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Optimization using Mahalanobis-Taguchi System for inductor component

F L M Safeiee¹ and M Y Abu¹

¹Faculty of Manufacturing and Mechatronic Engineering Technology, Universiti Malaysia Pahang, 26600, Malaysia

Abstract. The fourth industrial revolution (IR 4.0) is built upon the digital revolution where technology and people are connected. It does not just present modern techniques for supporting aspects within industry but cover as well the sustainability. Thus, it is very important for electric and electronic (E&E) industry to develop a new technique for a better quality evaluation of product. The aim of this work is to apply Mahalanobis-Taguchi System (MTS) in production environment at E&E industry for a better quality evaluation. MTS is used to classify normal and abnormal observations and optimize various parameters in workstation to produce a better quality product. This work found that positive gain through signal to ratio (SNR) indicated the quality of system still in good condition from February with 0.1244 until December with 0.4432 after insignificant variable have been removed. This work also suggested condition of core should be removed since the variable does not contribute to the system along 2018. Meanwhile, some variables are showed inconsistency of significant to the system such as wire condition, epoxy condition, lead part condition and soldering condition. This concluded that MTS is a practical method for classification and optimization in the industry.

1. Introduction

IR 4.0 is currently a pursuing research topic which convergence of several emerging concepts and new technologies such as radio-frequency identification, big data, cloud computing, smart sensors, machine learning, robotics, additive manufacturing, artificial intelligence, augment reality and internet of things [1]. The advanced technologies involved in IR 4.0 are restructuring entire production systems by transforming analog and centralized workflows into digital and decentralized production processes which have high potential to significantly increase production productivity [2]. In Malaysia, the Ministry of International Trade and Industry (MITI) said the IR 4.0 was critical to boost the industrial and economic growth and for Malaysia's economy to reach MYR 2 trillion target within the next eight years as announced recently by Prime Minister of Malaysia. Now, manufacturers in Malaysia are encouraged to automate and embrace the fourth industrial revolution or industry 4.0 in an effort to transform Malaysia's manufacturing landscape by helping reduce reliance on manual labour and keep exports competitive. Together with government actually private sector to be the real engine of growth in the fourth industrial revolution.

The objective of this work is to apply MTS specifically for classification and optimization which developed by P.C Mahalanobis and G. Taguchi at E&E industry. This work is expected to offer contributions to the current literature by providing an additional evidence and information on the impact of MTS to the industry.



2. Literature review

In 1936, a well-known Indian statistician Prasanta Chandra Mahalanobis developed the Mahalanobis Distance (MD) to identify members of a group defined by characteristics. Meanwhile in 1950s, Taguchi's robust engineering was introduced by Genichi Taguchi to improve the engineering quality [3]. Subsequently, Genichi Taguchi integrated the idea toward MTS for robust engineering by providing a means to define the reference group and measure the degree of abnormality of individual observations. Then, [4] applied the MTS for the purpose of diagnosis and pattern recognition issue using a case study of liver disease diagnosis. Theoretically, MTS is a pattern recognition technology that aids in quantitative decisions by constructing a multivariate measurement scale using a data analytic method. Multivariate data must be available on a "normal" group of items and a number of "abnormal" items that may sometimes be classified into groups based on the severity levels of the abnormalities [5]. In this approach, MD as a discriminant analysis approach, which is based on correlations between variables is used to determine the similarity, identify and analyze different patterns with respect to the mean of the reference space. Then, MD is used to produce an accurate prediction in multidimensional systems by constructing a measurement scale. There are several works related to MTS. [6] applied MTS to the big-end diameter of connecting rod to distinguish between two distinct ranges within the remanufacturability process spectrum. [7] provided a systematic analysis of the data set on the main journal diameter of crankshaft. [8] provided a systematic pattern recognition using MTS by constructing a scatter diagram which could support decision making of particular industry on 14 main journals of crankshaft belong to 7 engine models with different numbers of samples. [9] classified crankshafts' end life into recovery operations based on the MTS. [10] and [11] developed a distinctive pattern of crankshaft and identify the critical and non-critical parameter of crankshaft based on the MTS, then applied the activity based costing as a method of estimation for the remanufacturing cost of crankshaft. [12] evaluated the criticality of parameters on the end of life crankshaft based on Taguchi's orthogonal array. Then, estimate the cost using traditional cost accounting by considering the critical parameters. [13] measured the degree of abnormality using MTS and diagnosed the parameters that influence the system. [14] and [15] proposed of MTS and time-driven activity-based costing in electric and electronic industry to evaluate the significant parameters and develop time equation and capacity cost rate respectively.

