ABSTRACT

Assembly Lines are production flow lines which meet the standard of commonalities in case of mass production and in low volume production as well. It needs high capital investment in installation and redesigning the paced lines. The customer requirements have changed over the times as there are multi variety and multi model lines resulting in either un-paced or semi-mechanical assembly lines. The present concept is of low volumes production which is important for cost efficient production. Real world assembly line balancing relate to finite set of work elements, and each element having relationship of processing time and precedence. Line balancing is an attempt to equal amount work to each work station to achieve the desired efficiency by concentrating the factors like minimizing work stations, minimizing work load variations and cycle time minimization. Precedence and precedence diagram play a vital role in maximizing work efficiency and assembly line operations. Lot size is also important in making a decision to design a line. This case study is aimed at the detailed investigation of mixed model assembly line (MALB) into present system of line/stations in relation to production volumes including the present line efficiency or operative efficiency. Also, suggesting the remedial solution for enhancement of this line efficiency in terms of no. of workstations and manpower allocated for this purpose.

Keywords: Assembly Line, Production Efficiency, Paced or Un-Paced Lines
INTRODUCTION

Assembly Process is an integral part of any manufacturing activity. The components, which are either finished or semi-finished are made to combine to produce the final product as desired by customer. This joining of various components is carried out in different stages known as work-stations. These work-stations are culmination of elemental breakup of the activities and combining them in a fashion as to have a smooth flow. In any assembly line, the important issues are precedence, cycle time at each stations and no. of work-stations. All organizations attempt to design the assembly line which is flawless and with maximum operative efficiency so as to have best utilization of available resources. These assembly Lines could either be paced, un-paced or combination of both. The paced assembly lines involve lot of capital expenditure and are dedicated to manufacture a single product with large volumes. In paced assembly lines, the movement of material from one work-station to another work-station is automatic. The time restriction also exists on the performance of each work-station. Where as, in un-paced assembly lines the movement of material is either manual or through conveyer with variable speed. The performance time at each work-station is also independent and therefore, it leads to either blockages or shortages of goods.

“An assembly line is a manufacturing process in which parts are added to a product in a sequential manner using optimally planned logistics to create a finished product in the fastest possible way. It is a flow-oriented production system where the productive units performing the operations, referred to as stations, are aligned in a serial manner”.

Over the years, the demand of the customer has changed and this change requirement is associated with numerous variables. This makes the assembly process more complex. In a recent survey, the major car manufacturer BMW offers $10^{32}$ variables in their product. The precedence diagram and the cycle time at each workstation dictate which type of model for layout is to be followed. This could be either straight line, U-shaped, Parallel lines and Bowl shaped. Assembly line process in automobile industry may be as long as with sixty work-stations including the large size of the goods. This necessitates introduction of partial automation in hazardous circumstances. e.g. Welding and Painting. The Indian environment calls for manual assemble line because of the cost and availability of skilled labor. Even world over most of the assembly line especially in automobile part manufacturing industry are manual in nature with semi-automation at some work-stations.

In view of varying customer demand, the present trend is to have multi model assembly lines (MMAL). The entire focus is on balancing the assembly line in such a fashion that the resources are optimally utilized thereby enhancing the line efficiency. The optimization process can be carried out through mathematical modeling or general genetic algorithm. These are the most acceptable methods for optimization. Though the assembly line balancing is going on since 1955 and a lot of work has been carried out since than yet, the application is far from the reality. Further the researches in 2006 ascertain that Real World Assembly Line Balancing is huge task as the variables are different from industry to industry and situation to situation especially in Automobile Sector.

\[
\text{Line Efficiency} = \frac{\text{Tct}}{\text{Tmax} \times \text{Tn}}
\]
Balancing Delay = \frac{T_{max} \cdot T_n - T_{ct}}{T_{max} \cdot T_n} \times 100

No. of Workstations = \frac{T_{ct}}{T_{max}}

Where, T_{ct} is total cycle time,
T_{max} is max. cycle time at each station,
And T_n is no. of workstations.

1.1 Benefits of Balancing
1) Reduction in work stations. This is achieved by combining tasks
2) Reduction in cycle time. This is clubbing of tasks.
3) Improvement in efficiency since waiting time is curtailed
4) Productivity Enhancement Better utilization of Men and M/c’s
5) Better space utilization, compact and functional Layout
6) Work load on stations balanced. As far as possible the tasks are combined
7) Optimization of resources, good use of men, m/c’s & materials
8) Less Scrap. As product moves in sequence the fault is detected
9) Cost saving in terms of space, production cost, rejection cost and inventories.

2.0 LITERATURE REVIEW

The Balancing of Assembly Line till date has been carried out to define problem, for the purpose of research work. Even with enormous academic effort in assembly line balancing, considerable gap still remains between requirements of real world and status of research.[5] The research on ALB is going on since 1955 and after a lapse of 55 years; the gap between industrial reality and academic theory still exists.[1] As per research execution of tasks assigned to every workstation following, balancing of assembly line, has been scarcely reported in scientific literature.

