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A CASE STUDY ON OPERATOR WORKLOAD BALANCING FOR ASSEMBLY STATIONS

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ABSTRACT
Workstation stability is one of the key requirements of any production industry. It gives smooth workflow in the shop and it is beneficial for the operators. In this article a detailed case study of an assembly process has been carried out for workload balancing of operators. The methodology used includes time study, process mapping, shifting of tasks and changing operation sequences. There are some important results obtained from which certain conclusions have been drawn about workstation stability. The results of the study can be further validated using simulation methods and can be implemented in the company.

KEYWORDS: Process mapping, productivity improvement, time study, workstation stability.

INTRODUCTION
In a production industry stability of a workstation plays a major role in successful development of product. The stability allows smooth workflow in the manufacturing shop. It is also beneficial to the workers because workers will get sufficient time to complete allotted tasks. The result of stability of the workstation indirectly improves quality of the product.

In case of sequence dependant workstations, the main objective of workload balancing is to develop a task sequence such that it will minimize the variation of workload between consecutive processing stations. Variation in the workload is the difference between a station with maximum work content in the system and all other stations in the system. This variation is nothing but cyclic idle time of a system. Hence to achieve maximum efficiency of the system it is necessary to minimize the variations in the workload of workstations in the system.

LITERATURE SURVEY
Zupan et al. (2015) have presented a case study on production line optimization using discrete event simulation methodology. With this the authors have obtained simulation model of balanced production line. This gave rise to production rate of process.

Roshani et al. (2015) proposes a mixed-integer mathematical programming model to solve the multi manned assembly line balancing problem. Using relationship equalities of multi-manned assembly line with a constant cycle time, the authors have obtained two different optimal solutions for two objectives such as cost oriented and time oriented objectives.

Grzechca et al. (2015) have presented a case study on line balancing. The authors have used splitting of tasks method and precedence graph which in their case improved the balancing without hampering the quality. This can also be done using process mapping method.

M L Bentaha et al. (2015) have reviewed line design as well as line balancing problems and their solution methods developed. Both deterministic and stochastic formulations for disassembly lines are considered in the review. The review is limited to line design and balancing under uncertainty.

Pandit et al. (2015) have presented a case study based on time and motion study. The article analyses bottlenecking problems arising in an assembly line and its solution for particular period of time. The results obtained can be evaluated using simulation methods.

METHODOLOGY
The detailed procedure that will be followed for workload balancing in the case study discussed is as described below:

First we must study the process flow of assembly. After that time required for each operation on each work station has to be calculated. Then mapping the processes will be done by changing the operation sequences or shifting the work content from highly utilized resource to less utilized resource. The idle time of the work station can be reduced by:

i. Calculating individual work content for each work station. Let's consider a case

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having two operators (operator A and B) for each work station. Time required to finish each assembly by operator A and operator B will be separately evaluated by conducting time study using stop watch method. To minimize the errors, three reading for each operation will be taken and average time will be considered for estimating the work content.

ii. Process flow sheets of operations carried out by operator A and operator B will be separately prepared. Calculated average work content will be added in each sheet.

iii. The total work content per cycle and idle time per cycle will be calculated separately for each operator.

The results will be displayed in graphical format and conclusions can be drawn based on present and proposed workload of assembly work stations

CASE STUDY

The studies have been carried out in the assembly section of generator manufacturing company. The name of the company is ABC Pvt. Ltd. (Note: The name of the company is not disclosed for confidentiality reasons. The company is working in engines and generator manufacturing business in India.) The case study focuses on only two subassembly workstations.

The case study is about operator wise work load analysis for assembly workstations. Individual workload of each operator is recorded during the studies. The sample process flow chart is shown in table 1. The process flow chart is prepared from process studies and after completing time study for the processes. The sample process chart shows type of the process and time required for each process in seconds.

Table 1: Sample Process Flow Chart

Sl no.	Description	Operation	Transport	Inspection	Delay	Storage	Time (in Sec)	Walk Distance (in Feet)
1	Wear all PPEs before starting the work assly.						30	2
2	Check app. Code.						30	
3	Check status of previous workstation assembly.						20	
4	Pick all tools required for assembly.						60	2
5	Check engine components aesthetically.						180	

The detailed operator wise time study report is tabulated in table 2, table 3, table 4 and table 5. The time mentioned in the time study report is average time of three readings.