3. Methodology

The E&E industry is one of Malaysia's leading industries which contributed 24.5 percent in manufacturing sector production. Malaysia also is a leading contributor in the global E&E chain. This work has been conducted at XXX Sdn. Bhd. as a global provider of electronic component for critical performance solution. Since the industry received a big demand on the inductor component from customers, this work selected that component as a subject matter. According to [16], MTS is developed into four stages:

Stage 1: Construction of measurement scale with the Mahalanobis space (MS) as a reference. The feature data from healthy products are collected to form the normal data set. Mahalanobis distance (MD)s that constitute reference space is known as MS. The value of MDs is around one.

Stage 2: Validation of MS. Observation of abnormal condition are selected out first. Their feature data sets are normalized using the mean and standard deviation of the normal data set. Then, the MDs are calculated using the normalized feature data and the covariance coefficient matrix of the normal data set. Then, the MD corresponding to the abnormal condition will be consider as out of MS. In other words, these abnormal condition associated MDs will have higher values.

Stage 3: Optimization. The useful features will be selected out using orthogonal arrays (OAs) and signal-to-noise ratios (S/N ratios). OAs is used to identify the important features by minimizing the different combination of original set of features. The number of columns in OAs in depend on the number of features. There are two levels factors that consist in OAs which are level 1 and level 2. Level 1 can be described as used which means including the feature in the calculation while level 2

can be described as unused which means excluding the feature in the calculation. The S/N ratios calculated only using the abnormal condition.

Stage 4: Diagnosis and prognosis. In this stage, MS reconstructed and the MDs of monitored product are calculated by using the useful features that identified in stage 3. If the value of MDs is within the MS, the monitor product will consider the normal product while the value of MDs is out of MS, the product will consider exhibit abnormal behaviors. The higher the MDs are, the more deviation between the monitored product and the normal one is.

The variables of inductor component can be classified into categorical and numerical data as shown in Table 1 with their normal and abnormal limit.

Table 1. Variables with limit

Variables	Numeric	Categorical	Normal limit	Abnormal limit
Wire condition		✓	1-3	4-6
Winding condition		✓	1-2	3-4
Epoxy condition		✓	1-3	4-6
Core condition		✓	1-5	6-10
Lead part condition		✓	1-3	4-6
Marking condition		✓	1-2	3-4
Soldering condition		✓	1-3	4-6

4. Result and discussion

After the data being investigated and separating process between healthy and unhealthy dataset, the calculation of the MD has been made by using MATLAB. The data has been provided by the company and the selection of unhealthy groups is according to the rejected type in all workstations for this component. Normal condition or healthy condition expressed in the Table 2. There are seven conditions with the normal numbers nearest to the one. Normal or healthy conditions where the unit component in good quality after inspection.

Table 2. Normal condition in February 2018

Number of Samples	Condition of wire	Condition of winding	Condition of epoxy	Condition of core	Condition of lead part	Condition of marking	Condition of soldering
1	2	1	1	3	2	2	2
2	2	2	1	5	3	2	3
.
5529	3	2	2	4	3	1	2
2230	2	1	2	1	3	1	2

Abnormal or unhealthy condition has 156 numbers of samples with seven conditions. The unhealthy condition decided by the rejected type of inductor component according to workstations. The data can be seen in Table 3

Table 3. Abnormal condition in February 2018

Number of Samples	Condition of wire	Condition of winding	Condition of epoxy	Condition of core	Condition of lead part	Condition of marking	Condition of soldering
1	5	3	6	8	5	3	6
2	6	4	4	10	5	3	4
.
155	5	4	6	7	4	4	5

156	4	3	5	8	5	3	5
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From the data analysis in February, one day has been selected which is fourteen February 2018. Two groups of data have been generated by using MATLAB to calculate the MD. MD result came out in graph as shown in Figure 1.

