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A new Heuristic Method RPW Method and Genetic algorithm techniques (hybrid method) For Evaluating Multi Product Assembly Line Balancing – A Case Study

Ashutosh Kumar*, [1], Hukam Singh[1], Ashutosh Kumar Rai[2], Avnish Kumar Shukla[1]
[1]Department of Mechanical Engineering, Krishna Engineering College, Ghaziabad (UP), India
[2]Department of Mechanical Engineering Delhi Technological University, Delhi India 110042

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Abstract

Assembly line production is one of the widely used production systems. The problem of Assembly Line Balancing deals with the distribution of activities among the workstations which lead to the maximum utilization of Human Resources and facilities without disturbing the work sequence. The problem is motivated by a vehicle-sequencing problem at an Automobile company, Gurugram. A new Heuristic Method i.e. RPW Method and Genetic algorithm techniques(hybrid method) for the Type-I of Multi Product of Assembly Line Balancing Problem(MALBP) have been used. The hybrid method has been developed which is based on the heuristic rules and formulae. The programme is coded in C#(C Sharp). The hybrid method was gave good solutions for straight line balancing problem. The present work of case study provided new knowledge to develop a better tool of assembly line balancing to solve real world problems more efficiently at the shortest possible time and it leads to increase line efficiency and production rate by reducing the number of workstations and also reducing balance delay and smoothness index.

1. Introduction

An assembly line is a sequence of workstations connected together by mechanical material handling equipments in which a dedicated group of tasks are performed in predetermined sequence. The total work content to be performed by the production system is split –up into economical individual work elements which are called task. Among the set of tasks there exist technological precedence relations. The assignment of these tasks to workstation along an assembly line to achieve same or close to same working time at each workstation. The goal of this assignment of task is to create a smooth and continuous flow of product through the assembly line for maximum productivity and minimum idle time at each workstation. A well-balanced assembly line has the advantage of high personnel and facility utilization and equity among the employees work loads.

Assembly lines are flow-oriented production systems which are typical in the industrial production of high quality standardized commodities and even gain importance in low volume production of customized products Among the decision problems which arises in managing such systems, assembly line balancing problems are important tasks in medium –term production planning **[1]**

Assembly line balancing is a classic problem in any business. Assembly is a process by which manufacturing parts are put together to make the finished product. An assembly line is a moving conveyer that passes a series of work stations in a uniform time interval . At each work stations, work is performed on the product by adding parts i.e. completing assembly operations by the operators. If work load is not well balanced, one operator may be busy while the other may remain idle which waste the loss of time, money and man hours. In such situation the efficiency and morale of the organization decreases leading to unhealthy work conditions**[2].**

1.1Multi-Product Line Balancing

Multi-product assembly lines assemble two or more products separately in batches, when more than one product variant has to be assembled in a line. The objective is to assign operations to workstations in order to balance the workload and minimize manpower requirements when more than one product variant has to be assembled in a line. Since assembly process and process times may not be the same for different products, a single line cannot be perfectly balanced for each of the products.

The evolution of the design of a product leads manufacturers to consider families of products. The design of the assembly line has to take this evolution into account as from single product to multi product.

***Corresponding Author,**
E-mail address: ashume2007@gmail.com

2. Problem Formulation

The assembly line balancing task is tedious and time consuming. For complex operations in industries like Automotive, computer manufacturing etc it becomes very tedious and time consuming. Also, all the things of assigning the operations on workstations are done manually, and hence skilled labour requires for this task. Though, the assurance cannot be given that the system is running with maximum efficiency. In many industries it has been seen that after assigning the task and implementing, it was found that most of the workstations are running idle, for which again corrective action is taken i.e. also a time consuming process.

A case study for assembly line balancing was proposed to be undertaken at a company of Motorcycle and Scooter in Manesar(Haryana) in consultation with the management of the company. The management agreed to provide all facilities for ALB of engine assembly of different models of bikes. The approach was adopted for ALB of different models of bikes like KTE,KWP,KRP and KVT of above mentioned company.

Despite recent advances in computational techniques and solution procedure efficiency, mathematical Programming and network-based optimization techniques are still computationally prohibitive beyond limited problem dimensions.Therefore, heuristic and Group Genetic Algorithm (GGA) still remain the only computationally efficient and sufficiently flexible methodologies capable of addressing large-scale, real-world ALB situations, particularly for the multi/mixed model.

In this case study, computer based approach has been developed for solving the mixed-model two-sided assembly line balancing problem considering minimizing the number of mated-stations (i.e.,the line length) and minimizing the number of stations (i.e., the number of operators) for a given cycle time.Objective function developed is for minimizing the number of mated-station (i.e.the line length) as the primary objective, and it also minimizes the number of stations (i.e.the number of operators) as a secondary objective. Constraint is the assignment constraint which ensures that each task is assigned to exactly one station. Another constraint is the precedence constraint which ensures that all precedence relations among tasks are satisfied. Also constraint is the cycle time constraint which ensures that each of the finish time of tasks for each model does not exceed the cycle time.

