Methods of Solving Assembly Line Balancing Problem

Dr. Raju N. Panchal¹, Anant D. Awasare², Sarafaraj. J. Mulani³

¹Professor, Mechanical Engineering Dept, AGTI’s DACOE Karad, (India)
²³Assistant Professor, Mechanical Engineering Dept, AGTI’s DACOE Karad, (India)

Abstract
One of the main issues concerning the development of an assembly line is how to arrange the tasks to be performed. This arrangement may be somewhat subjective, but has to be dictated by implied rules set forth by the production sequence. For the manufacturing of any item, there are some sequences of tasks that must be followed. The assembly line balancing problem (ALB) originated with the invention of the assembly line. However, during the initial years of the assembly line’s existence, only trial-and-error methods were used to balance the lines. Since then, there have been numerous methods developed to solve the different forms of the ALB. Development of assembly line and then balancing of the assembly line is having importance from the productivity point of view. As most of the small scale and medium scale industries are not following the various techniques available for line balancing or even line developing which may cause the loss of the productivity.

Keywords—Assembly Line, Line Balancing, Production Sequence.

I. Introduction
The concept of manufacturing assembly line (AL) was first introduced by Henry Ford in the early 1900’s. It was designed to be an efficient, highly productive way of manufacturing a particular product. The basic assembly line consists of a set of workstations arranged in a linear fashion, with each station connected by a material handling device. The basic movement of material through an assembly line begins with a part being fed into the first station at a predetermined feed rate. A station is considered any point on the assembly line in which a task is performed on the part. These tasks can be performed by machinery, robots, and or human operators. Once the part enters a station, a task is then performed on the part, and the part is fed to the next operation. The time it takes to complete a task at each operation is known as the process time. The cycle time of an assembly line is predetermined by a desired production rate. This production rate is set so that the desired amount of end product is produced within a certain time period.

Assembly Process:-
Definition & Types
Definition: Assembly involves the joining together of two or more separate parts to form a new entity (Assembly or subassembly).

The processes used to accomplish the assembly of the components can be divided into three major categories.

1. Mechanical Fastening – Mechanical action to hold components together.
   - Threaded fasteners - screws, bolts, nuts etc.
   - Rivets, crimping and other methods
   - Press fits
   - Snap fits – temporary interface of the two parts C-ring.
   - Sewing and stitching – for soft, thin material.

2. Joining Methods – welding, brazing and soldering
3. Adhesive Bonding – thermoplastic, thermosetting (chemical reaction)

**Terminology:**

1. **Minimum Rational Work Element**

Minimum rational work element is the smallest practical indivisible tasks into which the job can be divided. These work elements cannot be subdivided further. Work carrier or base part in components added at each station. Example: drilling a hole, screw and nut etc.

\[ T_{ej} \] where \( j \) is used to identify the element out of the ‘n’ elements that make up the total work.

2. **Total Work Content**

Total work, \( T_{wc} \), content is the aggregate of all the work elements to be done on the line. \( T_{wc} = \sum T_{e} \)

3. **Workstation Process Time**

Work is performed either manually or by some automatic device. The work performed at station consists of one or more of the individual work elements. \( \sum T_{S} = \sum T_{e} \)

4. **Cycle Time**

Cycle time, \( T_{c} \), is the ideal or theoretical cycle time of the flow line, which is the time interval between parts coming off the line. When consider efficiency, \( E \), the ideal cycle time must be reduce.

\[ T_{c} \leq \frac{R_{p}}{E} \]

Where \( R_{p} \) is production rate.

* At efficiencies less than 100% the ideal cycle time must be reduced (or ideal production rate must be increased).

* The minimum possible value of \( T_{c} \) is established by the bottleneck station, the one with the largest value of \( T_{s} \). \( T_{c} \geq T_{s} \) max \( T_{c} \geq T_{ej} \)

5. **Precedence Constraints**

Technological sequencing requirements, the order in which the work elements can be accomplished is limited.

6. **Precedence Diagram**

A graphical representation of the sequence of work elements is defined by the precedence constraints.

7. **Balance Delay (Balancing Loss)**

Balance delay is a measure of the line efficiency which results from idle time due to imperfect allocation of work among stations. \( D = \frac{nT - T}{nT} \)

II. **Literature Review**

Following is a list of researchers who has worked in area of Line balancing. The combination with the following literature research on the latest news on Line balancing is expected to make the investigation as complete as possible.

Johan Hakansson et al. [1] have focused on mixed-model assembly line balancing and sequencing problems, including different line layouts. The study was undertaken in collaboration with a company to assist in mapping current state of the art. Balancing problems affect businesses long-term strategic decisions and are complex problems with regard to installation and rebalancing of assembly lines. Sequencing concerns decisions of short-term problem sequencing approaches include level scheduling, mixed-model sequencing. Level scheduling constructs a sequence of variants to create efficient deliveries supported by the just-in-time concept, whereas both mixed-model sequencing aim to minimize violations of a work station’s capacity through constructing a sequence, which alternates variants with high and low work intensity. Five layouts were considered, single, mixed-model, multimodal, two-sided and U-shaped assembly lines. These layouts...
were evaluated on the basis of the manufactured products, size and space at the production plant, economic resources, number of required operators and machinery.

