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"ENHANCEMENT OF FABRICATION UNIT OF AN AUTOMOBILE INDUSTRY BY IMPLEMENTING LEAN MANUFACTURING PRINCIPLES"

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ABSTRACT

All the automobile industries are striving too hard to achieve their objectives because of changing global scenario in terms of high quality expectation, reduced cost of production and increased productivity. Therefore value adding process is necessary to achieve this perfection; hence implementing lean manufacturing system is becoming a core competency for any type of organizations to sustain. The study has been undertaken at existing Fabrication business unit (FBU) of Backhoe loader manufactured by an automobile industry to enhance the productivity of FBU by identifying the bottleneck stations and non value added activities to implement lean. Subsequently the improvement actions have been established and implemented using different lean tools like line balancing and layout planning. Hence fixed station based system has been replaced by lean slat conveyor based system which resulted in reduced cycle time, Fork Lift free operation, Dedicated Manpower reduction, Improved Productivity, Tack Time based defined work process, Ergonomics and Automatic Transfer System.

Keywords: slat conveyor system, Lean manufacturing, line balancing, layout planning, productivity improvement

I. INTRODUCTION

Lean principles defines the value of the product/service as perceived by the customer and then making the flow in-line with the customer pull and striving for perfection through continuous improvement to eliminate waste by sorting out Value Added activity(VA) and Non- Value Added activity(NVA). The sources for the NVA activity wastes are Transportation, Inventory, Motion Waiting, Overproduction, over processing and Defects. The NVA activity waste is vital hurdle for VA activity. Elimination of these wastes is achieved through the successful implementation of lean elements [1]. 5S, OEE (over all equipment effectiveness), 8 step practical problem solving (PPS),Pareto analysis, elimination of waste, kaizen, setup time reduction, process mapping, value stream mapping(VSM), quick and easy kaizen, SPC/control charting, 5 why, automation, continuous improvement, continuous flow, visual control, design for six sigma(DFSS), cellular manufacturing, production levelling, kanban, line balancing, voice of the customer, ANOVAs, Work standardization, work simplification, fish born diagram, takt time, poka-yoke/ mistake proofing, these are all lean tools to get a maximum benefits.

II. LITERATURE REVIEW

Christian Becker et al.., [2] indicated that assembly line balancing research which traditionally was focused upon simple problems has evolved towards formulating and solving generalized problems with different additional characteristics such as cost functions & equipment selection.

Rong et al.., [3] proposed the formation of one-piece flow production system based on FACO method. They targeted on the just-in-time aspect of the production system and provided a multi-objective evaluation model whose aim is to minimize cycle time, changeover count, cell load variation, number of cells and maximize the extent to which items are completed in a cell.

Santosh kumar et al.., [4] applied the lean tool by time measurement and line balance efficiency method. They reduced the cycle time in a truck body assembly line and improved efficiency in that product line. Also said that lean manufacturing is a business philosophy that continuously improves the process involve in manufacturing.

Bianca et al.., [5] pointed out the ergonomical issues that occur after the lean acceptance. They also stated that more and more companies are interested in the well-being and satisfaction of human resources. Their paper presents a qualitative briefing and review in order to understand the evolution of lean implication.

Pandit et al.., [6] found that with the help of line balancing it was possible to improve productivity and achieve better utilization of resources. The less attention on accuracy of standard time and poor work arrangement were identified as the root cause for low efficiency and increase in layout utilization by changing the position of equipment or by introducing the new machine into the layout.

Singh B et al.., [7] replaced the traditional cells with irregular material flows by U-shaped production lines. In the U shaped lines also, problem starts when higher changeover and setup times, unbalanced manufacturing cells, lower effectiveness of the equipments exists. Also found that adoption of continual improvements environment can reduce the problem where setup, changeover times are reduced to negligible, flow is regular and paced by a cycle time and is controlled by pull signals lines are operated as mixed-model lines and each station is able to produce any product.

Aulakh et al.., [8] discussed importance of five elements of lean i.e. manufacturing flow, organisation, process control, metrics and logistics to appreciate the synergetic effect of each element on others, towards making an organization lean.

