Optimization of Assembly Line Balancing with Resource Constraint using NSGA-II: A Case Study

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Abstract**—***Abstract Assembly line balancing type-e problem with resource constraint (ALBE-RC) is an attempt to assign the tasks to a minimal number of workstation with minimum cycle time by considering the resource constraint. Due to rapid growth in manufacturing and limited number of resources in industry, all the tasks that used the same resources will be performed in the same workstation such that the precedence relations are not violated. In this work, an implementation of an elitist non-dominated sorting genetic algorithm (NSGA-II) is proposed to optimise ALBE-RC case study. An industrial case study was conducted in an electronic company and a product known as HM72A-10 series model has been selected for the case study. The results from the optimization shows that the number of workstations are extensively decreased as well as the number of resources used. The improvement of line efficiency, busy and idle time also indicates that the optimization results are better that the existing one. The validation from industrial expert provides evidence that the proposed method is applicable and can be implemented for line balancing.*

Keywords—Assembly Line Balancing, Type-E, Resource constraint, NSGA-II.

I. INTRODUCTION

An assembly line is one of manufacturing process comprises of a sequence of workstation in which a set of necessary task to assemble a product are performed. The aim of line balancing is to assign the tasks to an ordered sequence of workstations, such that the precedence relations are not violated and some performance measures are optimised (eg: maximise the line efficiency, minimise the number of workstations and minimise the cycle time). ALB is the decision problem of optimally partitioning the assembly tasks among the workstations related to some objectives [1]. Previous researchers make an assumption that any of assembly task can be performed and can be assigned to any workstation [2-5]. However, in reality each workstation has their own capabilities and specialization.

To the best of author knowledge, there is only a small number of research which consider resource constraint in ALB works [6-9]. Interestingly, none of them consider resource constraint in assembly line balancing type-e (ALB-E) problem itself. Most of previous researcher used traditional GAs as an optimization technique in ALB problem [10-12]. Yet, the implementation of NSGA-II in ALBE-RC has not been given great attention by the researchers [13]. In this work, assembly tasks that used the same resources i.e. machine, tool, and worker will be assigned in one workstation according to the precedence and cycle time constraint. Deb et al. introduced NSGA-II to accommodate a complex and real-world optimization problem for multi-objective function [14, 15]. Besides than incorporate elitism-preserving technique, NSGA-II also has the capabilities to find better solutions.

This paper presents an optimization of assembly line balancing type-E problem with resource constraint (ALBE-RC) on a selected industrial case study by using NSGA-II. The case study was conducted in an electronic company, which produced electronic components in Malaysia.

II. ELITIST NON-DOMINATED SORTING GENETIC ALGORITHM (NSGA-II)

Elitist Non-dominated Sorting Genetic Algorithm (NSGA-II) is an optimization algorithm developed by Deb et.al in the year of 2000. This algorithm was developed based on evolutionary algorithm, with modification in determining the leader in evolution process. Instead of having the best solution leader, the NSGA-II calculate the Crowding Distance to determine the leader [14-16].

NSGA-II procedure starts with initializing a random population P_i of size N_{pop}. The algorithm is then decoded into feasible sequences using topological sort. The fitness of feasible chromosomes is calculated by evaluate the objective functions. Later, a non-dominated sorting approach is applied to generate Pareto-optimal set. The entire population is sorted using non-dominated sorting approach to identify the non-dominated set $F = (F_1, F_2, \ldots, Fi)$. The parent population is filled with set F according to non-domination rank. If $F > N_{pop}$, the last front will be selected based on higher crowding distance (*CD)*. Since NSGA-II used the selection strategy based on crowding distance, it will gives an estimation of the density of selected solutions. The tournament competition between two random-pair of solutions from parent population is performed to determine the domination rank. The population will be sorted in decreasing rank of level according to each objective function. Solution with better rank is filled in parent pool. Meanwhile, the solution with the same rank but remains in a less crowded area will be selected. The tournament selection is repeated until the parent pool is fully occupied to generate children. New offspring population Q_i of size N_{pop} is generated from P_i by crossover and mutation