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PRODUCTIVITY IMPROVEMENT USING DPE-ASSEMBLY LINE BALANCING

Sarab Deo Prasad, Vikas Sharma, Ayush Jain
Tata Technologies Ltd., Lucknow, Uttar Pradesh, India

Dilip Kumar Sahu
Tata Technologies Ltd., Pune, Maharashtra, India

Abstract: **Assembly lines have been a significant development for managing operations-- a mode that allows high-volume, low-cost standardized production. These benefits are often offset by drawbacks: perceptions of Fordist assembly lines consider them to be rigid and inflexible (Abernathy, 1978; Piore and Sabel, 1984; Womack, Jones and Roos, 1990). Tolliday and Zeitlin's (1992) title "Between Fordism and Flexibility" perfectly expresses this dichotomous perspective: that the two are on opposite poles. Our understanding of assembly lines is implicitly constrained by the theory surrounding assembly line balancing (ALB) describing how such systems should be designed for maximum efficiency.**

The line balancing problem is well established in the Operations Research literature. Salveson (1955) first described and mathematically formulated the problem, and an extensive literature followed (Erel and Sarin, 1998; Boysen, Fliedner and Scholl, 2007; Wild, 1972) with many variants and extensions of the basic model. These analyses have focused on maximizing line efficiency rather than their overall operational effectiveness or strategic use. Erel and Sarin (1998) observed that ALB theory was not widely used, but suggested this was because racticing managers were unfamiliar with the relevant theoretical developments. They also noted that managers often considered broader issues than simple line optimization; however, those issues were not explored.

I. INTRODUCTION:

In this era of globalization, competition is becoming ever more intense. Manufacturing companies must not only compete locally but also on a global basis. Reducing manufacturing costs without sacrificing product quality is vital for the survival of manufacturing companies in a global market. With increasing market competition, assembly line balancing plays an important role for the industries to obtain low cost product by properly utilizing line capacity. Line balancing is an effective tool for improved line efficiency by better assignment of operations to stations with necessary manpower, thereby throughput of the line is increased. Line Balancing (LB) is the problem of assigning operation to workstation along an assembly line, in such a way that assignment is optimal in some sense. In manufacturing field, planning schedule is vital for production planning especially for mixed model assembly. Assembly line should be designed and balanced to satisfy the demand from customers. This study mainly focuses on improving overall efficiency of mix model assembly line by reducing the non-value added activities, cycle time and distribution of work load at each work station through line balancing. The methodology adopted includes calculation of cycle time of process, identifying the non –value-added activities, calculating total work load on station and distribution of work load on each workstation using line balancing, in order to improve the efficiency of line with the help of DELMIA Process Engineer.

II. BRIEF BACKGROUND:

This study is based on assembly shop problem. It was required to evaluate line efficiency and to improve it further in order to make assembly line more efficient. In this case majority of the operations are performed manually. With variation in demand of multiple products it was observed that idle time of the manpower increases. When two products Product A and Product B were considered, there were difference in number of processes and their cycle time. It was also observed that total standard man hours (SMH) for both the products considered was differing substantially. Assigning the processes for the two products in effective manner was required for better line utilization and to reduce operator idle time.

This study aims to determine the current line efficiency for the two products manufactured, identify the improvement opportunities in order to maximize the line balancing efficiency. It also aims to minimizing the number of workers and minimizing the balance line delay time (sum of idle time). Results will help the

Company to solve the inefficiency in the assembly line. Production Manager will get the analysis and action points for improving the line Efficiency rate of the assembly line, which can be applied for gaining benefits. This study will help the manufacturer to improve their assembly line balancing and will benefit by minimizing manpower and maximizing line efficiency.

The concept of Assembly Line Balancing

Line balancing is about arranging a production line so that there is an even flow of production from one work station to the next. Line balancing also a successful tool to reduce bottleneck by balancing the task time of each work station so that there are no delays and nobody is overburden with their task.

Terminology used in assembly line balancing

According to Pekin (2006), manufacturing a product on **assembly lines** requires dividing the total work into a set of elementary operations. A **task** is the smallest, individual work element of the total work content. **Task time** or **processing time** is the necessary time to perform a task by any specific equipment. The same or different equipment might be required to produce the tasks.

The area within a workplace equipped with special operators and/or machines for accomplishing tasks is called **workstation.**

Cycle time is the time between the completion times of two consecutive units. Since the tasks are the smallest work elements, in a simple assembly line balancing problem the cycle time cannot be smaller than the largest time of a task.

The **work content** of a station is the sum of the processing times of the tasks assigned to a workstation.

Classifications of assembly line systems

Assembly lines can be classified as single-model, mixed-model, and multi-model systems according to the number of models that are present on the line.

Single-Model Assembly lines have been used in single type or model production only. There are large quantities of the products, which have the same physical design on the line. Here, operators who work at a workstation execute the same amount of work when a sequence of products goes past them at a constant speed.

Mixed-Model Assembly lines are usually used to assemble two or more different models of the same product simultaneously. On the line, the produced items keep changing from model to model continuously.

Multi-Model Assembly lines. Several (similar) products are manufactured on one or several assembly lines. Because of significant differences in the production processes, rearrangements of the line equipment are required when product changes occur. Consequently, the products are assembled in separate batches in order to minimize set-up inefficiencies. While enlarging batch sizes reduces set-up costs, inventory costs are increased. (Scholl 1998)

Two types of assembly line balancing problems are:

1. Type-I problems: where the required production rate (i.e. Cycle time), assembly tasks, tasks times, and precedence requirements will be given and the objective is to minimize the number of workstations.