D. L. Sinde et al.., [9] stated that Lean manufacturing also looks ahead on the elimination of wastes from assembly lines and inventory and the concept of mass production essentially involves the Line Balancing in assembly of identical or interchangeable parts or components into the final product in various stages at different workstations.

Based on the above literature survey, case study was carried out at JCB Faridabad Fabrication unit (FBU) of Backhoe loader to enhance the productivity of FBU by implementing different lean manufacturing principles.

III. COMPANY AND FABRICATION SHOP BACKGROUND

JCB India Limited, a fully owned subsidiary of J.C. Bamford Excavators Limited of United Kingdom is ranked in the top 5 manufacturers of earthmoving and construction equipment in the world. JCB is the world number one producer for backhoe loaders.

First of all, the machined sheets & pre-build parts are brought in the logistics area. Metal sheets from which main frames, rear frames, Boom/Dippers are to be welded are moved to fabrication shop. Engines are moved to skid sub-assembly line and the gears & rear–axle parts are moved to transmission line. The existing fabrication shop shown in fig.1 which is having Rear frame cell, Loader Tower Robotic Cell, Loader Tower Boring Cell(mounting holes of loader tower is machined & fabricated with the help of CNC), Press Shop(Bevelling machines which cuts & chamfers, Radial Drilling Machines, Hydraulic Press to make their surface levelled), Boom/Dipper Robotic Welding, Main Frame Welding in which MIG welding of different parts of 3DX & other variants of Backhoe loader or the product which is to be fabricated is done and then after their machining, finishing and surface smoothening etc. mainframes are moved to paint shop.

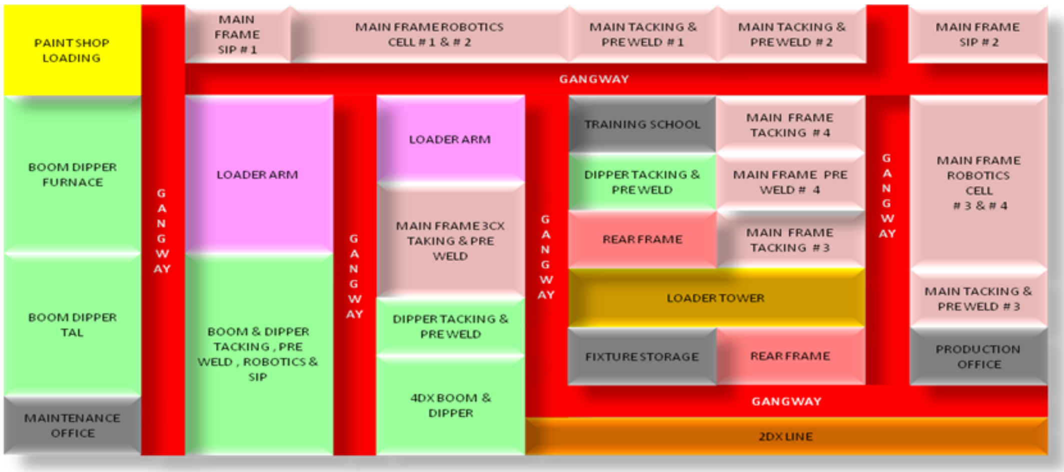
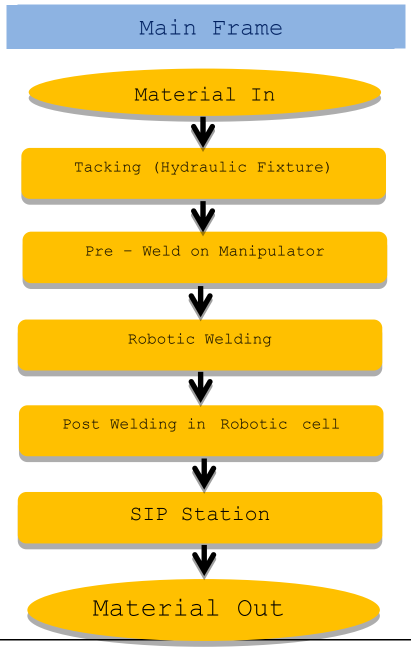


