UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Information and Communication Technology

DETERMINING OPTIMAL PROCESS MEAN FOR SMALL AND MEDIUM JUICE PROCESSING INDUSTRIES USING MARKOVIAN MODEL

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DETERMINING OPTIMAL PROCESS MEAN FOR SMALL AND MEDIUM JUICE PROCESSING INDUSTRIES USING MARKOVIAN MODEL

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A thesis submitted

in fulfillment of the requirements for the degree of Master of Science in

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2014

DECLARATION

I declare that this thesis entitle “Determining Optimal Process Mean for Small and Medium Juice Processing Industries Using Markovian Model” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Information and Communication Technology.

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Supervisor Name	:	**ASSOCIATE PROFESSOR DR ABD SAMAD BIN HASAN BASARI**
Date	:	……………………..............

DEDICATION

Dear Allah

I devoted my life and death to You, Allah. May my life is within Your guidance.

Dear My Parent

Thank you for your sacrifice and love. No such compensate except from Allah.

Dear My Beloved Husband

Your support, patience and encouragement give me strength to finish this study. May Allah bless us.

Dear Teachers

Thank you for all the knowledge. May your knowledge are beneficial and useful for all humanity.

Dear My Siblings

Thank you for your support and love. May Allah forgive us.

Dear My Children

May Allah guide and protect us to be good Muslims.

ABSTRACT

The determination of process mean is important in industries especially for items that governed by laws and regulations on net content labelling. Thus, the economic selection of optimum process mean is critically significant since it will directly affect the quality characteristic of item. By assuming the quality characteristic is normally distributed, an item that undergoes the juice filling in the container can be classified as accepted product, under-filled or over-filled by the system which is successfully transform to the finishing product. This research is focused on the setting of process mean in juice processing industries, especially before production starts as it is important in order to produce an item that fulfil within the specification limit with the aim of gaining the maximum profit. Moreover the determination of optimal mean value involves a complex decisions and small and medium enterprises (SME's) constraint is especially in financial point of view. The Markovian model is chosen as it considers the long-term probabilities in dynamic system. In this research, the analysis of selecting the process mean of juice filling in the bottle in the SME production is presented. Three main objectives are stated, namely, to propose a Markovian model for mean value estimation as a main parameter estimation of expected profit estimation, to simplify the process of selecting optimal mean value estimation in Markovian model using quartile-based method and to evaluate the performance of Markovian model using iteration rate for estimation in juice processing industries. The process of juice filling from the raw materials until end products is developed based on the single-stage process. The Markovian model that considered the under-filled and over-filled products is proposed in the study. By varying the under-filled and over-filled cost, the analysis shows the significant results of Markovian model to determine process mean which maximizes the expected profit per item. The simplification method of targeting process mean by using quartile-based is also performed in order to reduce and minimize the searching iteration process of optimal mean. The variation of juice minimum volume in the bottle is set from 1% to 10% lower than upper limit value of each bottle that available in the market. The variation is needed in order to evaluate the trends of process mean determination. The main contribution of this research is the Markovian model that is used in juice processing industries, which refer to the accepted bottles, under-filled bottles and over-filled bottles. From the different state of finished product, the determination of optimal process mean is referred to the maximum profit gained. Besides, the simplification method of searching the optimal process mean has shown a significant outcomes which reduce and minimize the iteration process. By varying the lower limit of amount in the bottle, one can see the trends of optimal process mean and yet use the variation as a guide to set the process mean before start the juice filling process.

