



Vol. XII & Issue No. 5 May - 2019

INDUSTRIAL ENGINEERING JOURNAL

THROUGHPUT IMPROVEMENT OF THE ASSEMBLY LINE BY THE APPLICATION OF MOST AND SIMULATION

A. Kamble
M. Telsang

ABSTRACT

Current global situation of fierce competition a company needs to reduce the idle time of operations in addition to improvement of the current working methods. This case study is conducted through application of Maynard Operation Sequence Technique (MOST) in the assembly line to capture the workflow activities descriptive workflow data for determining the Non Value Added activities. Discrete Event Simulation approach is used to give the effective solution. It is more efficient and less time-consuming method for optimization and redesigning the assembly line. Simulation approach used to select the best system which gives the effective solution to the problem. MOST work study is carried out to standardize the work by minimizing the NVA. From the statistics of the operators on the assembly line, clearly after redesigning the system, optimizing the work assignment and changing the position of the station in the layout, the waiting time, and the idle time of some of the station get reduced. The further process simulation reduces the takt time as per customer order and increases the production rate up to 20% by reducing the takt time from 15 min. to 13 min. In this paper WITNESS simulation software is used for analysis the assembly line.

KEYWORDS: *Throughput improvement, M.O.S.T. works study, Discrete Event Simulation, Takt time reduction, assembly simulation.*

1. INTRODUCTION

In this paper, MOST work study is carried out to minimize the non-value added activities for standardizing the work. Furthermore, to analyze the assembly line, discrete event simulation software is used which more efficient and less-time is consuming for optimizing and redesigning the assembly line. To select the best system which gives the effective solution, simulation approach is used. Discrete Event Simulation (DES), with the incorporation of a computer is becoming an effective tool for studying the operations of a production system. It is very important to simulate the production system, to predict the behaviour of the production system and follow up the dynamic properties of every single process.

The simulation approach is one of the best tools to study the performance of the system like throughput, resource utilization, profitability, etc. Without movement of the system physically, which disrupt the process. Industries are currently facing challenges to meet the customer demands. One of the challenges is to assemble a number of products. Another is to optimal utilization of resources, proper work assignment and engaging the required level of manpower. Furthermore, because of more NVA, idle and waiting time, the problem of underutilization of resources which are available. The company will not get efficient production who is using the assembly line because of imperfect design of assembly line. And at the same time the company has no more chance to survive in the market and competition. To reduce or minimize the bottleneck operations, necessity of proper balancing of the assembly line is required in order to balance the assembly line and also to improve the efficiency of the assembly line. [5]

In this paper discrete event simulation approach is used to redesign and optimize the production system. To select well-

balanced system, the simulation will be carried out by using WITNESS software and standardizing the work by using the MOST techniques. The further optimization of the redesigned system will be done by using simulation approach. Like lean manufacturing, JIT, Kanban and pull system, overall equipment efficiency optimization based on different manufacturing theories is carried out. For optimization of performance, the companies nowadays use the lean system as a reference model. Therefore, the researcher focuses his work to use simulation approach in studying the production processes as well as optimization of system. Any excess stock and overproduction is considered as a waste for any manufacturing organization. [6]

2. REVIEW OF LITERATURE

Mokhtar [7] used Witness simulation software for the optimization of the production line of a company. In order to optimize the production line and to manage the bottleneck operations, they presented three alternative solutions. The first alternative about reducing the idle time by eliminating the required workstation. The Second alternative for the critical processes by adding the new workstations wherever required. This alternative is related to increasing the production with extra capacity, and the third alternative is for optimizing the product output by reducing the cycle time. Wirabhuan et al. [8] they simulate the assembly model by using ARENA, Microsoft Excel was used for statistics to balance the assembly line, re-layout and process enhancement. They compare the result from the simulation model of an existing and proposed simulation model to improve the truck assembly line. Propster et al. they recommended the simulation software tool for simulating the worker flexibility, according to the sequence and variation of production demand. Furthermore, they introduce an approach

of using the simulation tool which validates the balancing of the assembly line. Vylen et al. [4] their target was to redesign the assembly process flow by the elimination of material wastage. They use value stream mapping walk to find out the source of material wastage, though there is no value addition on the part. The result shows a drastic improvement in productivity, reduction in the rejections; reduction in the manufacturing lead time and also the manufacturing cost.

