

Analysis and Improvement of an Enterprise Production Line Based on the Technology of Value Stream Mapping

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Abstract—With the rapid development of the global economy, the competition among manufacturing enterprises is becoming more and more fierce. Many enterprises begin to worry about the economic status and pay attention to the improvement and management of the production process existing in the production system. Taking a mobile phone loudspeaker production enterprise as the research object, after investigation and research for some days in the company, the paper analyzes the whole process of production. By using the value stream mapping analysis technology, the paper draws up the value stream mapping of production status, calculates takt time of this production line, and analyzes the bottleneck process existing in the production system of enterprises. With the knowledge of industrial engineering, the paper deletes and combines the working procedure, optimizes the problem of the bottleneck procedure, changes the push production into the pull production to improve the production line, then draws up the company's future production value stream mapping, in this way, the manager can intuitively see the implementation situation of improvement programs in the production line. Lastly the paper makes a comparison and analysis between the production status before and after improvement.

Keywords—*value stream mapping; motion analysis; procedure analysis*

I. INTRODUCTION

At present, a new round of competition in science and industrial structure is being staged all over the world, and countries are competing for the leading position in the future economic and social development. It is urgent to speed up the development and progress of our industry. In order to improve the efficiency of enterprise production, many enterprises are looking for a new method to improve the problems existing in enterprise production. Some enterprises have gradually started to adopt the value stream mapping analysis method. Instead of focusing on production lines, they have shifted the focus of production management to integrating enterprise supply chains, optimizing production processes, improving production processes, and straightening out product design, ordering and purchasing. Manufacturing and order processing and other activities related to the point, ultimately to provide customers with high-quality products and services [1].

Many domestic scholars have studied the improvement of the production line of the enterprise. Gu Tao[2] used the stopwatch method to test the processing time of each process on the compressor cylinder block production line of a company. Zhou Xiaofei[3] established the simulation model. After analyzing the results, the author found out which bottleneck processes existed in the production line, and then put forward the improvement scheme for the production process of the production line. Zhang Zhiqiang[4] and others took the assembly process of automobile seat as the research object. They put forward the improvement scheme in improving the processing order and balancing the production line by using the ECRS principle in industrial engineering. As a word, they firstly analyze the takt beat, and focused on the bottleneck process, and explore ways to improve the balance of the production line. Then combine the relevant methods of industrial engineering. Finally the layout of the bottleneck process and the redistribution of the work content are improved.

The paper mainly studies the improvement of production line of a loudspeaker production enterprise, enriches the research and application field of value stream mapping, and analyzes the value stream activity of a cell phone speaker production system. Aiming at the problems of low production efficiency, long manufacturing cycle and serious waste in production site, the production system is optimized based on the improvement principle of lean value stream.

II. GENERAL SITUATION OF ENTERPRISE

A. Introduction to the Present Situation of Enterprise Production

The company is a manufacturer of mobile phone speakers, and it uses SAP system to manage the operation of the entire production system. Sales department forecasts order is based on customers' historical orders. Then the order information is sent to the production control department. The production control department formulates weekly production plan according to the order. Master production schedule includes detailed information such as product model, quantity, online date, off line date, worker arrangement and so on. Master production schedule will be discussed at the production

scheduling meeting. After the plan has approved, the purchasing department will draw up the material requirements planning for raw material purchase. Production control department, purchasing department and production workshop shall meet three times a week to ensure the implementation of the production plan, and the production plan shall be fed back to the main production plan for adjustment. After master production schedule has been determined, the plan shall be carried out in accordance with the plan. The product is sent to the finished product warehouse after the product is off line. Customers can choose to pick up the finished product, or delivered by the company. After that, customer order is sent back to the sales department, and the sales department makes a correction.

The basic conditions of the enterprise's production lines are that firstly the working time of the enterprise is six days a week, and the daily production shift system is two shifts, effective time of each shift work is eight hours. Secondly, five workers per shift are responsible for checking the operation of the machines in each working procedure and two workers in each group need to be packed, and each shift shall be packed in groups. Thirdly, customer demand is 2000 pieces per week. Fourthly, supplier supplies to the warehouse once a week.

TABLE I. BASIC INFORMATION OF PRODUCTION LINE

Number of work stations	Work station name	Process processing time / s	Number of workers
1	External filling of front cover	300	1
2	Sound film scan	1	0
3	Front cover code	3	1
4	Combinatorial scavenging code	1	0
5	Front cover flip	60	0
6	Internal filling glue	300	1
7	Glue curing	600	1
8	supersonic welding	900	1
9	pack	180	2

“Table I” shows the basic information of the production line such as the name of the processing station, the processing time and the number of workers.