2. Type-II problems: where the numbers of workstations or production employees is fixed and the objective is to minimize the cycle time, maximize the production rate and to identify total number of operators and their allocation to each station.

These types of balancing problems are generally occurring when the organization wants to produce the more number of items using a fixed number of workstations without purchasing new machines or expanding its facilities.

III. PROBLEM STATEMENT:

One of the Assembly line of the organization was studied and observed following points.

There are two different types of model currently manufacture at the assembly line.

- Product A
- Product B

Work content of Product A is higher than Product B. Therefore, when Product B is manufactured at the line, some of the operators are seating idle and when Product A comes then they are much more loaded with tasks. This is causing manpower idle time and also reduces the line efficiency. There is overall uneven distribution of workload.

1. Reducing line efficiency.

In flow line production the product moves to one workstation due to time restriction. Once it’s get stuck due to accumulation in certain workstation, it exceeds the cycle time in that station. Faster station is limited by slowest station. Thus, decreasing the rate of productivity.

2. Unbalance workloads

Due to uneven workloads on operator idle time increases.

IV. PROJECT OBJECTIVE:

Following objectives are expected at the end of the project:

- To improve productivity and achieve maximum efficiency for Product A and Product B
- Suggest Optimum number of workers for Product A & Product B
- Uniform distribution of work among the line
- Maximize labor utilization hence minimize labor cost
- Minimize idle time

V. RESEARCH METHODOLOGY:

Bottleneck stations and excessive workers are common problems arise in assembly line. These are the major problems that encounter and yet need to be overcome as soon as possible. Line in-charges often encounters this problem and if this happen it will decrease the line efficiency and the target run rate. In preventing these problems, engineers should come out with a solution in order to fix these problems. One way to do so is using line balancing method. This aim is to minimizing workloads and workers on the assembly line while meeting a required output. Research methodology adopted is described below.

5.1 Types of Research Design: -
Qualitative method:

- **Case Study -** Study the existing scenario of Assembly line for finding out the current line efficiency and the bottleneck.
- **Interview –** Interview required to understand the current scenario of the line and what are the expectation required by Production manager.
- **Observation -** Manual observation on Assembly line and operator’s movement during their performing operations.

Quantitative method: -

- **Survey** - Survey from operators regarding no. of processes difference between Product A and Product B and at which stations.

5.2 Nature and Source of Data Collection: -
Qualitative data: -

- Interview from Production manager and supervisors
- Interview from Line operators.

Quantitative data: -

- Current document and records regarding Line from Production manager
- Number of Processes and their time observation from line

5.3 Tools and Techniques to be used: -
Delmia Process Engineer Automatic Line Balancing tool used for Assembly Line balancing
Automatic Line Balancing is a procedure aiming at the interactive automatic balancing of manual assembly lines.

Using Automatic Line Balancing

- Optimization and efficiency of manual assembly lines
- Interactive, graphical balancing
- Selection, distribution and arrangement of operational steps
- Spatial arrangement of materials along the assembly line
- Storage and documentation of the planning results

Yielding planning results
Optimized efficiency of the assembly line according to the following criteria:

- Conditions of sequence
- Cycle times
- Conditions of assignment
- Conditions of position
- Area restrictions

Comparing with planning alternative

- Station assignment
- Identification numbers (number of colleagues, number of stations,
- Average balancing compensation, average station times, and max. station times)
- Quick, quality-increased assembly planning

5.4 Methods to be used for data collection: -
Primary Data: Primary data collection from Interview through Production manager.
Examples of data collected from Production manager,

- Takt Time (min)
- No. of technicians
- No. of stations
- Total available time per Shift
- Production Ratio

Secondary Data: Secondary data collected from directly line,
Example of Data collection from production manager

- Process time using Stop watch
- Process constraints

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VI. INPUT COLLECTION: -

6.1 Basic Data: -

Type of Product	Product A/ Product B
Assembly Line Takt Time (min)	2.93
No. of Technician	32
No. of Station	12
Total available time per shift(min)	440
Production Ratio	**120** Product A/ **30** Product B
No. of Processes in Product A	27
No. of Processes in Product B	20

Table 6 (a): Input Data Collection

6.2 Process Data: -

Product A & Product B Process Details						
S. No.	**Process No**	**Station No.**	**Process Name**	**Cycle Time (Min)**	**Work Content (Min)**	**Applicable model**
1	10	1	Process 1	1.63	2.08	Product A/Product B
2	20	1	Process 2	1.98	1.98	Product A
3	30	1	Process 3	1.55	1.55	Product B
4	40	1	Process 4	3.1	6.2	Product B
5	50	2	Process 5	3.83	7.66	Product A/Product B
6	60	3	Process 6	1.98	1.98	Product A
7	70	3	Process 7	1.24	3.84	Product A/Product B
8	80	3	Process 8	0.77	1.54	Product B
9	90	3	Process 9	1.51	3.02	Product A
10	100	4	Process 10	1.43	2.86	Product A
11	110	4	Process 11	0.58	1.15	Product A
12	120	4	Process 12	0.77	1.54	Product A
13	130	5	Process 13	3.54	3.54	Product A/Product B
14	140	5	Process 14	1.24	1.24	Product A/Product B
15	150	6	Process 15	2.46	2.46	Product A/Product B
16	160	7	Process 16	0.44	0.89	Product A/Product B
17	170	7	Process 17	1.34	2.69	Product A/Product B
18	180	8	Process 18	4.68	9.36	Product A/Product B
19	190	9	Process 19	0.51	1.02	Product A/Product B
20	200	9	Process 20	1.31	1.31	Product A
21	210	9	Process 21	1.9	1.9	Product A

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22	220	9	Process 22	1.07	1.07	Product A
23	230	9	Process 23	0.58	1.15	Product A
24	240	9	Process 24	0.7	1.39	Product B
25	250	9	Process 25	0.7	1.39	Product A/Product B
26	260	10	Process 26	0.8	1.6	Product A/Product B
27	270	10	Process 27	0.65	1.31	Product A/Product B
28	280	11	Process 28	2.47	4.95	Product A
29	290	11	Process 29	3.92	7.84	Product A/Product B
30	300	12	Process 30	1.97	2.31	Product A/Product B
31	310	12	Process 31	1.74	2.05	Product A/Product B

Table 6 (b): Input Data Collection

*Due to data confidentiality actual process name not used, in place of actual name dummy process name considered.