Fig.1: Existing Layout of Fabrication shop

IV. CASE STUDY OF MAINFRAME FABRICATION UNIT

4.1. Process Flow

In Main Frame fabrication Process, first of all different parts of the main frame are assembled or arranged by tacking them in main frame tacking fixture cell. Then, it is pre-welded in pre-welding zone where simple welding spots are done on the main frame. Then, the main frame is moved to two Robotic cell stations. Then moved to Manual welding shop where those parts are welded which can’t be welded in Robotic cell. At the last mainframe moved to SIP (Standard Inspection Procedure station). On SIP station standard inspection(by gauges), MIG welding of remaining child parts, buffing, chipping, grinding and dimension checking have been done according to standard specifications list. After that quality have been checked then transferred to stress receiving furnace & paint shop then assembly line. Process flow of mainframe fabrication & snapshot of mainframe is shown below in fig. 2 and fig.3 respectively.

<table>
<tr><th>Process Flow (Main Frame)</th><th>Component Detail (Main Frame)</th></tr>
<tr><td>


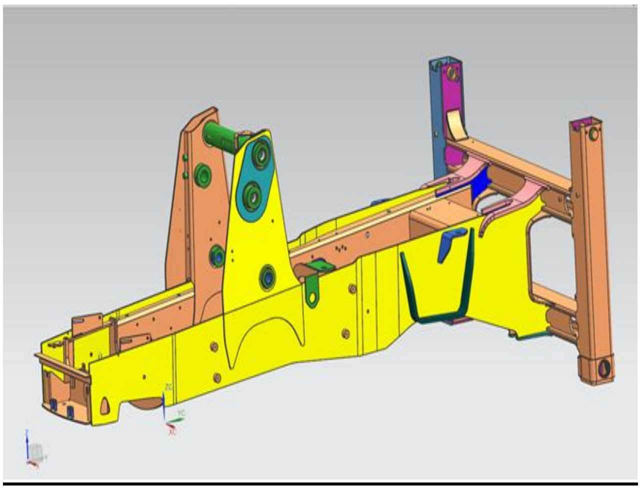
</td><td>
A. Length of Mainframe : 3.7 Mtr
B. Width of Mainframe : 2.3 Mtr
C. Weight of Mainframe : 1500 kg

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Fig.2: Process Flow

Fig.3: Snapshot of Mainframe

4.2 Preliminary analysis

The system diagnosis began with the direct observation of the operators and workflow. To identify which process is crowded Pareto analysis has been done. First Pareto analysis of manpower distribution in mainframe fabrication process has been done and shown below in fig. 4. To revarify, Pareto analysis of quantity output per shift stage has been done and shown in fig.5. Pareto analysis and machine/manpower study shown in Table 1 are indicating that SIP stage of Mainframe fabrication is the most significant, bottleneck process, having non-value added activities and should be paretize to implement lean as there is a chance of reduction in cycle time, manpower reduction and increment in output at SIP stations.

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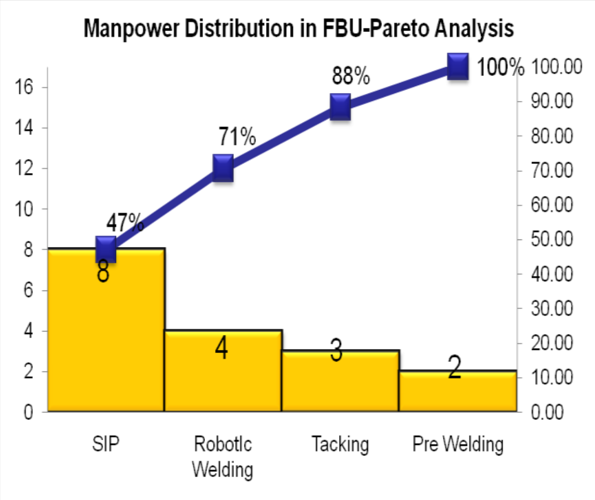

