Optimization of Woven Fabric Production Process Using Multi Response Taguchi, GRA and PCA

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Abstract

The purposes of this research is to determine the optimal process parameters of woven fabric production process and the rank of factors that influence the responses of the fabric, namely tensile strength, tear strength, air permeability, drape ability and pilling. In this research, Taguchi method was used in the optimization of woven fabric production by involving four factors, namely weft yarn type, weft density, air pressure and warp tension each with three levels. Orthogonal Array L9 for experiment. Grey relational analysis and principal component analysis was used to determine the optimal process parameters. The results of experiments showed that the sixth treatment of the orthogonal array has the highest rank with a value of 0.803. The optimal settings are TC 30 of weft yarn type, 68 of weft density, 3 bar of air pressure and 1.75 kN of warp tension. Analysis of variance with minitab that weft yarn type become the most influence and significant factors of the responses.

Keywords
Taguchi, Grey Relational Analysis, Principal Component Analysis, Optimization, Woven Fabric.

1. Introduction

According to Nazar et al. (2020), textile are products that will always be needed in human life. Therefore, the textile industry is required to meet the needs in accordance with popuation growth. The textile industry is one of the Indonesian goverment's priorities in the era of industrial revolution 4.0. The textile industry in general includes yarn making, fabric making (weaving, knitting, and non wovens), fabric refinement (dyeing and printing), and garment. Yarn making is the process of converting fiber into yarn through the following stages, called spinning. The woven cloth manufacturing is the process of crossing a piece of cloth or several strands of yarn between the warp and weft become a fabric. Fabric refinement is an advanced process from raw fabric (greige) to ready-to-use (finished) fabric through the stages of the preparation process, refinement and special refinement. Meanwhile, the garment is the process of making clothes or other finished products.

Currently, the weaving industry uses air jet loom, rapier and shuttle to produce the woven fabric. The air jet loom has high speed and make it results in the highest productivity compared to other types of machines. One of machines that use air jet loom is Picanol Omniplus Air Jet Machine. Woven fabrics are produced using yarns with a combination of cotton, rayon and polyester. The textile industry does not yet have a knowledge about the right combination of cotton, rayon and polyester yarns as well as the optimal machine settings to produce high quality woven fabrics. The quality and comfortness of the material is a determining factor for consumers to choose the product to be purchased. Shansan et al. (2017) explained that quality is an important factor for companies to succeed in the market. Costa (2010) pointed the importance of maintaining quality and ensuring the quality characteristics in term of target values and variability which must be kept at minimal. The better the quality of the woven fabric, the higher the customer satisfaction and eventually will increase the demand. The woven fabric manufacturer must also pay attention to the comfort of the material. The comfort of the material on the woven fabric can be felt with the air permeability and drape test. The air permeability of the cloth makes one's clothes not sweat a lot, while the drape test on the cloth makes one comfortable when the woven fabric bends.

Taguchi method is one of the efficient and effective optimization methods for improving product quality. According to Shaker et al. (2015), the main advantage of Taguchi lies in its simplicity and ease of adapting more complex experiments (including the number of factors with a different number of levels) and providing information that adds to the least number of experiments. Wahyudin et al. (2017) pointed Taguchi method brings the benefit into the short running experiments due to its robust orthogonal array pattern and the main advantage can be to lessen the number of experiment, time and cost. One of the he drawbacks of the Taguchi method is that it can be used only for single response (Kuo and H, 2009). Thus, in multi-response optimization, other or additional methods are needed to perform the analysis. In this study, used are Grey Relational Analysis (GRA) and Principal Component Analysis (PCA) which have been widely used to solve multi-response optimization problem. GRA is used to resolve the interrelationships among several responses. In this approach the grey relational value is obtained to analyze the relational level of several responses. Lin and Lin (2002) has tried a grey relational based approach to solve the multi-response problem in the Taguchi method. PCA is a mathematical procedure that transforms orthogonally multi-variables that have been to be correlated with each other, into new multi-components that are not correlated with each other.

