ASSEMBLY LINE BALANCING BY RPW METHOD IN LANGUAGE C++

SANDIP KUMAR MISHRA¹, ASHISH MANORIA²

¹Faculty of Department of Mechanical Engineering, SRGI, Jhansi
²Faculty of Department of Mechanical Engineering, SATI, Vidisha

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.

Assembly Line Balancing, or simply Line Balancing (LB), is the problem of assigning operations to workstations along an assembly line, in such a way that the assignment be optimal in some sense. Ever since Henry Ford's introduction of assembly lines, LB has been an optimization problem of significant industrial importance: the efficiency difference between an optimal and a sub-optimal assignment can yield economies (or waste) reaching huge amount of money per year. Assembly line balancing problems have been conventionally classified into four types in which type II focuses on minimizing the total cycle time keeping number of work stations constant and type I minimizing the work stations for a given cycle time. The present work is based on the Heuristic Method for simple assembly line balancing problem. The Ranked Positional Weight Method is used in this case, (A New Approach of Assembly Line Balancing using Rank Positional Weight Method coded in C++ ). The data were collected from a light duty commercial vehicle factory situated in Pithampur and problem has been taken into consideration. The program is coded in C++. The software showed satisfactory result when run on given data by giving the optimal solution to the present Assembly Line Workstation for the product thereby reducing the manpower required for the existing setup.

1 INTRODUCTION

Assembly Line balancing is a classic problem in manufacturing business. First, the manufacturing engineer constructs an assembly work diagram showing all work elements (tasks) and their precedence relations. Then the cycle time is selected according to the production demands. The problem is then to group the tasks into a number of stations such that (1) the precedence relation is preserved, i.e., no task can be done unless all its preceding work elements have been completed, and (2) the process time of each station does not exceed the cycle time. Many line-balancing algorithms are based on heuristic methods. No efficient computational methods for the exact solution are known. The methods used for solving ALB
problems are handled in two ways, either manually or by computer. Manual methods can be used to solve small-scale ALB problems (usually for problems with less than 15 jobs); large-scale and integrated problems have to be solved with the aid of computers. The computer-aided assembly line balancing methods must allow the exploration of a wide range of alternatives of allocating tasks to the different stations. Assembly line balancing is a traditional approach to elaboration of a first rough layout of a production line. This approach is appropriate for manual and mono-product assembly environment where the primary concern is the balancing of tasks among assembly workers while keeping labor costs to a minimum. The evolution of the design of a product leads manufacturers to consider families of products. The design of the assembly line has to consider this evolution. Assembly line balancing (ALB) relates to a finite set of work elements or tasks, each having an operation processing time and a set of precedence relations, which specify the permissible orderings of the tasks. One of the problems in organizing mass production is how to group work tasks to be performed on workstations to achieve the desired level of performance. Line balancing is an attempt to allocate equal amounts of work to the various workstations along the line. The fundamental line-balancing problem is how to assign a set of tasks to an ordered set of workstations, such that the precedence relations are satisfied and some measure of performance is optimized when designing an assembly line, the following restrictions must be imposed on the grouping of work elements.

1. Precedence relationship.

2. The number of work elements cannot be greater than the number of workstations. The minimum number of workstations is one.

3. The cycle time (amount of time available at each station as well as the time between successive units coming off the line) is greater than or equal to the maximum of any station time and of the time of any work element \( T_i \). The station time should not exceed the cycle time.

There can be two main goals while balancing an assembly line

1. Minimization of the number of workstations for a given cycle time.

2. Minimization of the cycle time for a given number of workstations
METHOD OF LINE BALANCING

HEURISTIC: HELGESON-BIRNIE (RANKED POSITIONAL WEIGHT) METHOD

Following steps are followed

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 the operation to the last operation of the network.

Step 3: Rank the work elements in descending order of ranked positional weight (R.P.W). Calculation of RPW would be explained in the example to follow.

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 5 until all operations are allotted to one station.

