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Reducing setup time in manufacturing cells In a JIT environment

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Abstract. Setup time is a major issue in Just-in-time environments. Even with a cellular manufacturing configuration, reduction of setup time is not fully insured and needs to be explicitly targeted. We have introduced a mathematical programming model which would reduce sequence-dependent setup time in manufacturing cells. Since the BIP model is NP hard, a solution approach based on a *Genetic Algorithm* has been improvised.

Introduction

Cellular manufacturing, which is an application of group technology (GT), has been recognized as one of the most recent technological innovations in job-shop or batch-type production to gain economic advantages similar to those of mass production [1,2,3,4,5]. In a JIT environment where cellular manufacturing approach is adopted in order to reduce the setup time, enhanced setup time techniques are required to attain competitive advantage in responding to a customer oriented market.

A Review of Setup Time Definition

Cox *et al.* [6], define setup as the work required to change a specific machine, work centre, or line from making the last good piece of a unit A to the first good piece of unit B [7]. The above definition is the closest to real life manufacturing. The significance of this definition is that it implies the important concept of *changeover* between two parts. Besides, common sense and real practice both imply that changeover must take place on a *common* machine In fact, setup time depends on three elements without which, part of the information for obtaining the changeover time would be missing. These elements are: incoming component part *i*, outgoing component part *i'* and the common machine *k,* as shown in Figure 1.

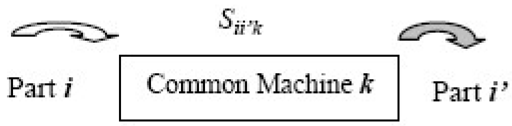

Fig. 1- Setup as joint changeover

This definition covers all different cases of changeover, for example, from uninstalling a previous die, say on a press, and installing a new die, to switching from a previous set of adjustments, say on an electronic device, to a new one, and so on. Consideration of all pairs of parts on different machines leads to a joint changeover matrix, $S_{ii'k}$, including the sequence-dependent setup times between pairs of parts having common machines. This information in companies is usually obtained from route sheets where the MCIM data is also obtained. It is obvious for a sequence-independent setup time that the corresponding input data for $S_{ii'k}$ and $S_{i'ik}$ will simply be equal.

Research Problem and Modeling

Consider manufacturing cells being deployed in a just-in-time environment where the orders are received and fulfilled on a periodic basis. The time for re-adjusting the equipment from one part to another is relatively large as compared to the corresponding processing time of those parts especially when batch sizes are small in JIT. The setup time is measured between every pair of different component parts and is generally sequence-dependent. The setup time between identical parts is considered zero. The setup time between different parts can be collected from the route sheets where other critical manufacturing information is recorded**.**

The objective is to simultaneously group machines and parts in relatively independent cells while minimizing sequence- dependent changeover times in the system.

Variables :

$x_{ipkl} = 1,$ *if part i visits machine k in position p in cell l, 0 otherwise*

$z_{il} = 1,$ *if part i visits cell l, 0 otherwise*

y_{kl} *No. of machine k in cell l*

$\lambda_{ipi'(p+1)kl}$ *A binary auxilliary variable assuming the value of 1, IFF both* x_{ipkl} *and* $x_{i'(p+1)kl}$ *equal 1*

Parameters :

$S_{ii'k}$ *joint sequence - dependent setup time for replacing part i with part i' on machine k*

C_k *unit cost of setup on machine k*

E_k *cost of having one unit of machine k in the system*

D_i *cost of moving one unit of part i between cells*

MAX_l *maximum number of machines allowed in a cell*

MIN_l *minimum number of machines allowed in a cell*

Formulation :

$$\sum_i \sum_p \sum_k \sum_l \lambda_{ipi'(p+1)kl} \cdot S_{ii'k} \cdot C_k + \sum_k E_k \sum_l y_{kl} + \sum_i D_i \cdot (\sum_l z_{il} - 1) \tag{1}$$

st.

