USING FITNESS FUNCTION TO SOLVE TWO-SIDED ASSEMBLY LINE BALANCING BY SPREAD SHEET

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Abstract— In this paper, the solution of two-sided assembly line balancing is conducted by using spread sheet model, in order to simplify the complex problem by way of simple code. The fitness function has been executed to evaluate the variety of solutions of two-sided assembly line balancing. With the objective to minimize the number of work stations, the random rule is run up to the maximum number of iterations, using the proposed method with different cycle times. The relation between fitness values and number of work stations were evaluated and presented in graph.

Keywords— Two sided assembly line balancing, spread- sheet, fitness function.

I. INTRODUCTION

Assembly line is widely used in various production systems. The goals of introducing an assembly line into a plant are to maximize efficiency and keep optimum costs. The problem related to optimally distributing assembly tasks among all workstations with respect to certain objectives, is called an assembly line balancing problem (ALBP). Assembly line can be one-sided or two-sided. One-sided assembly lines are most widely studied in ALBP while less attention is paid to two-sided assembly line balancing problems (2-SALBP). The 2-SALBP is an extension of simple ALBP when different assembly tasks are carried out on the same product, in parallel, on both left and right-hand sides of the line. Compared to simple assembly line, two-sided assembly lines can shorten the line length, lower the cost of tools and fixtures, and reduce material handling and operator movement [1]. Therefore, the 2-SALBP has prominent research significance and practical value.

In spite of these preface benefits, some complex restrictions exist when balancing two-sided assembly lines, such as operation direction constraints, positional, positive–negative zoning constraints, and synchronous task constraints. Hence, the 2-SALBP is much more complex and the development of new balancing techniques is needed. The design and balancing of two-sided assembly lines was first studied by Bartholdi [1] using a balancing algorithm based on the first-fit rule (FFR). A Genetic Algorithm (GA) was applied to solve 2-SALBP with positional constraints [6] [7]. A branch and bound was introduced as an algorithm to minimize the line length of a two-sided assembly line [16]. The station-oriented enumeration algorithm that was integrated with the Hoffmann heuristic was also developed to solve 2-SALBP [4]. The first attempt to show how an Ant Colony Heuristic (ACH) could be applied to solve 2-SALBP with zoning constraints was discussed in 1998 [2]. Tabu Search (TS) algorithm for 2-SALBP considering line efficiency and smoothness index as performance criteria was also introduced [9]. The proposed pre-emptive goal programme for precise goals and a fuzzy goal programme for imprecise goals were developed to minimize the number of work stations [10].

A Mixed Integer Programming (MIP) model was also investigated and proposed with a Simulated Annealing (SA) algorithm for solving 2-SALBP to minimise the number of mated stations [11]. Simaria and Vilarinho (2009) presented an Ant Colony Optimization (ACO) algorithm to address the mixed-model 2-SALBP, and built a balancing solution that considered precedence, zoning, capacity, and side and synchronism constraints [15].

The first Bee Algorithm (BA) application to 2-SALBP and employed fuzzy mathematical programming were presented to solve the two-sided assembly-line balancing problem with zoning constraint so as to minimize the number of stations for a given cycle time. An extensive computational study was carried out and the results were compared with the results of several algorithms from the literature such as ant colony optimization and tabu search.

The two-sided assembly-line balancing problem is considered more realistic by employing positional, zoning and synchronous task constraints and by utilizing fuzzy approaches so as to maximize both work slackness index and line efficiency and minimize total balance delay. Bees Algorithm was used as a search mechanism for obtaining good solutions, extensive computational results were then presented [13].

Several researchers introduced a mixed integer, non-linear programming model for fully constrained in order to describe the problem formally. Due to the complexity of the problem, swarm intelligence based bee algorithm and Artificial Bee Colony (ABC) algorithms were implemented to evaluate the performance. However, the addition of positional, zoning and synchronous task constraints constitute the problem to be much more complex and these factors were important for practical applications. The extensive computational study results indicate that BA and ABC Algorithms obtained approximately the same results [8] [12].

A simple efficient approach was introduced to implement the line balancing problem in spread-sheets by array formula to provide an interesting and easily understood technique [14]. The array formula approach with an interesting simple precedence coding system were combined to present an efficient spreadsheet for performing assembly line balancing using priority rules method. This paper presented task coding to show completed tasks and to ensure the task will not be scheduled a second time [5]. The simple assembly line balancing by spreadsheet has been modified to accommodate the methodology for solving two-sided assembly line balancing problem. In addition, random task selection was added to conventional priority rules to present the effect of multi-solutions on two-sided assembly line balancing. Tests were conducted to evaluate the performance of the spreadsheet methodology and the random priority rule had generated better performance results for the two-sided assembly line balancing problem [3].

Referring to the literature review, no published paper has dealt with solution of two-sided assembly line balancing problems in spreadsheet using Artificial Bee Colony algorithm with a simple coding system. This paper presents the result of using such system for solving the 2-SALBP. The organization of this paper is as follows: the next section illustrates fitness function in spread sheet method. Section 4 discusses the results and last section present conclusion.

