OPTIMAL PRODUCTION VOLUME OF RUBBER GLOVES MOLD FOR RUBBER GLOVES PRODUCTION PLANNING

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KEYWORDS

Production planning, Rubber glove, Rubber glove Mold.

ABSTRACT

The production process of rubber glove is the continuous production line which the hand-shaped ceramic molds are installed and dipped into the concentrated latex to form the rubber gloves. Since, the rubber gloves are diverse in terms of size, surfaces and types of latex, the multiple molds and latex are changed and used in a production process in order to produce rubber gloves from customer requirement. Thus, the changing of mold is extremely complex for production ratio which the rubber glove production planning will be employed to meet anticipate customer orders. This research therefore develops the mathematical model to find the optimal quantity of molds and rubber gloves production planning. Finally, the developed model is applied to an example data set to find the minimum total volume of rubber gloves in every mold for keeping the minimal volume of inventory.

INTRODUCTION

Rubber gloves industry has become increasing significant for Thai economy. At present, a large volume of natural latex is used for producing rubber gloves which extracted from rubber trees. Rubber is one of the important industrial crops for Thailand, both for the local consumption and the global market. From the export data of Thai Custom Department in 2014 it was found that rubber gloves had contributed an enormous export values to Thai economy. The uses of gloves as part of infection control within healthcare will be increased extensively in the near future, as at present people are more and more aware of their health and cleanliness. The growth of sale will also affect the manufactures to serve their customer needs.

Rubber gloves industry has a complicate and complex process in production planning due to several of type and size of products. Moreover, each type of glove uses different raw materials to produce. The process of producing rubber gloves is forming by dipping each size hand-shaped ceramic mold into a tank full of concentrated latex with the length of time. Moreover, the machines will be run all the time. The volume of production in each batch will depend on a number of hand-shaped ceramic molds which are set up within each machine by size and type of mold. Therefore, in production planning process, it is obligatory to find a number of hand-shaped ceramic molds which are fit with orders from customers. Excess or shortage items should be minimal in each type and size of production run. If the production planning process does not match with customers' orders, it is necessary to stop the production run in order to set up the machine again by changing molds. This will result in loosing time and budget in setting up the machines.

Most of the literature in the area of production management for the rubber glove industry is related to the structure of the rubber industry (Haan et al. 2003), production improvement (Jirasukprasert et al. 2012) and economics and environment (Rattanapana et al. 2012. The researches on production planning for the rubber gloves manufacturing are still limited. Klomsae et al. 2012 present an applied mathematical model for rubber latex industry decision planning, that covers purchase and storage over a multi-period timeframe, with due consideration of product aging and deterioration through each time period. However, there has not been research related to the production planning of rubber glove products involving the mold. Thus, this paper presents the production planning and scheduling for rubber gloves with mixed mold sizes and types.

Most production planning and scheduling has been done by applying mathematical models (Hsu et al. 2011, Wen-Chiung et al. 2012 and Yan et al. 2013). Birger R. et. al. 2013 present the mathematical model for multi-product multi-period aggregate production-distribution planning problem with mould sharing between plants.
This paper aims to create a mathematical model for rubber glove production planning and scheduling for multi-glove products, multi-molds, multi-concentrated latex and multi-production lines for multi-periods to plan production in order to meet the customer requirement.

The paper is structured as follows: In section 2, we provide general information about type of rubber gloves and rubber gloves production machine describe the production planning process. Then, the problem statement is discussed in section 3 and the mathematical model of the problem is developed in section 4. A numerical example and its computational results are presented in Section 5. Finally, concluding remarks and further work are provided in the last section.

RUBBER GLOVES INFORMATION

The types of rubber gloves, hand-shaped ceramic molds and concentrated latex are described in this section.

Types of Rubber Gloves

Generally, here are three main types of rubber glove i.e. 1) medical glove, 2) industrial glove and 3) household glove. Details are as follows:

a) Medical Glove

Medical gloves use during medical procedures to prevent contamination between caregivers and patients. Medical glove can be divided into two major types which are surgical and examination. Surgical gloves are generally sterile and feature extra long reinforced cuffs. Generally, these gloves are thicker for use in higher-risk clinical applications for extra protection. So, high technology process in production and sensitive procedures are necessary to make sure that manufacturers of these devices have a higher standard. Examination gloves are available as either sterile or non-sterile which made from 100% synthetic latex, both powder-free and powered. Medical gloves are regulated by the Food and Drug Administration (FDA) to make sure that manufacturers can meet performance criteria such as leak and tear resistance.

