ASSEMBLING LINES EQUILIBRATION EFFICIENCY

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Abstract: *The treated problem in this paper is to equilibrate and assembling line in order to obtain a desired cadence during the line functional duration, minimizing the workstations number, but still considering the precedence constrains. Usage of WinQSB and Flexible Line Balancing software aimed to follow to obtain an efficient equilibration of the production line accounting all the imposed restrictions.*

Key words: *efficiency, heuristically methods, optimisation, graph, cadence*

THEORETICAL NOTIONS

In the first decade of the XXth century made the appearance organizing the production lines in flow, especially after 1920, when took place an extension of the large scale and mass production in the industrial developed countries.

The base problem in organising these production lines in flow is to balance them.

But thus appears a series of problems bound to balancing, from which we can mention the different degree of technical endowment for the production line, operators' ability, grouping the phases in operations (the rhythmicity principle being just partially respected) or the tasks accomplish level.

Equilibration process supposes equalisation of all execution times. But very rare is possible to accomplish a perfect line equilibration, always appearing supplementary times at least to one operation.

In Neagu's conception, balancing a production line involves achieving several conditions, such as:

1. Splitting the process into independent phases;
2. Identifying and defining the restrictions concerning the grouping of phases in operations.
3. Establishing the minimum number of process operations and the number of posts for each operation.
4. Applying a method of balancing, as to achieve an effective balancing, taking into account the restrictions imposed;
5. Calculating line balancing efficiency.

The methods used in balancing technological lines are: exact methods and heuristic methods.

PROBLEM DATA

In the assembling workshop of a company currently has 6 workstations, denoted by A – F and 10 activities. The required productivity is of 1000 products/change, providing for a break of 20 minutes at mid-morning and another after lunch.

The processing times are presented in table 1.

Table 1

Working place name	Operations name	Operation times	Operation times summary
L1	A	1,1	1,1
L2	B	4	6,5
	C	0,5	
	D	2	
L3	E	0,3	0,7
	F	0,4	
L4	G	3,4	4,2
	H	0,8	
L5	I	0,7	0,7
L6	J	0,3	0,3
TOTAL		12,7	

The question arises in determining the minimum number of workstations and calculating the assembling line equilibration efficiency.

SOLVING THE PROBLEM USING THE WINQSB SOFTWARE

Production lines equilibration process supposes allocation of some activities on sequential working stations based on precedence relations between the activities. The objective is to fit in production time and demands using a minimal number of working stations.

The line cadence is the first parameter use as a starting point in the equilibration process.

This has to fit between:

$t_{max} \leq T \leq \Sigma\, t_i$

$4 \leq T \leq 12{,}7$

First, are introduced the problem specifications, respectively the type (Line Balancing), the optimization criteria, the problem title, the number of activities, the time measuring unit and the number of coordinates (2/3). The corresponding table is showed in figure 1.

Task Number	Task Name	Task Time in minute	Task Isolated (Y/N)	Immediate Successor (task number separated by ,)
1	Task 1	1.1	No	2,3,4
2	Task 2	4	No	5
3	Task 3	0.5	No	5
4	Task 4	1.2	No	6
5	Task 5	0.3	No	7
6	Task 6	0.4	No	8
7	Task 7	3.4	No	9
8	Task 8	0.8	No	9
9	Task 9	0.7	No	10
10	Task 10	0.3	No	

Fig.1. Table containing the problem input data

WinQSB offers three alternative solutions to solve this problem:

- Heuristic Procedure;
- Optimization method: "Best-Bud" search;

- Random generating: COMSOAL (COmputer Method of Sequencing Operations for Assembly Lines).

The "Best-Bud" search usually finds an optimal solution, which does not always happen with the heuristic methods.

Solving COMSOAL randomly generates a number of solutions and chooses the best. The procedure ends if an optimal solution has been found.

In the present case the COMSOAL solution is chosen (figure 2).

03-12-2013 15:35:24	Line Station	Number of Operators	Task Assigned	Task Name	Task Time	Time Unassigned	% Idleness
1	1	1	1	Task 1	1,10	3,30	75,00%
2			4	Task 4	1,20	2,10	47,73%
3			3	Task 3	0,50	1,60	36,36%
4			6	Task 6	0,40	1,20	27,27%
5			8	Task 8	0,80	0,40	9,09%
6	2	1	2	Task 2	4	0,40	9,09%
7			5	Task 5	0,30	0,10	2,27%
8	3	1	7	Task 7	3,40	1	22,73%
9			9	Task 9	0,70	0,30	6,82%
10			10	Task 10	0,30	0	0,00%
	Solved by	COMSOAL	Type	Generation			

Fig.2. The solution table – COMSOAL

The solution can be presented synthetically (figure 3).

