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## Generating Efficient Production Plans for Heater Manufacturing Industry

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# Generating Efficient Production Plans for Heater Manufacturing Industry

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**Abstract.** Nowadays, manufacturers in Malaysia as well as global have been facing challenges in order to overcome the uncertainty of demand fluctuations, supplier capability and achieved customer expectations and satisfaction. To increase competitiveness in global market, manufacturers from various aspects keep one's eyes open on lean implementation and factory automation. This journal aims to develop an efficient production plans for heater manufacturing industry in order to achieve higher productivity and reduce wastes. With the traditional production line which had been implemented for years, several difficulties have been faced by company. For instance, abundance numbers of worker in production line which is not fully utilize and product quality is highly depends on skilled operators due to manual process. Smoothness index is used to determine the improvement of proposed production plan. Although minimization of smoothness index is essential in solving line balancing problem, this research has highlighted that researcher or company shall not rely on smoothness index alone while other aspect such as acceptable productivity and minimization of human resource should be considered.

## 1. Introduction

Nowadays, significant numbers of companies in Malaysia adopted different lean manufacturing management tools in order to increase the efficiency of production and the competitive of company itself in the corresponding industry. Meanwhile, manufacturers in Malaysia as well as global have been facing challenges in order to overcome the uncertainty of demand fluctuations, supplier capability and achieved customer expectations and satisfaction (Wong et al., 2009). Lean and factory automation is then become popular topic among manufacturer as both aspects brings significant benefits for the growth of company, such as: reduction of operating costs, shorten lead time by 50% to 90%, better quality control, process queues cut by 70%, space saving, continuous improvement (Dutta & Banerjee., 2014) and reduction of human resource.

In this research project, the company is involved in heater manufacturing background. This company was established in 90's and now becoming one of the leading enterprises which having diverse and global interests in heat & temperature manufacturing and service industry. With the traditional production line which had been implemented for years, several difficulties have been faced by this company for years such as having abundance numbers of operator in their production line and the operator's productivity is not fully utilize. In order to increase the competitive and break through the traditional manufacturing production difficulty, the company plans to adopt a suitable lean



manufacturing tools to their traditional production line and upgrade their production plants by automation in order to increase productivity as well as quality with the minimum overhead cost.

Nowadays, numerous lean management tools especially just in time (JIT), total quality management (TQM), and supply chain management (SCM) have been implemented in industrial in response to increment of competitive pressure which concerning more on improved product quality, increased responsiveness, shorter lead times and lower cost (Kannan et al., 2004). Lean manufacturing, lean production or simple “lean” laid down a basic principle of production philosophy. Lean is also a set of tools and techniques that aims to identify and eliminate all wastes during operations (Powell et. al., 2014) and organize mass production. For instance, Just-In-Time is a philosophy that commonly practice in manufacturing industry. It aims to produce required amount of zero-defect goods at the right place and right time, which mainly concern through improving capabilities, eliminating wastes and continuous flow of production (Monden, 1998). TQM is a system of continuously improves on employing participative management that focuses more on the customer requirements (Monden, 1998). In addition, supply chain management (SCM) refers to the management of controlling the flow of raw materials or final products. SCM involves the motion of raw materials, final products and work-in-process inventory. In addition, reducing and streamlining the supplier base (Krause & Ellram, 1997), develop strategic alliances and work together with suppliers in order to meet customer’s expectation (Copacino, 1996) and involving suppliers’ participation at the early stage of product development process (Ragatz et al., 1997) are included in managing the supply chain in order to facilitate managing supplier relationships.

Lean system provides great benefit on financial savings of a company and can minimize excessive inventory. From a view from businessman, excessive stock, especially for those who applied mass production, will used up a lot of spaces and significant amount of money will be invested to maintain it. These stocks sometimes might not be the assets for the company but the liabilities. Especially when the number of inventories is high, the situation will be more obvious and easier to differentiate. Even more than that, eliminate inventories by implement lean systems can prevent other problems due to excessive inventories or over production. There are opportunities for the company to pay cost for handling damage and for the products becoming obsolete. However, successful of lean manufacturing implementation is highly depends on several factors. Several critical success factors were identified in prior study which are: leadership and management, skills and expertise, supportive organizational culture, and financial support (Achanga et al., 2006).