Bures and Pivodova [1] focus on comparison for time standardization. They compared two-time systems basic MOST and MTM-1 and the methods from REFA methodology. By using these two methods they compare the results. The researcher's aim was to demonstrate accuracy, reliability, and deviations of methods. Yadav [3] uses MOST work study for the TATA engine assembly line. His work is based on his methodology in which they start with selection of the system and then, they decide suitable cycle times for the work stations, requirements of the work stations, and implementation of parallel lines for the assembly system. By combining the workstation, they decided an optimal number of workstations. Tuan [2] they studied on the problem of non-optimal operations in the organization. It is because of the NVA activities involvement and the inefficient methods such as more travelling distance, material wastage and the imbalance of material flow. They use MOST for the value engineering and value addition. Furthermore, they develop the new methods and work standards for layout design of the workplace. They found that there is improvement in material handling and work flow, because of redesigning the process.

4. MOST TECHNIQUE

Table. 1 Moves and Sequence model used in MOST

Type	Sequence model	Sub-activities/Parameters
1. General moves	A B G A B P A	A- Action distance
Movement of an object through air		B - Motion of the body
		G - Gain control
		P – Placing the object
2. Controlled moves	A B G M X I A	M - Move controlled
		X – Process time

To carry out the MOST work study, the sequence models and the sub-activities or parameters are used as shown in table 1.

3. METHODOLOGY

This paper deals with the investigation of existing assembly line and processes carried out at each station, using MOST work study on each activity. The focus is to identify the improvement areas to minimize the cycle time of operation of the redesigned assembly line and increase the rate of production by redesigning the assembly line with proper work assignment.

1. Study the main assembly and sub assembly system.
2. Time study of system by using MOST technique to standardize the process.
3. Modelling and simulation of the existing system using WITNESS.
4. Determine the critical parameters in terms of waiting, idle time, workload involved, material movement i.e. NVA activities.
5. Implementation of the modular fixtures at some of the required station, changing the position of operator workstations, improvements in work assignment to achieve the single piece flow of the assemblies.
6. Modelling and simulation of the redesigned system to get the required throughput.
7. After simulation, the Comparison in the statistics of the existing and redesigned system.

4.1 Time units used in MOST

MOST work study uses the TMU (Time Measurement Units) as shown in table 2 below.

Table. 2 Time units used in MOST study

1 TMU = 0.00001 hour	1 hour = 100,000 TMU
1 TMU = 0.0006 minute	1 minute = 1667 TMU
1 TMU = 0.036 second	1 second = 27.8 TMU

Table 3 shows the MOST calculation of Ferrite transformer (one of the sub-assembly station) is done as shown below.

Frequency of operations carried out by the operator is indicated in the bracket.

Table.3 Most calculation of sub activities

Ferrite transformer assembly		Total										TMU 2980	SEC 107.28	Act 130	
1	Lifting of ferrite transformer	A3	B6	G1	A3	B0	P3	A1					170	6.12	-
2	Lifting of bracket	A1	B3	G1	A1	B0	P3	A1					100	3.6	-
3	Fitment of bracket	A1 (2)	B0	G1 (2)	A1 (2)	B3	P3 (2)	F24 (2)	A 1				670	24.12	-
					M 0	X0	I3								
4	Tool use screw driver	A1	B3	G1	A1 (2)	B3	P6 (2)	F16 (2)	A 1	B 0	P 1	A 1	570	20.52	-
5	Rotate the ferrite transformer	A1	B0	G3	A1	B0	P6	A1					120	4.32	-
6	Fitment	A1 (2)	B0	G1 (2)	A1 (2)	B3	P3 (2)	F24 (2)	A 1				640	23.04	-
7	Tool use screw driver	A1	B3	G1	A1 (2)	B3	P6 (2)	F16 (2)	A 1	B 0	P 1	A 1	570	20.52	-
8	Place subassembly into rack	A1	B0	G1	A3	B3	P3	A3					140	5.04	-

Calculation of cycle time for 1st operation:

$$A3 B6 G1 A3 B0 P3 A1 = 17 \times 10 = 170 \text{ TMU} = 170 \times 0.036 = 6.12 \text{ sec.}$$

4.2 Calculation of existing and redesigned system

When the production is set to match the rate of customer demand, the Takt time is the average time between the start of assembling one unit and the start of assembling the next unit. It simply reflects the rate of production needed to match the required demand of the customer. To achieve the demand of 35 machines per day, then there should be a takt time of 13 min. It can be calculated as follows-

Available time = (shift time – allowances) Shift time = 600 min (10 hours),

Allowances = Lunch time + (2 x tea breaks) = 30 min + (2 x 15) min = 60 min

Available time = (600 – 60) min. = 540 min.