03-12-2013	Item	Result
1	Desired Cycle Time in minute	4,40
2	Number of Line Stations	3
3	Number of Required Operators	3
4	Total Available Time in minute	13,20
5	Total Task Time in minute	12,70
6	Total Idle Time in minute	0,50
7	Balance Delay (%)	3,79%
	Optimal Solution has been obtained by	
	COMSOAL Type Random Generation	
	Number of Solution Generated: 100	

Fig.3. The problem results presented synthetically

The optimal way to place the assembly line stations are presented graphically as shown in figure 4.

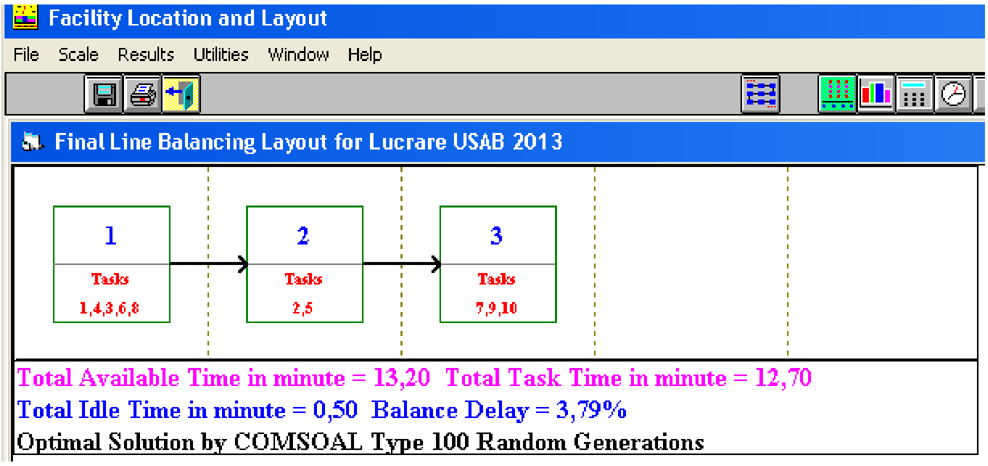


Fig.4. Working stations location according to COMSOAL

It can be noticed that the optimal solution involves using 3 workstations on which the 10 activities will be assigned as in figure 4. The available time for a cycle is 13,2 minutes, of which 12,7 minutes represents the duration of activities, and 0,5 minutes represents the stationary time for the production cycle.

The efficiency of the production cycle (figures 3 and 4) is:

E_f = (Total Task Time / Total Available Time) x 100 = (12,7/13,2) x 100 = 96,21%

and the delay of the production cycle is:

(0,5/13,2) x 100 = 3,79%.

Using the heuristic methods offered by WinQSB is obtained the same production cycle efficiency in our case.

SOLVING THE PROBLEM USING THE FLEXIBLE LINE BALANCING SOFTWARE

The initial situation of the production line after entering input data under matrix form, having the graph associated to the problem (figure 5), shows an efficiency of the line by 79,4% (figure 6).

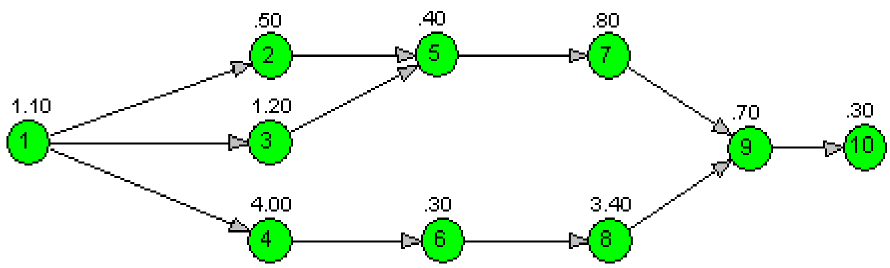


Fig.5. Graph associated to the problem

At an cadence of 4 minutes, an efficiency of 79,4% (fig.6), is obtained, working on 4 workstations, at an cadence of 4,4 minutes, the number of the workstations is reduced to 3 (fig.7), and efficiency increases to 96,2%.

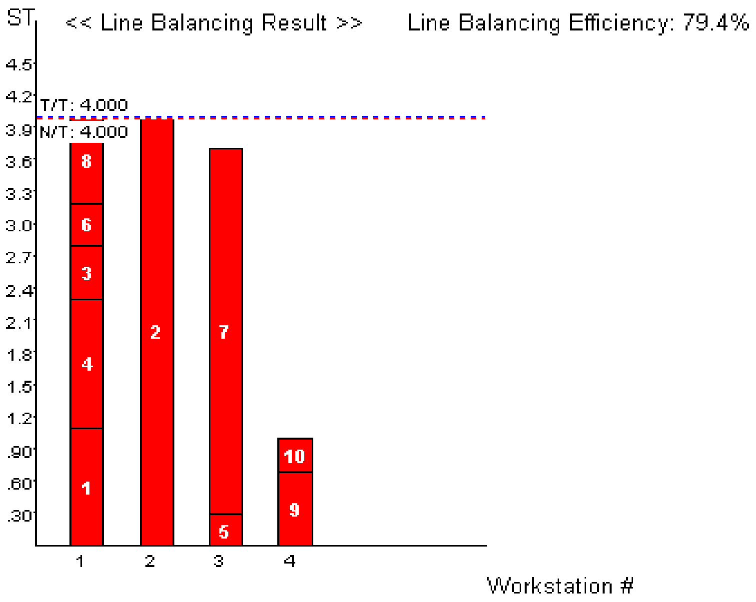


Fig.6. Graphical representation of the operations on positions to a 4 minutes cadence of the lines