ABSTRAK

Penentuan min proses adalah penting dalam industri terutamanya pada barangan yang dikawal oleh undang-undang dan peraturan-peraturan yang berkaitan dengan pelabelan kandungan bersih. Oleh itu, pemilihan proses optimum yang ekonomik adalah amat penting kerana ia secara langsung akan memberi kesan terhadap ciri kualiti item tersebut. Dengan menganggap ciri kualiti adalah normal, setiap bekas yang diisi dengan jus itu akan diklasifikasikan sebagai produk yang diterima, produk yang diisi kurang atau produk yang terlebih isi. Kajian ini memberi tumpuan kepada penetapan proses min dalam industri pemprosesan jus, terutamanya sebelum pengeluaran bermula kerana ia penting untuk menghasilkan item yang memenuhi had spesifikasi untuk mendapatkan keuntungan maksimum. Seterusnya, penentuan nilai min yang optimum melibatkan keputusan yang kompleks dan ini akan menjadi kekangan kepada Industri Kecil dan Sederhana (IKS) terutamanya dari sudut kewangan. Model Markovian dipilih kerana ia mengambil kira kebarangkalian jangka panjang dalam sistem dinamik. Dalam kajian ini, analisis untuk memilih min proses dalam pengisian jus ke dalam botol dalam pengeluaran IKS ditonjolkan. Tiga objektif utama telah dikenalpasti, iaitu untuk mencadangkan model Markovian dalam mencari nilai min yang optimum iaitu parameter utama dalam mencapai keuntungan, untuk memudahkan proses memilih anggaran nilai min yang optimum dalam model Markovian menggunakan kaedah asa kuartil dan menilai prestasi model Markovian menggunakan anggaran kadar pengulangan dalam industri pemprosesan jus. Proses pengisian jus dari bahan mentah sehingga produk akhir adalah dibangunkan berdasarkan proses satu peringkat. Model Markovian ini mempertimbangkan produk yang diisi kurang atau yang terlebih isi. Dengan mengubah kos produk yang diisi kurang dan produk yang diisi lebih, hasil analisis menunjukkan dapatan yang signifikan penggunaan model Markovian dalam menentukan min proses bagi setiap item. Kaedah permudahan dalam mencari target min proses menggunakan asas pengulangan dilakukan untuk mengurangkan dan meminimumkan pengulangan proses pencarian min yang optimum. Variasi jus yang minimum dalam botol ditetapkan daripada 1% ke 10% lebih rendah daripada nilai had atas setiap botol yang terdapat dalam pasaran. Sumbangan utama dalam kajian ini adalah melibatkan model Markovian yang digunakan dalam industri pemprosesan jus, yang merujuk kepada botol yang diterima, botol yang diisi kurang dan botol yang diisi lebih. Berdasarkan kepada keadaan yang berbeza, penentuan min proses yang optimum adalah merujuk kepada pencapaian keuntungan yang maksimum. Selain itu, kaedah yang mudah dalam mencari min proses yang optimum telah menunjukkan hasil yang signifikan iaitu dengan mengurangkan dan meminimumkan proses yang berulang. Dengan mengubah had yang lebih rendah daripada jumlah di dalam botol, kita boleh melihat trend proses min yang optimum dan menggunakan variasi ini sebagai panduan untuk menetapkan min proses sebelum memulakan proses pengisian jus.

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LIST OF ABBREVIATIONS

SME - Small and Medium Enterprise
NP - Non-deterministic Polynomial-time
MRL - median run length
P - transition probability matrix
S - set
p - probability
M - fundamental matrix
I - identity matrix
m_{11} - expected number of times in the long run
F - long run absorption probability matrix
A - identity matrix which represent the probability of staying in a state
O - matrix representing the probabilities of escaping an absorbing state (always zero)
R - matrix that contains probabilities of going from non-absorbing state to any absorbing state
Q - matrix that contains probabilities of going from non-absorbing state to any non- absorbing state
f_{12} - probability of item being accepted
f_{13} - probability of item being scrapped
SP - selling price
PC - processing cost
SC - scrap cost
RC - rework cost
OC - over-filled cost
UC - under-filled cost
EPR - expected profit per item
ϕ - probability
exp - exponent

μ - mean

U - upper limit

L - lower limit

Q_1 - first quartile

Q_3 - third quartile

IQ_1 - first inter-quartile

IQ_3 - third inter-quartile

ml - millilitre

σ -standard deviation

ln -natural logarithm

LIST OF PUBLICATIONS

Published in Journal

1. Abd. Samad Hasan Basari, Hazlina Razali, Burairah Hussin, Siti Azirah Asmai,, Nuzulha Khilwani Ibrahim, Abdul Samad Shibghatullah, Applied Markovian Approach for Determining Optimal Process Means in Single Stage SME Production System. 2011. *International Journal for Advances in Computer Science,* 2 (3), pp. 1 – 7.

2. Abd. Samad Hasan Basari, Hazlina Razali, Burairah Hussin, Siti Azirah Asmai, Nuzulha Khilwani Ibrahim, Abdul Samad Shibghatullah, Markovian Approach Enhancement to Simplify Optimal Mean Estimation. 2014. *Applied Mathematical Sciences,* 8 (111), pp.5507-5516.

Seminar/ Workshop/ Conference Papers

1. Abd. Samad Hasan Basari, Hazlina Razali, Burairah Hussin, Siti Azirah Asmai, Nuzulha Khilwani Ibrahim, Abdul Samad Shibghatullah, Optimal Mean Value Estimation Via Markovian Approach, *ICEI 2012*, Melaka Malaysia, 4-5 April 2012.

2. Abd. Samad Hasan Basari, Hazlina Razali, Burairah Hussin, Siti Azirah Asmai, Nuzulha Khilwani Ibrahim, Abdul Samad Shibghatullah, The Integration of Simple Markov Model in Solving Single Line Production System, *2011 7th International Conference on IT in Asia (CITA),* Sarawak, Malaysia, 12-14 July 2011. pp. 159-162.