Here the aim was to find out/ reduce number of work stations for the specified industries. The assembly line balancing would assign the tasks according to the precedence relations and some other constraints to each workstation for maximum efficiency possible, and thereby achieving the maximum productivity. The objective was to assign the tasks to the workstations such that the idle time would be less and the working of each workstation would be closer to cycle time.

3. Methodology

The methodology used for solving the problem of assembly line balancing was Heuristics method and Group Genetic Algorithm(GGA) method. In the present work, the Heuristic Method with genetic algorithm was used to solve the mixed model assembly line balancing problem of type I (MMALBP-I). There were three objectives to be achieved: to minimize the number of workstations, maximize the workload smoothness between workstations, and maximize the workload smoothness within workstations.

3.1 Developed Assembly Line Balancing

For the above problem, a computerized hybrid system has been developed which is based on the heuristic rules and formulae. To solve this problem Heuristic based Rank Positional Weight (RPW) was used with Group Genetic Algorithm. The heuristic based RPW was very suitable and gives more stable results for large number tasks while GGA is used for getting mixed-models assembly line balancing problems. The most important feature of this system is its utility and simplicity for any number of activities to be performed for assembly.

The computerized hybrid system uses the applications of Heuristic and GGA for better results. This system gives the results for mixed model as well as for multi- product assembly line balancing. The system has been developed using the concept 'C++' programming. It is an effective and suitable language for implementation, ease in file handling and better presentation. Hence, the computerized system logic was coded with "C++" programming language. The developed system can be used for any number of tasks which are to be performed on the products. In this system data was entered as number of tasks, task number, task time, precedence, and cycle time. The program runs separately for each variety and results were checked with the present situation.

In this work, a new heuristic namely, RPW Method with GGA for solving Deterministic Assembly Line Balancing problem has been developed. This will be very much useful for the industries to design mass production systems with improved productivity and to compete and survive in the competitive industrial sector in the era of globalization. These results can provide a broad guideline for designing an assembly line in a mass production system with improved productivity. This heuristic is experimented with several problems generated randomly. The performance of the heuristic is compared with that of the existing set of Heuristics methods of Assembly Line Balancing. For this purpose an experiment was designed using a KTE, KWP etc. models of HMSI. Software in C# has been developed for testing the problem.

3.2 Performance Parameters

The performance parameters which were used for analysis of different methods of Assembly Line Balancing are Line Efficiency, Balance Delay and Smoothness Index. The Line Efficiency is used for the calculation of efficiency of the Assembly Line. Line Efficiency represents positive achievement in line utilization of all resources and is the key representation of economic performance. Balance Efficiency and Smoothness Index are representative of the distribution of work with consequent personnel satisfaction combined with increased opportunities for greater output.

3.2.1 Line Efficiency (LE) – It is expressed as ratio of total station time to the cycle time multiplied by the number of workstations.

$$LE = \frac{\sum_{i=1}^{K} ST_i}{c.K}.100\%$$

where: K= total number of workstations,
c = cycle time and ST_i =station time of station i.

3.2.2 Balance Efficiency is Balance Delay which indicates the amount of time lost due to imperfect balancing as a ratio to the total time available i.e.

$$d = \left(\frac{wT_S - T_{wc}}{wT_S}\right)$$

where, d= Balance Delay. A balance delay of zero indicates a perfect balance.

3.2.3 Smoothness Index (SI) – describes relative smoothness for a given assembly line balance. Perfect balance is indicated by smoothness index 0. Smaller value of SI means that more the line is balanced.

$$SI = \sqrt{\sum_{i=1}^{K} \left(ST_{\max} - ST_i\right)^2}$$

where: $ST_{\max}$ = maximum station time (in most cases cycle time), ST_i = station time of station i

4. Results and Discussion

The heuristic methods like Largest Candidate Rule, Kilbridge And Wester Method, Moodie-Young Method and RPW Method with GGA were applied to the Assembly Line of HMSI. The collected information like description of task, task time, cycle time of line and precedence diagram of Assembly Line were provided to the approach of each Heuristic method and the different parameters like efficiency, balance delay and smoothness index of each station by each method are calculated. The results of all parameters for assembly line are compared. The number of maximum and minimum efficiency and its values were calculated by using all above methods and results are compared among them. The Balance Delay and Smoothness Index were also calculated and compared by applying these methods. The most appropriate method is selected on the basis of comparison for balancing the assembly line and the results of this method were compared to the already existing method of assembly line.

