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Study for balance rate of a machining line

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ABSTRACT

To achieve the target of Lean Manufacturing and JIT Production and reduce the cost, the balance rate was a key factor used to evaluate the efficiency of a production line balancing. At first, the current status of the machining line was investigated and simulated, and secondly the bottleneck steps were found out, then the project for an optimal target value was laid out. Lastly, a series of standard operating steps were implemented and the effect until the desire results was achieved. Then the balance rate was improved. As the simulating result shown, the case was improved both in productivity and quality, and wasting was reduced on the aspects of staff, time, equipment and operator.

KEYWORDS

Production line balancing;
Balance rate;
Operation standardizing.

INTRODUCTION

Most of manufacturing production lines are multi-process, streamlined and continuous operation production lines which had been segmented. Now due to division of labour, the complication of work had been reduced, lead to job proficiency be promoted easily, and operating efficiency be improved finally.

However, no matter in theory or in practice the operating time for each processes can not be exactly the same, so the phenomenon uneven workload can not be eliminated. In addition to causing unnecessary loss of working hours, but also it caused accumulation of a large number of WIP (work in progress). The worst case, it may lead to the suspension of production.

The balancing production line was a such technology or method which was used to make each operating time as equal possible as through adjusting the workload and averaging all the operating processes. It was the most important method in production process design and the operating standardization.

BALANCE RATE OF A LINE

If all the processes ware not completed by one person, then there must be a division of labor and co-operation. So averaging the amounts of workload between the labors and the machines can make a direct impact on the overall efficiency of the entire production line. To measure the efficiency of this production process the standard is the balancing rate which was shown as in following equation:

$$BR = \frac{\sum T_i}{CT \times W} \times 100\% \quad (1)$$

Where,

BR- Balance Rate for a Line;

T_i - Time for Each Process;

CT - Cycle Time of Operating;

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W - Total Workers (Operators);
And

$$CT = \frac{3600(s)}{Q} \quad (2)$$

Where,
S -Time in seconds (Second):
Q -Output per hour (Quantity).

Operating cycle time CT, a certain period of time to complete a product in the production line, it was determined by the longest process time (Pitch Time) of the production line. Because no matter how fast the operating time of other processes it can only be determined in the Pitch Time to send a product in a cycle time, and the others of the stations in which the operating time is less than the cycle time will be keeping to wait, so there will be a certain loss of the working time and load, the proportion of the total working hours occupied by operating time was balancing ratio.

To measure the balance level of a production line, it was necessary to set a quantitative value to indicate the balance level, the value is the line balance rate (balancing ratio) or balanced loss rate (Losing Ratio), expressed as a percentage:

$$Losing Ratio(\%) = 1 - Balancing Ratio(\%) \quad (3)$$

As shown in equation (3), the imbalance indicates that the waste not yet be eliminated—namely the level of the operating cost would be greatly increased.

Considerations of balancing production line:

Constraints to improve balancing:

For most manufacturing production lines, there ware many processes may not be completely controlled with flexibility, owing to the limitation of equipment capabilities, the number of employees and the proficiency of staff, particularly in aspects of the capacities of each machine. Because not all large-scale equipments can be increased or decreased discretionarily, it may involve an investment of substantial capital and fixed assets. To solve this problem, the average production load method has been used to different products and different processes. The average of all production for different products and processes will eliminate the fluctuations caused by different loads and different products, and it requires innovation in the methods of making the production plan, such as changing a single species mass production into a multi-item continuous production. The implementation of the process needs to be based on the standard time study.

Surveying production capacity:

Two parts in an engine production line have been chosen separately, to survey the balance rate about the capacity of the line and the WIP of the parts. The both results are shown in Figure 1 and Figure 2.