$$Takt \text{ time} = \frac{540 \times 0.85 \times 1}{30} = 15.3 \text{ min. (approximately 15 min.)} = 900 \text{ sec.}$$

b) Redesigned takt time for 35 machines per day

a) Existing takt time for 30 machines per day

$$Takt \text{ time} = \frac{\text{Available time} \times \text{Operator efficiency} \times \text{No. of shift}}{\text{Output}}$$

$$Takt \text{ time} = \frac{540 \times 0.85 \times 1}{35} = 13.11 \text{ min. (approximately 13 min.)} = 780 \text{ sec.}$$

Table. 4 Existing cycle time of the assembly stations

Sr. No.	Operation	MOST Time (sec.)
1	Base assembly	77.04
2	Tray assembly	448.08
3	Fan assembly	212.64
4	Ferrite transformer assembly	157.28
5	Front cover assembly	351.32
6	Back cover assembly	68.04
7	Front bezel assembly	703.84
8	Back bezel assembly	202.32
9	PCB assembly	770.04
10	Heat sink assembly	840
11	Base tapping	56.88

12	Tray tapping	55.44
13	Main assembly 1 st stage	795.72
14	Main assembly 2 nd stage	819.52
15	Main assembly 4 th stage	678.56
16	Main assembly 5 th stage	634.48

To study the movement of the operator in between work stations, MOST study has been carried out of the sub-assembly and main assembly line. Because of MOST, It helps in improvement in the production rate by standardization of the work. Table 4 shows the time required for completion of the operations.[9]

5. EXISTING WORK ASSIGNMENT

Table 5 shows the existing work assigned to the operators and the cycle time required for completion of this operation.

Table. 5 Existing work assignment

Operators	Work assigned	Cycle Time stopwatch (Sec.)	MOST (Sec)
A	PCB	840	770.04
B	Front bezel assembly	740	703.84
C	Tray /Base/ Ferrite bracket assembly	882	794.72
D	B. Bezel /Fan/ F. cover / B. cover assembly	967	834.32
E	heat sink IGBT assembly	872.4	840
F	Diode assembly	872.4	840
G	1 st station Main assembly	852.6	795.72
H	2 nd station Main assembly	855	819.52
I	3 rd station Main assembly	678	678
J	4 th station Main assembly	720	678.56
K	5 th station Main assembly	658.8	634.48
L	6 th station Main assembly	660	660

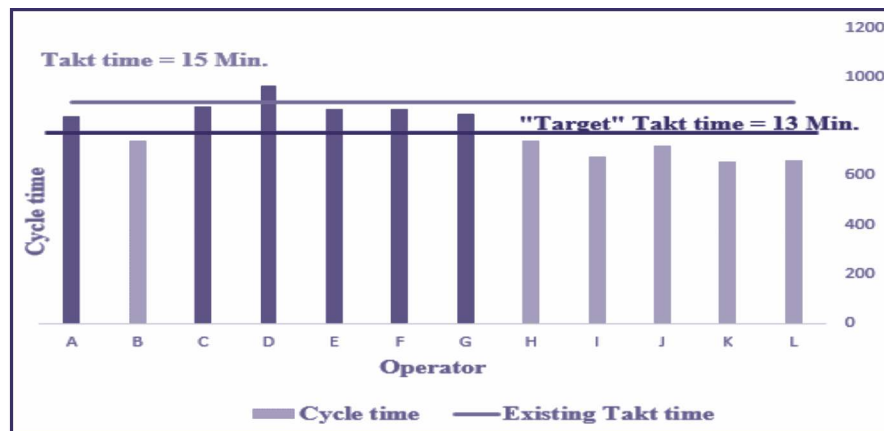


Fig. 2 Graphical representation of existing work assignment

The graphical representation of the work assigned to the operator in existing system is as shown in figure 2. It is shown in figure that, there are two lines. One line indicates the takt time of the existing system shown by blue line and other black line indicates the takt time line of the redesigned assembly system having 13 min. takt time. For the redesigned assembly line, the bottleneck operations are shown by red column as shown above. Some of the operator shave less work is assigned and some operator have more work is assigned. Because of

this, there is a problem of underutilization of the operator whose work is less. The operator C and D having cycle time of 794.72 sec. and 834.32 sec. respectively, which is more than the other operators and also above the existing takt time line (15 min.). Furthermore, the main assembly work stations are waiting and idle for some time to complete the required sub-assemblies. This shows the unbalancing of the work assignment of the system.