6.3 Assumptions: -

- Worker utilization taken up to 100%
- Twelve stations taken for balancing
- Feasibility of operation allocation to stations need to be checked
- Process Precedence are considered during Line Balancing
- Downtime not considered

6.4 Constraints: -

- Process precedence is fixed in nature.
- Lot of time consumed in Quality Checking.
- Cross travel along the line is not possible due to height of conveyor.
- Some of processes needs to be redesigned as it involves ergonomically unsafe body movements & thus loss of efficiency.

VII. PROCESS STUDY: -

7.1 Process Graph Mapping As per Precedence in DPE: -

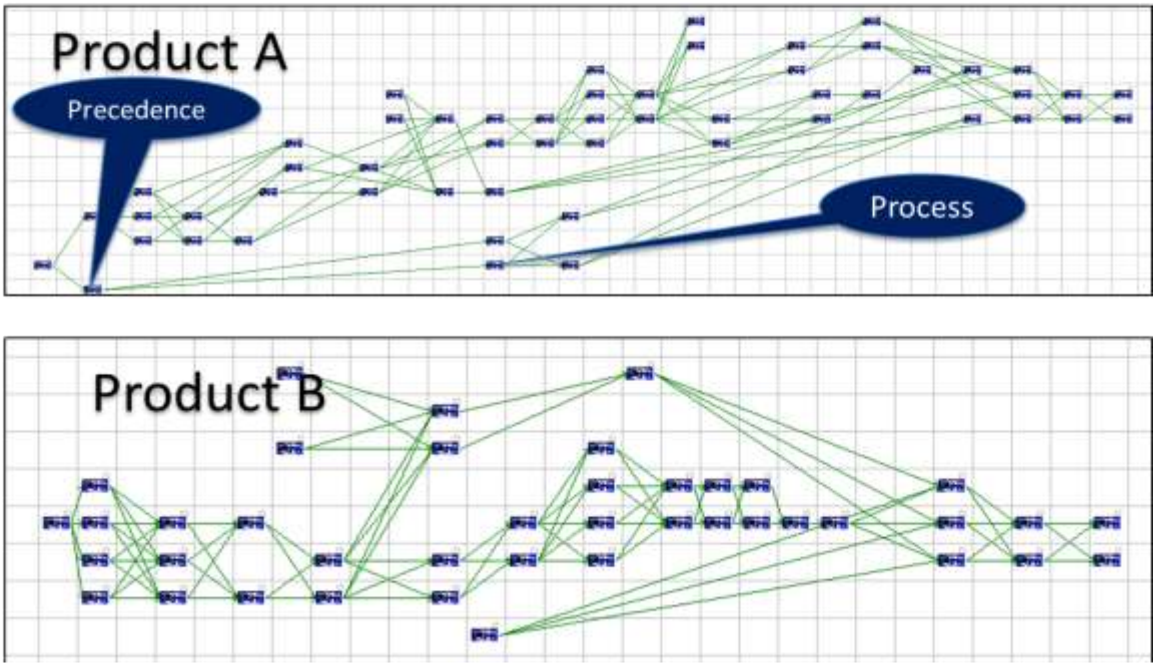

Fig. 7(a): Process Graph

7.2 Process Graph Mapping As per Precedence in DPE: -

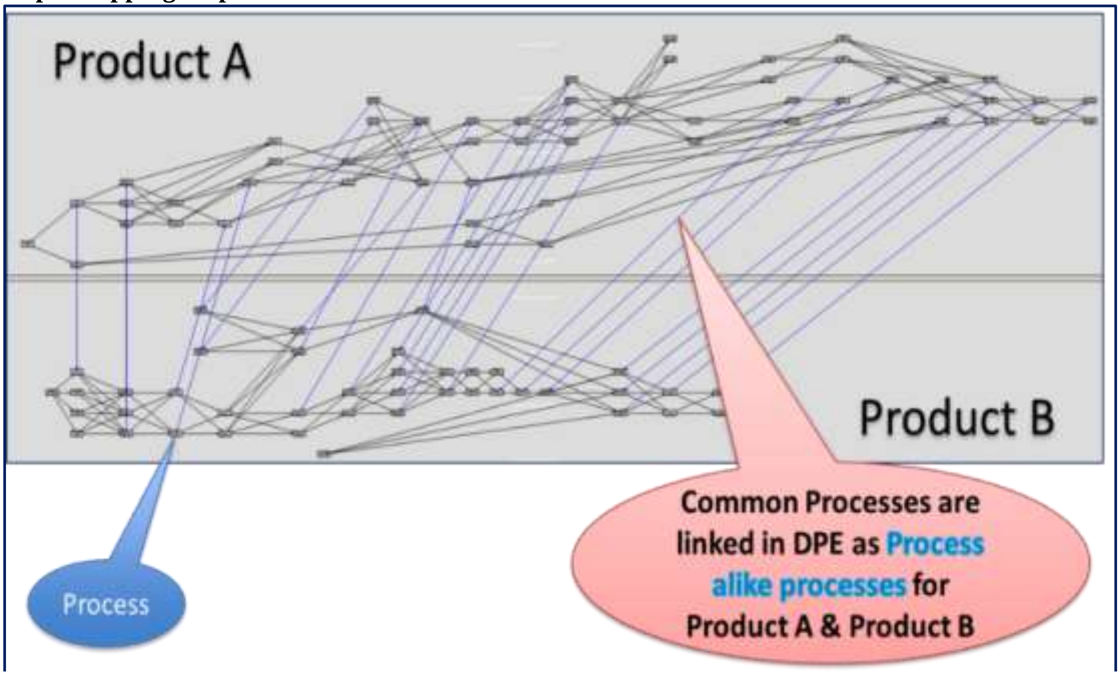

Fig. 7(b): Process Graph

VIII. RESULTS & FINDINGS: -

8.1 Line Balancing Result: -

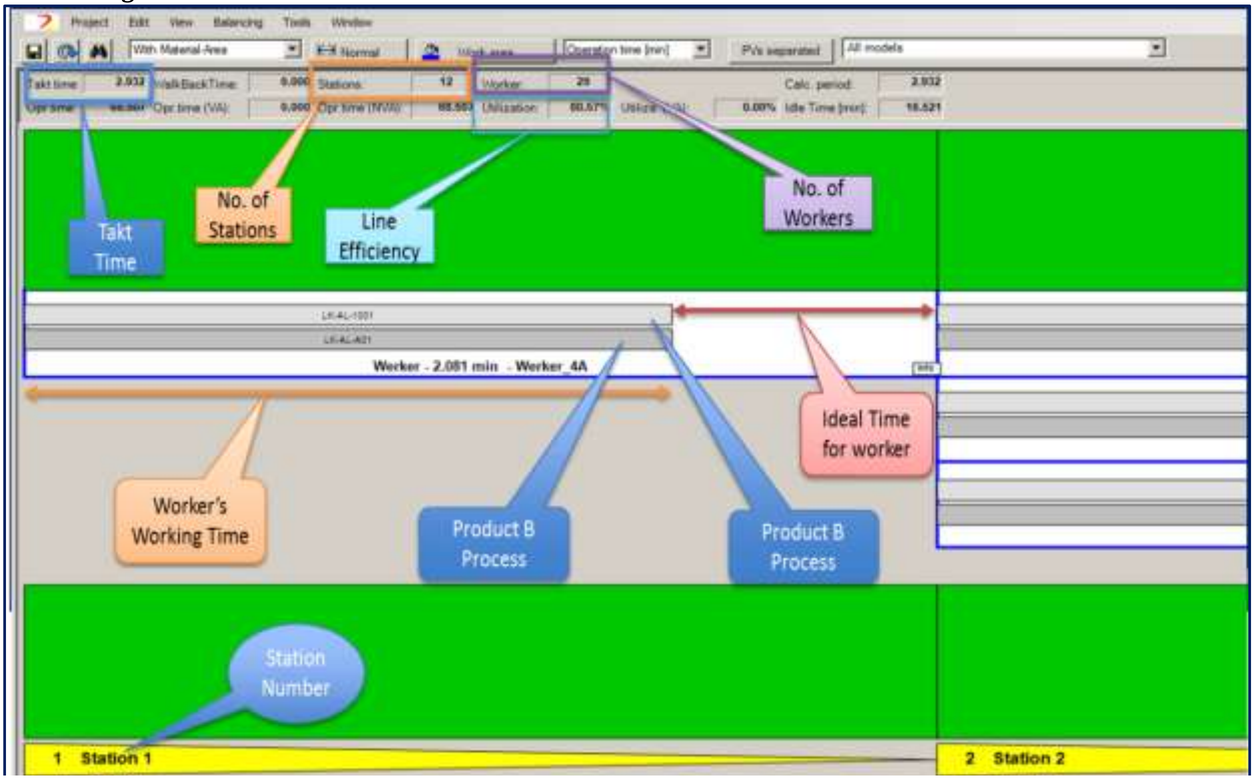

Fig. 8(a): Line Balancing Results

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Details	Existing Process Details	Proposed Process Details
Type of Product	Product A/ Product B	Product A/ Product B
Assembly Line Takt Time (min)	2.93	2.93
No. of Technician	32	29
No. of Station	12	12
Total available time per shift(min)	440	440
Production Ratio	**120** Product A/ **30** Product B	**121** Product A/ **30** Product B
No. of Processes in Product A	27	27
No. of Processes in Product B	20	20
Total Common Processes	16	16

Table 8 (a): Input Data Collection

8.2 Assumptions for Proposed Line: -

- Process 2 is an independent process - stock after Process 2 : 60 Nos
- Product B stock after completing below 2 processes: 10 Nos.
- ✓ Process 3 (Independent Process)
- ✓ Process 4 (Independent Process)

8.3 Assumptions for Proposed Line: -

Workers optimized from station 1 for below processes:

- Process 2
- Process 3
- Process 4

All the above processes done by the workers which are Idle at the time of Product B Assembly.