4.1 Hybrid Method

The procedure of this method is similar to the RPW method with basic difference is that allocation of work elements or tasks having same RPW and Rank are then subjected to gentic algorithm procedure.The priority rules are based on task time, the number successors and the number of predessor. The assignment of work elements to the work station is carried out in the following manner

a) The work with the highest positional weight was selected and assigned to the first workstation.
b) The unassigned time was calculated for the work-station by calculating the cumulative time of all works units assigned to the station and this sum was subtracted from the cycle time.
c) The work unit was selected with the next highest positional weight and attempted to assign it to the work-station.
d) If the positional weight and rank of two tasks is same, then the priority rule is followed for assigning of work elements to the workstation according to task time first.
e) If the positional weight, rank and task time of task is same for two or more work elements, then the priority is based on the number of predecessors.
f) If all above parameters are same for two or more different work elements, then priority for assigning of task to workstation is on the basis of number successors.
g) Unassigned work unit is assigned with the highest positional weight to the second work-station, and preceded through the preceding step in the same manner.

The assigning of work units are continued untill the assembly line balancing problem is found.

The approach of hybrid method (RPW method with GGA) is applied in the collected data of all tasks of assembly line of HMSI models and it is found that the rank is not same for any task so the allocation of work elements or tasks to each station is similar to RPW method. It is suitable for solving the balancing problem when the precedence diagram of Assembly Line is complex having some parallel assembly line of product flow. This type of product flow occurs in case of Multi Product Assembly Line Balancing Problem. So this method is suitable and most appropriate technique for balancing Mixed Multi Product Balancing System when the data is vide and complex.

Due to the similarity for assigning of tasks to each workstation, this case study leads to give the performance parameters It is observed that maximum efficiency of 100% was found at 13 work stations

(14, 24, 25, 27, 35, 39, 40, 42, 47, 54, 57, 60 and 62) and minimum efficiency (38.46%) was observed at 1 work station (71) only. Similarly, minimum Balance Delay of 13 work stations(14, 24, 25, 27, 35, 39, 40, 42, 47, 54, 57, 60 and 62) were 0 % and maximum for 1 work station(Station71) is 61.54%. The Smoothness Index of 13 work stations(14, 24, 25, 27, 35, 39, 40, 42, 47, 54, 57, 60 and 62) were minimum i.e.0 and one work station (71) had maximum value of SI i.e.16.

4.2. Analysis Of Case Study

In the course of line balancing, the idle time and the number of workstations on the assembly line was minimized so as to maximize the efficiency of the production line. All the required data is measured and the parameters such as elapsed time at each work station, efficiencies, number of workers, time of each of the workstations etc. is calculated from the existing line. After allocating the work elements on new assembly line, the cost of production and effectiveness of the new line was computed and compared with those of the existing one.

The developed hybrid method was applied in an automotive assembly line for improving the performance. The assembly line has 75 workstations, 229 tasks with cycle time equal to 26 sec. After implementing the hybrid method it was possible to reduce the number of workstations to 71 (a reduction of 4 workstations) considering the same number of tasks with the same cycle time. Further, productivity improved from 81.20% to 85.75%.

Table 4.1 Performance Parameters of Existing practice Vs Developed Method

S.N.	Performanc Parameters	Existing Practice	Developed Method
1	Cycle Time	26	26
2	No.ofWork stations	75	71

Similarly, there has been a reduction of balance delay of about 4.64% showing that the time lost due to imperfect balancing is less in case of hybrid system as compared to the current practice being followed in the organization. Smoothness index also shows a declining trend i.e. 32.16% reduction, indicating a better balanced production line.

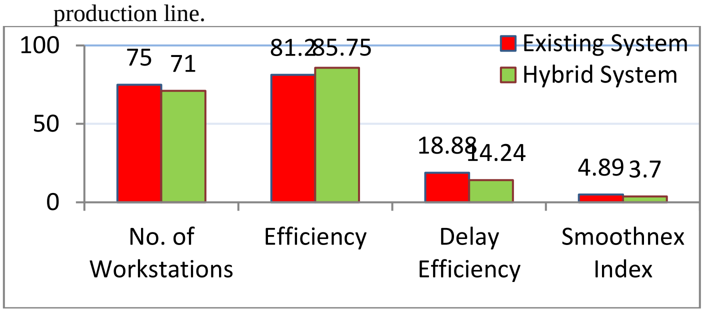

Fig. 1 Existing Practice Vs Developed Method- A Comparison

Fig. 1 shows the comparative variation of performance parameters in case of existing practice being followed at Scooter and motorcycle company in Gurgaon and the developed hybrid assembly line balancing metho d. After implementing the hybrid method it was possible to reduce the number of workstations to 71 (a reduction of 4 workstations) considering the same number of tasks with the same cycle time. Further, productivity improved from 81.20% to 85.75%.

5 Conclusions

This system helped to improve the workstation allocation thereby getting optimum task assignment on each workstation for line balancing problem .The system helped in reducing the number of operators required on the balanced workstations. The computerized system lead to reduce number of stations and gives optimum number of stations based on RPW technique. By reducing the number of work stations, the assembly line result in achieving maximum productivity. The new production line is found to have been increased by a significant amount reducing the overall production cost per unit by increasing line efficiency and reducing delay time.

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