RESEARCH ARTICLE

Analysis and Improvement on the Production Capacity of the Line of Product S

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Abstract: Production capacity, a technical parameter which not only reflects the process capacity of the company but also shows the production scale, is the principle for enterprises to make business plans. Both the overcapacity and the shortage have an impact on the management. Firstly, the background and the signification of production capacity are presented in this paper. Then company M is taken as an example to analyze the production capacity of the line of product S. Thirdly, reasons of the low production capacity and how to optimize the line of product S based on the methods of industrial engineering and other engineering techniques are elaborated. Finally the performance of the line of product S after improvement is measured and evaluated.
Keywords: Production capacity; Assembly line balance; Shop floor improvement; Line performance

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1 Introduction

Henry Ford invented the first auto assembly line in the 20th century, who reduced cycle time from 12.5h to 2.8h[1,2]. Now the production line is widely used in automotive, appliance, electronics, machinery and other industries[3]. But how to balance the lines' capacity and load is the key to the production efficiency[4, 5].

The following three parts are included: analyzing the status of the product S and production capacity, improving and optimizing the production capacity of product S, analyzing the performance of the improved production line of product S, and validating the effectiveness.

2 Background of product S

Company M is a big mobile phone manufacturer. Product S is one of the components of mobile phone. On the production line of product S, there are 13 workstations and 17 workers. It needs 3 hot-melt-machines.

3 The present capacity of product S

50,000 pcs of Product S are produced each month in order to supply other companies in time. The stopwatch is used to measure the work stations' duration and Fig.1 shows the working duration of each work station[6].

Fig.1 shows that the two work stations: load copper-nuts and load right shrapnel last the longest, i.e. 16.58s and 16.57s. There are 3s or 4s more than other work stations. So the production line’s pressure is great and the following work station must wait. Consequently, the two work stations are bottleneck stations.

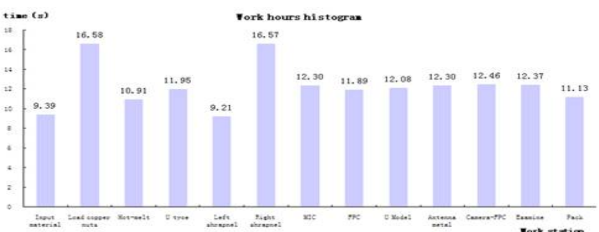

Figure 1 Work duration histogram of production line

Then calculate the production lines' UPH, the rate of balance and the loss rate of balance.

$$UPH = \frac{1h}{\text{time of bottleneck workstation}} = 217\,(pcs) \quad (1)$$

$$\text{Rate of balance} = \frac{\sum t_i}{N \times CT} \times 100\% = 73.84\% \quad (2)$$

$$\text{Loss rate of balance} = 1 - 73.84\% = 26.16\% \quad (3)$$

Since company M prescribes the effective production time of product S is 200 hours every month, but the UPH is 250pcs, it takes extra 34pcs in the production line. Consequently, fish-bone diagram (Fig.2) is utilized to analyze the reasons of low capacity which can not meet the requirements of company M[7]. It is concluded that main reasons for the low productivity are as follows: Firstly, in the workstation of loading copper nuts, the workers use awl to load copper nuts. Secondly, the output of the workstation of hot-melting copper nuts is not stable. Thirdly, the utilization rate of such work station is low, i.e. hot-melting slip-resistant article and hot-melting shrapnel's man-machine.

Figure 2 The fish-bone diagram

4 Improvement of workstation

Considering the three reasons for the production capacity, the following three workstations should be improved: station of loading copper nuts, hot-melting copper nuts, hot-melt slip-resistant article and shrapnel.

4.1 Work station of loading copper nuts

In the work station of loading copper nuts, four workers are equipped to load copper nuts, and the total working time is 66.31seconds. So the following workstations must wait for it.

Now use the techniques of 5W1H (Table 1) to analyze and improve it [6].

Table 1 "5W1H"

Item	Test point	Question	Answer
The first question	Goal	What	Load copper nut
	Reason	Why	Requirement
	Time	When	Working times
	Place	Where	Clean room assembly workshop
	Man	Who	Ordinary operation of the staff
	Method	How	use copper nut awl
The second question	Goal	Is it necessary to do?	Yes
	Reason	Why do it	Requirement
	Time	Why do we need to do at this time	Requirement
	Place	Why do we need to do here	Requirement
	Man	Why do we need this person to do	Requirement
	Method	Why does it take to do so	Requirement
The third question	Goal	Whether other more appropriate goal	No
	Reason	Do not need to do	No
	Time	Whether other more appropriate time	No
	Place	Whether other more suitable locations	No
	Man	Whether other more appropriate man	No
	Method	Whether other more appropriate methods and tools	Yes, use Vacuum suction pen

After these questions, we can find, the worker can use vacuum suction pen instead of awl to load copper nuts. In order to verify the possibility of improvement, some workers are chosen and divided into two groups, each group has 10 staff, one group use awl, the other use vacuum suction pen to load copper nut while all the other conditions are the same. Stopwatches are put into use to measure the two groups' speed. The result is that the group of using vacuum suction pen spends less time. And all the members using vacuum suction pen agree that the use of vacuum suction pen absorb copper nuts more easily which are not easy to drag out and load.