Woven fabric can be classified according to the type of woven used, trade name, weight of fabric, color-giving method, and end-use. Flexibility is one of the important characteristics of woven fabric (Adanur, 2001). According to Ga (2017) there are several factors influence the characteristics of woven fabrics, namely woven structures, warp thread and weft yarn. The main purpose of woven fabric is to develop new fabrics that have the most appropriate properties for end-use applications to achieve an increase in the level of fabric quality (Turhan and Eren, 2011). Masaeli et al. (2014) conducted an experiment by combining the types of weft yarn type, woven fabric, weft density, air pressure and warp closure time with two responses, namely the angle of fabrics folding and fabrics pilling. Sarpkaya et al. (2015) conducted a research by combining the factors of woven fabrics, the intensity of dyeing and the number of the fabrics lifting with two responses namely the tensile strength in fabrics elongation. Meanwhile, Umair et al. (2017) conducted an experiment by combining the angular factors of the degree of the yarn, woven fabric and type of yarn with seven responses namely crimped grey and after washed fabric, weight of fabric, thickness of fabric, stiffness of fabric, flexibility of fabric and air permeability.

2. Literature Review

Masaeli et al. (2014) in his research using the L18 orthogonal array to get the optimal setting on the factors and levels, while the processing of the two responses uses the gray relational analysis method. The results obtained for the pilling response of the fabric after using Anova, namely the woven fabric and the weft are significant factors, while the affecting the response of the folds of the fabric after using Anova only the woven factor was significant. Then the results of the significant factors for both responses after the Anova and gray relational analysis stated that the woven fabric and the weft were significant factors.

Sarpkaya et al. (2015) in his research using the L9 orthogonal array to get the optimal setting for the factors and levels, while the response processing uses the gray relational analysis method. The response of the tensile strength of the fabric and the elongation of the fabric is related, that is, if the tensile strength of the fabric increases, the creep will also increase. In this study, the response there are 4 namely fabric tensile strength (warp direction), fabric tensile strength (weft direction), fabric stretch (warp direction) and fabric stretch (weft direction) which are then processed using gray relational analysis converted into one response, then the input settings or factors can be identified. The results showed that the optimal setting was 2/1 twill fabric, 1% dyeing intensity and without consideration of fabric combinations.

Meanwhile, Umair et al. (2017) in his research carried out simultaneous optimization of the properties of woven fabrics using factor analysis. The study also states that the properties of woven fabrics are influenced by the structure of the yarn and/or woven fabric. The results of the study stated that woven fabrics with a low degree of twist angle on twill weave got the most optimal results.

In this research, we extend the research of Nazar et al. (2020) by adding two more responses and an additional method of PCA to determine a better result. A combination experiment of factors of the weft yarn type, weft density, air pressure and warp tension with a response of the fabric tensile strength, tear strength, air permeability, drape ability and pilling was conducted using the method of multi response Taguchi, GRA and PCA.

3. Methods

Table 1 shows the factors and the respected levels used in this research. There are four factors involved in the experiment, namely weft yarn type, weft density, air pressure and warp tension with three levels each.

Table 1. Factors and Level

Factors	**Level**		
	1	2	3
Weft Yarn Type	Cotton 30	TC 30	TR 30
Weft Density	62	65	68
Air Pressure	3 bar	4 bar	5 bar
Warp Tension	1.5 kN	1.75 kN	2 kN

Taguchi explained that quality improvement is a continuous effort to reduce product variance around the target value. To fulfill this, Taguchi proposed an experiment using Orthogonal Arrays (OA). The Taguchi method serves to determine the number of experiments to be carried out and determine the optimal value for each desired response. Taguchi method was one of the most widely used approaches to solve parameter design problems (Hsu, 2012). Further, according to Anthony (2000), Taguchi parameter design is widely accepted methodology among researchers and practitioners to control quality, improve product quality and process performance at a low cost. In this problem, optimization of some responses only received limited attention among researchers and practitioners. In complex experimental processes, we often have to optimize multiple responses simultaneously rather than optimizing one response at a time. In a multi-response problem, the goal is to determine the optimal settings for factors and process variables that will simultaneously optimize multiple responses. This problem can be settled with the use of grey relational analysis, the multi-objective optimization techniques that convert multiple performance into single grey relational grade value to evaluate overall performance characteristics.