The production line of the mobile phone loudspeaker has nine stations. Each station is arranged according to the linear arrangement. The semi-finished product of the automatic front shroud is filled with glue outside the first station and checked by CCD. The processing quantity of each batch is 15. Then there was the second station, which had a scanning device that scanned the sound film from the third production line, and would then code the front shroud of the first station over the outer glue. A machine then flips the front shroud, then glue the front shroud, solidifies the glue, and after putting the sound film on the front shroud, puts the sound

film and the front shroud on the front cover. The shroud is welded by ultrasonic welding machine. Finally, the sound film is packaged by the workers and stored in the finished product storehouse for shipment. The current Program flow chart of the enterprise is shown in “Table II”.

TABLE II. CURRENT PROGRAM FLOW CHART OF MOBILE SPEAKER MANUFACTURER

	project	number of times	time/s			
			processing	check up		
Work name: mobile phone speaker production	processing ○	9	2345			
	check up □	3	4			
	carry →	0	0			
	wait D	2	259800			
	lay in ▽	0	0			
job instruction	time/s	Process series				
		processing	check up	carry	wait	lay in
1 wait for automatic front cover on line	259200	○	□	→	D	▽
2 automatic front cover external filling	300	●	□	→	D	▽
3 CCD examination	1	○	■	→	D	▽
4 Sound release film on tooling	600	○	□	→	D	▽
5 tone film scan code	1	●	□	→	D	▽
6 front cover code	3	●	□	→	D	▽
7 the front cover and the sound film scan the code together	1	●	□	→	D	▽
8 front cover flip	600	●	□	→	D	▽
9 dozen internal filling glue	300	●	□	→	D	▽
10 Carry out CCD inspection	1	○	■	→	D	▽
11 glue curing	600	●	□	→	D	▽
12 ultrasonic welding	900	●	□	→	D	▽
13. Test the height of welded parts	2	○	■	→	D	▽
14 packing	180	●	□	→	D	▽

B. Value Stream Mapping of Enterprise Production

According to the data of production system, the value stream mapping is drawn.

Production control department and purchasing department meet three times a week to ensure that raw material can support the master production schedule. The

production control department issues the master production schedule every week to the daily task. Production workshop receives the production plan, and sends the material requirement information to the warehouse, and the warehouse separately distributes the material to each work station. Order requirements are within the normal schedule, finished goods warehouse inventory can meet customer needs, customers can submit orders to the finished goods warehouse to pick up, or by the sales department to send the departure information to the finished product warehouse. The supplier sends the raw material directly to the raw material warehouse, and the material department referencing the material requirement of each work station to realize the material distribution using trolley. The materials flow between stations is oriented to inventory production, so each station exists in WIP inventory. Time flow consists of increment time and non-increment time[5]. The value-added time is processing time, and the non-value-added time is the unnecessary waiting time and the interval between the processes. The increment time is 2345s and the total production time is 262375s.

C. Analysis of Production Status Based on Value Stream Mapping

Production capacity analysis means that the company's production system can produce products that meet the customer's needs. The take time refers to the ratio of effective working time and the quantity of customer demand in a certain period of time. For the company's mobile phone loudspeaker product, its take time equals 172.8s.

It can be concluded that firstly glue curing is a special process and is not considered for the time being and ultrasonic welding is a complex work which cannot be effectively solved in short term because of limited time. Secondly, the production and processing time of the first process and the sixth process is 300s and 300s respectively, which exceeds the take time. Finally, the processing time of the packing process is 180 s, which exceeds the take time. At this time, the bottleneck process of the production line is found, and measures should be taken to make the production time lower than the take time 172.8 s.

The mode of production adopted by enterprises is propulsive production. Each process in the value stream operates as an island, producing and pushing forward the product, regardless of the actual needs of the downstream customer. There is a lot waiting in this process, and the result is that the value-added time to produce a product is very short, and it takes a long time for the product to pass through the factory. At the same time, due to excessive inventory of in-process products between workshop production lines, the cost of inventory is as high as 2 million per year, which is not a small expense to the enterprise.

III. IMPROVEMENT PROGRAMME OF ENTERPRISE PRODUCTION LINE

A. Improvement Programme of Production Process

Through the analysis of "Table II", it can be found that the waiting time of the whole process is 259800s, the processing time is 2345s, and the waiting time is much longer than the processing time. We use the 5W1H questioning technology and the ECRS principle to analyze the production process of the mobile phone speaker manufacturer[6].