The use of vacuum suction pen, because of its absorption edge, is not easy to make nut out, facilitate copper nuts and position. But it can fully avoid the advantages of the use of awl to load copper nuts which position nut hard and easily fall them off. By loading the vacuum suction pen, the operation time can be reduced from 16.68s to 12.20s. Three operators will be arranged to complete the task, the number of workers can cut down to one and the cycle time can also be reduced to 4.48s. Therefore, the bottleneck in this work station is released.

4.2 Work station of hot-melting copper nuts

Although we can use vacuum suction pen to load copper nuts instead of awl and it is easy to load and the nuts is not easy to fall off, the fact is that the copper nuts are still to fall off after the production line. So the operator will make copper nut fit on the place without tools, or put the product on the hot-melt machine to hot-melt carefully; or when a product is with two or more copper nuts off, the operator must return the product to the previous workstation to load the copper nuts again by flowing production line. As a result, the operators would largely waste time and a number of operators may also get arms pain. The impact of external factors results in the instability of cycling time of hot-melting, accumulated product in the grave and the capability of the production.

This workstations' cycle time is 10.91s, so there is not much room for improving. The situation of instability because of the impact of external factors will sometimes lead to the working time of 10.91s. In order to meet the needs of the output, the operator will inevitably come to fatigue. Even if the operator does it normally, he can not accomplish the task. Therefore, TRIZ techniques are introduced to resolve contradict [8].

Through the contradiction matrix, It can be found that four new rules are available, i.e. 11th Article-pre-compensation, 19th Article-the role of cyclical, 21st Article-emergency operations, 27th Article-use the low cost products to replace. Compared one by one, we choose the 19th article, which is the role of cyclical. Through the cyclical effect we can replace it by the utilization of auto fixed cycle hot-melt.

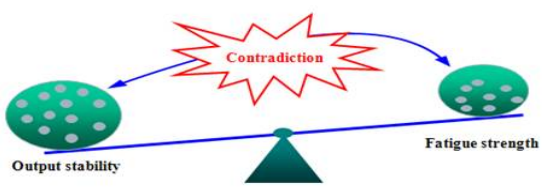

Figure 3 The TRIZ contradict diagram

However, it is very danger when the machine is replaced by auto hot-melt, it will lead to the probability of an accident. In order to prevent the accident, the method of Fool-proof can be used to improve the situation. By exploring with the technical workers, infrared thermograph automatic identification technology on the machine. Is installed. When the workers' hands are in the operation, the hot melt machine does not work until workers' hands leave the operator. This will not only ensure the safety of workers but also production efficiency and product quality.

After improvement working time is 10.95s. Now the start switch is abolished and an infrared thermograph automatic identification technology is installed on the machine. It can reduce the operators' fatigue and ensure the stability of the output.

4.3 Workstation of hot-melting slip-resistant article and shrapnel

Table 2. Human-machine analysis- Hot-melt slip-resistant

Man			**Machine**	
Get 1pcs product and slip-resistant		0.84	6.99	Working
Install slip-resistant into product		1.09		
Wait		5.06		
Get product from machine		0.83	3.05	Wait
Fit product onto the frame		1.94		
Start switch		0.28		
Examine and Lay down product		1.00	1.00	Working
Statistics project	Working hours	Spare time	Cyclic time	Time utilization
Man	5.98	5.06	11.04	54.17%
Machine	7.99	3.05	11.04	72.37%

In workstations of hot-melting slip-resistant article and shrapnel, the human-machine utilization of the two workstations is very low. Table 2 and 3 present the human-machine analysis of the two workstations. It is obvious that the utilization of the production line capacity is low.

In the hot-melt slip-resistant workstation utilization rate is 54.17% and 72.37%; the hot-melting shrapnel is 50.77% and 72.16%.

Table 3 Human-machine analysis- Hot shrapnel

Man			**Machine**	
Get 1pcs product and shrapnel		0.62	6.6	Working
Install shrapnel into product		0.57		
Wait		5.41		
Get product from machine		0.79	3.06	Wait
Fit product onto the frame		1.92		
Start switch		0.35		
Examine and Lay down product		1.33	1.33	Working
Statistics project	Working hours	Spare time	Cyclic time	Time utilization
Man	5.58	5.41	10.99	50.77%
Machine	7.93	3.06	10.99	72.16%

So we organized a special meeting, and invited different workers to participate. Everyone expresses their views and takes full advantage of the power of the public. We get three viable schemes by the method of brainstorming. The first scheme is one operator loading slip-resistant and shrapnel, one operator with hot-melt slip-resistant and shrapnel by two machines. The second scheme is one operator loading slip-resistant and shrapnel, one operator with hot-melt slip-resistant and shrapnel, but the machine have two sets of governance. The third scheme is one operator loading slip-resistant and shrapnel, one operator hot-melt slip-resistant and shrapnel Machine. And the machine use one set of governance, the governance is combined that can hot-melt slip-resistant and shrapnel.

