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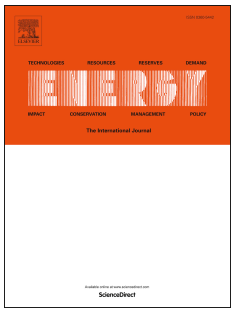

Mathematical modeling and evolutionary generation of rule sets for energy-efficient flexible job shops

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Mathematical modeling and evolutionary generation of rule sets for energy-efficient flexible job shops

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Abstract: As environmental awareness grows, sustainable scheduling is attracting increasing attention. The purposes of this paper are obtain the lower bound of energy-efficient flexible job shops with machine selection, job sequencing, and machine on-off decision making via a new mathematical model and to discover more energy-efficient rules with easy implementation in real practice via an efficient Gene Expression Programming (eGEP) algorithm. This paper first formulates a novel mixed-integer linear mathematical model to achieve effective machine selection, job sequencing, and machine off-on decision making. Then for the purpose of avoiding the empirical combination, five attributes exerting direct influence on the total energy consumption are extracted and consequently involved in the evolutionary process of eGEP. Furthermore, diversified rule mining operations with multi-gene representation and self-study are designed to enhance the search space and solutions quality. And, unsupervised learning is utilized in which global best and current worst are set to guide evolution direction since the learning progress has no prior knowledge. Experimental results show that machine off-on decisions efficiently reduce the total energy consumption; and, the discovered rules reach the lower bound calculated by GAMS/CPLEX in small problems and have significant superiority over other dispatching rules in energy saving.

Keywords: Linear mathematical model; Dispatching rules; Energy saving; Gene expression programming; Flexible job shop scheduling

1. Introduction

As the dual pressure of environmental issues and energy costs, manufacturers need innovative measures to promote energy efficiency. There is evidence that in manufacturing processes, scheduling jobs by assigning them to certain pre-defined machines at right time reduces the energy consumption of machine systems [1-4]. And, switching off/on machines at right time is also regarded as an efficient way for energy saving [5-8]. However, most of the current energy-oriented scheduling research are single machine or flow shop oriented. For flexible jobshops scheduling problems considering energy consumption, machine selection and job sequencing are considered, but switching off/on machines decision making is ignored. To the best of our knowledge, there is no literature reported on the general mathematical model for optimizing machine selection, job sequencing and machine switch decision simultaneously.

For optimizing this scheduling problem, the existing research mainly focused on the conventional methods [9] and meta-heuristics methods [8, 10-13]. For the lack of convenience and