Q: which processes need to wait?

A: wait for automatic front shroud to wire and put sound film on tooling.

Q: can these two processes be deleted?

A: since you have to wait for the supplier to supply before starting production, it is inevitable to wait for the automatic front shroud and cannot be removed. Putting the sound film on the tooling can be deleted.

Q: why can we cancel the process of putting the sound film on the tooling?

A: because the removal of this process not only does not affect the entire enterprise production, but also greatly reduces the 10min waiting time.

Q: are there any processes that can be merged?

A: yes.

Q: which two processes can be combined?

Answer: automatic front shroud external filling and front shroud scanning process can be combined.

Q: why can we merge?

A: because the two processes are not continuous, and there are processes in the middle, the process is duplicated.

The improved process flow chart is shown in "Table III" below.

TABLE III. IMPROVED PROCESS FLOW CHART OF MOBILE SPEAKER MANUFACTURING ENTERPRISE

		project	number of times	time/s		
		processing	check up	carry	wait	lay in
Work name: mobile phone speaker production		processing	8	2345		
		check up	3	4		
		carry	0	0		
		wait	1	172800		
		lay in	0	0		
job instruction	time/s	Process series				
		processing	check up	carry	wait	lay in
1 wait for automatic front cover on line	172800					
2 automatic front cover outside the patch and scan code	303					
3 CCD examination	1					
4 tone film scan code	1					
5 the front cover and the sound film scan the code together	1					
6 front cover flip	60					
7 dozen internal filling glue	300					
8 CCD check	1					
9 glue curing	600					
10 ultrasonic welding inspection	900					
11. Test the height of welded parts	2					
12 packing	180					

We can see that the process of producing mobile phone loudspeakers has been reduced from 14 to 12, and the number of waiting times has been reduced. At the same time, the supply time of suppliers has been reduced by one day, and the waiting time from 72.17 hours to 48 hours.

B. Improvement Programme of Production Process

From the above analysis, it is concluded that packaging is the bottleneck of the production line. Because the workers had not received professional packaging training, everyone had their own packaging habit. One of the workers was selected to record the packaging of a mobile phone speaker. "Table IV" shows that only one hand is moving and the other hand is in the state of stopping and waiting. In addition, in

the last series of actions, such as sealing and sticking seams, the left and right hand actions is carried out too often.

TABLE IV. ANALYSIS OF PACKING ACTION OF WORKERS BEFORE IMPROVEMENT

Left hand action	time			Right hand action
	analyse	Time (MOD)	analysis mode	
Action narration				Action description
wait	BD	5	M4G1	Packing box
Grab the box.	M3G1	4	M4P0	Put the box in front of you
Auxiliary right-hand stand up packing box	M1P0	1	M1P0	Stand up the box
Folding box side ear	M1P0	1	M1P0	Folding box side ear
Folding lid	M1P0M2P0	3	M1P0M2P0	Folding lid
Grab the box.	H	9	M4G1 M4P0	Place the speaker in the box
Grab the box.	BD	4	M2P2	Put the speaker in the box
Put the box on the workbench	M3P0	4	M3G1	Place the installation instructions in front of you
Folding installation manual	M2P0 M3P0	5	M2P0M3P0	Folding installation manual
Pick up the box	M3G0 M3P0	8	M3P2M3P0	Put the instructions in the box
Folding box, another side ear.	M2G0 M1P0	3	M2G0 M1P0	Folding box, another side ear.
Folding lid	M1P0 M2P0	3	M1P0M2P0	Folding lid
Take the seal and stick the X2	M3G0	6	M3P0	Place the box on the workbench X2
Auxiliary right hand	H	16	M3G3 M2P0	Tear off the seal and hold on to X2
Put down the seal X2	M2P0	4	BD	Wait for X2
Put the box in your right hand	M3G0 M3P0	12	M3P2	Align the seal against the gap X2
Auxiliary right hand	H	2	M1P0	Attach the seal and grab the box X2
Box into a large box amount	M4P0	4	BD	wait
		94		

Improvements are mainly considered that firstly, the worker's two hands should be packed at the same time as possible on the premise of satisfying the actual situation. Secondly, it can be considered a chute arranged on the workbench, then lower the finished box placed on the table, so that workers in the packaging directly after the packing box into the slide slot box along the slot into the finished box. Thirdly there are boxes which can be saved from the sealing, so the action of the sealing strip can be canceled. Finally, consider setting a convex edge on the workbench near the

worker's body to prevent workers from putting back the box while they are putting the loudspeaker, and after one phone speaker is taken, the other speakers automatically slide down, eliminating the need to tilt the body at a certain angle to reach the next phone speaker.

