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Flow shop scheduling problem with maintenance coordination: A new approach

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***Abstract*— This study investigates the coordination of production scheduling and maintenance planning in the flow shop scheduling environment. The problem is considered in a bi-objective form, minimizing the makespan as the production scheduling criterion and minimizing the system unavailability as the maintenance planning criterion. The time interval between consecutive maintenance activities as well as the number of maintenance activities on each machine is assumed to be non-fixed. A mixed integer programming formulation of the problem is presented. A special case of the problem, named as *single server maintenance* is also studied. A bi-objective ant colony system algorithm is presented to solve the problem in focus. Computational experiments are provided in two directions. Firstly, two scenarios are defined for the heuristic information part of the algorithm, using CDS and NEH heuristics. Experiments are provided to select the better scenario. Moreover, a local search is incorporated into the proposed algorithm and two scenarios are defined for this purpose. Some experiments are also provided to select the appropriate local search algorithm.**

Keywords-flow shop scheduling; preventive maintenance; coordination; non-fixed time interval; ant colony system

I. INTRODUCTION

In the classical scheduling problems, machines are assumed to be available through the whole planning horizon, although this assumption may not be true in many practical environments, as machines may become unavailable during certain periods of planning horizon. Preventive maintenance is the main cause of unavailability of machines. There are some research relaxing this unrealistic assumption, mainly the approach called "machine scheduling with availability constraints" where the number of preventive maintenance periods and their intervals are fixed and known in advance.

As an early result, [1] showed that the two machine flow shop problem with preemptive jobs becomes NP-hard, if there is a single unavailable period on one machine. A detailed review on the so-called approach is recently provided in [2]. The drawback of this approach is that the maintenance planning is always advantaged to the production scheduling. Advantaging maintenance activities to the production jobs may result in systems with low performance, as the system productivity is highly influenced with both the production and the maintenance decisions. In addition, the production and the maintenance activities are highly interdependent and ignoring this may result in unsatisfied demand or machine breakdowns [3]. To overcome this drawback, [3] proposed the "joint production and scheduling approach", in which the simultaneous scheduling of both scheduling and maintenance activities is presented.

Few papers have focused on the so-called joint approach. In the original contribution in [3], the problem was defined in the parallel machine environment and formulated in a bi-objective form. Minimization of the makespan and minimization of the system unavailability were considered as the two objective functions. In the joint production and maintenance scheduling approach, the periodic preventive maintenance is considered in which the period between two consecutive maintenance activities is fixed. The maintenance problem is to find the best maintenance period for each machine in a way to minimize the system unavailability. The same problem was also investigated in [4] and [5]. The model was considered in the flexible job shop scheduling environment in [6]. There is no work investigating the joint model in the flow shop scheduling environment. In this approach, the fixed time intervals between consecutive maintenance activities seem to be problematic. In other words, this assumption may result in the intervention of the production and the maintenance activities.

In this paper, a new approach is proposed to overcome the problem of simultaneous production and maintenance scheduling, in the flow shop scheduling environment. In the proposed approach, the time intervals between maintenance activities as well as their number are decision variables. For the production scheduling part, makespan i.e. the finishing time of the last job in order is the performance measure. The performance measure for the maintenance part is the system