Assembly line balancing problem was identified in this research. It is one of the most well studied problem. In order to solve the line balancing problem, one of the often used fitness solution is the smoothness index (SI) (Fathi & Ghobakhloo, 2014). The objective in line balancing problem is to minimize SI, which evenly distribute the workload amongst the workstations, in order to reduce slacks between each workstation and eventually increase productivity or shorten the lead time (Fathi & Ghobakhloo, 2014; Hu et al., 2014). In this paper, minimization of SI may not satisfy the objective which is minimize the number of workstations or human resources. We then show that the lead time was shorten and number of workstations is able to be reduced without minimizing SI. Therefore, SI should not be used as the fitness solution in the studies that targeting at minimizing human resources or number of workstations.

2. Observation

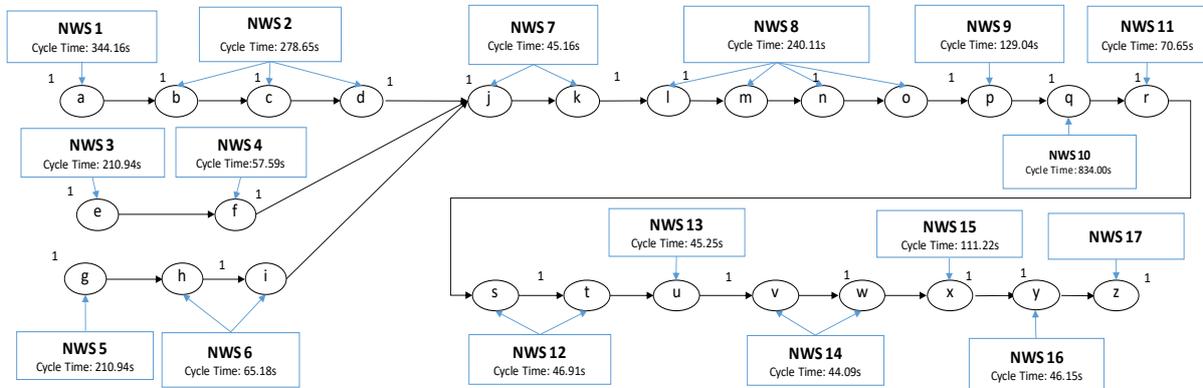


Figure 1 Existing Production Plan

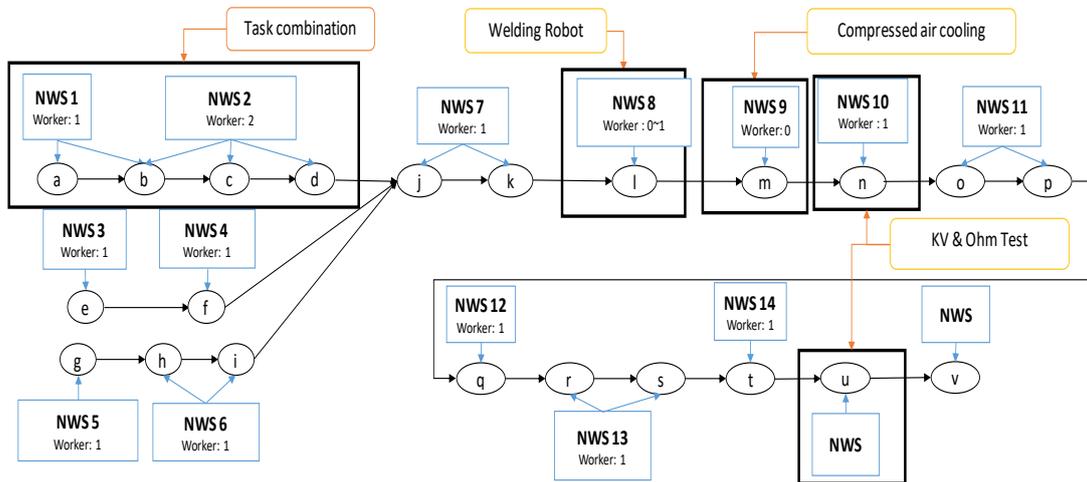


Figure 2 Proposed Production Plan

Figure 1 shows the existing production plan while figure 2 shows the overall proposed production plan. Production line in company A consists of 17 workstations and 21 operators performing 26 tasks. Most of the process is done manually by operators. Thus, there are slacking among operators and the product quality is highly depends on skilled worker. In order to improve the productivity and product quality, some of the process can be modified and is suggested to be replaced by automation.

