Heuristic Based Approaches to Solve Cells Formation Problem in Cellular Manufacturing Systems

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English summary

To compete, companies try to improve their response to accelerated market changes continually. So a single manufacturing system isn't enough to achieve this fast response. Integrating more than one manufacturing system will give more flexibility and minimal costs. Family of parts are allocated to production cells, which are formed of homogenous sets of equipment, in cellular manufacturing systems (CMSs). When using typical CMSs, each cell is dedicated to the production of a certain product family, which reduces the amount of material handled and the amount of effort in process. But despite this, such systems are unable to meet the current market demands for a dynamic component mix and production agility. Recently published work addresses the notion of incorporating features from the growing reconfigurable manufacturing paradigm into CMS design, resulting in the reconfigurable cellular manufacturing system (RCMS) concept. In the design of industrial systems, facility layout design (FLD) is a critical consideration. The configuration of conventional systems often changes once the basic design has been completed. As the market's needs change more often, layout configurations must be adaptable enough to reconfigure the arrangement of resources to meet new production requirements while minimizing material handling and maximizing savings.

As a result, the goal of this thesis is to provide a design methodology for cellular and reconfigurable manufacturing systems that may be used in the real world in a variety of applications in industry. The whole study strategy is participatory and cooperative with two case industries with manufacturing properties. Practical relevance and novelty of results are both important criteria, which draws on both prior research as well as practical experience. The research process includes data collection and analysis as well as an organizational action to ensure both these criteria are met. Consequently, multiple research methodologies are adopted to meet unique research issues that occur over the long-term evolving partnership with the case firms. The research methodologies employed comprise systematic literature reviews for establishing conceptual specifications for the methodology, in-depth case studies, The research in this thesis proposes an interactive methodology for the facility layout design (FLD) in the context of the integration between the reconfigurable manufacturing system (RMS) and the dynamic cellular manufacturing system (DCMS).

Firstly, the thesis proposes a heuristic-based two-stage approach to tackle the CMS-related problems. In the first stage, a mathematical model is developed to concurrently solve cell formation and workers' assignment problems (CFWAP). The worker's selection is determined by their performance in operating a machine for a specific part, measured by the defect rate resulting from assigning the worker to a machine. The model's objective is to minimize the weighted sum of the total inter-cell, intra-cell movements, operation, and defect costs. In the second stage, based on the output of the mathematical model in the first stage, a nonlinear mathematical model is developed to solve the problem related to the layout design of the cellular

manufacturing system (LDCMS). The actual dimensions of machines and the aisle distances between them are considered in LDCMS to find out the best possible allocation of the machines and cells within the entire system. A comparison is conducted between numerical examples from the literature to show the efficiency and the validation of this two-stage heuristic approach. The results show that the proposed method can optimally tackle the aforementioned CMS-related problems within a reasonable time. To the best of our knowledge, this is the first study that integrates the CFWAP with LDCMS, considering all these practical and manufacturing features. It should be noted that the proposed approach has been applied as a real case study for a central workshop on die manufacturing company in Egypt. The results depict a significant reduction in the company's total associated costs by achieving up to 23% savings from applying the proposed method.

Secondly, an RMS problem was formulated by a comprehensive mixed-integer nonlinear model (MINLM) to minimise several cost components, like procurement of base machines and their auxiliary modules, operation and set-up costs, reconfiguration and relocation costs, and material handling costs. By incorporating several manufacturing attributes and industrial factors such as alternative processing routes, lot splitting, operation sequence, machine dimensions, and aisle distances. It should be noted that the proposed approach has been applied as a real case study for a leaf spring manufacturing company in Egypt. The results depict a significant reduction in the company's total associated costs.

The presented thesis uses three approaches to solve each proposed model. The first approach is the exact solution method, which uses the branch and bound algorithm to find the optimal solution. The second approach is a novel heuristic method developed to get the optimum allocation of resources in the system (i.e. machines, parts, and workers) in a reasonable time. The third approach uses a meta-heuristic method-based genetic algorithm to find optimal and near-optimal solutions for larger problem sizes. A comparison between these three approaches is conducted. Finally, two different real-life case studies are used to verify and validate the applicability of the proposed model.

The results show that the model is a general and applicable model that satisfies and is compatible with different industries. The heuristic approach could reach the optimal solution better than the meta-heuristic-based genetic algorithm approach and less time than the exact method. The meta-heuristic approach solves the model problems with large size instances.