Fig.4: Pareto analysis-Manpower distribution

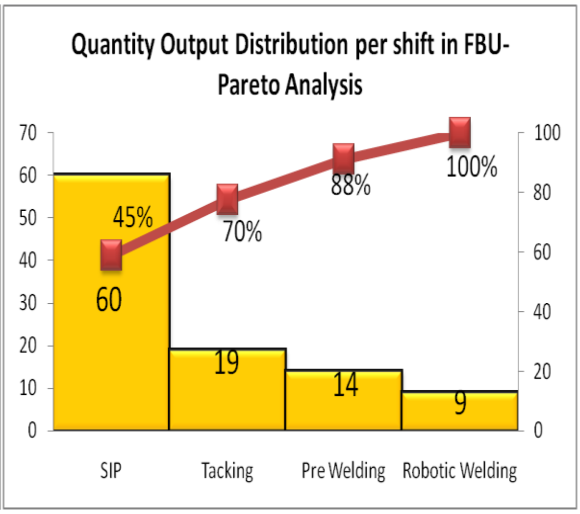

Fig.5: Pareto analysis-Output distribution

Table 1: Machine/Manpower Study of Mainframe fabrication Processes

Stages	**Equipments / Process Involved**	**Manpower Involved**	**Status**
Tacking	✓ Hydraulic fixtures ✓ Welding machines	Due to size of component 3 persons are required as per sop	Standard
Pre-Welding	✓ Welding machines	As per weld length calculation 2 persons are required as per sop	Standard
Robotic Welding	✓ Robotic welding machine	4 persons are required as per sop	Standard
SIP	✓ Gauge checking ✓ Welding ✓ Welding defect identifications ✓ Buffing operations ✓ Finishing operations	8 persons involved per station	Non-structured

4.3 Case Study of Existing Mainframe SIP Stations

Existing Mainframe SIP stations have been chosen for the detailed study of status on lean manufacturing implementation. Currently there are two static stations for mainframe SIP stage in which there are three sub-stations in every SIP station. Out of three sub-stations two sub-stations are having scissor lift where buffing, chipping, gauzing process are executed including sub-station 1 process and sub-station 1 is only for welding, masking, sealing, loading of material as there is no scissor lift here . 3DX, 3CX, 4DX & 2DX Models of backhoe loader are used to go for SIP stages. Existing layout of SIP Station is indicated below in fig 6.

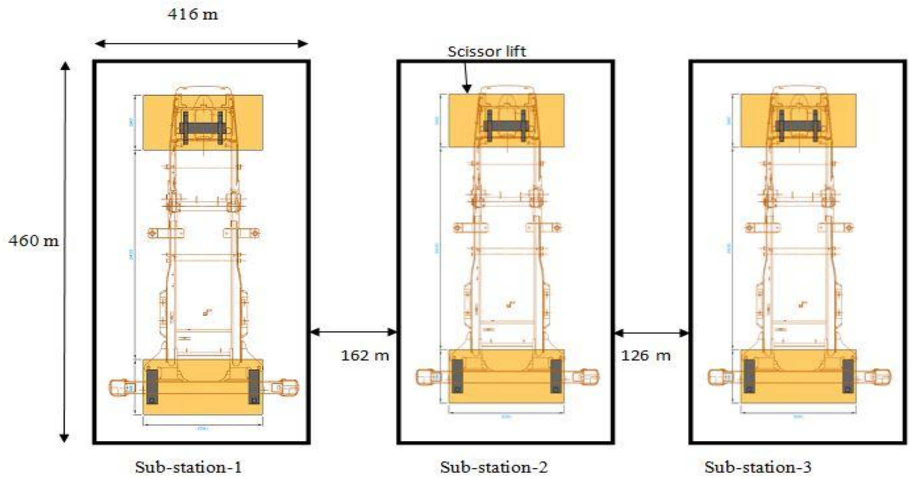

Fig.6: Existing Layout of SIP fixed station

After the direct observation, the SIP station was evaluated using the methods-study and time study techniques. This analysis has as main objective of the establishment and the normalization of procedures to allow a maximum effectiveness and quality at SIP. It will be accomplished through the improvement of some processes and procedures and through the suitability of the workstations resources (operators, equipment and tools) to the nature of the operations. From the below table, it is concluded that the average process time taking of a single mainframe at SIP station is approx 28 min and No of mainframe coming out of SIP stations in 2 shift (9.5 hr each) is approx 60 considering 90% efficiency and total manpower at SIP station is 16 (8 per SIP station) .