The main objective of the company is to reduce the product lead time and reduce manpower in each station. After study on the process flow, researcher suggests implement task combination and task simplification in NWS 1 and NWS 2, welding robot in NWS 8 and compressed air-cooling in NWS 9. Result is showed in next section.

**Table 1** Time Study of Existing Production Plan

Task Number	Task Name	Number of workers	Process Time (s)	No. of Precedence	Immediate Predecessors
a	Press & Solder stud to cap	1	6.93	0	-
b	Solder heater to top cap - loading	1	27.85	1	a
c	Solder heater to top cap - Apply flux and insert filler	1	38.26	1	b
d	Solder heater to top cap - soldering	1	103.07	1	c
e	Solder brass bushes to outlet pipe	1	45.36	0	-
f	Brazing outlet pipe to bottom cap	1	31.14	1	e
g	Solder brass bushes to inlet pipe	1	22.15	0	-
h	Brazing inlet pipe to tank	1	32.58	1	g
i	Brazing PS connector to tank	1	27.42	1	h
j	Press top cap to tank	1	22.96	3	d, f, i
k	Press bottom cap to tank	1	17.68	1	j
l	Weld top cap to tank	1	48.15	1	k
m	Apply flux	1	22.87	1	l
n	Insert C-share filler to welding point	1	34.57	1	m
o	Induction welding bottom cap to tank	1	53.17	1	n
p	Cleaning	1	834.00	1	o
q	Cooling	1	35.03	1	p
r	Puncture / insulation / ohm test	1	10.37	1	q
s	Silicone sealant	1	11.46	1	r
t	Ceramic bead insert	1	45.25	1	s
u	Hydraulic Press	1	19.77	1	t
v	Terminal spot welding	1	11.08	1	u
w	Hipot Test	1	40.44	1	v
x	Air leak test	1	46.15	1	w
y	Puncture / insulation test	1	53.52	1	x
z	Final Check	1		1	y

In order to increase productivity, line balancing is needed in production line. Task combination and simplification are suggested in NWS 1 and NWS 2 based on the time study result and work of nature. From the time study, process time of task 'a' is much shorter than other process while process 'd' having the longest process time. Although process 'd' is divides into two station to do induction welding simultaneously, there are idleness in task 'b' and 'c'. Hence, task combination is introduced in order to reduce the idle time in between task 'b' & 'c' and reduce manpower. Proposed plan is suggested that 1 operator doing both task 'b' and 'c'. While operator in NWS 1, he should weld 30 pieces of top cap every time and then continue task 'b'.

Robot welding will be used in NWS 8 in order to improve the welding productivity and quality. A jig is designed to hold the heater element and send into desired position. An estimated time of 40 seconds per unit is made for the object with 7cm diameter. Besides of increasing in productivity, robot welding benefits the company by standardizing welding performance and reduce the number of operators. There are 3 operators include skilled operator that doing welding in current NWS 8. By implementing robot welding, operators can be eliminated in NWS 8. In addition, robot welding may reduce cleaning station as robot welding require minimum cleaning on excessive flux after welding process. Moreover, a standardize welding performance can reduce the occurrence of leakage and thus improve the defect rate in air leak test station.

### 3. Result and Analysis

Table 2 consist of process time for each workstation in exsiting production plan and proposed production plan. The results showed that process time remain unchanged in NWS 1 and NWS 2. Although process time remain unchanged, one operator has been eliminated from NWS 2. Besides, process time is drastically reduced in NWS 8 and 4 operators have been eliminated.