2. LITERATURE REVIEW

A potential consequence of establishing an assembly line operation is the occurrence of occupational injuries and illnesses among the work force. A subset of these injuries / illnesses, as described by [5], is work related musculoskeletal disorders (WRMSDs). This term is used as an overall descriptor for diseases and disorders affecting the joints, muscles, tendons, ligaments, cartilage, nerves, and blood vessels of the neck and upper extremities. A common attribute shared by WRMSDs is that they cannot be attributed to a single accusatory incident or accident. They is pathological processes whose signs and symptoms (i.e. discomfort, fatigue, pain) gradually manifest themselves over time. In assembly line
balancing, the allocation of tasks to workstations may in fact have a substantial impact on the prevalence and severity of WRMSDs found among the personnel manning each workstation. Although different variations of the assembly line balancing problem have been explored by researchers [8] [12], little concern has been given to the physical demands placed on the workers when assigning tasks to workstations. In addition, the initial assumption found in most of the research on the SALBP-2 is that the product being manufactured follows a linear path across workstations. Under this type of linear or I-Shaped configuration, material flows in one direction, starting with the first workstation and ending with the last workstation. However, an alternative flow is available in which the manufactured part follows a U-shaped path. Under this type of configuration, material flows in two directions, starting and ending with the first workstation. Research which examines the impact of this type of configuration on cycle time and the minimum number of required workstations is somewhat limited [11] [15]. A U-shaped line may reduce the cycle time or the number of workstations required when compared to an I-shaped line. However, whether or not that solution will be found is dependent upon the search method used. Various search methods have been applied to the assembly line balancing problem including integer programming [8], dynamic programming [6] ranking heuristics [4], and bi-directional branching strategies [16]. Recently, another search method has been applied to the SALBP-2 and 3 bases many of its mechanisms on the Darwinian principle of natural selection. Known as genetic algorithms (GA), these are evolutionary methods of search that can obtain good solutions in multi-modal, discontinuous, non-differentiable, and noisy response environments [2]. The biologically inspired aspects of this algorithm can be seen in its five basic steps which [7] described. In the first step a number of solutions are randomly generated. This set of solutions represents the population of a GA. In the second step, each solution in the population is evaluated with respect to the objective function. In the evaluation, each solution is assigned a fitness that is a measure of how well this solution satisfies the objective function. The third stage entails reproducing solutions for survival based upon their fitness. Reproduction is probabilistic in that the more fit the solution, the more likely it is chosen for survival'. New solutions are created from the surviving solutions in the fourth stage, known as recombination. The two forms of recombination utilized by GA's are crossover and mutation. In crossover, two survivors (i.e. parents) exchange parts of their configurations that represent their respective solutions. The second form of recombination is mutation in which the configuration of a single parent is randomly altered. This mutation results in a new offspring solution that is different from its parent. In the fifth and final step, replacement, the newly formed solutions become the population of the next generation. Steps 2-5 are repeated until a stopping criterion is reached. This criterion can be a limit on the number of generations or a level of fitness. GAs designed by [1] [12] have been effectively applied to SALBP-2. However, these algorithms focused on optimizing only a single criterion, cycle time. A GA used by [9] addressed multiple objectives when trying to solve an SALBP-2. In this case, the objectives were minimizing cycle time and maximizing task relatedness. Issues of worker safety were not considered by the authors. The algorithms presented in this paper will attempt to find line balances that minimize cycle time and minimize the maximum loss of grip strength capacity incurred by a worker assigned to the assembly line.
3. PROBLEM IDENTIFICATION AND DATA COLLECTION

Assembly Line Balancing Problem: A Case Study

The decision problem of optimally partitioning (balancing) the assembly work (tasks) among the stations with respect to some objective is known as the assembly line balancing problem (ALBP). While balancing the assembly line the aim is either to reduce the cycle time or to reduce the Workstation if possible by setting the optimum solution using the latest available techniques. Here our aim is to reduce the cycle time. The assembly line balancing problem can be explained as to 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 is to assign the tasks to the workstations such that the idle time should be less and the working of each workstation should be closer to cycle time. Till now, 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. In addition, all the things of assigning the operations on workstations are done manually and hence skilled labor requires for this task. However, we cannot give assurance that the system is running with maximum efficiency. In many industries, it has seen that after assigning the task and implementing it we found that most of the workstations are running idle, for which again corrective action is taken i.e. also a time consuming process.

CONSTRAINTS IN LINE BALANCING PROBLEM

1. We should know precedence relationship for each operation
2. Divide the tasks into maximum number of activities possible.
3. The number of workstations should not be more than total number of tasks i.e. Restriction on number of workstation should be there.
4. Station time individually should not be more than cycle time.
5. No operation found more than cycle time sort it and check it by apply number of workers on it to have within cycle time or separate the operation if possible

FORMULATION OF PROBLEM

Eicher Motors Limited Pithampur (Distt. - Dhar)