Table 2 shows the detailed time study for operator A of coupling workstation.

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Table 2: Time Study For Operator A of Workstation Coupling

Sr. no.	Description	Time (in Sec)
1	Pick hand gloves from personal locker & cottons from consumable cupboard. Wear helmet.	30
2	Check the BOM availability on workstation of given plan. If there is no BOM copy then pick it from the team leader.	20
3	Select the engine as per plan & BOM.	50
4	Go to the tools trolley. Pick required tools.	60
5	Go near the selected engine, loose mounting bolts.	120
6	Pick check sheet from workstation & fill it as per parameter mentioned.	86
7	Pick required tools.	70
8	Go to the tools trolley. Pick component A.	10
9	Pick required tools.	15
10	Assemble component B with component A. Tight it.	87
11	Collect all sockets & spanners & keep it on tools trolley.	10
12	Loose drain plug of engine.	52
13	Pick lub oil tray & cotton.	36
14	Pick assembled component B and fit it to engine.	42
15	Tight it.	60
16	Clean the component B.	5
17	Keep the oil tray in its original location.	5
18	Keep the engine on the coupling fixture. Check whether the engine is properly rest or not.	100
19	Pick component C.	60
20	Fit component C to the crankcase.	80
21	Tight the fasteners.	60
22	Fit it on baseframe.	120
23	Tight the fasteners.	40
24	Pick component D and fit it to component C.	120
25	Tight all nuts of component D.	60
26	Select the alternator as per BOM.	13
27	Check the alternator aesthetically.	60
28	Remove alternator fasteners.	53
29	Pick alternator resting plate.	20
30	Remove the locking plates.	177
31	Clean the alternator by cotton.	86
32	Remove the side mesh of alternator.	106
33	Fill the check sheet.	90
34	Locate the disc of alternator to the flywheel of engine. Couple the alternator to engine.	105
35	Pick fasteners as per BOM in required qty.	60
36	Guide the alternator housing bolts.	319
37	Tight the housing bolts.	550
38	Apply torque and make white marker dot on it.	286
39	Fill the applied torque value in check sheet.	60
40	Remove engine fan.	107
41	Pick required tools from tools trolley.	40
42	Rotate the crank pulley manually.	120
43	Guide the inside coupling bolts.	265
44	Tight the bolts.	263
45	Apply torque and make white marker dot on it.	400
46	Keep the tools in tool trolley.	20
47	Fill the check sheet as per parameter mentioned.	20
48	Pick engine fan, fastener & fit it to engine.	210
49	Pick torque wrench.	24
50	Torque the fan bolts & mark the white dot on it.	33

51	Keep the tools in tools trolley.	13
52	Pick coupling register & make entry of engine-alt. coupling. Pick logical card & fill it. Fill the genset check list properly.	215
53	Remove the D-shackle from alternator & keep it to the storage area.	30
	Total Workload	**4786**

Description of the operation and respective average time taken for the operation is tabulated. Table 3 shows detailed time study for operator B of workstation coupling.

Table 3: Time Study for Operator B of Workstation Coupling

Sr. no.	Description	Average Time (in Sec)
1	Pick hand gloves from personal locker & cottons from consumable cupboard. Wear helmet.	30
2	Check the engine aesthetically.	260
3	Check the oil level of engine.	20
4	Pick the crane.	180
5	Hang the 2 slings of the belt.	90
6	With the help of remaining 2 slings hold the engine.	30
7	Check the engine parameters.	30
8	Keep the accessories box on control panel station.	20
9	Lift the engine by crane and bring the engine to the coupling fixture.	300
10	Keep the engine on the coupling fixture. Check whether the engine is properly rest or not.	100
11	Remove belts from the engine & position the crane.	60
12	Pick the cotton & clean the engine.	97
13	Pick engine fitment tools.	97
14	Pick D- shackle from its storage & attach to alternator lifting hook.	20
15	Pick the crane.	60
16	Bring the alternator to the assembly area.	218
17	Fit the alternator resting plate to the alternator manually.	108
18	Couple alternator to engine.	105
19	Pick fasteners as per BOM	60
20	Guide the alternator housing bolts.	319
21	Tight the housing bolts.	550
22	Apply torque and make white marker dot on it.	286
23	Ensure proper matching of disc holes with the flywheel.	120
24	Pick inside coupling bolts & washers as per BOM.	125
25	Guide the inside coupling bolts.	265
26	Tight the inside coupling bolts.	264
27	Apply torque and make white marker dot on it.	400
28	Pick alternator mesh & reassemble it to the alternator.	255
29	Remove D-shackle & fit it to alternator.	10
30	Pick crane from its location & hold coupling.	240
31	Lift the coupling by crane for mounting on baseframe.	660
32	Keep the crane on its original position.	20
	Total Workload	**5041**

