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Scheduling for Re-entrant Hybrid Flowshop Based on Wolf Pack Algorithm

Han Zhonghua[1,2, a], Tian Xutian[3, b], Ma Xiaofu[4, c], Lin Shuo[5, d]

[1]Faculty of Information and Control Engineering, Shenyang Jianzhu University, Liaoning, 110168, China

[2]Digital Factory Department, Shenyang Institute of Automation, CAS, Shenyang, 110016, China

[3]Information＆Control Engineering Faculty, Shenyang Jianzhu University,Liaoning,110168,China

[4]Department of Electrical and Computer Engineering, Virginia Tech, Blacksburg, VA, USA,24060

[5]Faculty of Information and Control Engineering, Shenyang Jianzhu University, Liaoning, 110168, China

[a]Email: xiaozhonghua1977@163.cn [b]Email: 996428445@qq.com [c]Email:xfma@vt.edu [d]Email:farewell_lin@163.com

Abstract: In order to solve the scheduling problems of Re-entrant Hybrid Flowshop (RHFS), this paper investigates the mathematical programming model of RHFS, and proposes the wolf pack based algorithm (WPA) as a global optimization method. Multi-Sticking Crape Masking procedure scheduling problems in painting workshop of a bus manufacturing enterprise are of typical features of RHFS. We regard it as an application objective of the proposed algorithm, applying WPA and multiple evolutionary algorithms to solve the problems. The results show that the algorithm can solve re-entrant scheduling problems of hybrid flowshop more effectively compared with other conventional methods.

1. Introduction

Flowshop scheduling problems are the key problems in the modern manufacturing industry [1-2]. There are many derived problems from the basic flowshop scheduling problems. One branch of them is the flexible flow-shop scheduling problem (FFSP). Because FFSP has been proved to be NP difficult, its research is very challenging. There exist effective algorithms [3-5] for the practical applications of FFSP. In 1993, Kumar [6] first put forward re-entrant lines [7-10]. Re-entrant manufacturing systems have the feature of traversing all re-entrant jobs that need to be re-inserted into the queue to be processed, which makes scheduling problems of re-entrant workshop with uncertainty, and is prone to cause obstruction of production. Therefore, it will make scheduling problems of re-entrant workshop much more complicate than those of the common. Recently, current works [11-13] mostly focus on solving the scheduling problems of flexible flowshop with reentrant procedure by utilizing the traditional meta-heuristic algorithms. So far, there is still limited literature on the scheduling problems of RHFS. So, in this paper, wolf pack algorithm (WPA) [14-15] based proposed in recent years is used to solve the problem. Compared with other meta-heuristic swarm intelligence algorithm, this algorithm has fast convergence rate and high optimal value.

2. Description and Model of Scheduling Problem of RHFS

2.1 Problem Description

During the scheduling process of RHFS, in the number nrm non-reentrant manufacturing process, each workstation consists of a set of the same work stations $M_1 \sim M_{nrm}$. In the number rm re-entrant manufacturing phase, each workstation composes a set of the same work stations $M_{nrm+1} \sim M_{nrm+rm}$; the job J_i needs to re-enter this phase rts_i times, while different job has its own re-entrant times. In this problem, each job in accordance with the formulated process flow goes through various workstations for processing. Each job will be processed for $nrm + rm \times rts_i$ times. The working process of job is shown in Figure 1.

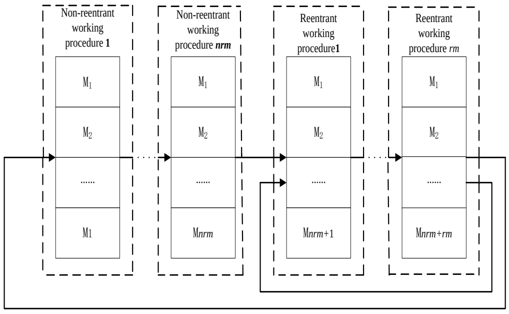

Figure 1 Working Process of RHFS

2.2 Description of Mathematical Model

FL_q represents the process flow of job, which is the collection of working procedure on the basis of the order of process flow of the job during the manufacturing process.

om_i indicates the sum of working procedure of the job during the process flow FL_q. Cumulative count will be done to the repetitive working procedure, $om \geq m$.

m signifies the total number of workshop processes.