8.4 Worker's Assignment on Each Station for Assembly Line:-

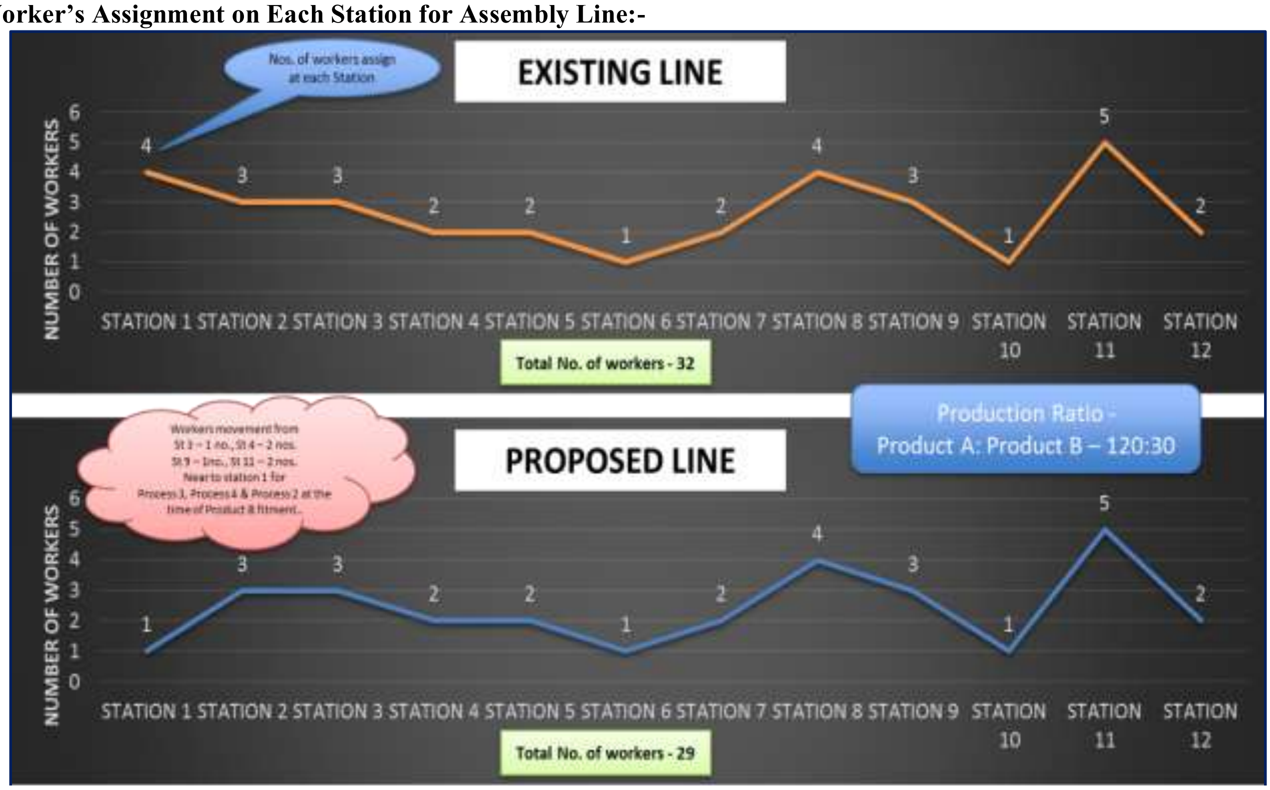

Fig. 8(b): Worker's Assignment

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8.5 Worker's Idle Time Bar Chart for Assembly Line: -