3. Abd. Samad Hasan Basari, Hazlina Razali, Burairah Hussin, Siti Azirah Asmai, Nuzulha Khilwani Ibrahim, Abdul Samad Shibghatullah, A Markovian Approach to Determine Optimal Means for SME Production Process, *MUiCET 2011*, 13 – 15 November 2011, Katerina Hotel, Batu Pahat.

CHAPTER 1

INTRODUCTION

1.1 Backgrounds

The selection of targeting process parameters plays an important role for manufacturers. The problem of targeting process parameters is concerned with the determination of optimal process parameters, namely mean and variance and is important in satisfying such a desirable goal especially in achieving the production target. In fact, the process mean and variance have been found to have significant impact of the profit that can result from a production system (Alshara, 2007). In production systems, the process mean represents the value at which each machine is set up to operate. It is one of the most important parameters that affect the efficiency of the quality control systems and the products' quality. Optimal targeting process has received a considerable attention from researchers as well as practitioners (Duffuaa and El-ga, 2013, Goethals and Cho, 2012 and Hong and Cho, 2007). This problem in not really new though, with research was dating back to the early 1950s. Since then, several researchers have proposed various models in order to achieve the optimum profit in the production.

The selection of optimum process mean will directly affect the process defective rate, production cost, rework cost, scrap cost and the cost of use. Production processes are usually designed in a way that the product satisfies a set of specifications. The aim is to find the optimum values of process parameters or machine settings that will achieve certain economic objectives which are usually refer as maximum profit. However, determining the optimal mean of manufacturing process involves a complex and very important decision especially in financial point of view. A number of models have been proposed in the literature for determining an optimum target based on mean or variance.

One of the ways to improve the quality characteristics is to ensure that the product deviates little from the customer defined process target of quality characteristics. By setting up the optimum target value or process mean is already known as a classical problem in quality control. The issue of determining the process mean is particularly important in industries such as food especially in liquid product, drug and cosmetic industries as it is critically important to industries which are governed by laws and regulations on net content labelling (Tahera et al., 2008 and Darwish, 2009). The laws require that the declaration of net content accurately expresses the actual net content. The improper selection of the process mean may affects defect rate, material cost, scrap or rework cost and possible losses due to the deviation of the product performance from the customer's or producer's target (Goethals and Cho, 2011 and Tahera et al., 2010).

The problem of selecting the most profitable mean value is very much being researched for manufacturing processes such as filling (Jordan and Smith, 2006), metal plating (Mukherjee and Ray, 2006) and grinding (Kwak, 2005 and Mukherjee and Ray, 2008). All products are inspected to determine whether their quality characteristics satisfy the lower and upper specification limits.

Normally conforming products are sold at a regular price, whereas non-conforming products are scrapped, reprocessed or sold at a discounted price. Typical the quality characteristic which are applicable for this strategy are weight, volume, number and concentration (Min-Koo et al., 2004). Products may deviate from the process mean because of variations in materials, labour and operational conditions. The process mean could be adjusted to the centre of lower and upper specification limits in order to ensure the proportion of the nonconforming items is minimized. However, this does not always guarantee the minimum total cost in relation with the manufacturing process. For the economic purpose, the decision of selecting a process mean should be based on the trade-off among production cost, payoff of conforming items, and the costs incurred due to nonconforming items. It is important to keep the machine settings at levels that would ensure the products conformity with the specifications limits. The specification limits, which are customer-driven requirements, whether internally or externally, are the desired boundaries of a quality characteristic.

As a result of advances in automated manufacturing systems, censoring technology and automatic inspection equipment, complete inspections are increasingly used to improve the outgoing quality of the product. Every product is inspected to determine whether its quality characteristic satisfies the specification limits (Lee et al., 2007 and Baudet et al., 2013).

One of the most important decision making problems encountered in a wide variety of industrial process is the determination of optimum process target by considering mean value as the main parameter. The optimum process mean setting is used to select the manufacturing target. The selection of the appropriate process parameters is of major interest and importance in satisfying such a desirable goal. A number of models have been proposed in the literature for determining an optimum target. According to

Taguchi (1986), if the process mean approaches the target value and the process standard deviation approaches zero, then the process is under optimum control.