Christian and Armin [2] had carried work on Assembly lines. Those are traditional and still attractive means of mass and large-scale series production. Since the early times of Henry Ford several developments took place which changed assembly lines from strictly paced and straight single-model lines to more flexible systems including, among others, Lines with parallel work stations or tasks, customer-oriented mixed-model and multi-model lines, U-shaped lines as well as unpaced lines with intermediate buffers. In any case, an important decision problem, called assembly line balancing problem, arises and has to be solved when configuring an assembly line. It consists of distributing the total workload for manufacturing any unit of the product to be assembled among the work stations along the line. Assembly line balancing research has traditionally focused on the simple assembly line balancing problem (SALBP) which has some restricting assumptions.

Roy and Khan [3] has presented Assembly Line production is one of the widely used basic principles in production system. The problem of Assembly Line Balancing deals with the distribution of activities among the workstations so that there will be maximum utilization of human resources and facilities without disturbing the work sequence. Research works mainly deals with minimization of idle time subject to precedence constraints. Lack of uniqueness in their optimum solutions has led to the present work where minimization of both balancing loss and system loss has been envisaged under the usual precedence constraints. The researchers suggested a generic approach for designing of an assembly line where, with a given number of workstations, one can efficiently arrive at the desired solution under different methods of search like simulation, heuristic etc. Thus, the main aim of this research is to redefine the objective of the Assembly Line Balancing Problem and sequentially handle Balancing Loss and System Loss.

Francesco Longo et al. [4] discussed the effective design of an assembly line for heaters production. Considering that the real plant still doesn’t exist, simulation has been used as cognitive tool. The simulation results highlight problems concerning high stress levels for some workers due to legs bending and ergonomic risks related to lifting tasks. The design of an assembly line and its workstations is characterized by two critical factors, the line balancing and the ergonomic optimization of each single workstation. The line balancing is strictly related to the number of workstations, process and set-up times, type of operations hand operated or automated. The ergonomic analysis allows evaluating potential hazard, musculoskeletal disorders, risks related to excessive weights as well as specific risk factors concerning lifting tasks or energy expenditure for the operation being performed.

Ponnambalam et al.[5] studied a multi-objective genetic algorithm to solve assembly line balancing problems. The performance criteria considered were the number of workstations, the line efficiency, the smoothness index before trade and transfer, and the smoothness index after trade and transfer. The developed genetic algorithm is compared with six popular heuristic algorithms, and rank and assign heuristic methods. For comparative evaluation, 20 networks were collected from open literature, and were used with five different cycle times. All the six heuristics and the genetic algorithm are coded in C++ language. It was found that the proposed genetic algorithm performs better in all the performance measures than the heuristics. However, the execution time for the GA is longer, because the GA searches for global optimal solutions with more iteration.

III. Methods of Line Balancing
1. Largest-Candidate Rule (LCR)

Procedure:
Step 1. List all elements in descending order of Te value, largest Te at the top of the list.
Step 2. To assign elements to the first workstation, start at the top of the list and work done, selecting the first feasible element for placement at the station. A feasible element is one that satisfies the precedence requirements and does not cause the sum of the Te value at station to exceed the cycle time Tc.
Step 3. Repeat step 2.

2. Kilbridge and Wester's Method (KWM)

1. It is a heuristic procedure which selects work elements for assignment to stations according to their position in the precedence diagram.
2. This overcomes one of the difficulties with the largest candidate rule (LCR), with which elements at the end of the precedence diagram might be the first candidates to be considered, simply because their values are large.

Procedure:
Step 1. Construct the precedence diagram so those nodes representing work elements of identical precedence are arranged vertically in columns.
Step 2. List the elements in order of their columns, column I at the top of the list. If an element can be located in more than one column, list all columns by the element to show the transferability of the element.
Step 3. To assign elements to workstations, start with the column I elements. Continue the assignment procedure in order of column number until the cycle time is reached (TC).

3. Ranked Positional Weights Method (RPW)

1. Introduced by Helgeson and Birnie in 1961.
2. Combined the LCR and K-W methods.
3. The RPW takes account of both the Te value of the element and its position in the precedence diagram.

Then, the elements are assigned to workstations in the general order of their RPW values.

Procedure:
Step 1. Calculate the RPW for each element by summing the elements Te together with the Te values for all the elements that follow it in the arrow chain of the precedence diagram.
Step 2. List the elements in the order of their RPW, largest RPW at the top of the list. For convenience, include the Te value and immediate predecessors for each element.
Step 3. Assign elements to stations according to RPW, avoiding precedence constraint and time cycle violations.

Comparison & Selection of Method

Compare LCR, K-W, and RPW

1. The RPW solution represents a more efficient assignment of work elements to station than either of the two preceding solutions.
2. However, this result is accordingly by the acceptance of cycle time Tc = 1 and make those methods different.
3. If the problem were reworked with Tc = 0.92 minute, it might be possible to duplicate the efficiency.

Conclusion:

The aims of the paper are improving the productivity and efficiency of an assembly line in industry. The objectives are to redesign the layout to improve line performance. Simulation is implemented in this project in order to analyse and investigate the problems occurring in assembly line.

Future Scope:

At present only RPW method is used for calculations. But new numerical tool can be used to predict the production behavior. In order to increase current production rate, the motion study and time study can be done in future and there is the scope of implementations of the techniques like MOST.
REFERENCES


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