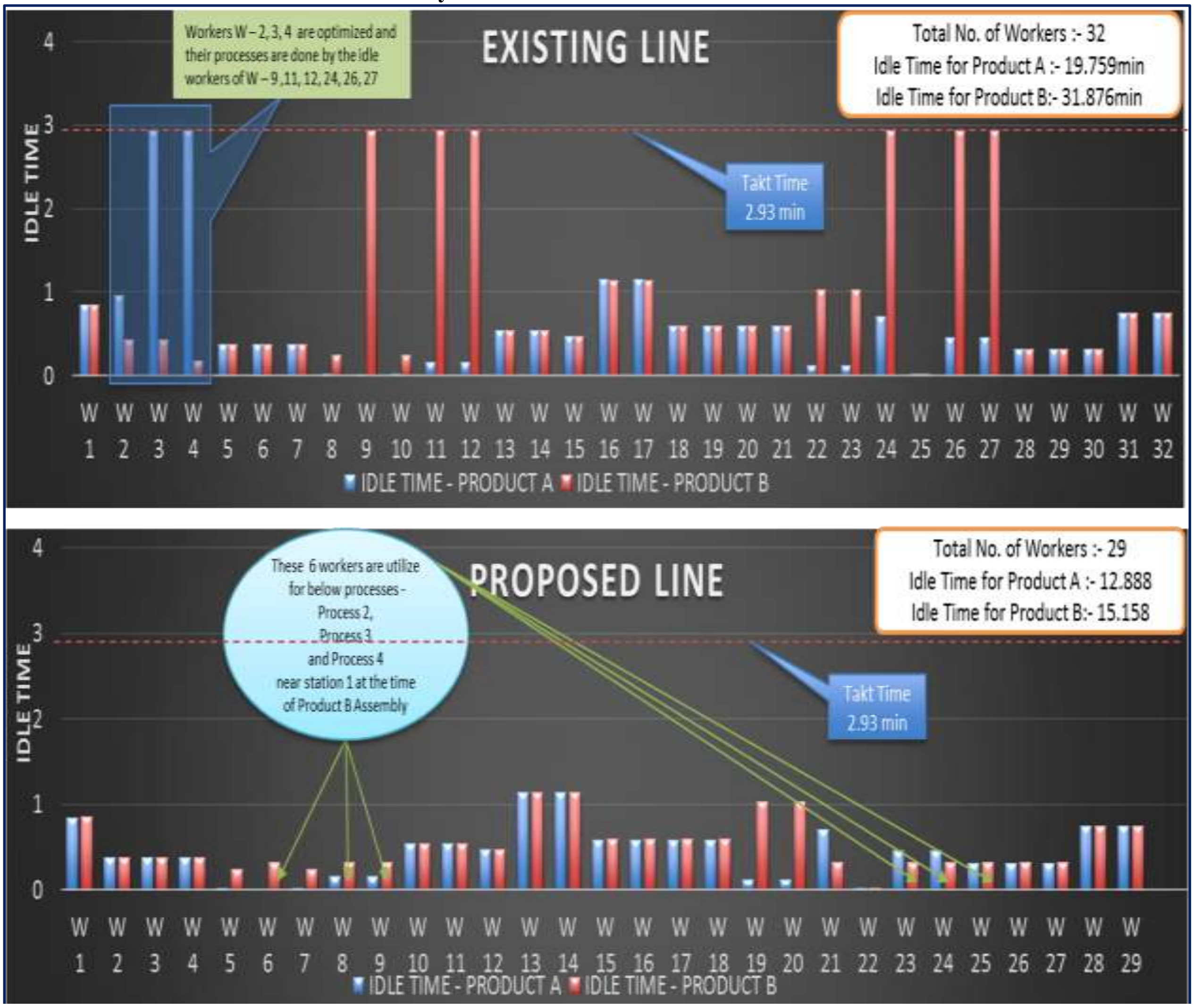

Fig. 8(c): Worker's Idle Time Bar Chart

8.6 Optimized Work Flow for Product A at Assembly Line: -

- In Existing Line Process 2 done at the time of Process 1 in sub assembly area of station 1.
- In Existing Line at station 1, one worker assigns for Process 2 which is independent process, are optimized in proposed line.
- This process will be done at the time of Product B fitment.
- At the time of Product B Assembly 3 Nos. of workers at Station 9 & Station 11 are Idle. So, we utilize these workers for 120 Nos. of "Process 2" process completion and keep stock of 120 Nos. Processed Process 2 (Used 60 nos. for same day and 60 nos. for next day).
- So, finally we optimized worker at station 1 in Proposed Line and utilize idle workers at the time of Product B fitment.
- Graphical representation are shown on next slide.

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8.7 Station Wise Worker's Utilization Chart for Product A - Assembly Line: -

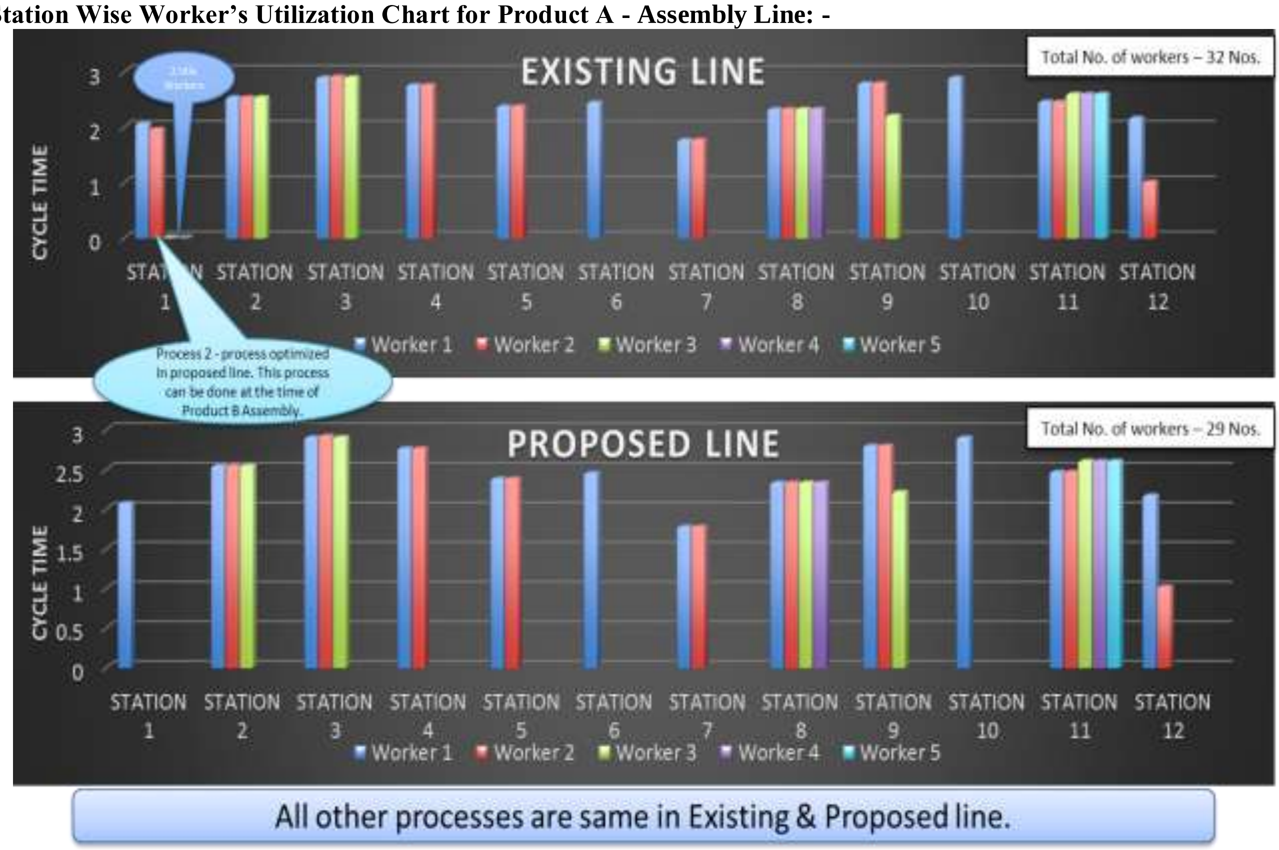

Fig. 8(d): Station Wise Worker's Utilization Chart

8.8 Process Time & Worker's Calculation for Product A:-

Below calculation indicates how we are utilizing the workers which are Idle at the time of Product B Assembly.

