Assessment of Integrated Assembly Sequence Planning and Line Balancing Optimization Using Metaheuristic Algorithms

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***Abstract*—In assembly optimization, there has been an integration of Assembly Sequence Planning (ASP) and Assembly Line Balancing (ALB) optimization, taking into account the advantages of improved solution quality, reduced error rates, and faster time-to-market for products. Previously, only a limited number of publications explored the integrated ASP and ALB optimization. These studies primarily compared the performance of algorithms within the Genetic Algorithm and Ant Colony Optimization classes. Moreover, the number of test problems used in these works was restricted to only three problems. In an ideal scenario, the efficacy of an algorithm can only be deduced when it is tested across a wide range of problem types. In this paper, the performance of six different metaheuristic algorithms for optimizing integrated ASP and ALB are compared. These algorithms include Genetic Algorithm (GA), Ant Colony Optimization (ACO), and Particle Swarm Optimization (PSO). To rigorously test these metaheuristic algorithms, 45 test problems of various sizes were employed to evaluate their performance across different categories. The results show that ACO outperforms in larger-sized problems, while PSO exhibits potential to be explored further due to its satisfactory overall performance in terms of solution quality and distribution.**

Keywords—Assembly sequence planning, line balancing, metaheuristics, manufacturing system, optimization

I. INTRODUCTION

In the past few years, there has been an emergence of diverse multi-objective optimization techniques aimed at addressing assembly optimization problems [1]. This growing interest among researchers in assembly optimization can be attributed to its complexity and its relevance in tackling real-world industrial issues. Researchers have classified assembly optimization research according to different stages of product development and production [2]. Particularly, Assembly Sequence Planning (ASP) and Assembly Line Balancing (ALB) have been identified as crucial activities within assembly optimization, as they significantly influence the efficiency of assembly processes.

ASP entails the arrangement of a specific assembly sequence for a product based on planners' heuristics and the product design description [3], [4]. Its primary objective is to determine the most optimal sequence for assembling a product from all feasible assembly sequences.

After achieving the optimal assembly sequence through ASP, the subsequent step involves allocating assembly jobs to workstations while ensuring a balanced workload across them. This process is known as Assembly Line Balancing (ALB), which aims to optimally distribute the assembly tasks among the stations, considering specific criteria [5], [6]. The main goal is to achieve equal or nearly equal workloads across all workstations, making it a crucial planning activity in production lines [7]. ALB focuses on identifying the optimal combination of assembly jobs that leads to a well-balanced workload across the workstations, aiming to achieve equal or nearly equal workloads [8].

Traditionally, ASP and ALB tasks were done separately due to their distinct roles in product development. However, with the demand for shorter product life cycles and increased competitiveness, manufacturers are now integrating certain activities to remain competitive. The integration of ASP and ALB in assembly optimization offers benefits like enhanced assembly plan quality, reduced manufacturing costs, and minimized planning errors [9]. Moreover, it accelerates time-to-market, supporting competitiveness [10].

As far as the authors are concerned, Genetic Algorithm (GA) and Ant Colony Optimization (ACO) are the primary techniques proposed for optimizing integrated ASP and ALB. Chen introduced a hybrid approach that combines GA with heuristic search for this purpose [11]. Similarly, Tseng and Tang explored the combination of ASP and ALB using a Genetic Algorithm, focusing on assembly "connectors" or the connector basis [10]. Researchers later adopted Hybrid Evolutionary Multi-objective Algorithms (HEMOA) based on GA [12]. On the other hand, Yang et al. (2013) proposed using ACO to optimize this problem, but they did not conduct any computational experiments to validate their concept [13]. Furthermore, another study by [14] presented ACO with consideration for the time required to move heavy parts in the workstation.

This study conducts a comparative analysis of various algorithms for optimizing multi-objective ASP and ALB. In addition to the GA and ACO algorithms, which have been proposed for this optimization task, the Particle Swarm Optimization (PSO) algorithm is also considered. PSO is a well-known algorithm used for individual ASP and ALB optimization [9]. The motivation behind this work lies in the advantages of integrating ASP and ALB and the curiosity to