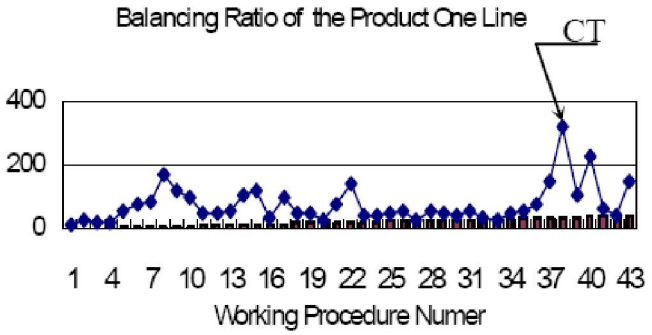

Figure 1 : Production balance rate

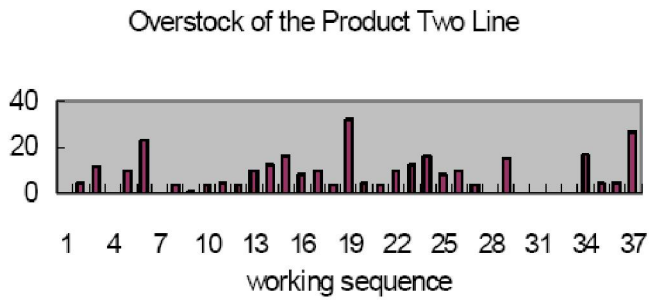

Figure 2 : WIP of each process

As shown in Figure1, the balance rate of this part's production line is obviously determined by the cycle time (CT), the longest process.

As shown in Figure 2, although the process time not be measured, but in respect of WIP of each process, the production line is in unbalancing status.

Expected result of improving line balancing:

To fulfill the zero waste and the target of the lean production (LP), the balancing rate reaches 95% was best. Naturally, the balance runs up to 95%~100% for a production line whether it was domestic or foreign, was almost non-existent under the premise of the division of operating labor. In other hand, from the actual state of the plant at home and abroad, when the plant's productivity stay at 60%~70%, it was in the situation that without any management and process improvement, there ware tremendous waste of productivity and problems of efficiency, because it shows that 30% to 40%

of the labor hours does not produce any value. And the balance rate stays at 70% to 80% show that management in a low level, problems of management and technical exist too; When the value reaches 80%~85%, showing the production management staff has done their business, but some improvements still can be done in IE technology; When the value exceeds 85%, showing that the management and IE technology both are at the relatively high status.

IMPROVING EXAMPLE OF LINE BALANCING

The improvements involving in increasing productivity, equipment utilization, staff motivation and rational machines layout, reducing costs and the work in progress (WIP) between the processes, to achieve the purpose of lean production and to minimize the waste. Following is a reconstruction example of the production line of a part of an auto engine, the lean production be pushed forward step by step. Obtained that the efficiency of lean production had been increased, meanwhile the staff, the equipment and operating time had been reduced. It should be noted that this process was implemented gradually, concrete steps ware: site investigation to get the current state of balance and analyze to find out the bottlenecks that had greatly impacted on the balance rate, after that the improvement programs and objectives should be proposed, then the measures be carried out and the results be evaluated lastly. Further more from different angles to improve, and ultimately achieve the best results.

As above, there was an example of a mass production line of a key part of the engine. The balance method for this production line is shown in Figure 3.

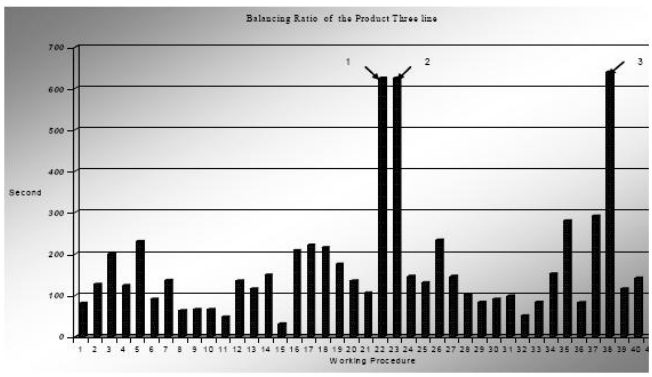

Figure 3 : Surveying production line capacity

Basic principles of improving balance

Adjusting process content:

Following this method to make the process time close to each other, the content of the bottleneck process will be shared by others processes. the reason of bottleneck process taking long cycle time should be checked at first, whether due to allowance is too big or other factors and there exist some adjustment difficulties. In the above example, to reduce processing time the improvement of the bottleneck processes named of 1, 2, 3 should be consideration firstly. Getting additional equipment may need a lot of money, so reform on the existing equipments may be more reasonable, making The special equipment become universal equipment. Of course, complex processes require carefully testing to ensure the suitability of equipment and product quality. This equipment can be quite doubled twice machines and leaving less processing cycle time. In addition, the downtime caused by equipment failure and the low quality of workpieces caused by defective and repair products should be also considered, to avoid schedule delaying and production Stagnating.