2.2.1 Assumption Variables and Basic constraints

$$At_{i,j,k}^{t_i} = \begin{cases} 0 & \text{Workpiece } J_i \text{ doesn't process on the work station } WS_{j,k} \text{ of } OP_j \text{ during the number } t_i \text{ working procedure.} \\ 1 & \text{Workpiece } J_i \text{ process on the work station } WS_{j,k} \text{ of } OP_j \text{ during the number } t_i \text{ working procedure} \end{cases}$$

Among them， $i \in \{1,.....,n\}$， $l \in \{1,.....,om\}$， $j \in \{1,.....,m\}$

$$\sum_{t_i=1}^{om_i} At_{i,j,k}^{t_i} = om_i \quad (1)$$

$$om_i = nrm + rm \times rts_i \quad (2)$$

Formula (1) shows that each job must traverse the process flow; formula (2) explains that the sum of working procedure of the job J_i during process flow FL_q is equal to the sum of times that the job J_i passes through the non-reentrant and the reentrant processes.

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3. Wolf Pack Algorithm

3.1. Implementation of WPA

Step1. The number of wolves in the initial wolf pack is n; the maximum iteration is $\max t$; the number q competing for leaderwolf is 4; the search direction is h, with the maximum searching times $\max dh$; the search step is $stepa$ while the moving step is $stepb$; and the number of the worst wolves is R. The location of each wolf is initialized.

Step2. q wolves which compete for leaderwolf start scouting behavior.

Step3. The best election will be the leaderwolf, while the others will move toward the location of leaderwolf.

Step4. The leaderwolf searches the prey which will be surrounded by other wolves.

Step5. According to the principle of distribution in wolf pack, we update the wolves, removing the worst R wolves, and randomly generating R wolves.

Step6. After an iteration, the next one goes on to determine whether the termination condition is met. If the condition is satisfied, we will exit the loop and record the result; otherwise, the procedure will go to Step2.

4. Verification and Analysis of Scheduling Problems of RHFS by WPA

During the Multi-Sticking Crape Masking procedure in painting workshop of the bus manufacturing enterprise, different color stripped pattern jet-printed on the bus body is based on the complexity of the color stripped template in advance by enterprise technicians. They divide the color strip into various colors. After a set of Sticking crape masking, spraying and stoving finish, a kind of color will be jet-printed, while an entire pattern will be formed through multiple jet-print. As a result, Multi-Sticking Crape Masking procedure is one of the typical re-entrant production phase. The procedure includes several working procedures and work stations. Due to different working abilities of technicians, the machining time of bus on work station is different. In this way, the procedure also has typical features of hybrid flowshop. Based on the application cases of scheduling problems of Multi-Sticking Crape Masking procedure in painting workshop, WPA is applied to global optimization so as to solve the scheduling problems of these hybrid flowshop with re-entrant procedure.

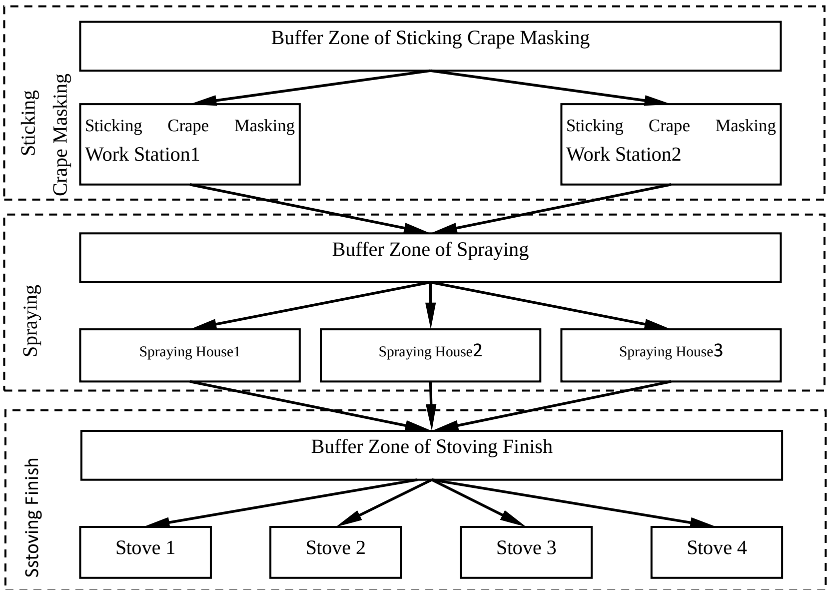

Figure 2 Deployment Diagram of Work Station in Multi-Sticking Crape Masking Procedure