Table 2: cycle time at SIP station

Cycle time at SIP station	
Mainframe Tag No.	**Cycle Time (in min)**
8AB17J558	22
8AB17J199	20
8AB17J198	22
8AB17J534	40
8AB17J532	28
8AB17J580	35
8AB17J188	28
8AB17J599	34
8AB17J583	29
	Average=28 min

Table 3: Process Time Taking at Single SIP Station

Process Time Taking at SIP Station				
Process	**No. of operators**	**Time (In Min)**		
		MF 1	**MF 2**	**MF 3**
Loading sequence & tacking	1	3.5	4	4.5
Welding	2	8	10	8.5
Buffing	2	9	8	9
Chipping	1	4	3	3.5
Sealant		0.5	1	0.5
Inspection (supervisor)	1+1=2 [Quality engineer -1]	3	2	2
Total	**8**	**28**	**28**	**28**

V. IMPLEMENTATION OF LEAN MANUFACTURING AT SIP STATION

From the detailed case study of SIP stations, according to Principle of SQCDM (S- Safety, Q- Quality, C- Cost, D- Delivery, M- Morale), it is concluded that there are non standard system and mixture of many small types of equipment available, chances of manpower reductions, no defined cycle time, no defined process, excess Idle time, Congested area, involvement of lots of non-value added activities, Very unsafe(multiple operators at same stations), Use of forklift for transporting mainframe from one station to another which is dangerous, Loading and unloading is directly onto the floor by the forklift so wear and tear of the material takes place. Some of the critical points identified at SIP stations were related with the main pillars of a manufacturing system, namely, "layout change" and "line balancing". Consequently, it was necessary to quantify the real impact of these critical points to be able to justify any modification, which at this level always imply a strong impact on the manufacturing system.

5.1 Proposed Layout of New Conveyor Based SIP Station

A new slat conveyor based SIP station was designed, proposed and shown below in fig. 7, 8 and 9. Specified work/operations and accordingly operators will be distributed to the 6 stations of the SIP. After SIP manufacturing on 6 conveyor based stations, mainframe will move forward to last and single 7th Quality SIP station on slat Conveyor. Conveyor will stop at Quality SIP Station. Main Frame will move up and down on existing designed Scissor Lift. Quality Person will inspect Main frame. Quality Persons will control the command for Conveyor run. Conveyor will runs for one pitch. Same operation will be repeated for next frame. When Frame will reach last station, manual unloading will be done through EOT (Electric overhead travelling crane). Conveyor Command control panel will be at Quality SIP Station. Space between each Frame should have enough space for one person moving around. Last Station will have sensor so that if Component is present in the last Station Conveyor will not run.

- Technical specifications of proposed new conveyor based SIP station

Proposed Type of Conveyor	: Twin Slat Conveyor
Mounting	: On floor
No. of Production Station	: 06
No. of Quality Station	: 01
Size of slat conveyor	: 600X200X10mm.
Width of Conveyor	: 2200 mm (space between two scissor lifts)
Usable Length of Conveyor	: 29 mtr
Programming Control	: PLC (Programmable logic controller)
Conveyor Control	: VFD (variable frequency drive)
Position Control	: Encoder & Sensors
Speed of Conveyor	: 2 mtr/min – 6 mtr/ min
Slat Top Height from Ground	: Min 350 mm
Mode of Run	: Stop & Go
Type of Flow	: Uni – Directional Lean Process Flow