Figure 3 below shows the rate of production of the subassembly stations. The rate of production of each operator is different as shown in the figure. Therefore the actual production rate of the shift will be 28 sub-assemblies. Means to the main assembly

line only 28 subassemblies will provide. The operator D has less production rate as compared to other station in existing sub-assembly stations because of its more cycle time

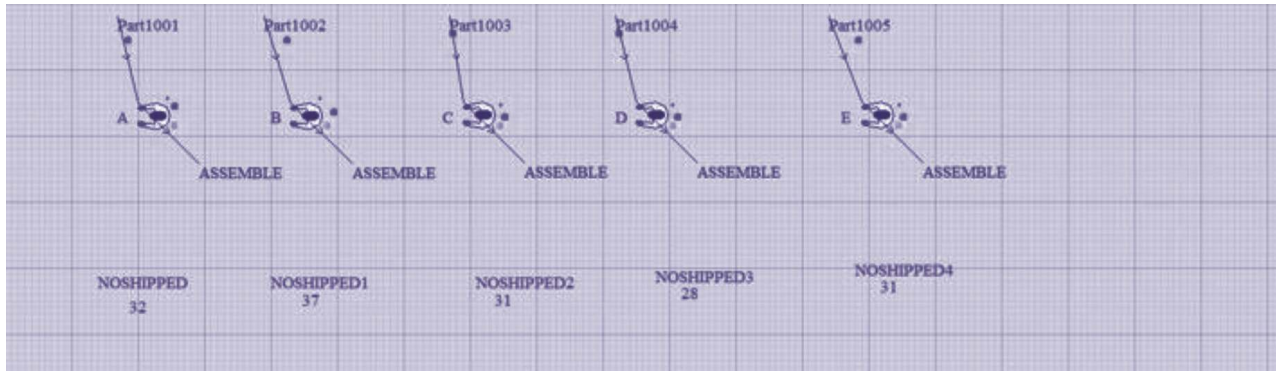


Fig. 3 Witness model of existing sub assembly station

Figure 4 below shows the simulation result of the existing main assembly line. It shows the utilization time of the main stations and percentage idling and waiting time.

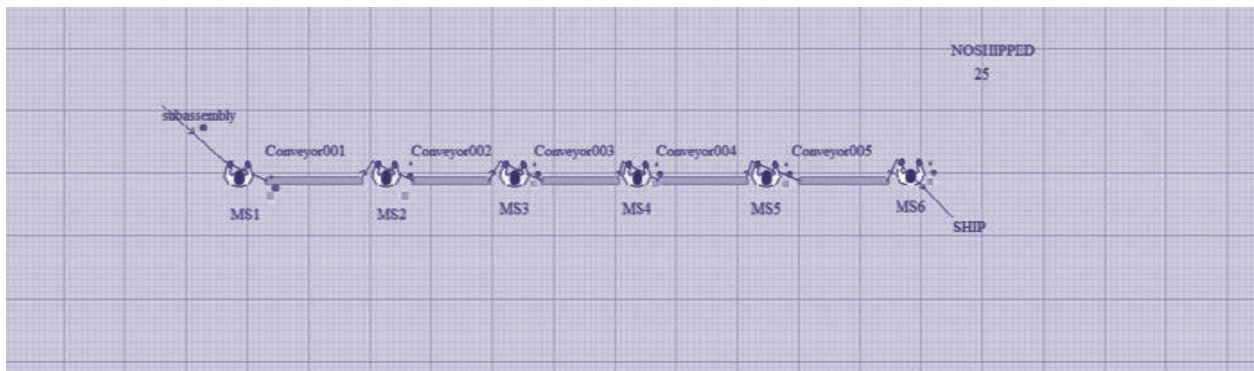
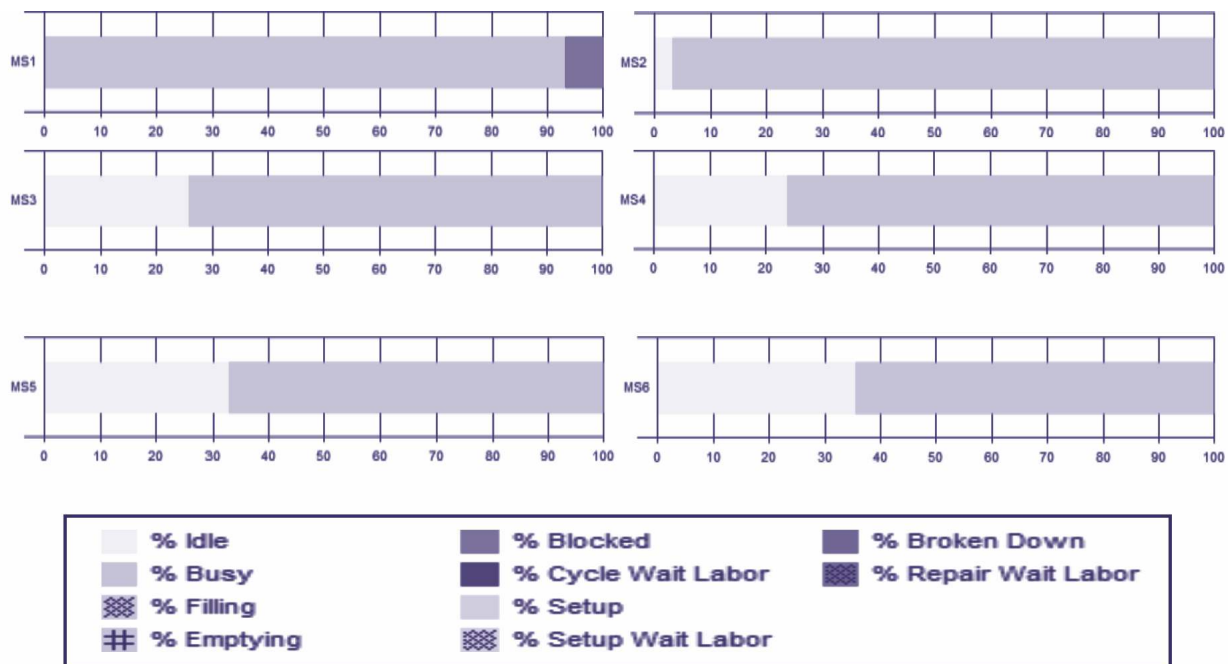


Fig. 4 Witness model of main assembly station



5.1 Identification of improvement are as

No of improvements are identified after analyzing the system, which includes the lack of standardization of work, more work station cycle time, improper work assignment, unwanted movement of workers in between stations, more idle time and waiting time at stations and unbalance of activities on the line. The Basic MOST technique is used so that it is easy to find the NVA activities carried out at the assembly line, which helps to increase the efficiency and the throughput of the assembly line. [9]

a) Elimination of the bottleneck

After studying the assembly line by using the MOST it is clear from figure 2 that the operator C (Base/tray/Ferrite bracket assembly)and operator D (Fan/B.BezeI/F.cover/B.cover assembly station)are the Bottle neck operations because they takes more time to complete the assembly. The operator C takes 794.72 sec. (13.24 min.) and D takes 834.32 sec. as shown in figure it is also observed that the operator at station E and F takes more time to supply the subassemblies to main line. The inventory of some of the operator station increases at a faster rate because of less cycle time, before providing to the main assembly.

b) Balancing the work content

The content of work differs from operator to operator as seen

from work assignment of the existing system. Thus to optimize the balancing of work content, operation's sequence and work assignment has to be changed. As well as the operations can be combined to achieve the optimization in the workflow.

c) Reduction of cycle time

To minimize the unwanted movement of the operator in between sub assembly and main assembly stations, conveyor can be provided on the sub assembly side so that the operator on the sub assembly station will place the sub assembly in the bin which is placed on the sub assembly conveyor, and after some time the conveyor will move forward to next station. Like this the bin will come to the last station contains the sub-assemblies required for making one final assembly. At the end of the conveyor, the first station operator on the main assembly line will take the bin at the end of the sub-assembly conveyor. It results in reduction of the intermediate movement of the main assembly operators (Operator 1 and 2). Redesigning the sub- assembly stations by changing the position of sub-assembly station (Heat Sink), it results in reduction of waiting time of station 1 on main line. Because some sub-assemblies are required from heat sink station to main assembly station 1. The modular fixture will be designed at some station (operator C and D), to reduce the cycle time of that stations. Because of this extra sub-assemblies of other stations can be made by this stations.

5.2 Optimization of work assignment for redesigned system

Table. 6 Optimize work assignment for redesigned system

	Base/Tray assembly	B. Bezel/ F. Cover assembly
Fan assembly	730	834.32
Ferrite bracket assembly	794.72	770

The takt time of the redesigned assembly line is 13 min. Some of the work stations having cycle time are nearer to the takt time like Front bezel assembly, PCB assembly and heat sink assembly. If we add more operation into this operations, then the cycle time will more than the required takt time. But there are stations having cycle time lower than the takt time like front cover assembly and Base Tray assembly station).

As shown above in table 4, the total cycle time of the base and tray assembly is 517.36 sec. If the operation of fan assembly is added to the base-tray operation, then the total cycle time will be of 730 sec. and if the operation of ferrite bracket is added, then the total cycle time will be 794.72 sec., but it is more than the takt time of the redesigned assembly system.

By studying the cycle time of the operations, the fan assembly is combined with the base and tray assembly station. Similarly, if fan assembly operation combine with front cover assembly station then the total cycle time will be 834.32 sec. Because of this the total time will exceed the takt time of the redesigned system. Therefore the ferrite bracket assembly is combined with the front cover assembly station.

6. WORK ASSIGNMENT FOR REDESIGNED SYSTEM

Table 7 below shows the cycle time of all the operators. By providing the modular fixtures at required stations and minimizing the bottleneck operations by changing the work content, the cycle time of all the stations reduced to below the redesigned takt time.

Table. 7 Work assignment for redesigned system

Operator	Cycle time (Redesigned)	Takt time (Sec.)
A	760	780
B	703.84	780

C	730	780
D	770	780
E	737.94	780
F	737.94	780
G	700	780
H	710	780
I	678	780
J	678.56	780
K	634.48	780
L	660	780

6.1 Validation of a redesigned system by simulation

Figure 5 shows the validation of the total assembly line by using simulation. On the conveyor, bins are provided in the redesigned system. After an equal interval of time, the sub-assembly conveyor will move forward and the operator on the sub-assembly station will put the sub-assembly into the bin, when that bin will come to that station. Finally, the bin will

approach to the final station after taking all subassembly required for one complete machine. The operator on the main assembly station will take that bin for completing the main assembly. It is clear from the validation of the redesigned system that on the 1st day 26 machines will ship and 9 machines will be in WIP. And 35 machines will ship from the 2nd day onwards.

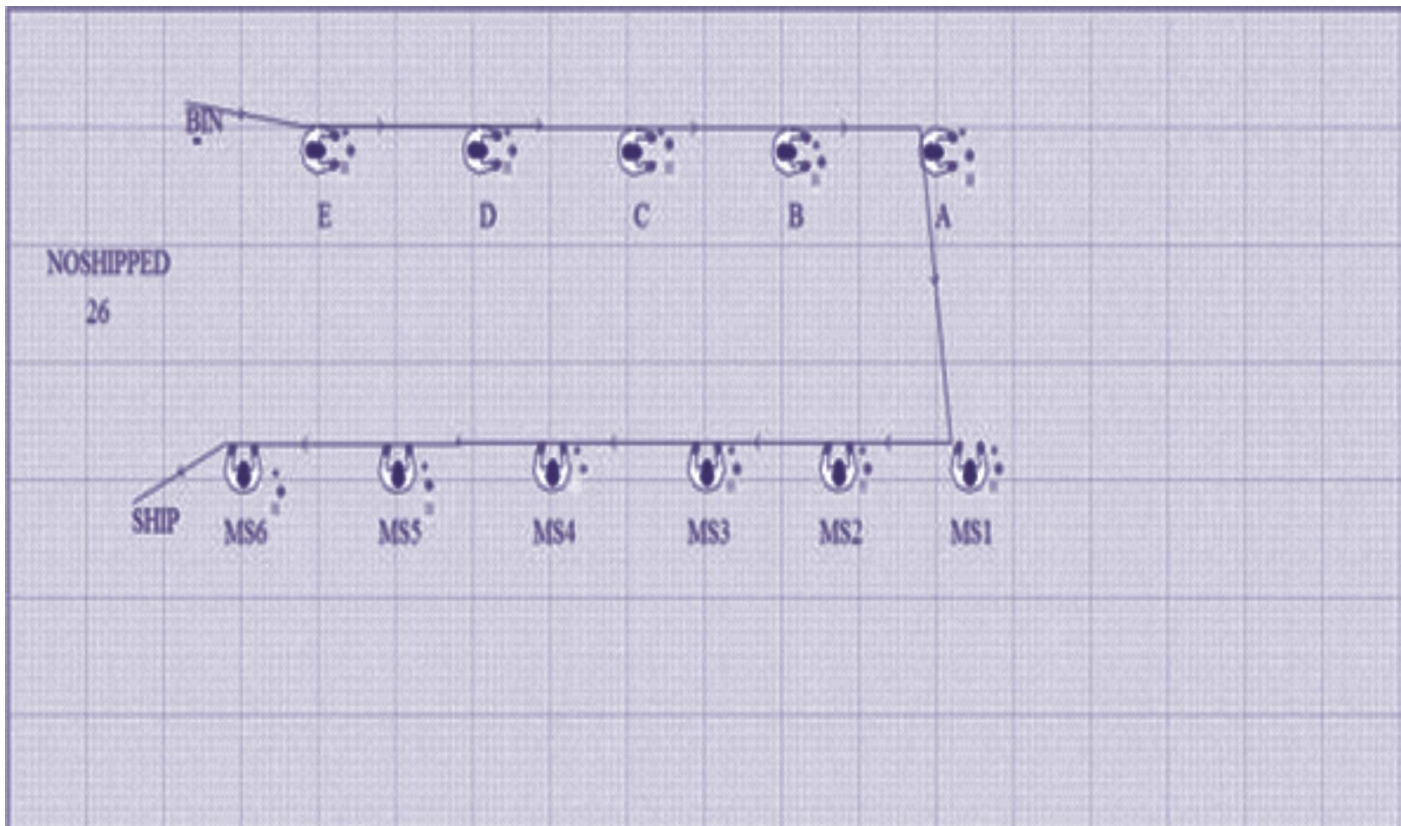


Fig. 5 Validation of the redesigned assembly line (13 min. takt time)

6.2 Results of the redesigned assembly line

It is clear from the statistics of the operator that, after redesigning the system, changing the position of the work station in the existing layout, optimizing the work assignment and providing the conveyor on the sub-assembly side, the idle

time and the waiting time of the station get reduced. Also the production rate has increased from 30 assemblies to 35 assemblies per day because of reducing the takt time of the assembly line. Table 8 below shows the statistics of the existing and resigned main assembly line work stations.

Table. 8 Statistics of main assembly line for existing and redesigned system

Operator	% Busy	% Idle	% Block	Operator	% Busy	% Idle	% Block
MS1	93.31	0	6.69	MS1	100	0	0
MS2	96.73	3.27	0	MS2	89.19	10.81	0
MS3	74.18	25.82	0	MS3	82.76	17.24	0
MS4	75.98	24.02	0	MS4	80.35	19.65	0
MS5	66.98	33.02	0	MS5	72.93	27.07	0
MS6	64.38	35.62	0	MS6	73.36	26.64	0