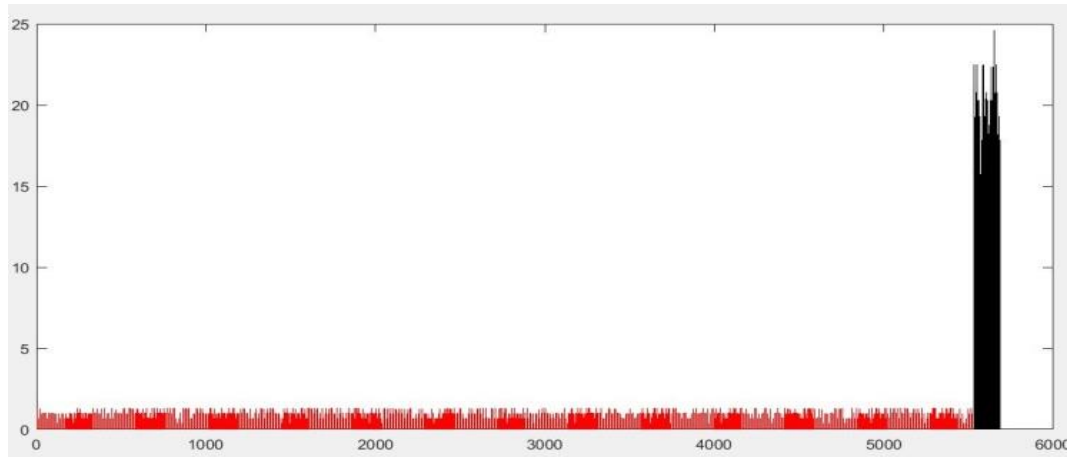


Figure 1. MD result with normal and abnormal conditions in February 2018

From the result, as can be seen in above there are two different colors which are red represent healthy group and dark color represent unhealthy group. The optimization occurred for both groups. Mean MD of healthy group with optimization is 0.9998, while mean MD of unhealthy group with optimization is 15.6538. There are seven conditions of parameter and after optimization there are two reductions occur. Then, the value of SNR gain is 0.1244. The ranges are from lowest to the highest for normal and abnormal conditions.

Lastly at the month of 2018, eighteen of December has been chosen with averagely 3493 number of samples in normal group conditions. Same as before, in Table 4 reveal the seven conditions of parameters and the two lowest and two highest ranks in normal conditions.

Table 4. Normal condition in December 2018

Number of Samples	Condition of wire	Condition of winding	Condition of epoxy	Condition of core	Condition of lead part	Condition of marking	Condition of soldering
1	3	1	1	5	2	1	2
2	3	2	1	4	3	2	1
.
3492	3	2	1	5	2	1	3
3493	1	2	1	2	2	2	3

Then, on abnormal group there are averagely 91 numbers of samples to be analyze as shown in Table 5. The abnormal conditions are from rejected type of conditions throughout the workstations.

Table 5. Abnormal condition in December 2018

Number of Samples	Condition of wire	Condition of winding	Condition of epoxy	Condition of core	Condition of lead part	Condition of marking	Condition of soldering
1	4	3	4	8	4	3	5
2	4	4	6	8	4	3	6

90	4	3	6	9	5	3	6
91	5	4	4	6	4	4	4

In Figure 2 is the result of MD that has been generated from the two groups, which are normal and abnormal. MD has been calculated to know how much the optimization occur for this month.

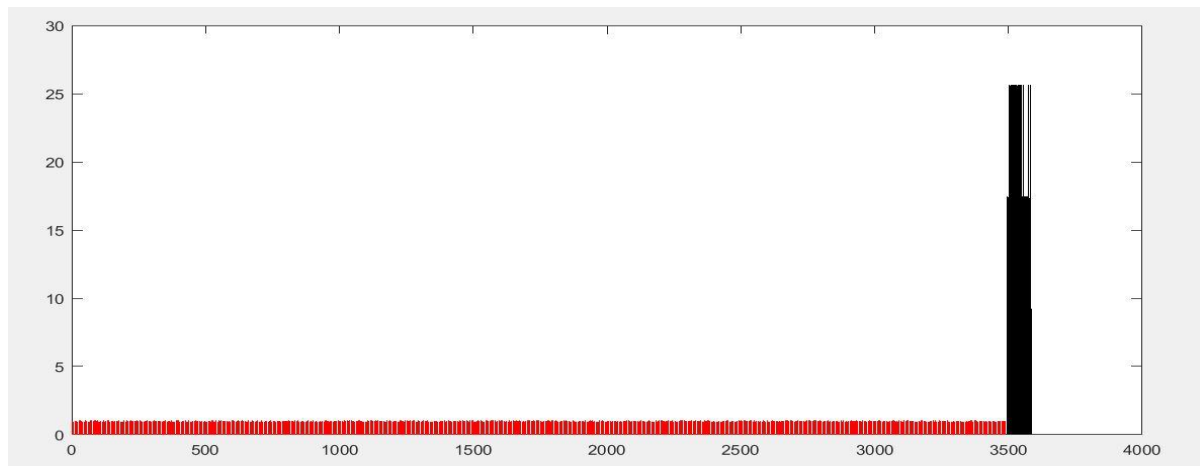


Figure 2. MD result with normal and abnormal conditions in December 2018

The result for MD for both groups of data showed and the red color represented normal and dark color represented abnormal. Mean MD of healthy group with optimization is 0.9997, while mean MD of unhealthy group with optimization is 18.2141. There are seven conditions of parameter and after optimization there five parameter reductions occur. Then, the value of SNR gain is 0.4432. The ranges are from lowest to the highest for normal and abnormal conditions. SNR gain in positive value is the good sign of data analysis in MTS. Parameter reduction has been occurred during data generated and MD result by using MATLAB. Optimization occurred and there is parameter reduction. Analysis in table below shows which condition of parameter has been selected after parameter reduction occurs.