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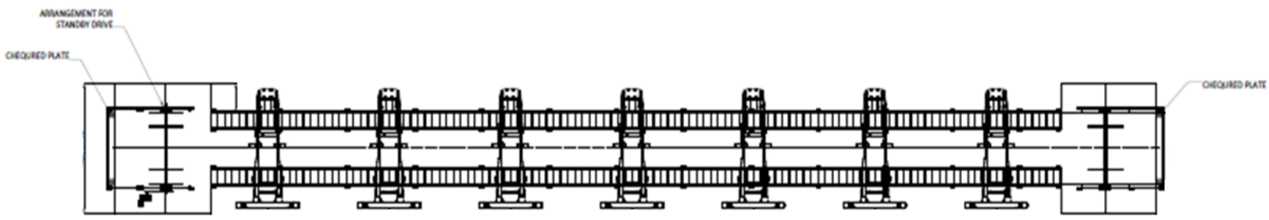

Fig. 7: Slat conveyor CAD drawing -1

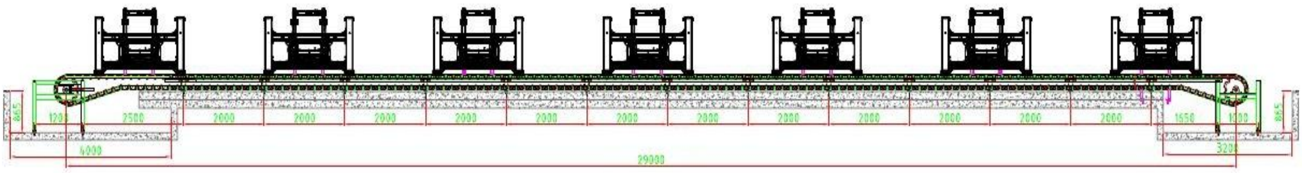

Fig. 8: Slat conveyor CAD drawing -2

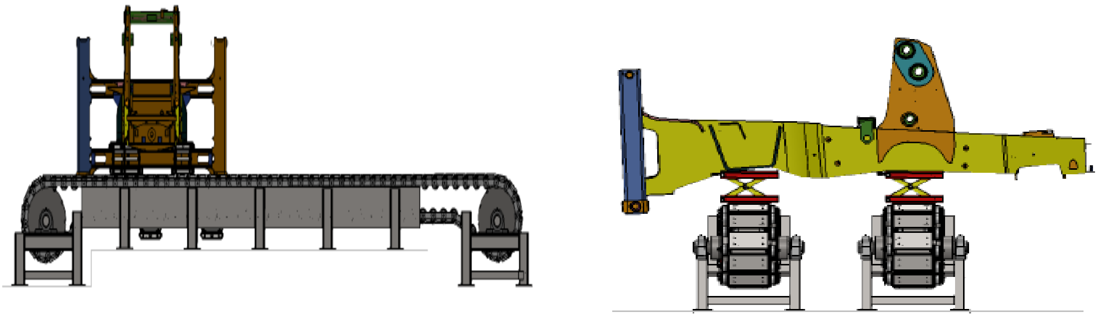

Fig. 9: Slat Conveyor – Conceptual drawing

There are two technical options in proposed conveyor based systems. After comparison of removal and fixed peg conveyor system, 2nd option i.e. Fixed peg slat conveyor based system of SIP station is proposed due to lesser cost as there will be no additional process and conveyor required.