**Table 2** Comparison Table of Existing Production Plan and Proposed Production Plan

Number of workstations, NWS	Original Task Number	New Task Number	Task Name	Number of workers	Previous Number of workers	New Process Time (s)	Existing Process Time (s)	No. of Precedence	Immediate Predecessors
1	a	a	Press & Solder stud to cap	1	1	6.93	6.93	0	-
2	b	b	Solder heater to top cap - loading	1	1	27.85	27.85	1	a
	c	c	Solder heater to top cap - Apply flux and insert filler			38.26	38.26	1	b
	d	d	Solder heater to top cap - soldering			82.46	103.07	1	c
3	e	e	Solder brass bushes to outlet pipe	1	1	45.36	45.36	0	-
4	f	f	Brazing outlet pipe to bottom cap	1	1	31.14	31.14	1	e
5	g	g	Solder brass bushes to inlet pipe	1	1	22.15	22.15	0	-
6	h	h	Brazing inlet pipe to tank	1	1	32.58	32.58	1	g
	i	i	Brazing PS connector to tank			27.42	27.42	1	h
7	j	j	Press top cap to tank	1	1	22.96	22.96	3	d, f, i
	k	k	Press bottom cap to tank			17.68	17.68	1	j
8	l	l	Weld top cap to tank	0	1	40	48.15	1	k
	m		Apply flux				22.87	1	
	n		Insert C-share filler to welding point				34.57	1	
o	Induction welding bottom cap to tank								
9	p	-	Cleaning	1	1	-	53.17	1	
10	q	m	Cooling	0	1	834.00	834.00	1	l
11	r	n	Puncture / insulation / ohm test	1	1	35.03	35.03	1	m
12	s	o	Silicone sealant	1	1	10.37	10.37	1	n
	t	p	Ceramic bead insert			11.46	11.46	1	o
13	u	q	Hydraulic Press	1	1	45.25	45.25	1	p
14	v	r	Terminal spot welding	1	1	19.77	19.77	1	q
	w	s	Hipot Test			11.08	11.08	1	r
15	x	t	Air leak test	1	1	40.44	40.44	1	s
16	y	u	Puncture / insulation test	1	1	46.15	46.15	1	t
17	z	v	Final Check	1	1	53.52	53.52	1	u
<b>TOTAL</b>				<b>15</b>	<b>21</b>	<b>1501.86</b>	<b>1641.23</b>		
				<b>Total Cycle Time</b>		<b>2203.22</b>	<b>2677.70</b>		

### 3.1. Smoothness Index

In line balancing, smoothness index (SI) is a useful tool which allows for evenly distributing the workload amongst the workstations. Formula of smoothness index is as below:

$$\text{Smoothness Index, } SI = \sqrt{\frac{\sum_{j=1}^M ((T_{max} - T_j)^2)}{M}}$$

$T_{max}$  = maximum workstation time

$T_j$  = the time of  $j^{th}$  workstation

$M$  = number of workers

In this research, SI were calculated for both original and proposed plan and comparison was done. Figure below is the SI for whole production plan. The result shows that original SI is 29.29 while new SI is 34.66. Although objective functions in line balancing is the minimization of SI, Fathi et al. claim that minimization of SI alone may not be the best solution to solve the line balancing problem (2018). Besides SI, minimization of number of work station or process shall be considered.

**Table 3** Smoothness Index

Smoothness Index	Original SI	New SI
Overall Production	28.95	34.25
NWS 8	31.85	40
NWS 1 & 2	24.93	28.79

#### 4. Conclusion and Future Improvement

A proposed production plan has been developed in this research. By comparing the smoothness index, SI of proposed production plan is slightly higher than original SI. However, proposed production plan able to reduce man power from 21 to 15 and skip cleaning station by replacing manual welding with robot welding. In general, number of workstations can be reduced from 17 to 16. Besides, process time in NWS 8, welding top cap and bottom cap, able to reduce from 240.11s to 40s.

Generally, smoothness index should take into consideration before implementing the production plan. However, researcher or company should not look into smoothness index alone without consider other determinant factors in real life application. In this research, factory should consider other factors such as increase of productivity, shorten lead time, reduction of human resource and number of workstation. In this research, slightly increase in smoothness index is acceptable with the reduction in human resource and lead time.

In addition, compressed air-cooling system can prevent product rejected due to moisture. This may lead to lower reject rate in first KV and Ohm test station. In future, after getting reject data from KV & Ohm test station, management can consider reduce the particular testing station to one only in each production line.

Shortly, this research had proposed a different view in solving line balancing problem. Company shall first prioritise their objective and look into others aspect besides smoothness index in order to select production plans accordingly. Similar researches should be studied for other line balancing problem. Moreover, such studies may be useful to develop production plan in similar industry

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