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AN OPTIMAL BALANCING OF ASSEMBLY LINE USING RPW TECHNIQUE

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Abstract - *The traditional assembly line balancing problem considers the manufacturing process of a product where production is specified in terms of a sequence of tasks that need to be assigned to workstations. Each task takes a known number of time units to complete. Also, precedence constraints exist among tasks: each task can be assigned to a station only after all its predecessors have been assigned to stations. The assembly line balancing problem arises and has to be solved when an assembly line has to be configured or redesigned. It consists of distributing the total work load for manufacturing any unit of the product to be assembled among the workstations along the line.*

In this paper Rank positional weight method is used to arrive to a feasible solution for a batch production unit to increase the production rate to 24 machines per day. Further using the same algorithm, better solutions are also proposed by reducing the cycle time and number of work stations.

Key words - *Assembly line balancing problem, Ranked position weighted method.*

1. INTRODUCTION

Assembly lines (ALs) are the most commonly used method in a mass production environment. They allow the assembly of products by workers with limited training and by dedicated machines and/or by robots. Assembly Line design (ALD) involves the design of products, processes and plant layout before the construction of the line itself. The design of efficient assembly workshops is a problem of considerable industrial importance. Assembly Lines are production systems composed of a succession of stations performing a set of tasks on the product passing through them. The assembled product takes its shape gradually starting with one part, with the remaining parts being attached at the various stations which are visited by the product. A paced Assembly Line is a usual topology for medium and high production volumes. In general, for simple products single linear Assembly Lines with possibly parallel stations can do the job. For complex products, the assembly system is mostly decomposed into sub-systems with their own cycle time, reliability, and stations requirements.

Nowadays companies around the world are producing high quality products to sell them at the lowest price possible. This is not because they don't want to earn more money through the sale of products. It is because they are facing the necessity of increasing their participation in the market because competitors also are selling products with high quality at the lowest price possible. There are several techniques to reduce operation costs. One of these techniques is called Line Balancing. The line balancing problem consists of assigning approximately the same amount of workload to each workstation (worker) in an assembly line. Line balancing involves selecting the appropriate combination work task to be performed at each work station so that the work is performed in a feasible sequence and approximately equal amounts of time are required at each of the work stations.

Performance evaluation generally involves two steps: (1) the mathematical model and (2) the model solution. Since it is difficult to find a simple model to describe a studied system, a simulation method must be used. A standardization of performance indices of line layout design must be defined, which could be minimization of the number of workstations, maximization of the production rate, minimization of cycle time etc. However there are some factors that may affect the performance of the system on which attention should be given like equipment cost, correlation between task times etc.

The incremental utilization heuristics simply add tasks to a workstation in order of task precedence one at time until utilization is 100% or is observed to fall. Then this procedure is repeated at the next workstation for the remaining tasks. This is appropriate when one or more task time is equal to or greater than the cycle time. The important advantage of this heuristics is that it is capable of solving line balancing problems regardless of the length of task times relative to the cycle time. Under certain circumstances, however, this heuristic creates the need for extra tools and equipment. If the primary focus of the analysis is to minimize the number of workstations or if the tools and equipment used in the production line are either numerous or inexpensive, this heuristic is appropriate.

2. LITERATURE SURVEY

A review of literature has been undertaken to understand different optimization technique used by different authors on assembly line balancing problems. Some of the recent papers review has helped to identify the suitable method to solve the assembly line problem which is presented below:

Ashish Manoria et. al. (2012) [12], described Rank positional weight method for Type I of the Simple Assembly Line Balancing Problem (SALB P) and multi product assembly line balancing problem (MALBP) for the hybrid system from the automotive industry which considered to assemble two models of commercial vehicles on the same assembly line which had most of their parts in common. The result showed that rank positional weight heuristic rule can produce good solutions for the straight line LBP. It was shown that the addition of an expert algorithm can improve the current solution. The study took a step in the direction of finding good result for the SALBP and MALBP. The major role of the study was to look these problems and introducing the expert system accordingly to minimize slack time at each work station and get task in shorter period of time.