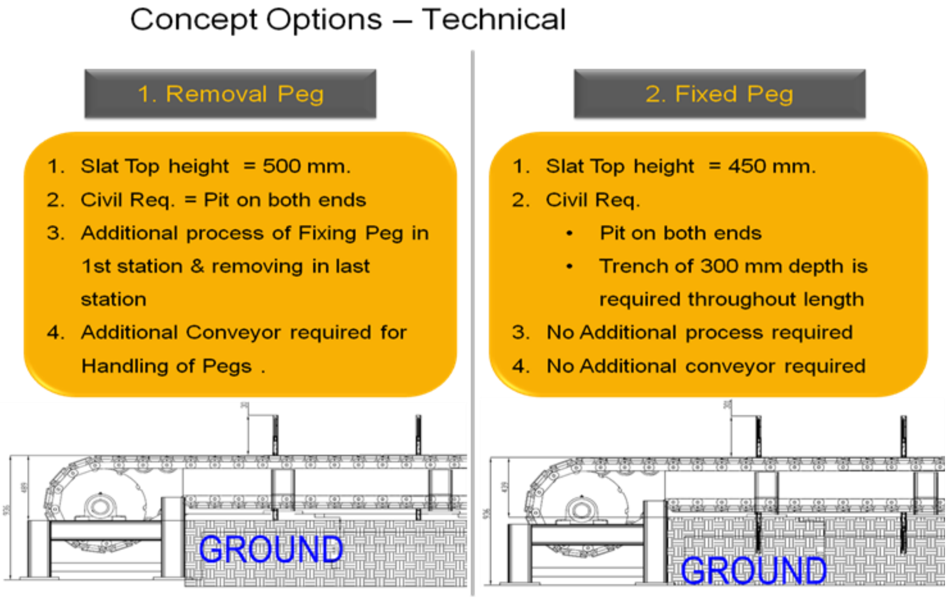

Fig. 10: Comparison between Removal and Fixed Peg

5.2 Line Balancing and Allocation of Work on SIP Stations

Line balancing is the process of assigning tasks to different workstations, so that all the workstations have approximately equal time requirements. The complexity is to assign the elements to an ordered sequence of stations. The line balancing method is used to reduce cycle time to increase the productivity and to minimize idle time of operators by working parallelly on stations.

Quadrant method is used to find out the work content of each quadrant of single mainframe. First mainframe is divided into four quadrants then the time required by each process in every quadrant was found out and shown below in table 4 and fig. 12 considering Table 2, total average process time taking of single mainframe is 28 min.

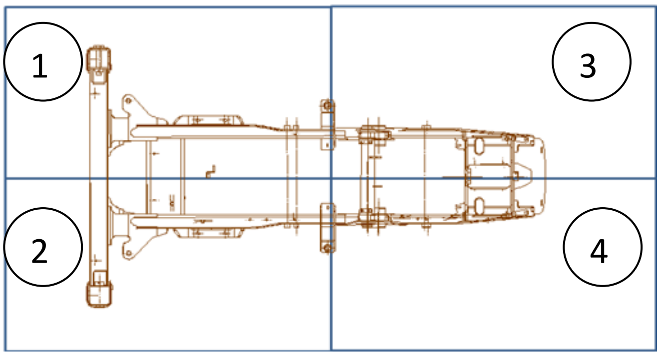

Fig. 11: Division of Mainframe into 4 quadrants

Table 4: Time Required by Each Process in 4 Quadrants

Quadrant	Loading sequence & tacking	Welding	Chipping	Buffing	Sealant	Inspection by supervisor
Quad 1	0.5 min	3 min	1 min	2.5 min	15 sec	0.5 min
Quad 2	0.5 min	3 min	1 min	2.5 min	15 sec	0.5 min
Quad 3	1.5 min	2 min	0.5 min	1.5 min	15 sec	0.5 min
Quad 4	1.5 min	2 min	0.5 min	1.5 min	15 sec	0.5 min

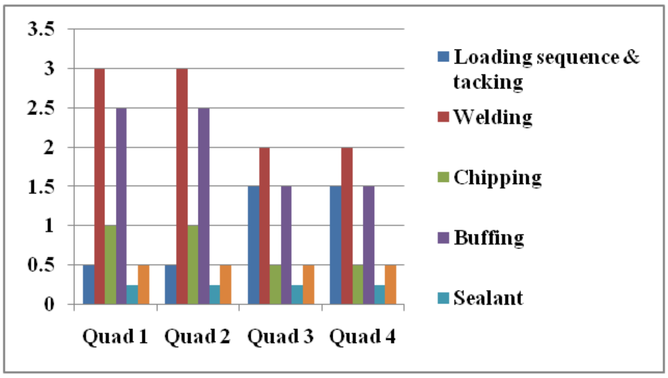

Fig. 12: Time required (in minute) by Each Process in 4 Quadrants

Now according to prioritization of process, quality and safety requirements, with the help of quadrant method, 28 min of operations and corresponding manpower are allotted on slat conveyor based 6 different SIP stations considering ergonomics philosophy and line balancing and shown below in table 5 and fig. 13.