Description of the operation and respective average time taken for the operation is tabulated. Table 4 shows detailed time study for operator A of workstation control panel.

Table 4: Time Study for Operator A of Workstation Control Panel

Sr. no.	Description	Average Time (in Sec)
1	Wear all PPEs before starting the work	30
2	Select a panel for assembly.	60
3	Check a control panel.	160
4	Match holes to baseframe.	110

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5	Pick bolts and washers fit on control panel tight them.	170
6	Select component A as per application code from storage area.	60
7	Cut the nylon rib on component A.	25
8	Loose the fasteners in control panel for connection of component A.	110
9	Remove the nuts from component A.	50
10	Insert the component A in control panel and fit nuts on it.	480
11	Then pick wires X,Y and fit them.	510
12	Tighten wires.	90
13	Insert the component A in terminal box.	180
14	Fit nut on component A and tighten it.	240
15	Loose nuts on alternator for fitment of component A.	60
16	Connect the component A with alternator as per sequence.	350
17	Tight all wires after fitting a nut and washers.	100
18	Insert component C in alternator and tighten it.	600
19	Pick component D and unpack from box.	180
20	Remove the screws in control panel for fitment of component D.	240
21	Pick component D and fit it in control panel.	200
22	Tighten the component D.	100
23	Connect the wires to component D.	360
24	Inspect the wires for fitment.	60
25	Pick component E and unpack from box.	30
26	Process E1.	100
27	Process E2.	60
28	Pick component E and Fit it on control panel.	120
29	Loose component E locks and then fit it to panel.	220
30	Tight the locks to component E fitment.	120
31	Connect all wires from control panel to component E.	815
32	Pick cables for assembly.	60
33	Pick bolts and assemble the cables and tighten the cable.	60
34	Pick white marker and mark it on cables.	30
35	Fill the checklist.	120
	Total Workload	**6230**

Description of the operation and respective average time taken for the operation is tabulated. Table 5 shows detailed time study for operator B of workstation control panel.

Table 5: Time Study for Operator B of Workstation Control Panel

Sr. no.	Description	Average Time (in Sec)
1	Wear all PPEs before starting the work.	30
2	First check the application code.	30
3	Check BOM.	30
4	Pick all tools for assembly.	120
5	Pick crane.	70
6	Lift down the belt crane towards the control panel and hang on it	50
7	Then lift the control panel.	180
8	Match holes on baseframe.	120
9	Pick bolts and washers fit on control panel tight them.	180
10	Remove alternator cover.	180
11	Pick alternator manual and check all required parameters.	180
12	Select component F as per application code and Fit it.	60
13	Process F1.	120
14	Pick component F and fit on alternator.	300
15	Tight all bolts properly.	120
16	Fit nut on component A and tighten it.	240
17	Pick component F plate.	30
18	Process F2.	180

19	Pick component G.	60
20	Insert component G in specific location.	5
21	Fit the component G in control panel.	240
22	Tight the nut in component G.	610
23	Insert component G in alternator and tighten it.	600
24	Couple the component G in alternator coupler.	240
25	Pick plate of component F and fit it on alternator.	290
26	Loose the nut on engine.	185
27	Insert the wiring on control panel and fit the nut.	470
28	Process G1.	110
29	As per requirement pick component H.	60
30	Process H1.	300
31	Process H2.	600
32	Check all assembly for surety of work.	180
	Total	**6170**

Suggestions

The time study of two workstations is evaluated above. The study needs to be balanced on the basis of workload. Following suggestions should be considered for balancing the workload.

i. In table 2 step numbers 37, 44 and step numbers 21, 26 from table 3 are carried out by both the operators A and B simultaneously. Operator A remains idle while operator B is tightening the bolt and vice-versa. If two tools are used for tightening, it can keep both operators working resulting into 50% reduction in the processing time.
ii. In table 4, step number 6, component A should be stored at control panel storage area. It can reduce 30 seconds of the operator A per cycle.
iii. The operation number 24 of operator B at coupling workstation (refer table 3) is shifted to operator A after operation number 34 (refer table 2).

RESULTS AND DISCUSSIONS

Based on above information tables for before and after condition are tabulated.

Before and After tables

Table 6: Before Condition

Before	
Workstation	**Average Time (Sec)**
Coupling(A)	5143
Coupling(B)	5398
Control panel(A)	6270
Control panel(B)	6170

Table 7: After Condition

After	
Workstation	**Average Time (Sec)**
Coupling(A)	5143
Coupling(B)	5398
Control panel(A)	6270
Control panel(B)	6170

Graphs

Based on table 6 and table 7, before and after condition graphs are plotted showing average workload time of each operator per cycle.

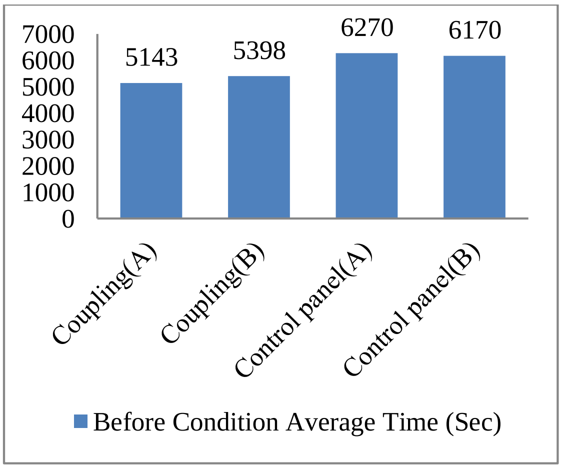

Fig. 1: graph showing workload before studies

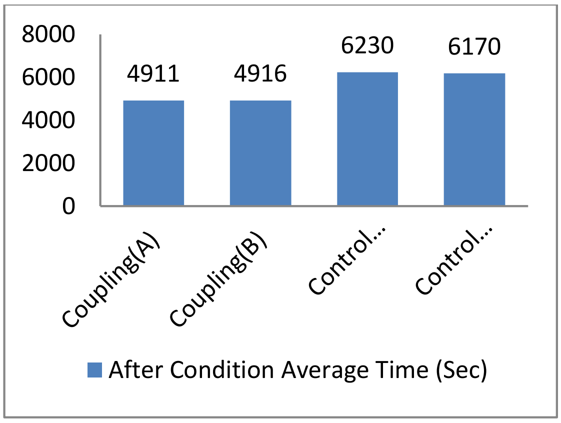

Fig. 2: graph showing workload after studies

Commentary on graphs and table

From table 6 and table 7 and based on Fig. 1 and Fig. 2 it is seen that:

For coupling station:

Total average workload time for operator A is 5143 seconds and total average workload time for operator A of workstation coupling after is 4911 seconds.The time is reduced by 232 seconds.

i. Total average workload time for operator B of workstation coupling before is 5398 seconds and total average workload time for operator B of workstation coupling after is 4916 seconds. The time is reduced by 482 seconds.
ii. Initially the time variation between workload time for operator A and B was 255 seconds and now it is 5 seconds per cycle.

For control panel station:

i. Total average workload time for operator A of workstation control panel before was 6270 seconds and Total average workload time for operator A of workstation control panel after was 6230 seconds. The time is reduced by 40 seconds for operator A.
ii. Initially the time variation between workload time for operator A and B was 100 seconds and now it is 60 seconds per cycle.

CONCLUSION AND FUTURE SCOPE

Based on above results, the productivity increase can be calculated. For coupling station the improvement in the productivity is 8.9% and it is 0.63% for the control panel station. Also, due to workload balancing the operators get more time which can be effectively used for the company. The method employed in this study is for balancing the workload within the single workstation. Further balancing can be done between the workstations to minimize time variations between the two stations. Also, results obtained in the above study can be validated using simulation methods and can be implemented in the industry.

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