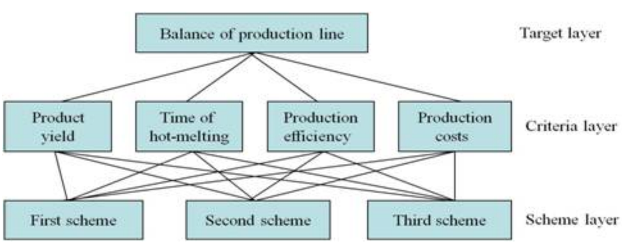

Figure 4 The model of AHP

Then use theory of AHP (Analytical Hierarchy Process)[9] to decide which one is the best scheme(Fig. 4), and some calculated value as follows.

$$\lambda_{\max} = \frac{1}{4}\left[\frac{2.577}{0.60} + \frac{0.994}{0.24} + \frac{0.402}{0.10} + \frac{0.245}{0.06}\right] = 4.123 \tag{4}$$

$$CI = \frac{4.123 - 4}{4 - 1} = 0.041 \tag{5}$$

$$CR = \frac{0.041}{0.52} = 0.0789 < 0.1 \tag{6}$$

$$\begin{bmatrix} S1 \\ S2 \\ S3 \end{bmatrix} = \begin{bmatrix} 0.539 & 0.065 & 0.122 & 0.111 \\ 0.164 & 0.199 & 0.230 & 0.222 \\ 0.297 & 0.735 & 0.628 & 0.677 \end{bmatrix} \begin{bmatrix} 0.602 \\ 0.236 \\ 0.099 \\ 0.062 \end{bmatrix} = \begin{bmatrix} 0.359 \\ 0.182 \\ 0.458 \end{bmatrix} \tag{7}$$

And λ_{max} is maximum eigenvalue, CI is consistency index, CR is consistency ratio, RI is random index, RI=0.52 [10], S1 ＞ S2 ＞ S3 is the score of the three schemes. S3 > S1 > S2, the third scheme is the best.

In order to compare the technology and cost after improvement, value engineering is introduced [11]. We know the third scheme is the best from Table 4.

Table 4 Value analysis (million yuan)

Item	**Technical feasibility**	**Function**	**Man Cost**	**Machine Cost**	**Total Cost**	**Output (/pcs)**	**Function value**
Original	√	General	730	100	830	1585998	1.9108419
S1	√	General	730	100	830	1461022	1.7602675
S2	√	General	730	50	780	1517086	1.9449821
S3	√	Best	730	50	780	1986394	2.5466597
Choice	S3 ＞ S2 ＞ Original ＞ S1						

Analysis of the work stations' human-machine utilization shows the utilization of human is 81.72%, and the utilization of machine is 83.20%. Both the utilization rates exceed 80%, while more than 75% is the company's requirement.

5 Performance comparison

All the three points are improved. Now the process of the product S had been changed. We can measure the work time by stopwatch. The data of the work time can be seen in Fig.5. We also can calculate the production lines' UPH, the rate of balance and the loss rate of balance (Table 5).

The improvement can enhance the manufacturing competitiveness and establish the product standards. All the workstation which need load copper nuts can use vacuum suction pen. The auto hot-melt machine can be brought into the hot-melt copper nut workstation.

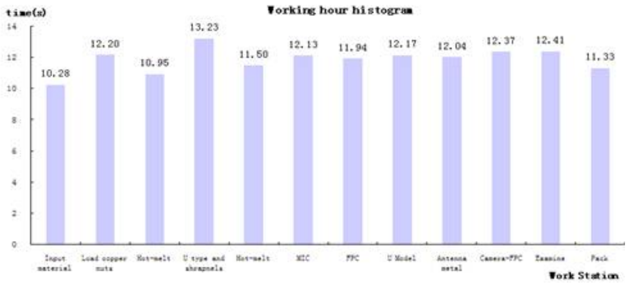

Figure 5 Working hour histogram

Table 5 Performance comparison

Program	**Before**	**After**	**Comparison**
UPH（pcs）	217	272	55
Man	17	15	2
Machine	3	2	1
Rate of balance	73.84%	89.79%	15.95%
Loss rate of balance	26.16%	10.21%	15.95%

6 Conclusion

Production capacity, which is one of the most principle for enterprises to make business plans. When capacity can be appropriate, it can be advantageous to enterprise's development. So how to balance the lines' capacity and load is the key to the production efficiency.

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