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An Efficient Process Analysis and Control Method for Tire Mixing Operation

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Abstract : Since tire production process is very complicated, company-wide management of it is very difficult, necessitating considerable amounts of capital and labors. Thus, productivity should be enhanced and maintained competitive by developing and applying effective production plans. Among major processes for tire manufacturing, consisting of mixing component preparation, building and curing, the mixing process is an essential and important step because the main component of tire, called compound, is formed at this step. Compound as a rubber synthesis with various characteristics plays its own role required for a tire as a finished product. Meanwhile, scheduling tire mixing process is similar to flexible job shop scheduling problem (FJSSP) because various kinds of compounds have their unique orders of operations, and a set of alternative machines can be used to process each operation. In addition, setup time required for different operations may differ due to alteration of additives. In other words, each operation of mixing processes requires different setup time depending on the previous one, and this kind of feature, called sequence dependent setup time (SDST), is a very important issue in traditional scheduling problems such as flexible job shop scheduling problems. However, despite of its importance, there exist few research works dealing with the tire mixing process. Thus, in this paper, we consider the scheduling problem for tire mixing process and suggest an efficient particle swarm optimization (PSO) algorithm to minimize the makespan for completing all the required jobs belonging to the process. Specifically, we design a particle encoding scheme for the considered scheduling problem, including a processing sequence for compounds and machine allocation information for each job operation, and a method for generating a tire mixing schedule from a given particle. At each iteration, the coordination and velocity of particles are updated, and the current solution is compared with new solution. This procedure is repeated until a stopping condition is satisfied. The performance of the proposed algorithm is validated through a numerical experiment by using some small-sized problem instances expressing the tire mixing process. Furthermore, we compare the solution of the proposed algorithm with it obtained by solving a mixed integer linear programming (MILP) model developed in previous research work. As for performance measure, we define an error rate which can evaluate the difference between two solutions. As a result, we show that PSO algorithm proposed in this paper outperforms MILP model with respect to the effectiveness and efficiency. As the direction for future work, we plan to consider scheduling problems in other processes such as building, curing. We can also extend our current work by considering other performance measures such as weighted makespan or processing times affected by aging or learning effects.

Keywords : compound, error rate, flexible job shop scheduling problem, makespan, particle encoding scheme, particle swarm optimization, sequence dependent setup time, tire mixing process

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