Eicher Motors Limited Pithampur is an automotive company for light duty and Heavy duty (LD and HD) Trucks. The company is located in pithampur, Dhar district near Indore (Madhya Pradesh). The company is having well equipped modern machineries for its assembly operations of trucks. Eicher Motors was founded in 1982 to manufacture a range of reliable, fuel-efficient commercial vehicles of contemporary technology. The unit manufactures and markets commercial vehicles with Gross Vehicle Weight (GVW) ranging from 5-25 tons. Today, Eicher Motors is one of the leading manufactures of commercial vehicles in India with a 33% market share in the 7T-11T segment. The success and growth
of this unit is a result of various customer-driven strategies. The manufacturing facility is situated in Central India - Pithampur, Madhya Pradesh. Eicher Motors has stepped into the Heavy Commercial Vehicle segment with its state-of-the-art HCV, the "Eicher 20.16", the first commercial vehicle designed and developed indigenously. Eicher Motors functions through a strong three-tier service network consisting of authorized distributors, service centers and company trained private mechanics. The vehicles are sold and serviced through a network of over 576 Authorized Contact Points all over India, supported by service centers and over 4500 company trained private mechanics, who are close at hand on all major highways throughout India to provide initial "first aid" to the vehicles if required. In 1986, Eicher Motors entered into a technical and financial collaboration with Mitsubishi Motor Corporation of Japan to manufacture the Canter range of vehicles.

The collected data is shown in tabular form

<table>
<thead>
<tr>
<th>Sr. no</th>
<th>Activity Description</th>
<th>Process/Task</th>
<th>Task Time (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For (10.90 LD Model)</td>
<td>Number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Main washing machine – wash</td>
<td>01</td>
<td>7.33</td>
</tr>
<tr>
<td>2</td>
<td>Main washing machine – unload</td>
<td>02</td>
<td>6.23</td>
</tr>
<tr>
<td>3</td>
<td>Painting – load/unload</td>
<td>03</td>
<td>4.00</td>
</tr>
<tr>
<td>4</td>
<td>Painting – Paint</td>
<td>04</td>
<td>1.50</td>
</tr>
<tr>
<td>5</td>
<td>HUB and DRUM washing m/c</td>
<td>05</td>
<td>4.36</td>
</tr>
<tr>
<td>6</td>
<td>HUB and DRUM wash</td>
<td>06</td>
<td>1.08</td>
</tr>
<tr>
<td>7</td>
<td>HUB BOLT PRESS-150 T</td>
<td>07</td>
<td>0.00</td>
</tr>
<tr>
<td>8</td>
<td>HUB and DRUM assembly</td>
<td>08</td>
<td>3.3</td>
</tr>
<tr>
<td>9</td>
<td>Bearing Races Press – 20T</td>
<td>09</td>
<td>3.1</td>
</tr>
<tr>
<td>10</td>
<td>HUB GREASING</td>
<td>10</td>
<td>2.3</td>
</tr>
<tr>
<td>11</td>
<td>OIL SEAL PRESSING</td>
<td>11</td>
<td>1.3</td>
</tr>
<tr>
<td>12</td>
<td>BEARING GREASING m/c</td>
<td>12</td>
<td>0.8</td>
</tr>
<tr>
<td>13</td>
<td>SHIM selection</td>
<td>13</td>
<td>4.00</td>
</tr>
<tr>
<td>14</td>
<td>Diff. Line – cases and crown assm.</td>
<td>14</td>
<td>0.00</td>
</tr>
<tr>
<td>15</td>
<td>PRESS-D</td>
<td>15</td>
<td>0.00</td>
</tr>
<tr>
<td>16</td>
<td>Diff. Line – Final assembly</td>
<td>16</td>
<td>0.00</td>
</tr>
<tr>
<td>17</td>
<td>Pinion, Retainer and Carrier assm.</td>
<td>17</td>
<td>0.00</td>
</tr>
<tr>
<td>18</td>
<td>PRESS-E</td>
<td>18</td>
<td>0.00</td>
</tr>
<tr>
<td>19</td>
<td>DIFF. LINE – case and crown assem</td>
<td>19</td>
<td>7.5</td>
</tr>
<tr>
<td>20</td>
<td>PRESS – B</td>
<td>20</td>
<td>3.93</td>
</tr>
<tr>
<td>21</td>
<td>FIXT, MD CHECKING</td>
<td>21</td>
<td>1.42</td>
</tr>
<tr>
<td>22</td>
<td>DIFF. LINE – final assembly</td>
<td>22</td>
<td>4.47</td>
</tr>
<tr>
<td>23</td>
<td>PRESS – C</td>
<td>23</td>
<td>4.28</td>
</tr>
<tr>
<td>24</td>
<td>SLAT CONVEYOR LH &amp; RH (ST-01)</td>
<td>24</td>
<td>6.75</td>
</tr>
<tr>
<td>25</td>
<td>SLAT CONVEYOR LH&amp;RH (ST-02)</td>
<td>25,26</td>
<td>8.73</td>
</tr>
<tr>
<td>26</td>
<td>SLAT CONVEYOR LH&amp;RH (ST-03)</td>
<td>27,28,29</td>
<td>3</td>
</tr>
</tbody>
</table>
For the above problem, an expert system has been developed which is based on the heuristic rules and formulae. To solve this problem Heuristic based Rank positional weight (RPW) is used. The Heuristic based RPW is very suitable and gives more stable results for large number tasks. The most important feature of this system is its utility and simplicity for any number of activities to be performed for assembling. This system will also help to improve the workstation allocation thereby getting optimum task assignment on each workstation for line balancing problem. The heuristic based approach is selectively incorporated within the system to get the optimum solution. Till now assembly line balancing is done only for single product by using Heuristic approach, here we are using Heuristic RPW method. This work introduces a new application for product mixed model assembly line balancing concept. The main purpose of this work is to design a system for mixed mode, multi product. This system can be implemented very easily to set up a new assembly line that too with good results. The main advantage of this system is that any unskilled or non-technical person can operate it with proper workstation allocation by getting maximum efficiency. This system will also save lot of time and skilled manpower require for manual work. The old method of balancing the line manually has been changed by using an expert system. The expert system is a programming language having being used the applications of Heuristic for the better results. This knowledge chunks characterized by a set of facts and heuristic rules. It plays an important role in meeting the technological sophistication requires in today’s competitive world. Industries are demanding the assistance of human experts to solve the complicated problems.