Grey relational analysis has the following steps (Lin and Lin, 2002):

1. Convert the original response data to S/N (Y_ij) ratio using the appropriate formula depending on the type of quality characteristic.
2. Normalization of Y_ij as Z_ij (0 ≤ Z_ij ≤ 1) with the following formula to avoid the effect of using different units and to reduce variability. Normalization is a transformation performed on a single input to distribute the data evenly and scale it into an acceptable range for further analysis

$$Z_{ij} = \frac{Y_{ij} - \min(Y_{ij}, i=1,2,\ldots,n)}{max(Y_{ij}, i=1,2,\ldots,n) - \min(Y_{ij}, i=1,2,\ldots,n)} \quad (1)$$

$$Z_{ij} = \frac{max(Y_{ij}, i=1,2,\ldots,n) - Y_{ij}}{max(Y_{ij}, i=1,2,\ldots,n) - \min(Y_{ij}, i=1,2,\ldots,n)} \quad (2)$$

$$Z_{ij} = \frac{(\mathrm{I}Y_{ij} - \mathrm{TI}) - \min(\mathrm{I}Y_{ij} - \mathrm{TI}, i=1,2,\ldots,n)}{max(Y_{ij}, i=1,\ 2,\ldots,n) - \min\ (Y_{ij}, i=1,\ 2,\ldots,n)} \quad (3)$$

3. Calculate the gray relational coefficient (GC) for the normalized value of the S/N ratio.

$$\mathrm{GC}_{ij} = \frac{\Delta_{min} + \lambda\Delta_{max}}{\Delta_{ij} + \lambda\Delta_{max}} \quad \begin{cases} \mathrm{i} = 1, 2, \ldots, \mathrm{n} - \text{ eksperimen} \\ \mathrm{j} = 1, 2, \ldots, \mathrm{n} - \text{respon} \end{cases} \quad (4)$$

4. Calculate the gray relational level (Gi).

$$G_i = \frac{1}{m} \sum \mathrm{GC}_{ij} \quad (5)$$

5. Use the response graph or the anova method and select the optimal level for the factor based on the maximum average Gi value.

PCA is a mathematical procedure that transforms orthogonally multi-variables that are thought to be correlated with each other, into a new multi-component (principal component) that is not correlated with each other. PCA has several steps as follows:

1. Normalization according to quality characteristics.

$$Z_{ij} = \frac{Y_{ij} - \min(Y_{ij}, i=1,2,\ldots,n)}{max(Y_{ij}, i=1,2,\ldots,n) - \min(Y_{ij}, i=1,2,\ldots,n)} \quad (6)$$

$$Z_{ij} = \frac{max(Y_{ij}, i=1,2,\ldots,n) - Y_{ij}}{max(Y_{ij}, i=1,2,\ldots,n) - \min(Y_{ij}, i=1,2,\ldots,n)} \quad (7)$$

$$Z_{ij} = \frac{(\mathrm{I}Y_{ij} - \mathrm{TI}) - \min(\mathrm{I}Y_{ij} - \mathrm{TI}, i=1,2,\ldots,n)}{max(Y_{ij}, i=1,\ 2,\ldots,n) - \min(Y_{ij}, i=1,\ 2,\ldots,n)} \quad (8)$$

2. Create a covariance variance matrix from the normalized data.

$$Y_{jk} = \frac{n \sum Y_{ij} Y_{ik} - (\sum Y_{jk})(\sum Y_{ik})}{\sqrt{\{n \sum y_{ij}^2 - (\sum y_{ij})^2\}\{n \sum y_{ij}^2 - (\sum y_{ij})^2\}}} \quad (9)$$

Y_{jk} : the correlation coefficient value of the j response GRC and k response

n : the number of responses observed

Y_{ij} : the value of the j response GRC in the i experiment

Y_{ik} : GRV value of the j-th response in the i experiment

3. Create a principal component (PC) equation from the eigenvalues of the covariancevariance matrix vector.
4. Calculate the principal component (PC) of the multiplication of the normalized results.
5. Calculate the anova

4. Data Collection

The calculation results of the signal to noise ratio tensile strength, tear strength, air permeability, drape ability and pilling are described in Table 2.

Table 2. Signal to Noise Ration for Each Response

Factor and Level				Signal to Noise Ratio				
				Tensile Strength	Tear Strength	Air Permeability	Drape Ability	Pilling
Cotton 30	62	3	1.5	24.554	58.51	26.021	-3.947	-12.041
Cotton 30	65	4	1.75	25.382	58.736	26.021	-3.938	-12.041
Cotton 30	68	5	2	25.327	58.726	25.575	-3.762	-11.186
TC 30	62	4	2	30.258	67.662	28.299	-4.163	-9.897
TC 30	65	5	1.5	30.325	67.48	26.444	-4.073	-10.238
TC 30	68	3	1.75	31.427	65.977	24.609	-3.675	-12.041
TR 30	62	5	1.75	30.021	68.104	27.959	-4.487	-10.881
TR 30	65	3	2	30.274	67.91	26.021	-3.995	-10.238
TR 30	68	4	1.5	31.226	68.698	24.082	-3.87	-6.021

The next step is to normalize the results of the SNR of each response according to its quality characteristics. The results of the normalization are shown in Table 3.