II. FITNESS FUNCTION IN SPREAD-SHEET MODEL

A. Fitness function

The study on two-sided assembly line balancing has generally focused on minimizing the number of stations according to a definite cycle time, known as type-1. The objective of two-sided ALB measured in this work is to minimize the number of stations for given cycle time. However, given two different solutions with same number of work stations, one may be better balanced than other. Hence we used a fitness function that consists of two objectives, ie-minimizing the number of work stations and obtaining balanced work station.

Fitness function is formally defined as in Eq. (1). [7]

$$f = 2\sqrt{\frac{\sum_{k=1}^{n}(ct-Sk)^{\wedge}2}{n}} + \frac{\sum_{k=1}^{n}(ct-Sk)}{n} \qquad (1)$$

Where: n is the number of stations,
ct is the cycle time, Sk is the kth station time.

The first part of fitness function aims to find the best balance among the solution that have the same number of stations while the second part minimize the number of stations in the solutions since the first objective is arbitrarily assumed to be more critical than the second, it is multiplied by two.

B. Two-sided assembly line balancing

The two-sided assembly line balancing has two parallel production lines, on the left and right sides. In production line for a single product, tasks can be simultaneously assigned to corresponding stations, and some specific tasks can be defined for assigned to matching stations, and some specific tasks can be defined for assignment to a specific side. For example, if a task is defined as a left side (L) or right side (R) task, it can be assigned to the station of the left side or right side of the production line consequently. Tasks defined as either side (E) can be assigned to either the left or right side of the production line. Moreover, tasks can be appropriately assigned to stations on both sides for synchronized assembly, thus reducing idle time without conflicting with the requirement. The stations of the left and right of the production line are known as mated-stations (positions), and are of the same in the cycle time, meaning one side has a companion relationship with the station on the other side. In Fig. (1), the number in brackets represent task time, the English alphabets represent the task assignment direction (L: left side; R: right side; E: either side), the numbers in circles represent task number, the arc is the process assembly precedence, and the total task time is 25 units. The spread sheet model is applied on two-sided assembly line balancing to make efficient and easy coding rather than other complex programming languages.

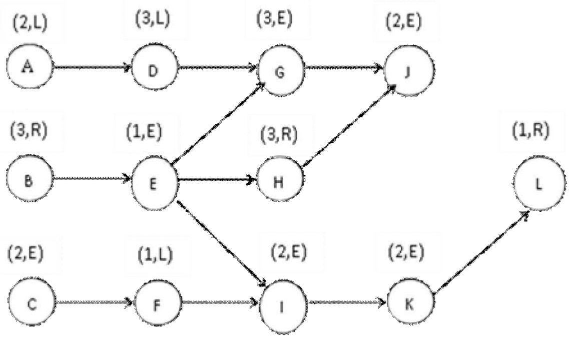


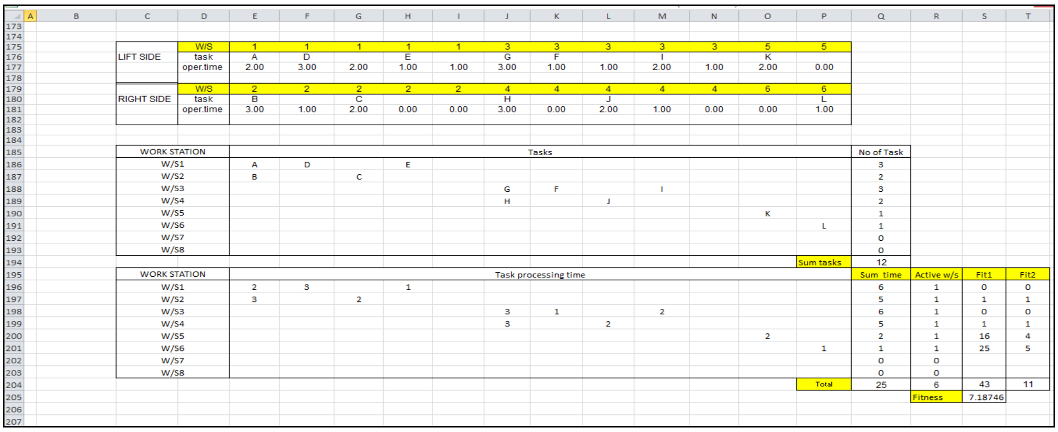
Figure (1) Example of a two-sided line balancing problem

C. Calculation of fitness function

Referring to literature review work on two-side assembly line balancing by Bareduan and Elteriki (2015), they applied balancing on two-sided without considering fitness of 2SALB. To compare between many solutions with different parameters, this work introduces the fitness function (1) in spread sheet to show the significance deferent between solutions and choose the feasible one which has minimum fitness value, especially if the solutions have the same work stations. Fig. (2) illustrates one solution of the problem shown in the network of Fig. (1). The steps involved are assigning the tasks to stations on both sides, calculate the tasks operation times in every station, subtract total operation time from cycle time and apply the results on equation (1) to get fitness of solution of two-sided assembly line balancing.

