, and 4 show different combinations of these three variables. In EVOP three variables program, a cycle is broken down into two blocks, each of which consists of a condition. The condition of zero, one, two, three, and four are inserted into block I, and the condition A, five, six, seven, eight is inserted into the block II. Reference conditions to run only once in each block (twice per cycle), and is expressed by the condition 0 and A [1].
Calculation of effect value that use as comparation to error limit in EVOP, Yates Algorithm in experimental design is used.

2.3. Yates Algorithm
Yates Algorithm method used to calculate the contrast and the sum of squares (SS) for each treatment combination in factorial design experiments 23.
2.4. The Analysis of Variance
Analysis of variance is a method of decomposing the total variability in a set of observations, as measured by the sum of the squares of these observations from their average, into component sums of squares that are associated with specifically defined sources of variation [13,14].

2.5. Normality Test Data
To check whether or not the population is normally distribution, then tested for normality using Chi Square test (X²).

3. Results and Discussion

3.1. Analysis of Variance
The calculation of ANOVA test using the ANOVA formula can be seen in Table 1.

| Source of Variation | Degree of Freedom | Sum of Squares | Central Square | F  |
|---------------------|-------------------|----------------|----------------|----|
| Treatment           | 9                 | 3.71           | 0.412          |    |
| Error               | 30                | 0.18           | 0.006          | 68.66 |
| Total               | 39                | 3.89           |                |    |

F table (9, 30) for the level of significance (α) = 0.05, F table = 2.21, F count > F table meaning that there is a real treatment effect or there is a difference between real treatment.

3.2. Normality Test
Test normality of data on the processing done by using Chi Square (X²). Based on the data obtained, the calculated X² value is 1.7014. According to the Chi Square table for α = 0.05 df = k-r-1. Because X² calculated = 1.7014 < X² table = 5.991, it means the data distributed normally.

3.3. Calculation of Average, Standard Deviation, effects, and Error Limits
In continuing EVOP program that considered is the change in the level of factor does not affect the quality of the product. EVOP calculations performed is a factorial design with three factors and two level factors, namely: stirring time (A) with a level of 10 minutes and 20 minutes; Drying temperature (B) with a level of 55° C and 65° C; and the drying time (C) with a level of 110 minutes and 130 minutes and a currently performed in the factory as a reference, namely the condition of stirring time (A) 15 minutes; drying temperature (B) 60 ° C; and the drying time (C) 120 minutes. Therefore, there are ten combinations of operation conditions. The results of 10 experiment conditions seen in Table 2.

| Table 2. Data Observations of Water Content |
|--------------------------------------------|
| Operation Condition | Replication | | | |
| | 1 | 2 | 3 | 4 |
| (1) | 7.41 | 7.44 | 7.54 | 7.52 |
| (2) | 8.12 | 8.03 | 8.02 | 7.94 |
| (3) | 7.18 | 7.11 | 7.13 | 7.13 |
| (4) | 7.25 | 7.25 | 7.27 | 7.25 |
| (5) | 7.18 | 7.26 | 7.03 | 7.00 |
| (6) | 7.53 | 7.48 | 7.50 | 7.42 |
| (7) | 7.24 | 7.31 | 7.34 | 7.20 |
| (8) | 6.84 | 6.97 | 6.90 | 6.96 |
| (9) | 7.61 | 7.82 | 7.65 | 7.82 |
| (10) | 7.31 | 7.24 | 7.47 | 7.42 |
The EVOP calculation begins by calculating the amount of water content for each cycle and operating conditions, then calculate average as follows:

Average cycle \( n = \frac{\text{total } n}{n} \)

The next step is to calculate the difference in the value of the average cycle by cycle water content values for block I and II.

\[ \text{Difference} = \text{average cycle (n-1)} - \text{the water content of the cycle}. \]

Next step is to calculate the standard deviation and the average standard deviation of Block I and Block II are as follow [15]:

\[ \text{Standard deviation} = \text{Range} \times f_{F_{K,n}} \]

\( f_{K,n} = \text{constant depending on number of replication and experiment per-cycle} \)

\( \text{Range} = \text{the difference value - the value of the smallest difference} \)

The following table shows the value of range, standard deviation the experiment

| Block | Cycle | Range | Standard Deviation |
|-------|-------|-------|--------------------|
|       | 1     | -     | -                  |
|       | 2     | 0.17  | 0.051              |
| I     | 3     | 0.305 | 0.106              |
|       | 4     | 0.216 | 0.08               |
|       | 1     | -     | -                  |
| II    | 2     | 0.28  | 0.084              |
|       | 3     | 0.26  | 0.091              |
|       | 4     | 0.223 | 0.0825             |

The calculation of average standard deviation for all cycle can be seen below:

Cycle 2:

\[
\text{Total } S = S_1 + S_2 = 0.051 + 0.084 = 0.135
\]

\[
\text{Average } S = \frac{0.135}{\frac{2n-2}{2}} = \frac{0.135}{2} = 0.0675
\]

The calculation of average standard deviation for all cycles carried out with the same formula for the entire block.

Cycle 3: 0.083  Cycle 4: 0.0824

The limit calculated by the following formula : Limit = \( \left( \frac{1.41}{\sqrt{n}} \right) \times S \) \hspace{1cm} (1)

The calculation of the limit of the main effects and interaction effects for each cycle happened by using the value of deviation's standards The calculation of the limit of the following effects:

Cycle 2 Limit = 0.0673, Cycle 3 Limit = 0.0675 and Cycle 4 Limit = 0.058

By using Yates Method effect value for each cycle found compare to the limit as shown in Table 4. From the Table 4 effect value factor A (stirring time), factor B (drying temperature), Factor C (drying time) and interaction among Factor ABC is smaller compared to error limit. This shows that factor stirring time, drying time and drying temperature are significance of confidence level.
Table 4. The Comparison of the Limit and the Factor of the Experiment

| Cycle | Factor | Effect  | Limit  |
|-------|--------|---------|--------|
| 2     | A      | -0.208  |        |
|       | B      | -0.443  | 0.0673 |
|       | C      | -0.390  |        |
|       | ABC    | -0.130  |        |
| 3     | A      | -0.21   | 0.0675 |
|       | B      | -0.441  |        |
|       | C      | -0.405  |        |
|       | ABC    | -0.094  |        |
| 4     | A      | -0.186  | 0.058  |
|       | B      | -0.437  |        |
|       | C      | -0.422  |        |
|       | ABC    | -0.066  |        |

4. Conclusion

The conditions before using EVOP are time 15 minutes, drying temperature 60 °C, and the drying time of 120 minutes, yielding a value of water content averaging 7.51%, far from the desired standard value is 7%. The required operating conditions to obtain the value of the standard water content of the calculation by the EVOP method is 65°C drying temperature, stirring time of 20 minutes and 130 minutes of drying time.

Determination of the conditions using Evolutionary Operation (EVOP) produces product water content of 6.90%. And the effect of factor A, B, C and interaction of ABC are significance to the confidence level.

The Company did not change its production capacity is 240 cartons per production cycle in by what has been done, so that operating conditions obtained from the calculation EVOP can produce a product quality standard value of water content. Companies can apply the method EVOP in the repair process continuing basis to maintain product quality and to be able to improve processes quickly, accurately, and continuous corresponding calculation results EVOP.

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