ASSUMPTIONS OF EXPERT SYSTEM

(1) A Task cannot split in two or more stations.
(2) I should not break precedence given.
(3) Cycle time is give and should be greater than the maximum task time required for any operation.
(4) All task must be processed and on given station only.
(5) Operations are fixed with proper allowances

ALGORITHM FOR EXPERT SYSTEM

(1) Establish station and assign the maximum positional weight to it.

Conditional statement: IF - for unassigned task (T1, T2,........., Tn)

The task with maximum RPW will be taken first and will be assigned.

(2) Condition for assigning the maximum possible task to a station

IF $S_{ij} = 0$ AND $St_{ij} \leq Tc$ AND $j \leq T_{\text{max}}$

It will assign the task to the station.
(3) Condition to check the tie in Positional Weights

IF $RPW_{ij} = RPW_{i} + lj$; THEN select task having longer time duration. Similarly, checking the tie for time i.e. $st_{time}$.

(4) Check to have assigned the task to next workstation.

IF $st_{time} > TC$ assign task to next station

(5) Forming the loop till the last task assigned

IF task $ij <= 0$ stop the program.

Flow Chart of the Program
4. RESULTS

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Comparison</th>
<th>Present</th>
<th>By Expert System</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>No. of Work Stations</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>02</td>
<td>Production Rate</td>
<td>64</td>
<td>66</td>
</tr>
<tr>
<td>03</td>
<td>Line Efficiency</td>
<td>71%</td>
<td>73%</td>
</tr>
<tr>
<td>04</td>
<td>No. of Workers</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>05</td>
<td>Cycle Time</td>
<td>7.5 min.</td>
<td>7.33 min.</td>
</tr>
</tbody>
</table>

Results of RPW technique

As we can see from table showing comparison of the present actual situation in assembly line and the output obtained from the Expert system which is showing the increase in the efficiency and reduction in cycle time for the given number of work stations.

5. CONCLUSIONS

The various assembly lines balancing type had been seen are looked for improvements for SALB. Two different approaches have been proposed to incorporate processing alternatives into ALB. The first is known as the equipment selection problem. It is based on the assumption that there is a fixed set of equipments (complete set of resources) exactly one of which has to be selected and assigned to a station. The alternative approach consists in assigning processes to tasks. In addition to line balancing, for each task exactly one processing alternative has to be chosen out of a set of possible one. Because these processes require resources, the problem can be interpreted as an (implicit)equipment design problem. The chosen processes are usually not independent to each other, which has to be reflected by considering possible synergies arising from jointly using resources for several tasks at a station or different types of assignment restrictions. The expert system showed that it had a good potential to solve the current industrial problem of assembly line balancing for multi products to have an optimum utilization of the resources. Furthermore the problem can be extended to solve the effective utilization of manpower for mixed model line balancing system.

REFERENCES