W. Grzechca et. al. (2014) [2], considered job shop structure connected with assembly line wherein heuristic method such as RPW technique help to obtain feasible solutions very quickly without time consumption. His article shows a method which allows finding a good schedule of complex system (job shop - assembly line and vice versa). Total completion time, number of stations or smoothness index were taken into account for choosing the end solution and results showed that the total completion times of different variant don’t differ from each other a lot.

Parudh Mahajan et. al. (2015) [5], presented a heuristic method that was based on critical path method compared to RPW method and SPT method for simple assembly line balancing. The research was mainly concerned with objectives of minimizing the number of workstations, improvement of smoothness index, mean absolute deviation (MAD) and increasing line efficiency. It was concluded that all three methods gave better results than the method used in the industry but heuristic method based on CPM given the better result in the industry considered.

Krantikumar B. Chavare et. al. (2015) [9], presented use of RPW method to develop the assembly line and balancing that line. It was found that RPW method is useful when the less or more data is available. Also with the help of RPW method, it is possible to find out the way to synchronies the work stations for the work flow and sequencing. So the bottlenecking of the assemblies can be reduced. In his case study, numbers of workstations was decided and proper layout was proposed based on RPW method. After the implementation of RPW method, production rate was increased by 25%.

3. CASE STUDY- INCREASING THE PRODUCTION RATE OF TRANSMIT MIXTURE USING RPW TECHNIQUE

The problem is taken from International Journal published by M. Mohan Prasad et. al. [11] who took up a project in a company located in Chennai. The main objective of their project was to increase the production by changing the layout of the assembly line in making of Transmit Mixer from 12 machines per day to 24 machines per day. They used COMSOAL (Computer Method for Sequencing Operations for Assembly Lines) and RPW (Ranked Positional Weight) algorithms to get the optimal solution.

This paper considers the data and other input variables same as that of the problem and the better solution is presented by

a) reducing the cycle time and
b) reducing the number of work stations

3.1 CYCLE TIME CALCULATION

Following data is provided to calculate the cycle time for the given problem:

Production volume (Requirement)	12 machines/shift
Shifts/day	2
Efficiency of worker	70%

Table 3.1: Given Data

Production time (T_P) = hours per shift × efficiency of worker
= 8×70%
= 5.6 hours = **336 minutes**

Cycle time (T_C) = production time / production volume
= 336/12 = **28 minutes**

3.2 STEPS INVOLVED IN RPW TECHNIQUE

Step 1: Draw the precedence diagram

Step 2: For each work element, determine the positional weight. It is the total time on the longest path from the beginning of operation to the last operation of the network.

Step 3: Rank the work elements in descending order of ranked positional weight (R.P.W).

Step 4: Assign the work element to a station. Choose the highest RPW element. Then, select the next one. Continue till cycle time is not violated. Follow the precedence constraints also.

Step 5: Repeat step 4 till all operations are allotted to one station.

Precedence Diagram

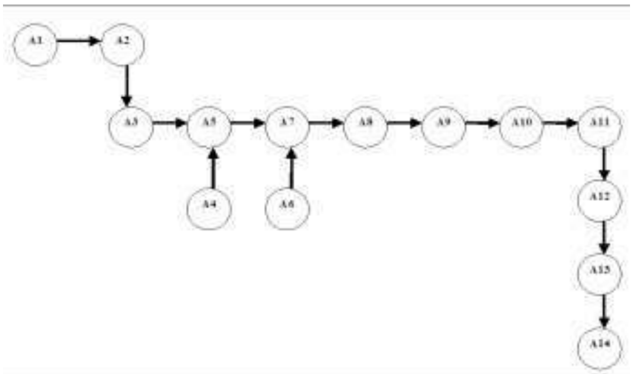

Fig. 3.1: Precedence Diagram

Positional Weight of Each Element

Element	Time (min)	RPW	Predecessor
A1	4	80	-
A2	3	76	A1
A3	6	73	A2
A4	6	73	-
A5	8	67	A3,A4
A6	4	63	-
A7	8	59	A5,A6
A8	8	51	A7
A9	15	43	A8
A10	2	28	A9
A11	10	26	A10
A12	6	16	A11
A13	6	10	A12
A14	4	4	A13

Table 3.2: Assigning RPW

Theoretical Calculations

Total task time (T_T) = Σ Task time = **90 minutes**

No. of work stations (W_N) = Total task time/Cycle time

= 90/28 = 3.21 = **4** (next high no.)