b) Industrial Glove

There are various types of industrial gloves which are produced to protect against a wide variety of hazards. Normally, determining which type of glove to use is depended upon the duration of the job, the type of conditions or the environment (wet or dry). These gloves are designed to ensure employee safety and sanitary conditions in the workplace and provide both strength and chemical protection. For example, heat or cut resistant gloves have different properties and compositions from chemical and oil resistant glove.

c) Household Glove

Household glove are generally used for domestic cleaning and food processing purposes. It provides ergonomic design to ensures excellent abrasion as well as cut and tear resistance. There are different designs and colour of this type of glove in order to attract housewives. The best rubber gloves should be durable, whilst allowing users to accomplish their tasks effectively.

Hand-shaped Ceramic Molds

A number of gloves to be produced depend on a number of molds which are set up in a machine. Normally,there are many kinds of rubber glove, for instance, just smooth skin or "dot" on the fingertips or plams that let users can touch device without smudging or scratching it. Moreover, there are many sizes of rubber gloves which suit for users' hand such as XS, S, M, L, XL or XXL. In each mold conveyor, it can be mixed every size and type of rubber gloves in one production line. Hence, planners should find out the exactly molds in their factories before making a production scheduling. Table 1 shows an example of molds for each item in a case study of this research.

Table 1: An Example of Molds for Each Item

Number of hand-shaped ceramic molds						
Type\size	XS	S	M	L	XL	XXL
Smooth Skin	10,000	20,000	50,000	50,000	20,000	10,000
Dots Balm	10,000	10,000	20,000	20,000	10,000	10,000
Dots Finger	10,000	10,000	10,000	10,000	10,000	10,000

Types of Concentrated Latex

Natural rubber is obtained from different species of rubber trees in form of latex which is called normal or field latex. The latex is then placed into a centrifuge to remove some of water and increase rubber content of the latex. After centrifuging, the material is known as concentrated latex, which contains about 60% rubber, are then compounded by adding other raw material ingredients to achieve the desired performance characteristics. On the other hand, synthetic latex is produced from a petrochemical which is developed as an alternative to natural latex for some people who are allergic reaction to natural latex rubber. The 4 types of latex used in this study are Natural latex, Synthetic white latex, Synthetic blue latex, and Synthetic black latex.

PROBLEM STATEMENT

The productions planning process of rubber gloves starts from the marketing department receives the orders from customers and sends them to the production planning department for scheduling. Normally, at the first step a planner will rearrange schedule according to due date and inform a plan to other departments such as logistics and transportation department. Afterwards, the planner will check on-hand inventory and calculate actual volumes that are needed to produce. It is necessary to consider capacity of each size in all production lines in real time in order to create production schedule of each machine. If the machine is not processing the same type of rubber gloves, it will be terminated to change ceramic molds; otherwise, that orders are cancelled. After the master production schedule (MPS) is set up, it will be returned to customers to confirm delivery time.

At present, a planner can get anticipated demand in each type and size of product in advance. A number of molds for each type and size to be fixed with each machine as well as running time process are calculated to be ensured that the products will be sent to customers on time. The amount of products depends on a number of molds which are set up at each machine by taking size and type of molds into consideration. Such process is very complicated and takes a long time for the production planner in operating and sometimes this can cause a mistake. Such optimization problem can effectively be solved using mathematical modeling. Figure 1 presents the conveyors of production lines which the molds are installed.

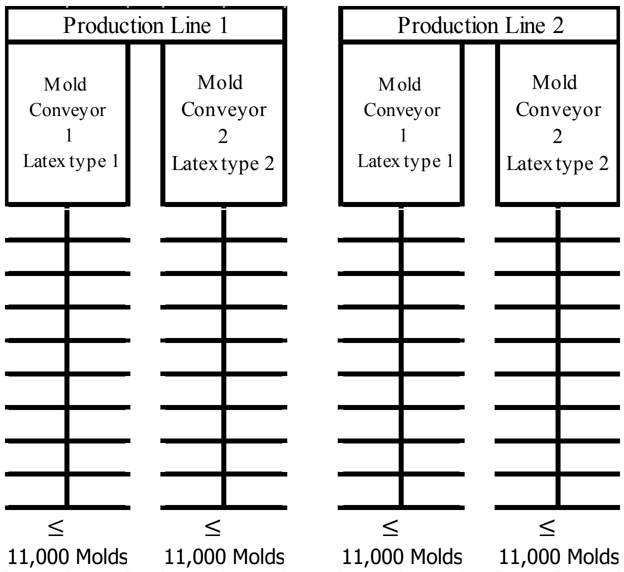

Figure 1: Mold Conveyors of Production Lines

Therefore, the production planning of rubber gloves is a process of bringing anticipated demand one month ahead to find the production volume in order to set up machines. Each machine is required to produce rubber gloves upon the customers demand. The followings are the conditions and limitation of rubber glove production machine.