Process Name	Process Time (min)	Qty. Required	Work Content(min)
Process 2	1.98	120	1.98 x 120 = 237.6
Total Work content			**237.6**

Table 8 (b): Process Time & Worker's data

Total 30 Nos. of Product B required per shift.
So, Total Idle time available for 3 workers at the time of Product B dropping on Line

= 3 X 30 X 2.93 = **263.7 min**.

Since,

Idle time of 3 workers are greater than total work content required for completing Process 2 which can be done on **Product A** only - 120 Nos.

So, these process can easily completed by idle workers.

Workers Idle time of 263.7 min is utilized in carrying out Process 2 at the time of Product B Assembly.

8.9 Optimized Work Flow for Product B Assembly Line:-

- In Existing Line Process 3 and Process 4 processes done at the time of Product B Assembly in sub assembly area of station 1.
- At station 1 - 3 nos. of workers assigned for Process 3 & Process 4 processes. These workers are hereby optimized in proposed line.
- As per our assumption we have taken initial stock of 10 nos. Product B after completing Process 3 & Process 4
- At the time of Product B fitment 3 workers at Station 3 & 4 are Idle. So, we utilize idle workers for completing these two processes at the time of 30 Nos. of Product B fitment.
- So, finally we optimized worker at station 1 in Proposed Line and utilize idle workers at the time of Product B fitment.

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- Graphical representation shown on next slide.

8.10 Station Wise Worker's Utilization Chart for Product B - Assembly Line:-

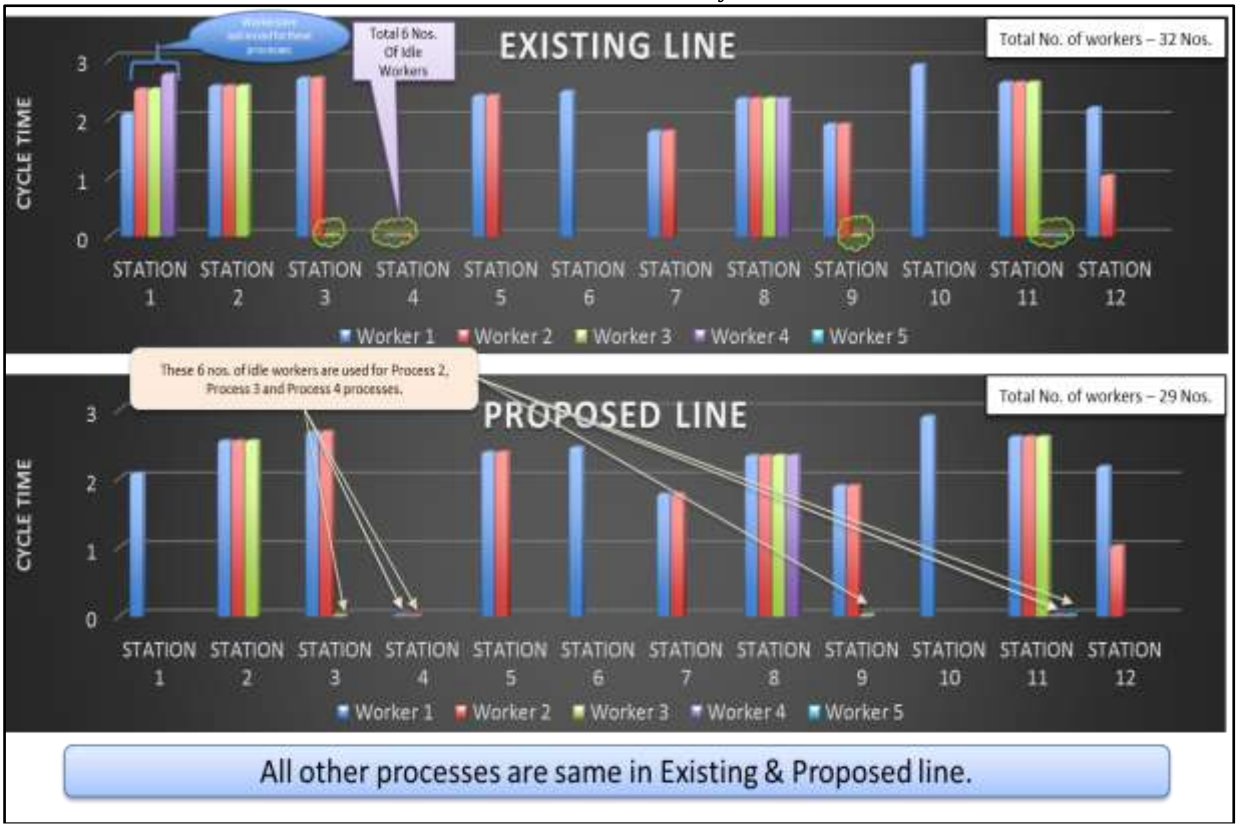

Fig. 8(e): Station Wise Worker's Utilization Chart

8.11 Process Time & Worker's Calculation for Product B:-

Below calculation indicates how we are utilizing the workers which are Idle at the time of Product B Assembly Line.