4. RESULTS

After the application of RPW technique following solution is obtained:

Cycle Time = 28 minutes			
Station No.	**Activities**	**Total Time (min)**	**Idle Time (min)**
1	A1,A2,A3,A4,A6	23	5
2	A5,A7,A8	24	4
3	A9,A10,A11	27	1
4	A12,A13,A14	16	12

Table 3.3: Optimal Solution for Cycle Time of 28 minutes

Performance Parameters

Line Efficiency = T_T/(T_C× W_N) = **80.36%**

Idle % = Total Idle time/(T_C× W_N) = **19.64%**

Production Volume = T_P/ T_C = **12 machines per shift**

Thus the production rate is increased as per the requirement. Now it is important to find out whether the assembly line can be further improved considering the same requirement without violating the precedence relationship? To answer this we have to follow iterative process by using the same RPW technique. It is possible either by reducing the cycle time or by reducing the number of workstations.

Following table shows the better optimal solutions by reducing the cycle time and number of workstations to the maximum possible extent considering the same input parameters.

Cycle Time = 27 minutes			
Station No.	**Activities**	**Total Time (min)**	**Idle Time (min)**
1	A1,A2,A3,A4,A5	27	0
2	A6,A7,A8	20	7
3	A9,A10,A11	27	0
4	A12,A13,A14	16	11

Table 3.4: Optimal Solution for Cycle Time of 27 minutes

Performance Parameters

Line Efficiency = T_T/(T_C× W_N) = **83.3%**

Idle % = Total Idle time/(T_C× W_N) = **16.67%**

Production Volume = T_P/ T_C = **12.44 machines per shift**

Cycle Time = 26 minutes			
Station No.	**Activities**	**Total Time (min)**	**Idle Time (min)**
1	A1,A2,A3,A4,A6	23	3
2	A5,A7,A8	24	2
3	A9,A10	17	9
4	A11,A12,A13,A14	26	0

Table 3.5: Optimal Solution for Cycle Time of 27 minutes

Performance Parameters

Line Efficiency = T_T/(T_C× W_N) = **86.53%**

Idle % = Total Idle time/(T_C× W_N) = **13.46%**

Production Volume = T_P/ T_C = **12.92 machines per shift**

Cycle Time = 31 minutes			
Station No.	**Activities**	**Total Time (min)**	**Idle Time (min)**
1	A1,A2,A3,A4,A5,A6	31	0
2	A7,A8,A9	31	0
3	A10,A11,A12,A13,A14	28	3

Table 3.6: Optimal Solution for No. of Workstation= 3

Performance Parameters

Line Efficiency = T_T/(T_C× W_N) = **96.77%**

Idle % = Total Idle time/(T_C× W_N) = **3.23%**

Production Volume = T_P/ T_C = **10.84 machines per shift**

5. CONCLUSIONS

The main purpose of this paper was to represent the use of RPW technique to develop the assembly line and balancing that line. This technique provided better solutions thereby improving line efficiency, reducing idle time within the station and also the production improvement. The results show that the RPW technique not only gives the feasible solution but possibility of improvising the solution by reducing the cycle time and number of work stations as well. The industry is able to meet its production requirement of doubling the output rate per shift (from 12 units per day to 24 units per day) which is a very big improvement. Moreover if it compromises slightly with the production volume, it is possible to improve line efficiency drastically from 80.36% to 96.77% and idle time from 19.64% to just 3.23% which in turn will result in best utilization of resources and less production cost.

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