Table 3. Normalization

Tensile Strength	Tear Strength	Air Permeability	Drape Ability	Pilling
0.000	0.000	0.460	0.665	1.000
0.120	0.022	0.460	0.676	1.000
0.112	0.021	0.354	0.893	0.858
0.830	0.898	1.000	0.399	0.644
0.840	0.880	0.560	0.510	0.700
1.000	0.733	0.125	1.000	1.000
0.795	0.942	0.919	0.000	0.807
0.832	0.923	0.460	0.606	0.700
0.971	1.000	0.000	0.760	0.000

After normalizing the data, the next step is to calculate the deviation sequence. The results of the deviation sequence calculation are shown in Table 4.

Table 4. Deviation Sequence

Tensile Strength	Tear Strength	Air Permeability	Drape Ability	Pilling
1.000	1.000	0.540	0.335	0.000
0.880	0.978	0.540	0.324	0.000
0.888	0.979	0.646	0.107	0.142
0.170	0.102	0.000	0.601	0.356
0.160	0.120	0.440	0.490	0.300
0.000	0.267	0.875	0.000	0.000
0.205	0.058	0.081	1.000	0.193
0.168	0.077	0.540	0.394	0.300
0.029	0.000	1.000	0.240	1.000

After getting the results from the deviation sequence, the gray relational coefficient is calculated. The results of the calculation of the gray relational coefficient are shown in Table 5.

Table 5. Grey Relational Coeficient

Tensile Strength	Tear Strength	Air Permeability	Drape Ability	Pilling
0.333	0.333	0.481	0.599	1.000
0.362	0.338	0.481	0.607	1.000
0.360	0.338	0.436	0.824	0.779
0.746	0.831	1.000	0.454	0.584
0.757	0.807	0.532	0.505	0.625
1.000	0.652	0.364	1.000	1.000
0.710	0.896	0.861	0.333	0.722
0.749	0.866	0.481	0.559	0.625
0.945	1.000	0.333	0.676	0.333

The next stage is to calculate the gray relational grade and sort the ranking. The results of the gray relational grade are shown in Table 6, while the response grey relational grade in Table 7. The results of the ANOVA shown in Figure 1. The results of the confirmation experiment are in Table 8.

Table 6. Grey Relational Grade

Eksperiment No	Grey Relational Grade	Rangking
1	0.549	8
2	0.558	7
3	0.547	9
4	0.723	2
5	0.645	6
6	0.803	1
7	0.704	3
8	0.656	5
9	0.657	4

Table 7. Response Grey Relational Grade

Level	Weft Yarn Type	Weft Density	Air Pressure	Warp Tension
1	0.55	0.66	0.67	0.62
2	0.72	0.62	0.65	0.69
3	0.67	0.67	0.63	0.64
Difference	0.17	0.05	0.04	0.07
Rangking	1	3	4	2

General Linear Model: GRG versus Weft Yarn Type, Warp Tension and Weft Density

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Factor            Type   Levels  Values
Weft Yarn Type    fixed       3  Cotton 30, TC 30, TR 30
Warp Tension      fixed       3  1.5 kN, 1.75 kN, 2 kN
Weft Density      fixed       3  62, 65, 68


Analysis of Variance for GRG, using Adjusted SS for Tests

Source            DF    Seq SS    Adj SS    Adj MS      F      P
Weft Yarn Type     2  0.046975  0.046975  0.023487  22.01  0.043
Warp Tension       2  0.007860  0.007860  0.003930   3.68  0.214
Weft Density       2  0.004062  0.004062  0.002031   1.90  0.344
Error              2  0.002134  0.002134  0.001067
Total              8  0.061031


S = 0.0326667   R-Sq = 96.50%   R-Sq(adj) = 86.01%
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Figure 1. ANOVA

Table 8. Confirmation Test

	Tensile Strength	Tear Strength	Air Permeability	Drape Test	Pilling
Optimal Experiment					
1	37.27	1990	17	0.66	4
Confirmation Experiment					
1	38	2000	20	0.68	4
2	40	2150	22	0.73	4

3	37.5	2060	18	0.70	4
x	38.5	2070	20	0.7	4

6. Results and Discussion

The results of the tensile strength and feed elongation tests that have been carried out show that the 6th experiment gets the largest value of SNR of 31.427. The 6th experiment was done with TC 30 of weft yarn type, 68 of weft density, 3 of bar air pressure and 1.75 kN of warp tension. The order of factors that influence the response of the tensile strength of the weft direction is the type of weft, weft density, air pressure and warp tension. The TC 30 weft yarn type consists of a mixture of tetoron or polyester and cotton. Polyester has the characteristics of high fiber strength properties because it is made from natural fibers, while the cotton blend has more strength than rayon. High weft density greatly affects the strength of the fabric, because the number of threads is proportional to the strength of the fabric.

The results of the weft-direction tear strength test that have been carried out show that the 9th experiment obtained an SNR value with larger characteristics, which is 68.698. The 9th experiment was done with TR 30 of weft yarn type, 68 of weft density, 4 of bar air pressure and 1.5kN of warp tension. The tear strength test is done using a pendulum swing with a certain load that can tear a cloth. The TR 30 material is the strongest in terms of fabric tearing because it contains a strong polyester material that resists the tearing because it comes from synthetic fibers combined with rayon fiber which has a higher stretch than cotton. High weft density is very influential on the results of the tear strength of the fabric, because the number of threads is proportional to the strength results.

The results of the air-permeability test that have been carried out show that the 4th experiment has an SNR value with larger the better characteristics, which is 28.299. The 4th experiment was done with TC 30 of weft yarn type, 62 of weft density, 4 of bar air pressure and 2 kN of warp tension. The type of fabric in the optimal combination has a flat fabric surface and a weave consisting of parallel warp and weft threads. The diameter of the warp and weft yarns looks smaller because it uses cotton yarn type number 40, while the weft yarn line is larger because it uses TC yarn type number 30 although it doesn't look significantly.

The results of the fabric drape test that have been carried out show that the 6th experiment gets the largest value with an average value of 0.66 and the SNR value with larger the better characteristics, which is -3.675. The 6th experiment was done with TC 30 of weft yarn type, 68 of weft density, 3 of bar air pressure and 1.75 kN of warp tension. Higher ductility of the fabric using a mixture of polyester material derived from synthetic fibers with cotton material which is more wrinkle/fall resistant than rayon fiber.

The results of the fabric pilling test that have been carried out show that the 9th experiment gets the largest value of the SNR value with the smaller the better characteristic, which is -6.021. The 9th experiment was done with TR 30 of weft yarn type, 68 of weft density, 4 of bar air pressure and 1.5 kN of warp tension. The order of factors that influence the pilling response of the fabric is the type of weft, warp tension, air pressure and weft density. Polyester and rayon materials are made of synthetic fibers which cause more pilling than natural fibers.

As shown in Figure 1, the result of ANOVA show that the type of weft has a significant effect on the GRG value because the P value is less than 0.05. While the warp tension factor and air pressure have no significant effect.
Based on the tests and experiments that have been carried out, the results of the confirmation experiment for the response of the tensile strength of the fabric have been optimal, namely 38.5 kg and greater than the experimental results of 37.27 kg. The confirmation experiment results agree with the response of the tear strength of the fabric, which is 2070 grams and is greater than the experimental results of 1990 grams. The confirmation experiment result for the response of the air-permeability is 20 mm/second which higher than the experimental results at 17 mm/second. The confirmation experiment results for the response to the slenderness of the fabric is 0.7 which greater than the experimental results of 0.66. Finally, the confirmation experimental results confirmed that the fabric pilling response at grade 4.

Based on the results of the experiments that have been carried out, the results under optimal conditions are the 6th experiment with TC 30 of weft yarn type, 68 of weft density, 3 of bar air pressure and 1.75 kN of warp tension. The combination of materials and settings on the air jet loom can be used as a reference for student learning on campus and the standard for determining the production process in the weaving industry by considering the final product of the woven fabric to be used.

6. Conclusion

Based on the experiments of woven fabrics manufacturing on the Picanol air jet machine that have been carried out in this study, the results showed that the weft yarn type had a significant effect on the response of the weft tensile strength and weft tear strength. Weft density has a significant effect on the response of air permeability and drape ability. All factors for the response to pilling fabrics have no significant effect. The results of research and processing of multiresponse optimization data using the GRA and PCA methods to produce woven fabrics with a combination of tensile strength, tear strength, air permeability, drape ability and pilling, namely the 6th experiment with TC 30 of weft yarn type, 68 of weft density, 3 of bar air pressure and 1.75 kN of warp tension. The results of the ANOVA showed that the weft yarn type had a significant effect on the GRG.

References

Adanur, S. Handbook of Weaving. CRC Press Taylor and Francis, Boca Raton, New York, 2001.

Anthony, J., Multi-response optimization in industrial experiments using Taguchi's quality loss fuction and principal component analysis. Quality and Reliability Engineering International, Vol. 16, Issue 1, pp. 3-8, 2000.

Costa, N.R.P., Simultaneous optimization of mean and standard deviation, Quality Engineering, Vol. 22, Issue 3, pp. 140-149, 2010.

GA, N., Using taguchi methodology to optimize woven fabrics air permeability, Journal of Textile Science and Engineering, Vol. 7, Issue 6, pp. 325-328, 2017.

Hsu, C.M., Improving the lighting performance of a 3535 packaged hi-power LED using genetic programming, quality loss functions and particle swarm optimization, Applied Soft Computing, Vol. 12, Issue 9, pp. 2933-2947, 2012.

Kuo, C. J and H. Tu., Gray Relational Analysis Approach for the Optimization of Process Setting in Textile Calendaring. Textile Research Journal, Vol. 79 (11), pp. 981-992. DOI: 10.1177/0040517508100627, 2009.

Lin, J & Lin, C., The use of the orthogonal array with grey relational analysis to optimize the electrical discharge machining process with multiple performance characteristic. International Journal of Machine Tools and Manufacture, Vol. 42 (2), 237-244 DOI: 10.1016/s0890-6955(01)00107-9, 2002.

Masaeli, R., Hasani, H., Shanbeh, M., Optimizing the physical properties of elastic-woven fabrics using Grey-Taguchi method, The Journal of The Textile Institute, Vol. 106, Issue 8, pp. 814-822, 2014.

Nazar, Y., Pujiyanto, E., and Rosyidi, C. N., Optimization of woven fabric production process on picanol omniplus ait jet machine using taguchi multi response and grey relational analysis methods, Proceeding of the 4th International Manufacturing Engineering Conference and The 5th Asia-Pacific Conference on Manufacturing System, Putrajaya, Malaysia, August 21-22, 2019, pp. 291-297, 2020.

Sarpkaya, C., Ozgur, E., Sabir, E.C., The optimization of woven fabric tensile strength with taguchi method based on grey relational analysis, Tekstil ve Konfeksiyon, Vol. 25, Issue 4, pp. 293-299, 2015.

Shaker, K., M.Umair, M. Maqsood, Y. Nawab, S. Ahmad, A. Rasheed, A. Basit., A Statistical Approach for Obtaining the Controlled Woven Fabric Width. Autex Reseacrh Journal, Vol. 15 (4): 275-79. DOI: 10.1515/aut-2015-0008, 2015.

Shanshan, L., He, Z., Vining, G., Simultaneous optimization of quality and reliability characteristics through designed experiment, Quality Engineering. Vol. 29, Issue 3, pp. 344-357, 2017.

Turhan, Y., Eren, R., The effect of loom settings on weaveability limits on air-jet weaving machines, Textile Research Journal, Vol. 82, Issue 2, pp. 172-182, 2011.

Umair, M., Shaker, K., Ahmad, N., Hussain, M., Jabbar, M., dan Nawab, Y., Simultaneous optimization of woven fabric properties using principal component analysis, Journal of Natural Fibers, Vol. 14, Issue 6, pp. 846-857, 2017.

Wahyudin, K. A., Murphiyanto, R. D. J., Perdana, M. K., and Kasih, T. P., Application of Taguchi Method and ANOVA in the Optimization of Dyeing Process on Cotton Knit Fabric to Reduce Re-dyeing Process. IOP Conference Series: Earth Enviromental Science 109 012023, 2017.

Biography

Yunus Nazar is an instructor in the department of weaving engineering at AK-Tekstil Solo, Surakarta, Indonesia. He earned his S.ST from Bandung Polytechnic Textile Technology and M.T from Sebelas Maret University. He has published conference papers and his research namely metode supplier selection textile material and optimization process in weaving.

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Cucuk Nur Rosyidi is a Professor in Industrial Engineering Department of Universitas Sebelas Maret Surakarta. His research interests include make or buy decision modeling, product design and development, and quality engineering. He currently serves as the head of a research group, namely Center of Research in Manufacturing Systems (CRiMS) which focuses on several issues, mainly in design and production optimization including make or buy decision, quality improvement, and inventory management.