Table 5: work allotted to 6 new SIP stations

Station	Work allotted	Quadrant	Total time taken
Station 1	Loading sequence , tacking & Sealant	ALL QUADRANTS	5 min
Station 2	Welding	QUAD 1 & QUAD 4	5 min
Station 3	Welding	QUAD 2 & QUAD 3	5 min
Station 4	Inspection and chipping	ALL QUADRANTS	5 min
Station 5	Buffing	QUAD 1 & QUAD 4	4 min
Station 6	Buffing	QUAD 2 & QUAD 3	4 min

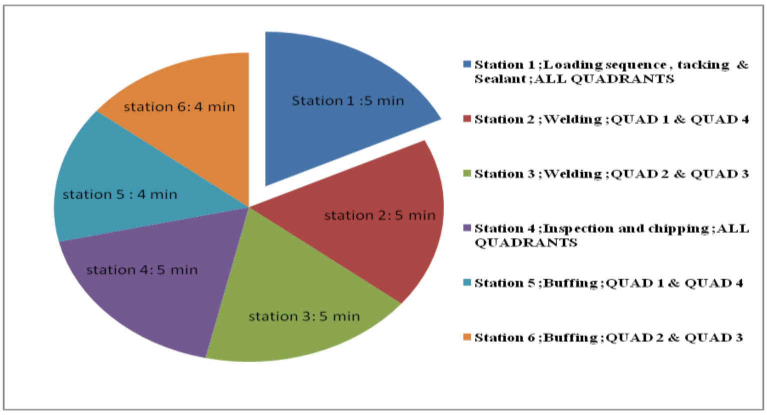

Fig. 13: Allocation of work on 6 SIP station & time distribution station wise

From the above line balancing and allocation of work to 6 different SIP stations, it is concluded that average cycle time of conveyor is 5 min as single station required maximum 5 min to complete their allotted work. Now considering minimum 15% process loss, average takt time of conveyor suggested is 6min for conveyor.

5.3 Calculation

5.3.1 Productivity

Takt time of new conveyor based SIP stations: 6 min

Duration of a single shift: 9.5 hr

Effective working time per shift: 8.5 hr

No of mainframe will come out of conveyor in 1 hr: $\frac{60\ min}{6\ min}$ =10

No of mainframe will come out of conveyor in 1 shift: 10*8.5 hr =85

No of mainframe comes out of existing SIP stations in 1 shift: 60

So, increment of production due to improvement: 85-60 = 25

Percentage of improvement in production = $\frac{(85-60)}{60}$ * 100 % = 41.67 %

5.3.2 Manpower

Table 6: Manpower reduction at New SIP station

Operation	Existing Manpower (both SIP station)	Proposed Manpower at New SIP
Loading sequence & tacking & sealant	2	1
Welding	4	4
Buffing	4	4
Chipping	2	1
Supervisor (Inspection)	2	1
Quality engineer	2	1
Total	**16**	**12**

Manpower is proposed in above Table 6 according to work allotted to different 6 SIP stations and one quality station. So there is a reduction in manpower = 16-12 = 4 person.

Percentage manpower reduction =$\frac{(16-12)}{16}$ * 100 % = 25 %

VI. CONCLUSION

Based on the studies after the implementation of lean, according to Principle of SQCDM (S- Safety, Q- Quality, C- Cost, D- Delivery and M- Morale) following results have been concluded.

(i) Safety- Fork Lift free operation, Safe Transfer Zone – Sensor controlled**,** Elimination of Lifting & dropping of chassis during transfer

(ii) Quality - Eliminate Metal to Metal Contact, No dent marks issue

(iii) Cost- No dedicated MHE (Material handling equipment) required**,** Dedicated Manpower reduction by 25%.

(iv) Delivery- Improved Productivity of SIP – Station based by 41.67%

(v) Morale- Defined work process – Tack Time based i.e. 6 min**,** Safe & Less Movement for Operator – Ergonomics**,** Automatic Transfer System; no idle time of worker as works done parallelly.

And the future scopes of this study are installation and commissioning.

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