D. Computational results in spreadsheet

The assigning of tasks on left side appear in cells E176 to P176. Similarly on right side is from cells E180 to P180. To calculate the fitness function of this solution, the tasks and operation times should be rearranged corresponding to work station before calculating total idle times to every work station. Then the fitness can be calculated as shown in Fig.(2) in cell S205.



		E	F	G	H	I	J	K	L	M	N	O	P
LIFT SIDE	W/S	1	1	1	1	1	3	3	3	3	3	5	5
	task	A	D		E		G	F		I		K	
	oper.time	2.00	3.00	2.00	1.00	1.00	3.00	1.00	1.00	2.00	1.00	2.00	0.00
RIGHT SIDE	W/S	2	2	2	2	2	4	4	4	4	4	6	6
	task	B		C			H		J				L
	oper.time	3.00	1.00	2.00	0.00	0.00	3.00	0.00	2.00	1.00	0.00	0.00	1.00

WORK STATION	Tasks												No of Task
W/S1	A	D		E									3
W/S2	B		C										2
W/S3						G	F		I				3
W/S4						H		J					2
W/S5											K		1
W/S6												L	1
W/S7													0
W/S8													0
												Sum tasks	12

WORK STATION	Task processing time												Sum time	Active w/s	Fit1	Fit2
W/S1	2	3		1									6	1	0	0
W/S2	3		2										5	1	1	1
W/S3						3	1		2				6	1	0	0
W/S4						3		2					5	1	1	1
W/S5											2		2	1	16	4
W/S6												1	1	1	25	5
W/S7													0	0		
W/S8													0	0		
												Total	25	6	43	11
														Fitness	7.18746	

Figure (2) Example of fitness calculation in two-sided line balancing problem

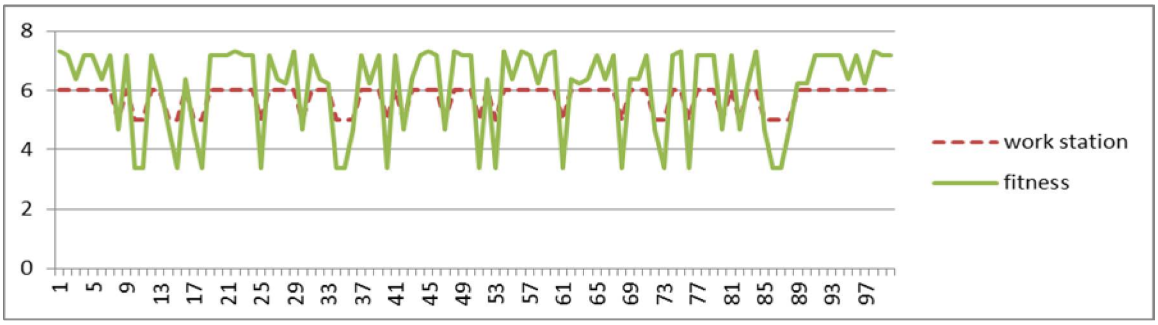


Fig. (3) The relation between work station and fitness

Table (1) the range of fitness value with ideal time and statistical parameters

Cycle time	Work stations	Total ideal time	Min. fitness value	Ideal time/workstation		Max. fitness value	Ideal time/workstation	
				mean	Standard deviation		mean	Standard deviation
5	6	5	2.994	0.833	0.752	4.199	0.833	1.602
6	5	5	3.366	1.000	0.707	4.687	1.000	1.732
	6	7	6.230	1.167	1.397	7.310	1.167	2.228
7	4	3	2.480	0.750	0.500	2.980	0.750	0.957
	5	10	6.190	2.000	0.707	6.060	2.000	2.422
	6	17	9.400	2.833	1.834	10.44	2.833	2.786
8	4	7	5.632	1.750	0.957	6.946	1.750	2.217
	5	15	10.848	3.000	2.828	11.432	3.000	3.240

III. DISCUSSION OF RESULTS

The example problem in Figure (2) was used to generate several solutions, and calculation of fitness in two-sided assembly line balancing solutions using a spreadsheet. Using the cycle time of 6 minutes, the solutions have different work station corresponding to fitness results, the minimum work station is 5 related to minimum fitness of 3.366 among 100 trial limit.

The graph in Fig. (3) Shows the direct proportional relation between the number of work stations and fitness through the number of trial. The correlation value is 0.94. Table (1) illustrates statistical analysis by spread sheet, the minimum fitness value with minimum work stations have low standard division of idle time, which means upright balancing of each work station.

CONCLUSION

This paper introduced an effective approach for calculating fitness function in spread sheet to get feasible solution of two-sided assembly line balancing. The two-sided assembly line dealt with in this paper are simple in that it considers the spread sheet coding , easy for obtaining new solutions with deferent results such as number of stations and fitness value. There is direct relation between number of work stations and fitness value among number of runs with fixed cycle time. The solution has minimum fitness function as well have good distribution of idle time among workstation. For future work, it is worth to consider application of other constraints such as position, zoning and synchronous on two-sided assembly line balancing in spread sheet to make it more applicable in meta- heuristic.

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