- The number of mold for each machine is limited.
- Each conveyor has the same piece of mold and run simultaneously.
- Each type and size of molds is limited.
- Each machine can mix 2 types of latex. In mold conveyor 1 and mold conveyor 2 must be the same latex.

Table 2 summarizes the conditions.

Table 2: Conditions of Rubber Glove Production Machine

Production line 1	
The machine runs 24 hours per day for 30 days for each production period.	
Rubber glove mold conveyor 1	Rubber glove mold conveyor 2
- It can be used only one type of latex. - The maximum hand-shaped ceramic molds are less than 11,000 pieces. Therefore, the maximum capacity per day is less than 11,000 × 26.81 (production rate of one ceramic mold per day) or 294,910 pieces per day. - Any size of ceramic molds can be mixed, however; ceramic molds are limited.	- It can be used only one type of latex. - The maximum hand-shaped ceramic molds are less than 11,000 pieces. Therefore, the maximum capacity per day is less than 11,000 × 26.81 (production rate of one ceramic mold per day) or 294,910 pieces per day. - Any size of ceramic molds can be mixed, however; ceramic molds are limited.

MATHEMATICAL MODEL

Details of indices, decision variables, parameters, objective functions, and constraints in production planning for rubber gloves in one month planning horizon are as follows:

Indices

i Type and size of hand-shaped ceramic mold; $i = 1, 2, 3, \ldots, I$

j Product type of latex; $j = 1, 2, 3, \ldots, J$

k Product type mold conveyor; $k = 1, 2, 3, \ldots, K$

l Production line; $l = 1, 2, 3, \ldots, L$

t Date; $t = 1, 2, 3, \ldots, 30$

Parameters

d_{ijt} Demand of rubber gloves for molds 'i' using latex 'j' in date 't'

s_{ijt} Inventory of rubber gloves for molds 'i' using latex 'j' in date 't'

c_{kl} Maximum capacity per day for mold conveyor 'k' in production line 'l'

m_i Maximum volume of rubber gloves using molds 'i'

Decision Variables

x_{ijklt} Quantity/Volume of rubber gloves from mold 'i' using latex 'j' by typing of mold conveyor 'k' in production line 'l' in date 't'

y_{jklt} Decision variable which will take on only possible states i.e. yes (1) or no (0) production by using latex 'j', typing of mold conveyor 'k' in production line 'l' in date 't'

Objective function

The objective function of the problem is to find the minimum total volume of rubber gloves in every mold '*i*' and latex '*j*' in 30 days, as shown in equation (1).

$$Min\ Z = \sum_{i=1}^{I}\sum_{j=1}^{J} s_{ij\,30} \qquad (1)$$

where

$$s_{ijt} = x_{ijklt} \cdot y_{jklt} + s_{ijt-1} - d_{ijt} \qquad ;\forall i, j,k,l,t \qquad (2)$$

Constraints

1. Quantity/Volume of rubber gloves from mold '*i*' using latex concentrate '*j*' by typing of mold conveyor '*k*' in production line '*l*' in date '*t*' is less than or equal to maximum capacity per day for mold conveyor '*k*' in production line '*l*'.

$$\sum_{i=1}^{I}\sum_{j=1}^{J} x_{ijklt} \le c_{kl} \qquad ;\forall k,l,t \qquad (3)$$

2. Quantity/Volume of rubber gloves from mold '*i*' using latex concentrate '*j*' by typing of conveyor '*k*' in production line '*l*' in date '*t*' is less than or equal to maximum volume of rubber gloves from using molds '*i*'.

$$\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} x_{ijklt} \le m_i \qquad ;\forall i,t \qquad (4)$$

3. The production of rubber gloves in every mold '*i*' in each conveyor belt '*k*' in production line '*l*' must be the same latex concentrate '*j*' only.

$$\sum_{j=1}^{J} y_{jklt} = 1 \qquad ;\forall k,l,t \qquad (5)$$

4. Shortage of rubber gloves for molds '*i*' using latex '*j*' in date '*t*' is not allowed.

$$s_{ijt} \ge 0 \qquad ;\forall i, j,t \qquad (6)$$

5. Constraints describing the decision variables.

$$x_{ijklt} \ge 0 \qquad ;\forall i,j,k,l,t \qquad (7)$$

$$y_{jklt} \in \{0,1\} \qquad ;\forall j,k,l,t \qquad (8)$$

The results from the production planning in each month using equation (1) to (8) will keep minimal on the volume of inventory of rubber gloves using mold '*i*' in every latex '*j*' in the final date of the time horizon. The schematic diagram in Table 3 shows the production quantity and demand of rubber gloves.