$$\lambda_{ipi'(p+1)kl} \geq x_{ipkl} + x_{i'(p+1)kl} - 1 \tag{2}$$

$$\sum_i x_{ipkl} \leq 1 \tag{3}$$

$$\sum_p \sum_l x_{ipkl} = 1 \tag{4}$$

$$\sum_i x_{ipkl} \geq \sum_i x_{i(p+1)kl} \tag{5}$$

$$x_{ipkl} \leq y_{kl} \tag{6}$$

$$\sum_k \sum_p x_{ipkl} \leq M^{\infty} \cdot z_{il} \tag{7}$$

$$\sum_k \sum_p x_{ipkl} \geq z_{il} \tag{8}$$

$$MIN_l \leq \sum_k y_{kl} \leq MAX_l \tag{9}$$

$$x_{ipkl}, y_{kl}, z_{il}, \lambda_{ip\,i'(p+1)kl} \quad 0,1 \text{ variable} \tag{10}$$

Solution Approach

We have proposed a GA-based heuristic to address the computation complexity of the problem. The chromosomal structure of the GA-based heuristic is depicted in Figure 2. Basically in this encoding, machine, encompasses the cell as opposed to the physical reality. The 0-1 decision variable, y_{kl}, indicates whether cell *l* is contained by machine *k*. When cell *l* is contained within machine k, then the binary decision variable, x_{ipkl} , indicates whether part i would lie in that contained cell in position p. The aforementioned decision variables are read directly from the chromosomes. Other variables such as z_{il} are indirectly decoded.

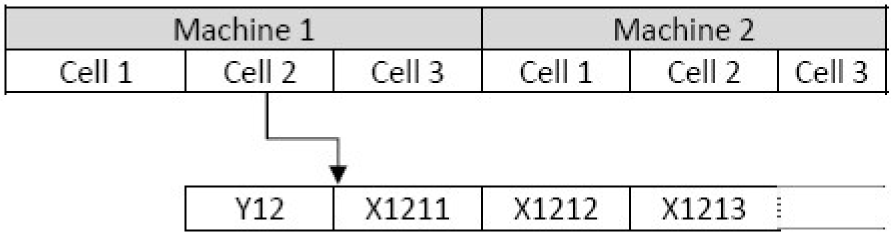

Fig.2-Chromosomal structure of the GA-based heuristic

The selection process is done through a *biased roulette wheel* where for each chromosome, a frequency is calculated. This frequency has been the reciprocal of the percentage of the objective value of the chromosome with respect to the total objective value of all chromosomes.

Two crossover operators, namely machine-level and part level have been designed to recombine the selected parent chromosomes in the mating pool. Mutation and rejuvenation process has been applied.

Illustrative Example

Table 1 shows the MCIM. A sample of the corresponding joint changeover matrix of the sample problem for machine 1 is shown in Table 2. The setup times are generated randomly within the range of 10 and 40 minutes.

Table 1-Machine-Component Incidence matrix

	Component Part									
Machine	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
M1	1	0	1	0	1	0	1	1	1	0
M2	1	1	1	1	1	1	1	0	1	0
M3	1	0	0	1	0	0	1	0	0	1
M4	1	1	0	0	1	0	0	0	0	0

Table 2—Joint changeover matrix for Machine 1

Parts	**1**	**2**	**3**	**4**	**5**	**6**	**7**	8	9	10
1			10		19		27	13	39	
2										
3	22				26		10	21	16	
4										
5	15		27				25	14	21	
6										
7	32		30		20			31	14	
8	26		20		37		21		17	
9	37		17		27		13	13		
10										

Table 3 indicates the solution which includes the sequence of processing of parts from left to right in each cell.

Table 3-Sequence-dependent solution by GA

C1	C2	C3
P1-P3-P7	P5	P8-P9
P1-P3-P2	P6-P4	P5-P7-P9
P4-P1	P10	P7
P2	P1	P5

Conclusion

In this paper, we presented an integer mathematical programming model that reduces sequence-dependent setup time in manufacturing cells and can be used as a general sub-model in advanced cellular manufacturing models in JIT.

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