Process Name	Process Time (min)	Qty. Required	Work Content(min)
Axle No. Punching	1.55	30	1.55 x 30 = 46.5
Spacer Ring Fitment	6.2	30	6.2 x 30 = 186
Total Work content			**232.5**

Table 8 (c): Process Time & Worker's data

Total 30 Nos. of Product B required per shift.
So, Total Idle time available for 3 workers at the time of Product B dropping at Line = 3 X 30 X 2.93 = **263.7 min**
Since,
Idle time of 3 workers are greater than total work content required for completing processes of Process 3 & Process 4 for 30 nos.

So, these processes can easily completed by 3 nos. of idle workers.
***Workers Idle time of 263.7 min is utilized in carrying out Process 3 & Process 4 at the time of Product B fitment.**

IX. FINAL OUTPUT:-

9.1 Process Time:
Product B

Process 3: - 1.55 min
Process 4: -6.2 min

Front Axle
Process 2: - 1.98 min
Takt Time: - 2.93 min

Process Name	**Process Time (min)**	**Qty. Required**	**Work Content(min)**
Process 3	1.55	30	1.55 x 30 = 46.5
Process 4	6.2	30	6.2 x 30 = 186
Process 2	1.98	120	1.98 x 120 = 237.6
Total Work content			470.1

Table 9 (a): Work Content calculation

	Calculations	**Total Time (min)**
Available Idle time for each workers	30 X 2.93	87.9
Total Idle time available for 6 workers	6 X 87.9	527.4
Total Idle time for these workers after completing all the above processes	(527.4 – 470.1)	57.3

Table 9 (b): Work content calculation

9.2 Summary of Results For Line Balancing:-

Total no. of Processes at Assembly Line – 31 nos.
Total Work Content –
Product A: - 74.17 min
Product B: - 61.95 min

Contents	**EXISTING**	**PROPOSED**
No. of Technicians	32	29
Utilization of line achieved (%)	76.36	80.57
Idle time		
Product A	19.75min	12.88min
Product B	31.87min	15.15min
Idle Workers Utilized Time	Nil	470.1 min

Table 9 (c): Summary report

X. CONCLUSION: -

This study addresses the evaluation of assembly line balancing solutions obtained through the Multi Model Assembly line balancing techniques using DELMIA Process Engineer. Based onMulti model Line balancing results using DPE We study the processes further and found some Processes of Product A are standalone processes which can be carried out as a subassembly during Product B Fitment as work content of Product B is lower than product A. We move workers from Assembly line to Sub Assembly area who are ideal during Product B Assembly on Line. With the help of this we can reduce numbers of worker from 32 to 29 and also increases the Assembly Line efficiency by 4%.

XI. REFERENCES: -

[1]. Boysen N, Fliedner M and School A 2007 A Classification of Assembly Line Balancing Problems Europan Journal of Operation Research 183

[2]. Kumar Naveen and DalgobindMahto 2013 Assembly Line Balancing: A Review of Developments and Trends in Approach to Industrial Application Global Journal of Researches in Engineering (GD) **XIII** II I

[3]. Kayar M 2012 Production and Productivity - Basic Principles and Applications Ekin Press, Bursa, Turkey

[4]. AdeppaAadarsh 2015 A Study on Basics of Assembly Line Balancing, International Journal on Emerging Technologies 294-297

[5]. Grzechca W 2016 Manufacturing in Flow Shop and Assembly Line Structure International Journal of Materials, Mechanics and Manufacturing **4**

[6]. Baybars I 1986 A survey of exact algorithms for simple assembly line Balancing problem Management Science **32** 11-17

[7]. Ere E and S. C. Sarin 1998 A survey of the assembly line balancing procedures Production Planning and Control **9** 414-434

[8]. Ponnambalam V, Poon S J, Shiflet G J, Keppens V M, Taylor R and Petculescu G 2003 Synthesis of iron-based bulk metallic glasses as nonferromagnetic amorphous steel alloys Applied Physics Letters **83** 6 1131-1133

[9]. Kayar M and Akyalçin ÖC 2014 Applying Different Heuristic Assembly Line Balancing Methods in the Apparel Industry and their Comparison FIBRES & TEXTILES in Eastern Europe **6** 108 8-19

[10]. Essafi Mohamed Essafi, Xavier Delorme and Alexandre Dolgui 2010 balancing lines with CNC machines: A multi-start ant based heuristic CIRP Journal of Manufacturing Science and Technology **2** 176–182av

[11]. Acar N and Estas S 1991 Planning and Control Studies on Discrete Manufacturing Systems National Productivity Center Publications 309, 3rd Edition, Ankara

[12]. Scholl A and Becker C 2006 A Survey on Problems and Methods in Generalized Assembly Line Balancing. European Journal of Operational Research **168** 3 1 694–715

[13]. Scholl A and Becker C 2006 State-of-the-Art Exact and Heuristic Solution Procedures for Simple Assembly Line Balancing European Journal of Operational Research **168** 3 1 666– 693

[14]. Suresh G, Vinod V V and Sahu S 1996 A Genetic Algorithm for Assembly Line Balancing, Production Planning and Control **7** 1 38–46

[15]. Santosh T. Ghutukade and Suresh M. Sawant 2013 Use of Ranked Position Weighted Method for Assembly Line Balancing International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974 Int. J. Adv. Engg. Res. Studies / II/ IV/July-Sept., 01- 03/2013

[16]. KuanEng Chong, Mohamed K. Omar and Nooh Abu Bakar 2008 Solving Assembly Line Balancing Problem using Genetic Algorithm with Heuristics-Treated Initial Population, Proceedings of the World Congress on Engineering **II** WCE July 2 - 4 London, U.K.

[17]. I. Baybars 1986 A survey of exact algorithms for simple assembly line balancing problem, Management Science **32** 11-17