Reasonable load for personnel and equipment:

To reduce the operators, as long as output per capita is increased equals to increase the balance rate, and lower cost per part. By means of an accurate investigation of the capacity of personnel and equipment to make sure that the redistribution of the work is reasonable and to minimize people's leisure time and equipment so as to improve efficiency, so the aim is to make the process with reasonable load of personnel and equipment.

Analysis of loads:

The load analysis about spare capacity includes the following three aspects, the machine spare capacity and the operator spare capacity as well as determining the number of operating machines by an operator.

To calculate how many machines can be operated simultaneously by an operator can be seen as following:

$$N = \frac{T + M}{T} \quad (4)$$

Where,

N : Number of operating the machines by an operator;

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T: Time required manual of operating machine;
(Including walking time between the machines);
M: Machining effectively time to finish the process.

According to the initial data of the effective work times including the machining time to finish and the operator time required for operating a machine, where only consider the time required for machine loading and unloading the work pieces. After a week simulation time, the WITNESS simulation results are presented in TABLE 1. The week output volume is based on two shifts.

TABLE 1 : SIMULATION RESULTS FOR MACHINE LOAD

No.	Busy(%)	Idle (%)	Setup(%)	Output	M(Min)	T(Setup)
01	13.76	15.83	5.22	619	1.00	0.38
02	83.81	11.37	4.83	517	7.29	0.42
03	29.64	64.63	5.73	516	2.58	0.50
04	53.03	40.33	6.64	516	4.63	0.58
05	24.08	71.69	4.23	515	2.10	0.37
06	7.67	87.53	4.8	515	0.67	0.42
07	14.53	78.84	6.62	515	1.27	0.58
08	24.83	70.25	4.91	515	2.17	0.43
09	27.66	59.55	12.79	514	2.42	1.12
10	5.71	89.5	4.79	514	0.50	0.42
11	15.76	75.42	8.89	514	1.38	0.78

Caculating Balance Rate: Calculation of the balance rate is bas

It can be seen from the simulation results in TABLE 1. The biggest load of the machines is up to 83.81% and the minimum is only 5.71%, which indicates a waste of resources within a week simulating time based on two shifts condition had been happened.

Caculating balance rate:

Calculation of the balance rate is based on the case in which all data are from the real line.

Scenario 1: Balance Rate When improving process time of the bottleneck from 900s down to 640s by adjusting the process content:

$$CT \rightarrow 900s \xrightarrow{\text{Adjusting}} 640s$$

$$N \rightarrow 2.6 = \frac{T+M}{T}, W \rightarrow 15$$

$$BR = \frac{\sum T_i}{CT \times W} \times 100\% = \frac{7100s}{640s \times 15} \times 100\% = 53\%$$

Scenario 2: Balance Rate When changing the special machine into a mix-products machine:

$$CT \rightarrow 900s \xrightarrow{\text{Mix-Machine}} 450s$$

$$N \rightarrow 2.2 = \frac{T+M}{T}, W \rightarrow 19$$

$$BR = \frac{\sum T_i}{CT \times W} \times 100\% = \frac{6057s}{450s \times 19} \times 100\% = 70\%$$

Scenario 3: Comprehensive Balance Rate:

$$CT \rightarrow 640\,s \xrightarrow{\text{Comprehens ive}} 320\,s$$

$$N \rightarrow 2.1 = \frac{T+M}{T}, W \rightarrow 20$$

$$BR = \frac{\sum T_i}{CT \times W} \times 100\,\% = \frac{5970\,s}{320\,s \times 20} \times 100\,\% = 93\,\%$$

In summary, the balance rate of the line is improved from 53% to 93% by adjusting the process content such as elimination, combination, rearrangement, simplification.