After the improvement of the work site, the workers were again observed and recorded, and the analysis of the improved workers' packing movements is shown in "Table V".

TABLE V. ANALYSIS OF PACKING MOVEMENTS OF WORKERS AFTER IMPROVEMENT

Left hand action	time			Right hand action
	Action narration	analysis	Time (MOD)	
Put the box in front of you	M3G1 M3P0	7	M3G1 M3P0	Put the box in front of you
Put the box up	M1P0	3	M1P0 M2P0	Auxiliary left-hand action
Folding box side ear	M1P0	1	M1P0	Folding box side ear
Folding lid	M1P0 M2P0	3	M1P0 M2P0	Folding lid
Place the speaker in the box	M4G1 M4P2	9	M4G1 M4P0	Place the speaker in the box
Put the speaker in the box	M2P0	4	M2P2	Put the speaker in the box
Place the installation instructions in front of you	M3G1	4	M3G1	Place the installation instructions in front of you
Folding installation manual	M2P0 M3P0	5	M2P0 M3P0	Folding installation manual
Put the instructions in the box	M3P2 M3P0	8	M3P2 M3P0	Put the instructions in the box
Auxiliary right hand	M1P0 M2P0	3	M1P0	Folding box, another side ear.
Auxiliary right hand	M1P0 M2P0	3	M1P0 M2P0	Folding lid
Put the box in a big box amount	M3P0	3	M3P0	Put the box in a big box
		53		

Comparing the model values in "Table IV" and "Table V", we can see that the total model value decreased from 94 to 53, and because of the 1 mod equals 0.129 s, the time for workers to pack a mobile phone speaker was reduced by 5.3s, and the time for packing a batch decreased by 79.5s. Therefore, the whole packing time was reduced from 180s to 100.5s, satisfying the requirement of less than 172.8 s production beat. As a result, packaging this bottleneck process has been improved.

C. Improvement Programme of Mode of Production

The above analysis shows that the current mobile phone loudspeaker production mode belongs to the push-type production. Production planning is determined by customer order information, and the planning order is reversed.

According to the order information, staff plans the production time of each process, and then pulls the purchasing department to purchase raw materials, and finally makes the whole production system produce according to the customer's demand completely, reduce the inventory of raw material, and shorten the whole production cycle.

D. Waste Improvement Scheme on Production Site

In the above analysis, the waste of movement is eliminated. After the internal and external filling of the automatic front shroud is finished, the CCD inspection will be carried out, but there will be a 5% and 8% probability of defective products. Therefore, it is suggested that enterprises should invest funds in the maintenance of production equipment, and regularly repair the machinery and equipment in order to improve the reliability of equipment processing and improve the qualified rate of loudspeakers.

The following "Table VI" shows the basic information of the improved production

TABLE VI. BASIC INFORMATION OF IMPROVED ENTERPRISE PRODUCTION LINE

Working procedure number	Process name	Process processing time/s	Number of workers / persons
1	The front cover is glued and coded.	303.0	1
2	Sound film scan	1.0	0
3	Modular sweep code	1.0	0
4	Front cover flip	60.0	0
5	Internal filling glue	300.0	1
6	Glue curing	600.0	1
7	supersonic welding	900.0	1
8	pack	100.5	2

E. Future Value Stream Mapping of Enterprise

The above analysis shows that the current mobile phone loudspeaker production mode belongs to the push-type production[7], [8]. Production planning is determined by customer order information, and the planning order is reversed. According to the order information, staff plans the production time of each process, and then pulls the purchasing department to purchase raw materials, and finally makes the whole production system produce according to the customer's demand completely, reduce the inventory of raw material, and shorten the whole production cycle.

IV. CONCLUSION

Comparing the value stream mapping, we can see that the value-added time of the enterprise decreased from 2345s to 2265.5s and the total production time decreased from 72.88hours to 48.68hours. The value-added time accounted for the total production time increased from 0.89% to 1.29. The number of workers required on the production line decreased from 7 to 6. The labor cost is saved, and the number of stations is reduced from 9 to 8, which shortens the length of production line. The comparison is shown in "Table VII".

TABLE VII. COMPARATIVE ANALYSIS BEFORE AND AFTER IMPROVEMENT

	Increment time / s	Production time per hour	Percentage of value added /%	Number / person	Digits
Before improvement	2345.00	72.88	0.89	7	9
After improvement	2265.50	48.68	1.29	6	8

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