According to Liu (2013), the production parameters in the system, such as the process mean, variance, specification limits and costs cannot be simply controlled or changed. This is due to the specification limits that being designed by engineers or they have satisfied with the standard given by the government. The value of variance could be determined by machines' characteristic, which also cannot be changed, or, the cost improvement may be too high. Therefore, the optimal process mean is the only parameter that can be controlled easily. It will have significant effect on cost reduction while maintaining high quality. Significant work has been done on modelling manufacturing systems to obtain the optimal process mean, typically by setting the objective of maximizing the profit or minimizing the overall cost (Shi et al., 2010 and Sharda and Banerjee, 2013).

Most of the researches assumed that each quality characteristic is performing a screening with 100% using an inspection scheme. The 100% inspection scheme implies that all items which are processed at any stage must be inspected. However in the case of Small and Medium Enterprise (SME) industries, 100% screening is such a constraint due to financial difficulty. According to National SME Development Council (2013), the definition of SME has been simplified under two categories, namely manufacturing and services and other sectors. As for manufacturing category, the micro companies is when the sales turnover is less than RM 300,000 or has full-time employees than 5 people. While for the small enterprise is when the sales turnover from RM 300,000 to less than RM 15 million or which has full-time employees from 5 to less than 75. While for medium enterprise when the sales turnover from RM 15 million to not exceeding RM 50 million or when the full-time employees from 75 to not exceeding 200. Companies beyond the limit are falls under large enterprise. SME plays an important role for generating the country's economic growth and also to sustain the regional and global economic recovery.

Since SME has limited capital, they are not able to upgrade the inspection process. Alternatively they refer to expert to perform the inspection. Other than that, the SME companies also facing problem to determine the amount of filling in each of the bottle as they are not equipped with high-end technology and machineries. To overcome this problem, they usually refer to expert in determining the filling amount. However, as for expert judgement also has its deficiency as their judgement are not guaranteed right and inconsistent. Due to this facts, the calculation of the optimum expected mean also could affect the real maximum expected profit.

1.2 Problem Statements

The challenge of Small and Medium Enterprise (SME) companies are to sustain their business as long as they can. One of the options is by maximizing the profit margin where the profit can be gained in early stages of the product development in the production line.

Basically, the filling process in SME food industries also facing difficulty as most of the companies is not equipped with high end technologies. Due to that, the initial setting of the process is by referring to the expert judgement which is based on their experience in consequence. However, the expert judgement in setting the initial value of process mean also not consistent. Thus, this will lead to inconsistency of filling the optimum amount of juice in the bottle.

The targeting problem has many applications and the most widespread application is the canning or filling problem in which the quality characteristic is the amount of fill, or ingredient, put in a can or bottle. For the filling or canning industry, the product needs to be produced within the specification limits. Normally, the product characteristic within the specifications is considered as the conforming item. Since the probability of producing a good item, *p*, can be controlled by setting the production process mean, it is possible to find the value of the process mean that will maximize the net profit per fill item.

Consider a certain quality characteristic, where a product is rejected if the products performances either falls above an upper specification limit or falls below a lower specification limit. If the product performance is higher than the upper limit, the product can be reworked, whereas the product is scrapped if it is falls below than lower limit (Chou et al., 2002, Bowling, 2004 and Selim and Al-Zu'bi, 2011). If the process target is set too low, then the proportion of non-conforming products becomes high, but the manufacturer may experience high rejection costs associated with non-conforming products. Therefore the determination of optimal mean value estimation is essential to provide a manufacturer an optimal value for their product specifications. This method will avoid them from facing loss due to penalty cost while customers do not need to pay the excessive quantity of the product.

As normally implemented in SME industries, there are only a few machines that are connected simultaneously in a serial line. Therefore, the inspection stage at each machine is important to determine the conformance item and yet to be categorized as accepted item. However, SME industry has not enough equipment to screen each item that being processed. Due to above mentioned scenario, the setting of mean process at each machine before starting the production is very important in order to avoid production loss and in consequence reducing the companies' profit. However, determining the optimal mean of manufacturing process involves a complex and essential decision especially in financial point of view.

In Alshara (2007) study, the author is also considering the filling system. However, the author noted that most of the literature in the filling system only deal with short-term probabilities (scrap or rework, for example), which does not give a true representation of the filling system. The author stated that the true system dynamics are well-presented by Markovian approach.

Based on the review above, the problem statement can be concluded as below:

1. The needs to develop a model that can fit the SME requirements during the production process.
2. In filling industries, setting of process mean before production starts is important in order to produce an item that fulfil within the specification limit with the aim of gaining the maximum profit.
3. Determining the optimal mean value involves a complex decisions and this will be the SME's constraint especially in financial point of view.

1.3 Research Questions

This research preliminary aim to propose a method for determining the process mean which satisfy the desirable goal of manufacturer which usually referring to maximum profit. Based on the problem statement above, the research question that will lead this research can be concluded as follows: