RESEARCH ARTICLE OPEN ACCESS

A COMPRESSIVE STUDY ON LINE BALANCING AND SIMULATION OF AN AUTOMATED PRODUCTION TRANSFER LINE

PRAVEEN.T*1, DR.B.KUMAR2,

*1 RESEARCH SCHOLAR ,DEPARTMENT OF MECHANICAL ENGINEERING, SUNRISE UNIVERSITY, ALWAR, RAJASTHAN, INDIA

2 RESEARCH SUPERVISOR, DEPARTMENT OF MECHANICAL ENGINEERING, SUNRISE UNIVERSITY, ALWAR, RAJASTHAN, INDIA

ABSTRACT

This paper presents an investigation on the line equalization of an automatic cylinder block production transfer line so as to reduce the whole cycle time associate degreed increase machine utilization in an automotive plant. Results were verified by model, that showed increased outturn and better machine utilization as a results of line balancing. Design/methodology/approach – 3 main operation lines of the transfer line were known as important and having the very best cycle time and were chosen for optimisation study. methods of re-sequencing of existing operations and tools were wont to reduce the cycle time of those important operations and to balance the line. Results of a simulation study using Simul8 software are conferred to demonstrate the rise in machine utilization and outturn as a results of line equalization. Findings – owing to line balancing, the cycle time of cylinder block line was reduced from 293.9 to 200 s, an virtually thirty two per cent reduction. This conjointly resulted in increased throughput and machine utilization. outturn was increased by sixty five per cent. Machine utilization was found to extend in any respect stations, with the very best increase at one station was recorded from forty eight to ninety five per cent thanks to equalization. Originality/value – Introduces a brand new application to line equalization of automotive engine block line. Demonstrates that effective methods of re-sequencing and ever-changing of tools will result in a lot of balanced line with increased outturn and better machining utilization, leading to higher productivity.

Keywords

Process planning, Line management, Transfer processes, Machining centres

I. INTRODUCTION

An automated production line in an exceedingly manufactory consists of a series of workstations organized in order that the product moves from one station to future, and at every station, a selected producing method is performed thereon. Such production lines square measure related to production. an automatic assembly line is that the most acceptable producing system, if quantities of product square measure terribly high and therefore the work may be divided into separate tasks that may be appointed to individual workstations. In an automatic production line, the workstations square measure connected by a elements transfer system whose feat is coordinated with the stations. In such system, no human workers are on the line, except to perform auxiliary functions like tool dynamic , loading and unloading of elements, and repair and maintenance activities (Groover, 1996). A transfer line is an automatic production line with a sequence of laborstations with automatic transfer of work units between stations. Transfer lines are wide utilized in mechanical and automotive trade for production of one sort of product. Transfer lines square measure typically valuable items of equipment; and square measure designed for job requiring high quantities of elements. A transfer line operates in cycles, like a manual line. every cycle consists of process times and the time to transfer elements to their individual next workstations. The slowest digital computer on the road sets the pace of the road, even as in line.

Line equalization is a vital issue to be thought of within the preliminary style stage for the flow line production system. it's wont to verify optimum allocation of operations at the workstations thus on minimize the cycle time of the road for a given range of workstations, or to reduce the amount of the workstations for a given cycle time, by equalizing the masses on the workstations.

Line equalization drawback is often related to style of manual assembly lines. whereas variety of researchers have self-addressed this drawback for assembly lines, very few folks have investigated the matter for machine-controlled production lines or transfer lines. familiar strategies of line equalization improvement issues can't be used directly for transfer lines as a result of the operations at every digital computer are dead at the same time and therefore the cycle time is up to the longest method time and not the total of method times.

II. LITERATURE OF SURVEY

Dolgui et al. (2005) have used a heuristic approach for transfer line balancing, where operations in each workstations are grouped into blocks, and the problem was to find the best assignment of operations to blocks that leads to the minimal transfer line cost. For this, they have applied a mixed integer programming approach and a graph optimization technique to solve the problem. Nkasu and Leung (1995) have presented a stochastic methodology for assembly line balancing, where various probably distributions are integrated within a modified COMSOAL algorithm as a means of addressing the uncertainties associated with key assembly line variables. Miltenburg (2002) has studied the balancing and scheduling of mixed-model U-shaped production lines. Zhao and De Souza (2000) have discussed the problem of genetic production line balancing for hard disk drive manufacturing and assembly. Vilarinho and Simaria (2002) have developed a mathematical programming method for the mixed-model assembly line balancing problem with parallel workstations and zoning constraints. Askin and Zhou (1997) have described a parallel station heuristic for mixed model production line balancing problem. Moodie and Young (1965) used a heuristic method of assigning available operations firstly in order to decrease the operation-time-value and secondly to exchange operations from workstations with the longest time with those of the shortest times. Published works indicate that very few studies have been made online balancing of transfer lines in automotive production environment.

This paper presents a detailed study of line balancing of a production transfer line of machining of automotive cylinder blocks with the aim of increasing the machine utilisation and throughput of the line. The required throughput is not achieved due to high cycle time of some of the operations in comparison to the cycle time recommended by the manufactures of the computer numerical control (CNC) machines. This causes the line imbalance. Three main operation lines of the transfer line were identified as critical and having the highest cycle time and were chosen for optimisation study. Strategies of re-sequencing of existing operations and tools were used to reduce the cycle time of these critical operations. Results of a simulation study using Simul8 software are also presented to demonstrate the increase in machine utilisation and throughput as a result of line balancing.

III. CYLINDER BLOCK PRODUCTION LINE

The cylinder block production line consists of 16 major operations served by an asynchronous conveyor. A portion of these operations consist of several machining workstations (including CNC machines). The cylinder blocks enter the framework at a loading station where they are loaded manually in a batch measure on to the conveyor. Each station can process only one part at once. Scarcely any parts are held as cradle after each operation for the conceivable starvation (condition in which a workstation is sit out of gear and waits for the past workstation to finish the machining on the component). Each operation has some associated scrap rate, which frames the percentage dismissed back to the framework. The main machining forms performed on the block consist of processing, penetrating, and reaming procedures to create countless on the block. All the operations are connected through conveyors and have a few cradles to avoid the situation of starvation in case of any breakdown before each operation on the conveyors.

Preparing starts at Operation#10 (OP10), where the blocks are loaded, and finishes at Operation#160 (OP160) with the final leak test, after passing through various operations. Operation#OP20, OP30 and OP70 play out the major machining operations and they each have two legs of parallel workstations. All different operations have single leg of workstations. The intermediate operations OP40, OP50 and OP60 are wash, leak test and bearing cap assembly operations, individually. At these operations, blocks are cleaned and the casting cavities are checked for the leaks. Bearing caps are assembled before the block experiences final major machining at OP70. Different operations on the line perform completing and testing operations.

IV. BALANCING OF MACHINING OPERATIONS

\The total cycle at an operation is obtained by adding both the machining time and non-machining time. The process duration can be diminished by eliminating or decreasing the value added activity and/or the non-value added activity. Non-value added activity is the time when an apparatus moves starting with one position then onto the next in the middle of the actual machining of a feature. In this study, the attention is on the reduction of value added activity, i.e. decreasing the actual machining time. There are several parameters that affect the value added activity. These include:

Spindle speed. Speed at which an instrument loaded on the axle rotates.

. Feed. Amount of material, evacuated at one stroke of machining.

. Cutting speed. Speed at which the cutting is done, which eventually calculates the cutting time of the process duration.

. Feed stroke. Length of material, evacuated at one stroke of machining.

. Tools utilized. This can be a major parameter affecting the process duration of the procedure. Process duration relies upon the device life of the instrument utilized and also in a roundabout way on its cost. Device life thusly relies upon various parameters of the instrument, for example, the device material and the apparatus geometry.

Line balancing can be done by two strategies:

1 by sequencing the apparatus such that all the stations finish the activity at the same time; and

2 changing the instruments either by changing the device geometry or by changing device material.

The strategy for line balancing was undertaken by taking a gander at the exact process duration distinction between each station and considering the potential outcomes of sequencing of devices or changing them. Changing the geometry of the device or material can increase the bolsters and speeds, which can ultimately lessen the process duration and also increase the device life to machine the operation.

3.1 Critical machining operations

The operation number OP20, OP30 and OP70 are distinguished as the three critical operations in the process because they have the most astounding process durations in the production line. OP20 and OP30 have two legs, each consisting of five workstations (STN3, STN4, STN5, STN7 and STN8) and OP70 also has two legs, each consisting of six workstations (STN3, STN4, STN6, STN7, STN9, STN10). These three operations can also be named as the transfer lines, because they transfer the component starting with one workstation then onto the next simultaneously inside the operation. Each workstation has several devices, controlled by the CNC program on the CNC machine.

The methodology of balancing was started by first analyzing the process durations of the operations from the procedure sheets. Whenever measured, the present process durations were observed to be not quite the same as that suggested in the process sheets. The CNC machine programs for the machining were composed in M and G codes. After detailed study of the CNC program bolstered into the machines, it was discovered that this distinction in process duration was because of the changes in parameters in the CNC program. A portion of the values of parameters like length of the cut, bolsters and speeds were changed for all procedures bringing about the change of the process duration from the suggested process duration. We will illustrate the system of line balancing of OP20 in full details. Similar methodology were adopted for OP30 and OP70. Before balancing, the most noteworthy part to part process duration in OP20 was 229 s at STN4, the most elevated process duration in OP30 was 293.9 s at STN3, and the most noteworthy process duration in OP70 was 210.3 s at STN4. Hence the process duration for cylinder block line was 293.9 s, being the most astounding of the three times. Line balancing was undertaken to lessen this process duration and to increase the machine utilization and throughput as explained beneath.

After handling at OP10, the conveyors push the cylinder block to that leg (An or B), which has finished the operation first. Each station has several instruments, which are arranged in a particular grouping to perform diverse machining operations with various tooling. There are a total of 39 operations performed in leg An of OP20. Table I demonstrates a summary of operations in each leg of OP20. A few instruments perform in excess of one operation on various part of the block.

Each operation has corresponding machining parameters and particular devices at which the machining is done.

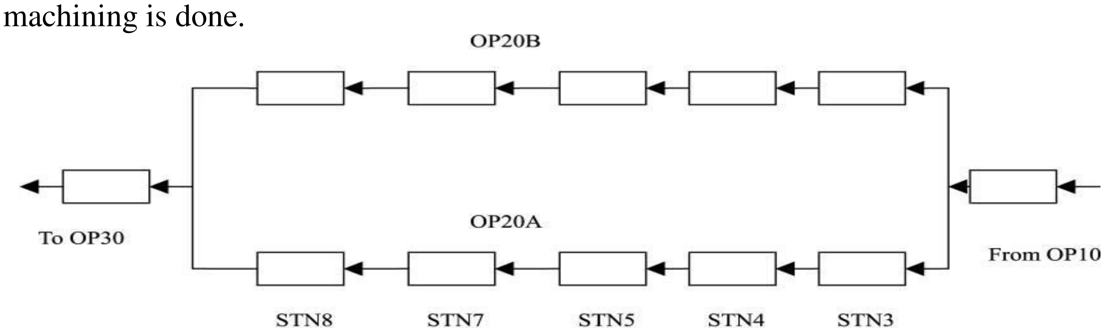


Figure 1 Transfer line of OP20

Figure 1 demonstrates the transfer line of OP20. It has two parallel legs An and B, meant by OP20A and OP20B, each consisting of identical arrangement of five workstations, named as STN3, STN4, STN5, STN7 and STN8. The previous operation is OP10 and succeeding operation is OP30. All three operations (OP10, OP20 and OP70) are transfer machines, which transfer the component starting with one station then onto the next simultaneously.

example, STN3 has ten different tools, which machine some specific features on the part as described below:

1 Tool 1. Milling cutter rough: mills the bearing cap mounting surface.

2 Tool 2.Special half round ball nose end mills: mills the crank half bores.

3 Tool 3. Milling cutter: rough mills the pan face of the block.

4 Tool 4. Milling cutter: finishes partially the bearing cap mounting earlier rough milled by Tool

5 Tool 5. Milling cutter: finishes the rest of the bearing cap mounting rough milled by Tool 1.

6 Tool 6. Pan face drill (twist drill): drills the MFG holes.

7 Tool 7. End mill: mills the crank bore oil drill.

8 Tool 8. Reamer: reams the MFG holes earlier drilled by Tool 6.

9 Tool 9. Drill: drills the crank bore oil drill earlier milled by Tool 7.

10 Tool 10. Touch sensor probe: checks the bearing cap mounting surface and pan face surface for its machining for proper dimensioning.

Every station has a fixed cycle time, which is the time taken by a part to be machined, or time required to complete a given process at that station. As the distance between each station is the same, the transfer time remains constant.

Table II shows the total machining (M/C) time, transfer time, current part-to-part cycle time (C/T) and the required C/T for all the five stations of OP20. In the second column of the table, OP20-3A denotes STN3 in leg A of OP20, and so on. The required cycle time of 201.6 s for all stations was obtained from CNC machine vendor's recommendations. It is noted that the cycle times of all stations except STN4 (OP20-4A) are below the required time.

Owing to high cycle time of station OP20-4A, the other stations before and after STN4A wait for it to complete the

Station name	Total operations	Total number of tools used	Types of operations
STN3 (OP20-3A)	12	10	Mill, bore, drill, ream, chamfer, sensing
STN4 (OP20-4A)	16	9	Mill, face, drill, ream, tap drill, tap, sensing

STN5 (OP20-5A)	3	3	Bore, undercut bore
STN7 (OP20-7A)	3	3	Rough bore, U/cut bore
STN8 (OP20-8A)	5	4	Oiling, lock notch, de-burring

Table I Operations performed in leg A of OP20

Table II Required C/T and current part-to-part C/T in OP20

Operation names	Station number	M/C time (s)	Transfer time (s)	Part-to part C/T (s)	Required C/T (s)
Pan face	OP20-3A	188.6	10	198.6	201.6
R/L bank	OP20-4A	219	10	229	201.6
R cyl rough	OP20-5A	166.6	10	145	201.6
L cyl rough	OP20-7A	168	10	145	201.6
C/B oil drill	OP20-8A	174.6	10	184.6	201.6

job. As a result, the block is processed after every 229 s on this leg, thus setting the cycle time of the block to be 229 s. Also it is noted in Table II, that the times taken by STN5 and 7 are much less compared to STN8. Therefore, it is necessary to balance the operations of leg A of OP20.

The following assumptions need to be considered to balance the critical operations:

. task element times are deterministic;

. task times are dependent on the tools used to perform that operation; and

. trials are just done for any station on leg A, with the same results applied to any station for leg B.

Table III shows the cycle time of each tool of various stations of OP20. Table III shows that only station 4A (STN4) is above the required time by 27.4 s. At STN4, the highest cycle time (44 s) is taken by Tool 1, which performs long operation and machines a number of features. It mills the left hand and right hand sides of the bank face (which is the flat surface on top of the block). Moreover, it also mills the VIN PAD of the block. Another problem identified with this operation was the formation of burr on the machined part. It was decided to shift the complete operation of Tool 1 to the other suitable station.

However, there are some constraints, which were taken into consideration before moving of Tool 1. These include:

. since the cycle time for Tool 1 at STN4 is 44 s, it can be moved only to that station, which has a cycle time of at least 44 s less than the required cycle time;

. if this tool is moved to any other station, then the rest of the sequence of STN4 should remain the same so that the succeeding tool can be used; and

. the orientation of the component being machined at STN4 by Tool 1 should be the same as at the station to which the tool is going to be moved.

The operation succeeding Tool 1 is the spot face operation, and does not depend on previous operation and can be done without milling the bank face, or the VIN PAD. Operations at STN5 and STN7 have cycle times 56.6 s less than the required time. There are, therefore, two options of moving Tool 1 to either of these stations. Also STN5 and STN7 machine the cylinder block in the same orientation as that used at STN4. Therefore, considering all these constraints and the available options, it was possible to move Tool 1 to either STN5 or STN7.

It was decided to sequence Tool 1 from STN4 after Tool 3 of STN5, so that the initial sequence is not affected. After this new tool sequence, the cycle time for STN4 drops down from 229 to 185 s, and the cycle time for STN5 increases from 144 to 189 s.

After performing this change, all the stations were found to operate below the required cycle time, but still the production line could be more balanced by changing some of the tools in terms of tool geometry or tool material.

Tool 1 at STN3A is the Rough Milling Cutter, which rough mills the cylinder bore. This tool has a problem of formation of burr and thus is considered for replacement with a new test tool. Machining trials were performed with this new tool, which runs at high speed and feeds. Trials with the new tool provided positive result by further reducing the cycle time and eliminating the burr. Table IV shows the comparison of the tool specifications.

After changing to the new Tool 1, the overall cycle time of the STN3 was reduced from 198.6 to 172 s. The new Tool 1 machines an extra feature and also eliminates burr, and, therefore, saves the time, which was initially utilized to manually remove the burr after completion of the operation.

After performing the above operations and tool changes, the cycle times of all the operations are found to be more balanced and below the required cycle time. This is shown in Figure 2, which compares the cycle times of all five stations of leg A of OP20 after the line balancing. The figure shows that OP20 is now more balanced than existing operation as the cycle times of all operations are now more levelled. For OP20, the highest cycle time is now 189 s at STN5 in leg A (STN5A). This is well below the highest cycle time of 229 s, which was found at STN4 before the line balancing.

Line balancing of other two critical operations, OP30 and OP70, were also carried out using the same strategy as described above, as both have two parallel legs. In both cases, the exact differences in cycle times at each station were considered with the possibility of sequencing the tools or changing them with new tools. For OP30, the highest cycle.

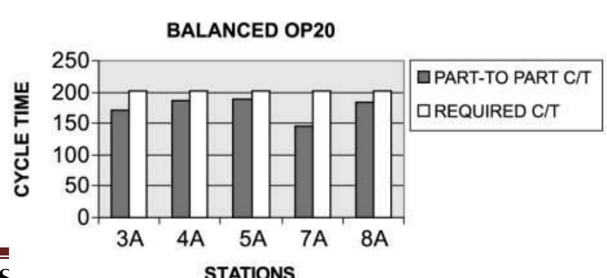
Table III Cycle time of individual tool of various stations of OP20

Stations	Cycle time (s) Tool 1	Tool 2	Tool 3	Tool 4	Tool 5	Tool 6	Tool 7	Too 8	Tool 9	Tool 10	Current cycle time (s)	Required cycle time (s)	Difference (s)
3A	25.39	21.70	20.82	16.05	16.19	12.63	18.74	13.70	39.10	14.24	198.6	201.6	3
4A	44.00	18.01	20.5	17.05	17.8	18.5	34.99	10.05	38.1	10.00	229	201.6	−27.4
5A	78.37	18.88	79.33								145	201.6	56.6
7A	78.88	19.25	79.85								145	201.6	56.6
8A	42.30	43.25	12.11	39.93	46.97						184.6	201.6	17

Table IV Comparison between the existing tool 1 and the new test tool 1 at STN3

Tool specifications	Comparisons data Existing tool 1	New test tool 1
Diameter of tool (mm)	110	100
Number of teeth	6	6
Revolutions (per min)	3,500	8,000
Cutting speed	1,200.0	2,500.0
Table feed	4,200.0	10,600.0
Feed/revolution	1.200	1.450
Feed/teeth	0.017	0.480

Figure 2 Cycle times at all stations after line balancing of OP20



time, after line balancing, was found to be 200 s in STN7, while the highest cycle time before balancing was 293.9 s at STN3. For OP70, the highest cycle time, after balancing, was found to be 199 s at STN3, while the highest cycle time before balancing was 210.3 s at STN4.

Analysing all the three operations of the cylinder block line, it was observed that OP30 has the highest cycle time in the whole line. Thus, after balancing the individual operations on all stations, the highest cycle time was found to be 200 s at STN7 of OP30. Thus after line balancing, the cycle time of cylinder block line was reduced from 293.9 to 200 s, an almost 32 per cent reduction.

4. SIMULATION OF CYLINDER BLOCK LINE

As the block line was very imbalanced initially, this has lead to less utilization of the machines and low throughput than required. The line was improved and balanced by the reduction of the process duration as talked about earlier. A PC simulation of the cylinder block line was performed utilizing the Simul8 software to evaluate the impact of reduction of the process duration on the throughput and machine utilization. The Simul8 simulation software allows the client to create a model utilizing components that speak to machines, cushions and parts.

The major information parameters utilized as a part of the simulation show are machine process duration, machine time between failure, machine time between repairs, travel time, entomb arrival times and batch estimate. As the machines in the OP20, OP30 and OP70 are all transfer machines, the total machining time incorporates the transfer time.For PC simulation of the block line in Simul8, the accompanying assumptions were made:

. one move every day with seven hours for each move, five days seven days;

. no meal breaks or tea breaks are considered in the move;

. the exponential probability distribution is adopted for the mean time amongst failure and mean time to repairs as the circumstances vary everyday in the current production;

. fixed probability distribution is adopted for process durations of the machines, as it remains constant in the current production;

. buffers are assumed to exist instead of the conveyors, as the software does not bolster conveyors totally; and

. travel times in the middle of the cushion and the succeeding operation is considered as insignificant.

Simulation models were created both for the current block line and also for the proposed block line obtained after line balancing and with the addition of third leg of operations. The original cylinder block line consists of a production line with 16 operations with several cushions in the middle of the operations.

The accuracy of simulation show was confirmed by comparing its throughput with the yield throughput of the block line. Throughput demonstrates what number of parts advanced through the production framework in a given interval of time. Utilizing the real time data of the info parameters, throughput was obtained from simulation show and was observed to be the same as obtained in the real framework. Both the actual existing line and the simulation show delivered the same throughput of parts every hour with the most noteworthy process duration of 293 s in STN3 of OP30. The simulation of the balanced demonstrated an increase of 65 for every penny in the throughput.

4.1 Machine utilization

Machine utilization is the ideal opportunity for which machine works. The impact of the reduction of process duration on machine utilization can be seen by studying the comparison of the working time, waiting time and blocked time of machines between the current block line and the balanced block line for each of the three main operations lines (OP20, OP30 and OP70).

Figure 3 demonstrates the comparison of machine utilization as far as machine working for the current line and the balanced line for each of the five stations of OP20. Figure 3 demonstrates that at all stations, machine utilization of OP20 has increased. The most elevated increase is found at STN5, where the percentage of machines working has increased from 48 to 95 for each penny because of balancing. The least increase is for STN4 at which the increase was from 76 to 93 for every penny. The line

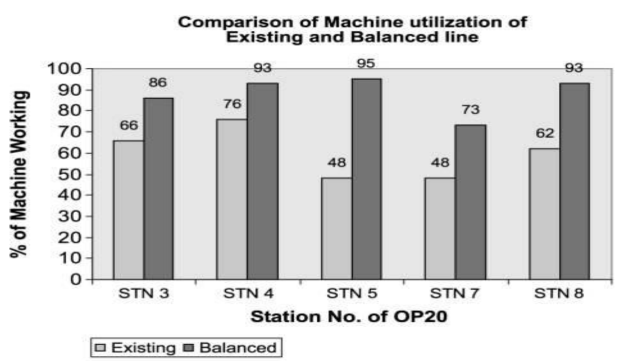


Figure 3 Comparison of machines working at all stations of OP20

balancing due to cycle time analysis has greatly improved the performance of machine utilization in OP20.

Figure 4 shows the comparison of blocked time of the machine for the existing line and the balanced line for each of the five stations of OP20. The machines are considered blocked in a case when the machine ahead of this machine undergoes a breakdown. For example, STN4 is blocked when STN3 undergoes a breakdown. Figure 4 shows that at all stations the percentage of machines blocked has greatly reduced due to line balancing of the production line. For STN7 and

STN8, there is no machine blocked in the balanced line, while there were 43 and 34 per cent machines blocked, respectively, in the existing line.

Figure 5 shows the comparison of waiting time for the existing line and the balanced line for each of the five stations of OP20. Machines show the waiting time when the machine ahead of it still processes the jobs and so it cannot accept any more jobs. Here, STN3 does not show any waiting time, as STN4 was not processing any job when STN3 completed its job. Figure 5 shows that at STN3, there is no waiting time for the machine, and at STN5, the waiting time has reduced from 14 to 3 per cent due to line balancing. But at STN7, the waiting time has increased due to STN8, which has a high cycle time compared to STN7. Also there is a slight increase in waiting time at STN8 due to similar reasons.

Figure 4 Comparisons of machine of blocked at all stations of OP20

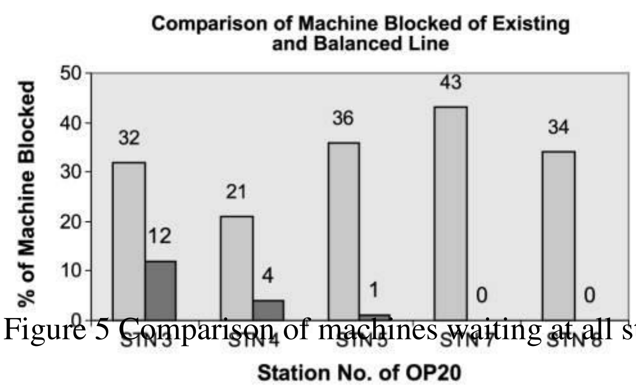
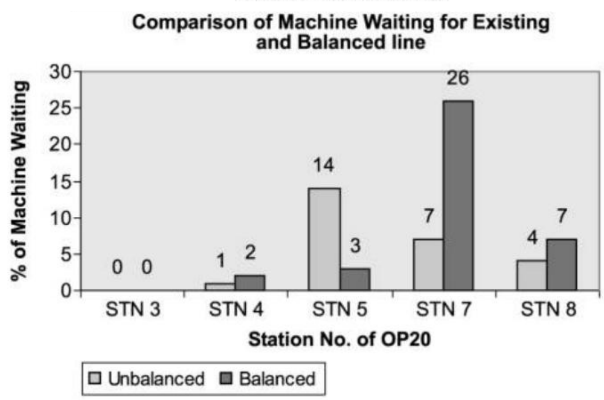


Figure 5 Comparison of machines waiting at all stations of OP20



Conclusions

This study has demonstrated that line balancing in an automated transfer production line can be achieved by re-sequencing of the cutting device operations and changing the cutting conditions of the instrument. Three major operations of the transfer line having most astounding process durations were distinguished as the critical operations and subsequently were decided for the optimization study. Amid the procedure, consideration was given to some technical and strategic constraints and at places assumptions were made because of lack of inadequate information.

Trials tests were performed with the new test tools proposed amid the optimization study. Line balancing brought about the process duration reduction by 32 for every penny on the production line. The balanced line also brought about increased throughput and higher machine utilization. PC simulation of the transfer line utilizing Simul8 software was utilized to evaluate the performance of transfer line when line balancing. With line balancing, the simulation demonstrate demonstrated an increase in throughput by 65 for each penny. Simulation study also demonstrated increased machine utilization and decreased number of blocked machines at all stations in the balanced production line. Additionally balancing of the line can be achieved by utilizing similar strategy and moving a portion of the tools starting with one operation then onto the next, which may additionally increase utilization of the machines.

REFERENCES

Askin, R.G. and Zhou, M. (1997), "A parallel station heuristic for the mixed-model production line balancing problem", International Journal of Production Research, Vol. 35 No. 11, pp. 3095-105.

Dolgui, A., Finel, B. and Vernadat, F. et al., (2005), "A heuristic approach for transfer lines balancing", Journal of Intelligent Manufacturing, Vol. 16, pp. 159-72.

Groover, M.P. (1996), Fundamentals of Modern Manufacturing: Materials, Processes and Systems, Prentice-Hall, Englewood Cliffs, NJ.

Miltenburg, J. (2002), "Balancing and scheduling mixed-model U-shaped production lines", International Journal of Flexible Manufacturing Systems, Vol. 14 No. 3, pp. 123-55.

Moodie, C.L. and Young, H.H. (1965), "A heuristic method of assembly line balancing for assumptions of constant or variable work element times", Journal of Industrial Engineering, Vol. 16 No. 1, pp. 23-9.

Nkasu, M.M. and Leung, K.H. (1995), "A stochastic approach to assembly line balancing", International Journal of Production Research, Vol. 33 No. 4, pp. 975-91.

Vilarinho, P.M. and Simaria, A.S. (2002), "A two-stage heuristic method for balancing mixed-model assembly lines with parallel workstations", International Journal of Production Research, Vol. 40 No. 6, pp. 1405-20.

Zhao, Z.Y. and De Souza, R. (2000), "Genetic production line-balancing for the hard disk drive industry", Int. J. of Advanced Manufacturing Technology, Vol. 16 No. 4, pp. 297-302.