NUMERICAL EXAMPLE

This section demonstrates a numerical example by applying mathematical model described in section 4 using a case company in Thailand. The objective of the study is to find the number of rubber gloves volume to be produced which keep inventory in the system at the minimal by considering the requirement of customers in each item and due date. An example of customer requirement of the rubber gloves for the smooth skin, XS size and natural latex gloves (Table 4). The first oder is due on the fifteen of the month and the total requirement is 5,000,000 pieces.

Table 4: Rubber Glove Production Demand

Customer Demand				
Type	Size	Type of Concentrated Latex	Volume (piece)	Due Date
Smooth Skin	XS	natural latex	5,000,000	15
Smooth Skin	S	natural latex	5,000,000	15
Smooth Skin	M	natural latex	5,000,000	15
Smooth Skin	L	natural latex	5,000,000	15
Smooth Skin	XL	natural latex	5,000,000	15
Smooth Skin	XXL	natural latex	5,000,000	15
Smooth Skin	XS	natural latex	2,000,000	20
Dots Balm	L	natural latex	5,000,000	20
Dots Balm	XL	natural latex	5,000,000	20

The results of production planning and scheduling of rubber gloves will be displayed in terms of decision cariables of the volume of gloves to be produced using mold *'i'* latex *'j'* for mold convenyor *'k'* on production line *'l'* at date *'t'*. An example of on hand inventory of rubber gloves is zero inventory in first period. All data will be computed under production ratio of a machine using Excel solver. The results of the volume of molds to be set up for a mold convenyer *'k'* on production line *'l'* at date *'t'* are demonstrated in Table 5. By applying these formula in a production planning procedure and adjusting mold by following computational results would result in the total of inventory volumes for every mold and latex in 30 days at the minimum.

CONCLUSION AND FURTHER STUDY

This paper, the mathematical model was formulated to minimize total volume of rubber gloves under limited resource constraints. A numerical example of case study was presented. The short-term scheduling time horizon for rubber gloves production is one month, however; this model can be extended for multi-stage decision making in the future. The proposed production planning and scheduling model can improve and organize several management decisions for producing, carrying inventories, and balancing utilization of machines in the short-term planning time horizon. However, for analysis process, it may need person who can understand mathematical precisely and take time to solve such problem. Consequently, developing decision support system (DSS) can assist and support decision makers in accommodating changes in the input information.

Table 3: The Production Volume Addressed in Mathematical Model for Rubber Glove Production Planning

