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# Production scheduling optimization in foundry using hybrid Particle Swarm Optimization algorithm

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**Abstract**

Scheduling in foundry consist a type of production where, the hot work-in-processes cannot wait between two successive operations and can be modeled as a flow shop scheduling problem with no-wait constraint. With the objective to reduce total flow time, the appropriate sequence of jobs for scheduling is essential, hence the problem can be observed as typical NP-hard combinatorial optimization problem. This paper, proposes hybridization of Particle Swarm Optimization with simulated annealing for planning and scheduling issues which are very complex because of the ever changing needs of customers and existing constraints in foundry. This Proposed Hybrid Particle Swarm Optimization algorithm represents solution by random key representation rule for converting the continuous position information values of particles to a discrete job permutation. The proposed hybrid particle swarm optimization algorithm initializes population efficiently with Nawaz-Enscore-Ham heuristic and uses evolutionary search guided by the mechanism of PSO and local search by mechanism of simulated Annealing by balancing both global exploration and local exploitation. The proposed hybrid particle swarm optimization algorithm try to bridge the gap between theory and practice by considering foundry environment, which will help planner to decide the sequence of production of jobs based against clients' orders and to develop efficient scheduling procedures for minimizing total flow time with relatively low computational efforts. Extensive computational experiments are carried out based on various casting's (job's) characteristics viz. casting type, mould size and type of alloy, where size of job (n) considered as 10,12,20,50 and 100. With respect to performance measure, Average Relative Percent Deviation which is popular in the scheduling literature, the proposed method performs better than Simulated Annealing and Particle Swarm Optimization.


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## 1. Introduction

Planning and scheduling of jobs is prime factor for deciding the competitive market position for any type of production environment. In this paper, we present a case study taken from foundry for finding efficient production plan for scheduling jobs on specified set of machines to minimize total flow time. The production process of foundry enterprise is assorted and complex with various physical and chemical changes happening at the same time [1]. So, in order to ensure complete production target a reasonable production planning along with stable operation of production is the major element for foundry enterprise. Foundry environment of any metal industry has a multistage process in which melted metal is converted into products sequentially by the processes of converting furnace, heating furnace, and rolling mill [2]. Distinctly, this represents a typical model of the flow shop where every job is processed by every machine in fixed order. Additionally foundry is a flow shop with no wait constraint which has a type of production where, the hot work-in-processes cannot wait between two successive operations.. Furthermore, as the size of the work-in-process of foundry is large, the storage capacity of the buffer between two successive machines is limited so in-process-inventory should be reduced. Thus, in order to reduce the in-process inventory, total flow time of jobs should be reduced. This is also generally treated as no wait process demand with resource constraint [3]. To respond to this call, in this paper, we are aiming at minimizing the total flow time (TFT) as an optimality criterion, as it determines total processing time of individual job on every machine. The research of no-wait flow shop with TFT objective is reasonably effective for any metal manufacturing industry.

The remainder of this paper is organized as follows. Section 2 describes production process of foundry. Section 3 formally defines and formulates NWFSSP. Section 4 describes metaheuristics PSO and SA along with detailed procedure for implementing the proposed metaheuristics. Section 5 evaluates empirically the proposed algorithm for foundry environment, and then compares the performance of the proposed metaheuristics with that of the best-so-far algorithms. Finally, concluding remarks are given in section 6.

## 2. Production Process in Foundry

The considered factory produces various casting products with variety of material combinations. Cast products produced based on the order of clients are of several sizes and with different material (alloy) combinations. The type of alloy decides Mechanical property like Tensile strength, Compressive Strength, Shear Modulus of Rupture, Tensile Modulus of Elasticity, Torsion Modulus of Elasticity, Endurance Limit, hardness, price etc. Castings are produced using moulds of various sizes, however, neither the number nor the type of moulds are restrictive. Each mould is filled with a single type of molten metal (ferrous/non ferrous). Client orders determine a set of production jobs that have to be processed in this system. Each job corresponds to a single alloy and mould type, which has to pass through consecutive stages with typical sequence. A foundry is a flow line production system in which the sequence of operations are fixed and the workflow is in a single direction. First step is to prepare moulds/cores using patterns as per the planned order. In second stage, molten metal from furnace is poured into ladder and then to mould, which is allowed to cool. Later, castings are knocked out from moulds, which are shot blasted to process further for finishing. Then, the finished castings are grouped, stored and undergo for heat treatment. Heat treated castings are fettled and undergo finishing process, and then they are inspected and dispatched to clients. A typical technological order of operations in a foundry is given in figure 1.

In the said process in the foundry, each stage is considered as a single machine. All castings (jobs) are passing through all nine stages in the same technological order [3] with defined job processing times for each stage. Because of technology requirements, a casting cannot wait between melting and pouring. In order to have appropriate utilization of furnace and work in process inventory (WIP) should be minimum. The time to prepare molten metal and the time for heat treatment strongly depends on a type of alloy used to produce a typical casting. The processing times assumed in the second and third stages cannot be changed because to maintain temperature of either heating or cooling as the prepared casting cannot be either too soft or too hard to be cut in the fourth stage of the technological process [4].