Table 6. Consistency of variables for each month

Month	Condition of wire	Condition of winding	Condition of epoxy	Condition of core	Condition of lead part	Condition of marking	Condition of soldering
Feb	√	√	√	×	×	√	√
March	×	√	×	×	√	√	×
April	√	√	√	×	×	√	×
May	√	√	√	×	√	√	√
June	×	√	√	×	√	√	×
July	√	√	√	×	×	√	×
Sept	×	√	√	×	×	√	√
Oct	×	√	×	×	×	√	√
Nov	×	√	√	×	×	√	×
Dec	×	√	×	×	×	√	×

According to the Table 6, the parameter with condition of winding and condition of marking are consistently selected for every month. Then, the condition of core is the most unselected parameter throughout the months. Then it can be remove. Then, SNR Gain also one of the result after generated

the normal and abnormal dataset. The value of SNR Gain has been recorded and the list as shown in Table 7.

Table 7. SNR Gain

Month	February	March	April	May	June	July	September	October	November	December
SNR Gain	0.1244	0.1914	0.1338	0.0439	0.0968	0.2344	0.1748	0.3202	0.3295	0.4432

SNR Gain in February, March, April, May, June, July, September, October, November and December are all in positive value. From the analysis can be conclude that, the positive sign in SNR Gain is very meaningful and in good condition.

5. Conclusion

This work successfully applied MTS on inductor component at E&E industry. This work found that positive gain through signal to ratio (SNR) indicated the quality of system still in good condition from February with 0.1244 until December with 0.4432 after insignificant variable have been removed. This work also suggested condition of core should be removed since the variable does not contribute to the system along 2018. Meanwhile, some variables are showed inconsistency of significant to the system such as wire condition, epoxy condition, lead part condition and soldering condition. This concluded that MTS is a practical method for classification and optimization in the industry.

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References

- [1] Li L 2017 *Technol. Forecast. Soc. Chang* **135**:66-74
- [2] Liao Y, Deschamps F, Loures EDFR and Ramos LFP 2017 *Int. J. Prod. Res.* **55**(12):3609–29
- [3] Su CT and Hsiao YH 2009 *IEEE Transactions on Knowledge and Data Engineering* **21**(2):192-205
- [4] Taguchi S 2000 *ASI Taguchi Symposium*
- [5] Woodall WH, Koudelik R, Tsui KL, Kim SB, Stoumbos ZG, Carvounis CP, Jugulum R, Taguchi G, Taguchi S, Wilkins JO, Abraham B, Variyath AM and Hawkins DM 2003 *Technometrics* **45**(1):1-30
- [6] Abu MY, Jamaludin KR, and Ramlie F 2014 *1st Inter., Materials, Ind., and Manuf., Conf.*, **845**:584-89
- [7] Abu MY and Jamaludin KR 2014 *1st Inter., Materials, Ind., and Manuf., Conf.*, **845**:883-88
- [8] Mohd Yazid A, Khairur Rijal J, Awaluddin MS and Emelia Sari 2015 *12th Global Conf., on Sustainable Manuf.*, **26**:258-63
- [9] Abu MY, Jamaluddin KR and Zakaria MA 2017 *Inter. Journal of Automotive and Mechanical Engineering* **13**(2):3413-22
- [10] Nik Mohd Kamil NN and Abu MY 2018 *Journal of Modern Manuf., Systems and Technology* **1**:39-51
- [11] Abu MY, Mohd Nor EE and Abd Rahman MS 2018 *IOP Conference Series: Materials Science and Engineering* **342**:1-10
- [12] Abu MY, Norizan NS and Abd Rahman MS 2018 *IOP Conference Series: Materials Science and Engineering* **342**:1-9
- [13] Azmi II, Zaini SNAM and Abu MY 2019 *Journal of Modern Manufacturing Systems and Technology* **3**:1-8

- [14] Nik Mohd Kamil NN, Abu MY, Zamrud NF and Mohd Safeiee FL 2020 *Pro., of the Inter., Manuf., Engineering Conf., & The Asia Pacific Conf., on Manuf., Systems* 108-14
- [15] Mohd Safeiee FL, Abu MY, Nik Mohd Kamil NN and Zamrud NF 2020 *Pro., of the Inter., Manuf., Engineering Conf., & The Asia Pacific Conf., on Manuf., Systems* 121-27
- [16] Ghasemi E, Aaghaie A and Cudney EA 2015 *International Journal of Quality & Reliability Management* **32**(3):291-307