Developing operating standards:

A standard operation consists of three elements: the standard operating cycle time; the work order of manual in a standard operating cycle; the standard number of WIP.

A comprehensive result that integrated the "Standard Operating" and the "Operating Instructions" is shown as in Figure 4, which is a combination of the figures and tabulates.

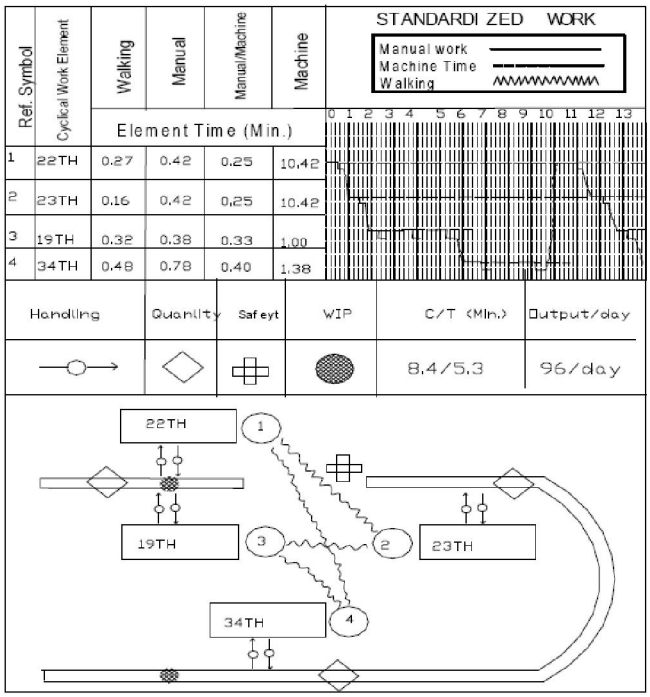

Figure 4 : Integrating guide of a standard operation

A simulation model about the production unit was established by using the WITNESS, a simulation software tool. Inputting the process data as given in Figure 4 to the model and running and observing the model, the operator workload of the process can be shown as in Figure 5.

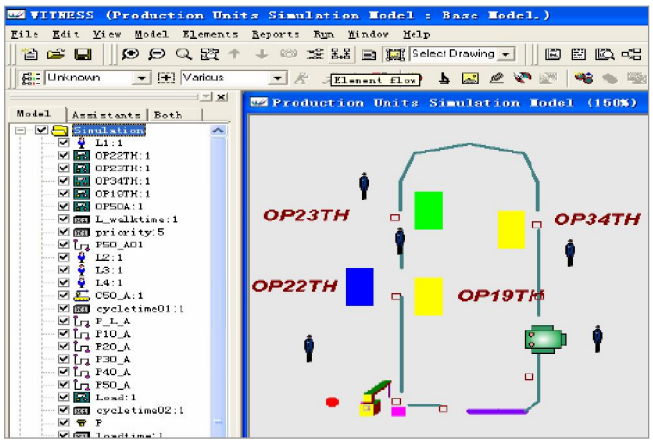

Figure 5 : Simulation model of a production unit

As the model simulation results, the operators' loads available were shown as in TABLE 2.

TABLE 2 : SIMULATION RESULTS FOR OPERATOR WORKLOAD

Name	Oper1	Oper2	Oper3	Oper4	Oper5
Busy(%)	78.93	31.97	33.84	33.8	43.13
Idle (%)	21.07	68.03	66.16	66.2	56.87

TABLE 2 shows that there was spare capacity to reduce the number of staff. Standardized operations will enable the operator to reach a higher percentage of effectiveness.

CONCLUSION

In balancing the production line, the more of process operation contents, the harder of adjustment to, so according to a initial balanced situation, the process simplified is the first step. The next direction is to pay attention to improve staff capacity, and reach gradually people can be more enthusiasm, and finally the formation of standardized operations will be made. The work to be more challenges and relatively complex tasks will let the operators to be stronger motivation. For the operation of traditional plant, the simulation results have shown that improvement methods mentioned in this article easy to improve the personnel and equipment as well as the efficiency of production line.

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