The first mathematical formulation on ALBP was carried out in 1955, with main focus on core problem of configuration which is assignment of tasks to stations. Later, it was confirmed that very small percentage of companies were using this method of mathematical modeling. Further 312 research papers were reviewed and 15 papers were identified which exclusively deal with balancing of real world assembly system.[3] The major problem with most approaches reported is that they generalize Assembly Line Balancing Optimization Problem in just one or two directions.[3] The real world line balancing has faced (In particular by automotive industry) many problems which requires tackling of that generalization. It is highly suggested to research ALB in automotive industry with Un-paced conditions.[3,7]

In spite of major advances in automation of Assembly Line Process, the majority of assembly lines rely on manual labor and especially so under Indian conditions. The balancing of such lines is a complex process because of variation in human performance. Non steady state of equilibrium is experienced on un-paced (Manual lines). This was further confirmed that most of the work on un-paced lines deals with problem under stable conditions.

Another type of Assembly Line i.e. Mixed Model assembly line is a flexible system with production of multi variety in small batches as per customer requirements. Under un-paced assembly lines, the configuration may be U-shape, parallel and double line. Under conditions of
multi model assembly line it would be needed to address in two ways i.e. line design and balancing of determination of production sequence for different models. The mixed models line is quite complex as it calls for interactions link between different models. The use of U-shaped Line Balancing stochastic tasks times is a very relevant, timely and practical problem which has become necessary reality.[6] It was further investigated that the availability large data to ascertain mean, variance and types of distribution is essential. U-line further becomes important because of application of JIT and its feasibility with U-line balancing.

In today business, the small and medium type of enterprise work on fixed worker (FW) basis.[9] Therefore, Walking worker hierarchy was proposed to minimize the workstations and the workers. Less the station/worker, less will be the line length. The process of WW concept improves in performance variation of human beings. This is to improve output and labor utilization including higher flexibility and efficiency. Cross training is essential for this type of line balancing.

3.0 CASE STUDY

In view of observations of Boysen et al. (2007), a case study was undertaken in Automobile Parts Manufacturing Industry manufacturing the multi model shock absorbers to cater the needs of Automobile Vehicles Manufacturers. The assembly line chosen for this purpose was the line manufacturing car shock absorbers. The line is manually operated with 9 work-stations and each work-station task has been defined in such a way that it is applicable to entire variety of shock absorbers. The output on daily basis is fixed at 1600 Nos. per day which at times falls down to an average of 1350 Nos. per day. The main reason for this slackness in output is because of starvation of raw material on the line. In general, 4 to 5 models of shock absorbers are taken per day with the defined lot size of 500 Nos. per model. Each batch on line is limited to 50 Nos. The initial study was conducted through work sampling to ascertain the utilization, manpower efficiency and the cycle time at each station. The results obtain showed that line utilization is at 81%, workman efficiency is 90% and the station cycle time hovering around 8 seconds on each station. There is 10% variance in the station time on the last 2 stations that is testing and sealing.

The following are the assumptions for this case study:

1. The availability of raw material is sufficient as per lot size.
2. Lot size is pre-defined and limited to 500 Nos.
3. There is no material in on-line at the beginning and at the end of the shift.
4. The production is carried out on two shift basis.
5. There are 9 work-stations are managed by 1 workman at each station.
6. There is no rejection and rework is almost negligible.
7. The activities of riveting, nut fixing, bottom sealing, oil filling, pushing the piston in cylinder, testing for compression and tension and sealing are mechanized.
8. The material movement is manual and no conveyor line is used.
9. The flow of the material is in a straight line.
10. No violation of precedence as there is no blockage or shortage.
11. The cycle time at each station is at par and the workman at each station immediately complete the task as it arrives from the succeeding stations.
3.2 Basic Data
In view of absence of standards of production it was essential to access and confirm the existing timings at each station including assessment of total cycle time including the maximum cycle time of a station. Initially, a sample survey was carried out to access the requirement of total no. of observations at a confidence level of +/- 5%. The period of study spreading over was for 38 days. Thus the total no. of observations during this period amounted to 3375 nos. Table 1 shows the observed cycle time at each work station.

<table>
<thead>
<tr>
<th>Work-Station</th>
<th>Task</th>
<th>Cycle-Time (in Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bottom Building</td>
<td>06</td>
</tr>
<tr>
<td>2</td>
<td>Crimping/Coining (M/c)</td>
<td>04</td>
</tr>
<tr>
<td>3</td>
<td>Prepare Mounting</td>
<td>06</td>
</tr>
<tr>
<td>4</td>
<td>Piston &amp; Riveting (M/c)</td>
<td>06</td>
</tr>
<tr>
<td>5</td>
<td>Cylinder Bottom Pressing (M/c)</td>
<td>06</td>
</tr>
<tr>
<td>6</td>
<td>Locating Piston in Cylinder and Oil Filling (M/c)</td>
<td>08</td>
</tr>
<tr>
<td>7</td>
<td>Push Piston in Cylinder (M/c)</td>
<td>06</td>
</tr>
<tr>
<td>8</td>
<td>Testing (Compression &amp; Tension on M/c)</td>
<td>08</td>
</tr>
<tr>
<td>9</td>
<td>Cylinder End Sealing</td>
<td>08</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>58</td>
</tr>
</tbody>
</table>