7. DISCUSSION

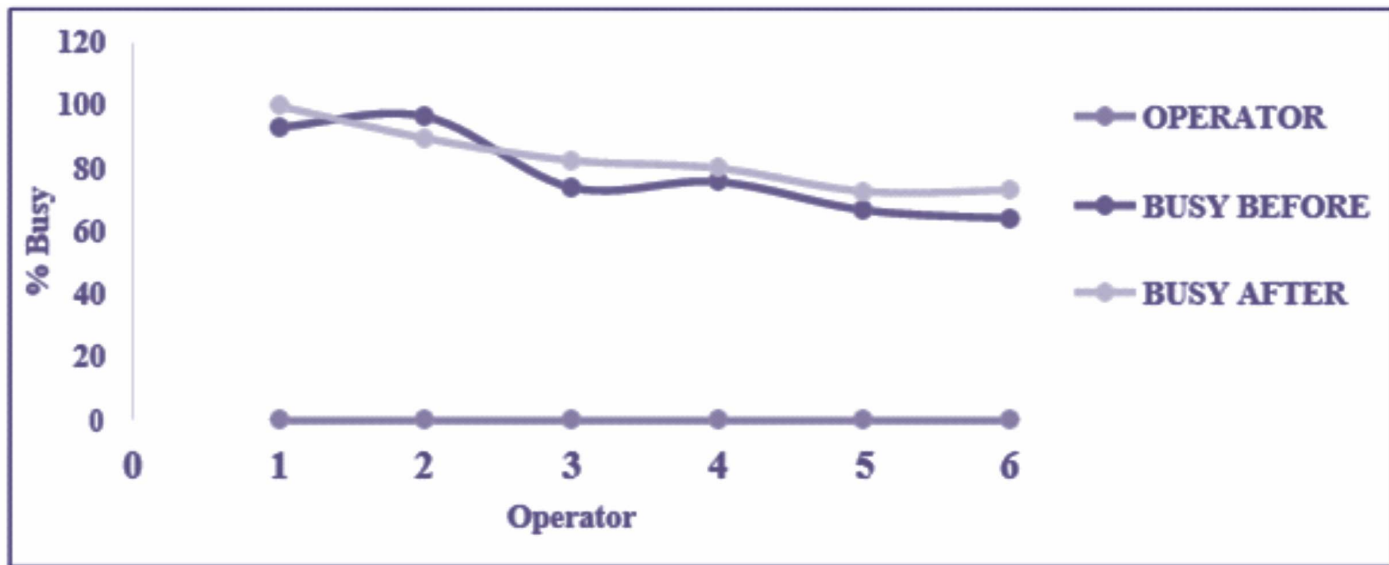


Fig. 6 Graphical representation of % busy operator

Figure 6 above shows the graphical representation of the operator busy in percentage. In the figure shows the comparison of the operators busy on the main assembly line, before and after redesigning the system. It is clear that, the operator % busy in the redesigned system is more as compared to the existing system. Because of NVA activities carried out by the operator 2nd like the movement from the workstation to take the assemblies which are required for that station the % busy is more.

The production rate of the existing system was 30 machines per shift, when the takt time of that line was 15 min., means after 15 min the one complete assembly should be complete per shift. But when the requirement of the machines changes from 30 to 36 machines per shift, then the takt time of the redesigned system should be reduced by 2 min. therefore the throughput of the redesigned assembly line is increases by 20%.

8. CONCLUSIONS

The objective of this paper was to redesign the existing system to improve and increase the throughput of the assembly line. Discrete Event Simulation is used to model an existing assembly line, to study the efficiency of the operator on the existing assembly line. In this paper, to analyze the NVA in the assembly line, M.O.S.T. work study has been carried out. The takt time of the assembly line has reduced by implementing the

improvements to 13 min. In the redesigned system, the optimization of work assignment has been done. The sub-assembly conveyor is provided, to achieve the single-piece flow of the sub-assemblies. Because of this, the sub-assembly operator's movement in between the station has been reduced. The time required for making the sub-assemblies has reduced by providing the modular fixtures at required work station whose cycle time is more than the takt time of the redesigned system. The simulation of the redesigned assembly line has been carried out. The waiting time of the operator on the main assembly line has been reduced by changing the position of the IGBT heat sink sub-assembly station. Because of this, the production rate of the line has improved.

REFERENCES

1. M. Bures, and P. Pivodova, Comparison of Time Standardization Methods on the Basis of Real Experiment, *Procedia Engineering* 100: pp. 466 - 474, 2014.
2. S. Tuan, Improvement of Workflow and Productivity through Application of Maynard Operation Sequence Technique (MOST), *Proceedings of the 2014 International Conference on Industrial Engineering and Operations Management Bali, Indonesia, 2014.*

3. T. Yadav, *Measurement Time Method for Engine Assembly Line with Help of Maynard Operating Sequencing Technique (MOST)*, *International journal of innovations in engineering and technology (IJET)* vol. 2 issue 2, 2013.
4. R. Vylen, et al., *Redesigning the Assembly Process Flow through Lean Strategy*, *International Conference on Challenges and Opportunities in Mechanical Engineering, Industrial Engineering and Management Studies (ICCOMIM-2012)*, pp. 11-13.
5. B. Chramcov, *The Optimization of Production System Using Simulation Optimization Tools in Witness*, *International journal of mathematics and computers in simulation Issue 2*, vol 7, 2013.
6. H. Zupan, N. Herakovic, *Production line balancing with discrete event simulation: A case study IFAC (International Federation of Automatic Control) - Papers on Line 48-3: 2305-2311*, 2015.
7. A. Mokhtar, et al., *Line Balancing and Optimization for Single Model Assembly Line at a Small Medium Industry (SMI)*, *university technical Malaysia Melaka*, 2007.
8. A. Wirabhuana, et al., *Simulation and re-engineering of truck assembly line*, *IEEE computer society*. 2008.
9. A. Kamble and M. Telsang, *Throughput improvement by redesigning the mixed model assembly line using simulation*, *International Journal of Process Systems Engineering*, vol. 4, No. 4, 2018.

AUTHORS

A. Kamble , Department of Mechanical Engineering, Sanjay Ghodawat University, Kolhapur, Maharashtra, India Email ID: akshaykamblemech@gmail.com

M. Telsang, Department of Mechanical Engineering, Sanjay Ghodawat University, Kolhapur, Maharashtra, India, Email ID : martand.telsang@gmail.com