The scheduling data adopt the actual production data of Multi-Sticking Crape Masking procedure in painting workshop of a bus manufacturing enterprise. The deployment diagram of work station in Multi-Sticking Crape Masking procedure is shown in Figure 2. $i \in \{1,.....,n\}$

Working procedure $\{OP_1, OP_2, OP_3\}$ respectively indicates Sticking crape masking, spraying and stoving finish, the three procedures of Multi-Sticking Crape Masking procedure. The work station number of these three procedures is $\{2,3,4\}$.In the course of scheduling process, the spraying house of spraying and the stove of stoving finish are treated as work station. The work station $\{J_1, J_2, J_3, J_4, J_5, J_6, J_7, J_8, J_9, J_{10}, J_{11}, J_{12}, J_{13}, J_{14}, J_{15}\}$ represents the body of 15 buses needed to be processed. These 15 buses belong to 15 types, and each type is processed according to its process flow. Each bus has diverse machining time in all working procedures due to different types. There is no human intervention in the stove during stoving finish. The same type has the same time of stoving finish in different stoves, so the machining time is only related to the types.

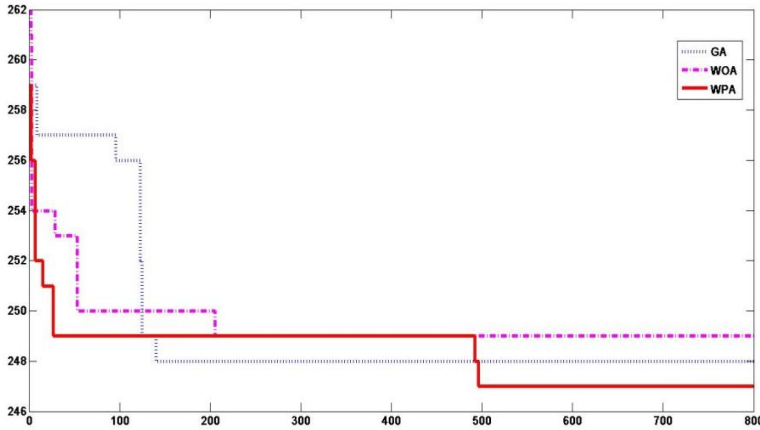

Figure 3 The Iterative Curve Diagram of Three kinds of algorithms to Solve the Scheduling Problems of Multi-Sticking Crape Masking Procedure in Painting Workshop

It can be seen from Figure 3 that with the increase of training generations, the fitness values of the 3 groups all gradually decrease and tend to be stable. In evolution of 100th generations, WPA with poor initial generation fitness can still obtain better fitness value. After 35th to 470th generation of local extremum, the algorithm can continue to evolve its vigor to jump out of local extremum, so as to get the better fitness value 247. From Figure 3, we can achieve better optimization results by using this algorithm to solve RHFS problems. Figure 4 shows the Gantt chart of the scheduling results, where the y-axis is the number of working procedure and work station, and the x-axis is the time.

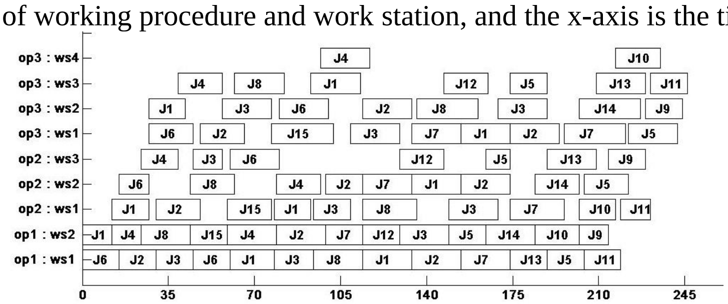

Figure 4 Gantt Chart of Scheduling Results of RHFS

5. Conclusion

This paper researches on the scheduling problems of RHFS based on many color strip in painting workshop of the bus manufacturing enterprise, proposing the scheduling problems of RHFS with a re-entrant system. What's more, we make problem description in the light of these problems, establish a mathematical model, and use WPA to solve the problems. We analyze the simulation results of various scale problems from the experiments, and compare with the results of other algorithms. The results show that WPA can obtain a satisfactory near-optimal solution in a reasonable time.

Acknowledgements
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