Figure 1 Precedence Diagram
The observations of study reveal that the line occupancy is 80% and the waiting is 20%. The accuracy of results is 10% and absolute accuracy as 0.0008. The derived confidence level is +/- 1.8% as against stipulated level of +/- 5%. The no. of workers under observations stands at 12 nos. The settled production target is 1600 nos. per shift (8 Hrs.). The total cycle time of all the stations put together is 58 seconds. The 20% waiting is the starvation of material on line. The average age of the workman’s on the line 50 years. The average wage of the workman on this line is Rs 31000 per month. The work commencement is normally late at beginning of shift and also after the closure of lunch hours. The same is applicable to tea intervals. Figure 3 shows the details of the working stations of this MALB.
3.3 Analysis
The above said observation as per table 1 has been further analyzed to ascertain the outcome for efficiency improvement including cutting down the delays.

<table>
<thead>
<tr>
<th>Data</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available time per day</td>
<td>8 Hours</td>
</tr>
<tr>
<td>Usable time per day @ 85% Efficiency</td>
<td>6.8 Hours or 24800 Secs.</td>
</tr>
<tr>
<td>Desired cycle time</td>
<td>24800/1600 = 15.5 secs.</td>
</tr>
<tr>
<td>Therefore, Desired Cycle time at each station</td>
<td>15.5 secs.</td>
</tr>
<tr>
<td>Average observed cycle time</td>
<td>9 secs.</td>
</tr>
<tr>
<td>Desired Nos. of workstations as per desired cycle time</td>
<td>58/15.5 = 3.74 say 4 Nos.</td>
</tr>
<tr>
<td>Existing line efficiency with 9 stations</td>
<td>80.5%</td>
</tr>
<tr>
<td>Existing balance delay with 9 stations</td>
<td>19.4%</td>
</tr>
<tr>
<td>Line efficiency with 4 nos. of workstations</td>
<td>89.3%</td>
</tr>
<tr>
<td>Balance delay with 4 nos. of workstations</td>
<td>10.7%</td>
</tr>
</tbody>
</table>

3.4 Results of case study
1. The partitioning of work into elements to constitute task on the station has not been done scientifically. Thus the no. of work-stations and the allocation of man-power does not match with the production requirements.
2. As per the observed cycle time at each work station through work sampling, the production capacity is 2300 Nos. per day instead of present output of 1600 Nos.
3. There are two alternatives to enhance the line efficiency
   a) Reduce no. of work stations thereby saving the manpower and generating a saving of Rs. 1500000/-.
   b) Alternatively maintain the existing manpower but enhance the production target to 2300 Nos. which is feasible to be produced as per available time per day and observed cycle time per day. This increase is almost 44% of the present output.
4. The action at point B can be initiated as per following table

<table>
<thead>
<tr>
<th>Production Quantity Per Shift</th>
<th>Variance from existing targets</th>
<th>Wage per month</th>
</tr>
</thead>
<tbody>
<tr>
<td>1600</td>
<td>0.00</td>
<td>Rs 31000/-</td>
</tr>
<tr>
<td>1900</td>
<td>+18.75%</td>
<td>+15%</td>
</tr>
<tr>
<td>2100</td>
<td>+31.25%</td>
<td>+20%</td>
</tr>
<tr>
<td>2300</td>
<td>+43.75%</td>
<td>+25%</td>
</tr>
<tr>
<td>2500</td>
<td>+56.25%</td>
<td>+30%</td>
</tr>
</tbody>
</table>
4.0 CONCLUSION

This case study establishes that the manual assembly lines need to be scientifically designed in terms of no. of workstations and the allocation of manpower thereof. The total work need to be partitioned in elemental task in a fashion that theoretical cycle time is maintained and also the constraint of maximum allowed time at a workstation is followed. In present case, the rule regarding no. of workstation and maximum cycle time at a station stands violated resulting in engagement of extra manpower including extra cost associated to production activity. This extra cost for existing volumes of production works out at Rs. 18.00 Lakhs per annum. Also, these extra workstations could have generated extra volume of production to the tune of 43.75%. Therefore, it is essential to design a line suiting to present requirement as it becomes difficult to break barriers at later stage especially when the customer demand is for more volumes and generation of additional revenues also, cutting the production cost and thereby enhancing the profitability.

The analysis clearly indicates that desired no. of workstations is much less as compared to existing workstations. Therefore, the line needs to be redesigned to achieve optimum efficiency. In this case study, the production of Shock Absorbers on this line is going on with 9 nos. of workstations for the last many years. Under the circumstances, it is suggested to retain same no. of workstations but increase the throughput to cut down the total cycle time and achieve optimum efficiency with reduced delays.
REFERENCES