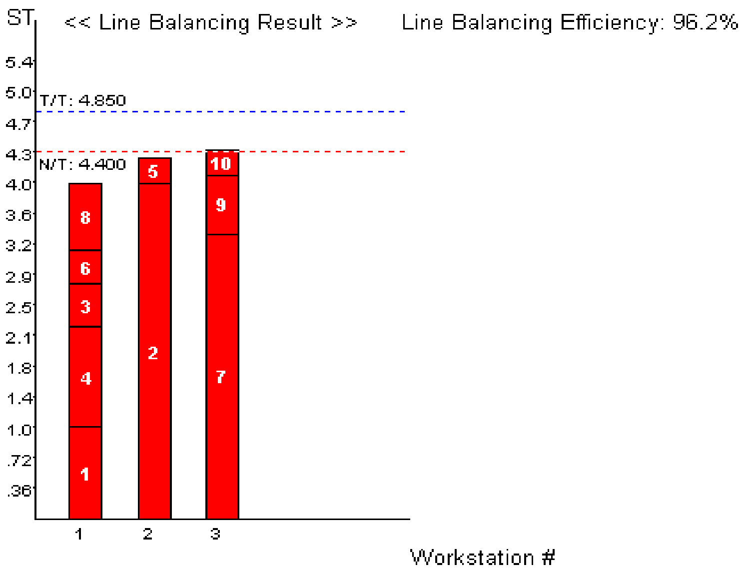
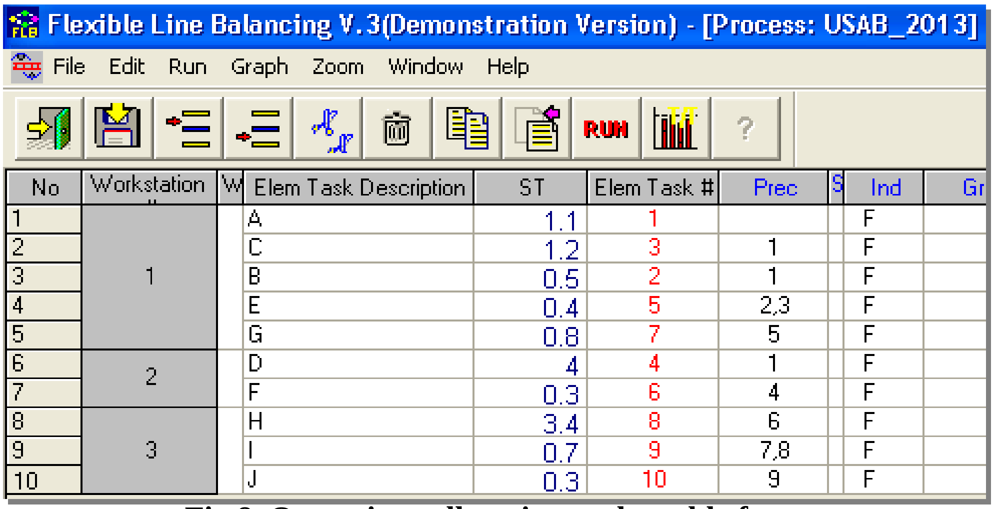


Fig.7. Graphical representation of the operations on positions at an cadence of the lines of 4,4 minutes

Operations allocation on the three working station is highlighted in figure 8.



No	Workstation	W	Elem Task Description	ST	Elem Task #	Prec	S	Ind	Gr
1	1		A	1.1	1			F	
2			C	1.2	3	1		F	
3			B	0.5	2	1		F	
4			E	0.4	5	2,3		F	
5			G	0.8	7	5		F	
6	2		D	4	4	1		F	
7			F	0.3	6	4		F	
8	3		H	3.4	8	6		F	
9			I	0.7	9	7,8		F	
10			J	0.3	10	9		F	

Fig.8. Operations allocation under table form

CONCLUSIONS

Using one of the alternative solutions offered by WinQSB software, namely COMSOAL, in order to solve this problem, the 10 activities are allocated only on 3 working stations, in difference to the actual situation which has 6 working stations. The available time for a cycle is 13,2 minutes, from which 12,7 minutes represent the activities duration.

The production cycle efficiency is high, namely 96,21%, even ideal would be100%, possible to reach only in theory, practically not.

The solution offered by Flexible Line Balancing software revealed exactly the same result for the case of 4,4 minute cadence.

In both cases the production cycle efficiency is 96,21%.

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