Rubber Gloves Production Volume of Mold *i*, Latex *j*, Mold Conveyer *k*, and Production Line *l*, in Date *t* (piece) X_{ijklt}								Rubber Gloves Demand of Mold *i*, Latex *j*, in Date *t* (piece) D_{ijt}			
Mold	Latex	Mold Conveyer	Production Line	Date of Production				Date of Rubber Glove Demant			
				t				*t*			
i	*j*	*k*	*l*	*1*	*2*	. . .	*30*	*1*	*2*	. . .	*30*
1	*1*	*1*	*1*	X_{11111}	X_{11112}	. . .	X_{111130}	D_{111}	D_{112}	. . .	D_{1130}
			2	X_{11121}	X_{11122}	. . .	X_{111230}				
			:	. . .	. . .	. . .	. . .				
			l	X_{111l1}	X_{111l2}	. . .	X_{111l30}				
		2	*1*	X_{11211}	X_{11212}	. . .	X_{112130}				
			2	X_{11221}	X_{11222}	. . .	X_{112230}				
			:	. . .	. . .	. . .	. . .				
			l	X_{112l1}	X_{112l2}	. . .	X_{112l30}				
		:	:	. . .	. . .	. . .	. . .				
		k	*l*	X_{11kl1}	X_{11kl2}	. . .	X_{11kl30}				
	2	*1*	*1*	X_{12111}	X_{12112}	. . .	X_{121130}	D_{121}	D_{122}	. . .	D_{1230}
			2	X_{12121}	X_{12122}	. . .	X_{121230}				
			:	. . .	. . .	. . .	. . .				
			l	X_{121l1}	X_{121l2}	. . .	X_{121l30}				
		2	*1*	X_{12211}	X_{12212}	. . .	X_{122130}				
			2	X_{12221}	X_{12222}	. . .	X_{122230}				
			:	. . .	. . .	. . .	. . .				
			l	X_{122l1}	X_{122l2}	. . .	X_{122l30}				
		:	:	. . .	. . .	. . .	. . .				
		k	*l*	X_{12kl1}	X_{12kl2}	. . .	X_{12kl30}				
	:	:	:	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	j	*k*	*l*	X_{1jkl1}	X_{1jkl2}	. . .	X_{1jkl30}	D_{1j1}	D_{1j2}	. . .	D_{1j30}
2	*1*	*1*	*1*	X_{21111}	X_{21112}	. . .	X_{211130}	D_{211}	D_{212}	. . .	D_{2130}
			2	X_{21121}	X_{21122}	. . .	X_{211230}				
			:	. . .	:	. . .	:				
			l	X_{211l1}	X_{211l2}	. . .	X_{211l30}				
		2	*1*	X_{21211}	X_{21212}	. . .	X_{212130}				
			2	X_{21221}	X_{21222}	. . .	X_{212230}				
			:	. . .	. . .	. . .	. . .				
			l	X_{212l1}	X_{212l2}	. . .	X_{212l30}				
		:	:	. . .	. . .	. . .	. . .				
		k	*l*	X_{21kl1}	X_{21kl2}	. . .	X_{21kl30}				
	2	*1*	*1*	X_{22111}	X_{22112}	. . .	X_{221130}	D_{221}	D_{222}	. . .	D_{2230}
			2	X_{22121}	X_{22122}	. . .	X_{221230}				
			:	. . .	. . .	. . .	. . .				
			l	X_{221l1}	X_{221l2}	. . .	X_{221l30}				
		2	*1*	X_{22211}	X_{22212}	. . .	X_{222130}				
			2	X_{22221}	X_{22222}	. . .	X_{222230}				
			:	. . .	. . .	. . .	. . .				
			l	X_{222l1}	X_{222l2}	. . .	X_{222l30}				
		:	:	. . .	. . .	. . .	. . .				
		k	*l*	X_{22kl1}	X_{22kl2}	. . .	X_{22kl30}				
	:	:	:	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	j	*k*	*l*	X_{2jkl1}	X_{2jkl2}	. . .	X_{2jkl30}	D_{2j1}	D_{2j2}	. . .	D_{2j30}
:	:	:	:	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
i	*j*	*k*	*l*	X_{ijkl1}	X_{ijkl2}	. . .	X_{ijkl30}	D_{ij1}	D_{ij2}	. . .	D_{ij30}

Table 5: Mold and Type of Concentrated Latex Installation Result

Mold and Latex Install Result (Piece)																				
Rubber Glove Production Machine			Smooth Skin Mold						Dots Balm Mold						Dots Finger Mold					
Production Line	Mold Convenyer	Type of Concentrated Latex	XS	S	M	L	XL	XXL	XS	S	M	L	XL	XXL	XS	S	M	L	XL	XXL
1	1	Natural latex	1,467	2,933	733		1,467	6,600					1,467							
		Synthetic white latex																		
		Synthetic blue latex																		
		Synthetic black latex																		
	2	Natural latex	1,630	1,731	2,078	1,100	1,467	4,094				1,100	1,467							
		Synthetic white latex																		
		Synthetic blue latex																		
		Synthetic black latex																		
2	1	Natural latex	2,933	1,467	2,933	733	1,945	1,976				733	1,945							
		Synthetic white latex																		
		Synthetic blue latex																		
		Synthetic black latex																		
	2	Natural latex	3,667	2,200	4,787		1,100	1,813					1,100							
		Synthetic white latex																		
		Synthetic blue latex																		
		Synthetic black latex																		
3	1	Natural latex	4,828	1,467	2,200	713	2,200	1,467				713	2,200							
		Synthetic white latex																		
		Synthetic blue latex																		
		Synthetic black latex																		
	2	Natural latex	3,300	2,933	5,093	0	1,467	1,874					733							
		Synthetic white latex																		
		Synthetic blue latex																		
		Synthetic black latex																		

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