Australian Journal of Basic and Applied Sciences, 10(18) December 2016, Pages: 176-180

AUSTRALIAN JOURNAL OF BASIC AND APPLIED SCIENCES

ISSN:1991-8178 EISSN: 2309-8414
Journal home page: www.ajbasweb.com

Machine Tool Scheduling Problem for Reconfigurable Manufacturing System (RMS)

[1]A. Bhargav, [2]N. Venkatachalapathi, [3]M.L.S. Deva Kumar

[1]*Department of mechanical Engineering, Annamacharya Institute of Technology and sciences, Rajampet, Kadapa (Dist), A.P., India*
[2]*Department of mechanical Engineering, Annamacharya Institute of Technology and sciences, Rajampet, Kadapa (Dist), A.P., India*
[3]*Department of mechanical Engineering, JNTUA college of Engineering, Ananthapuramu, A.P., India,*

Address For Correspondence:
Bhargav A., Ph.D (Dept of Mechanical Engineering) Research Scholar, Research and Development Centre, Annamacharaya Institute of Technology and sciences Rajampet,Kadapa (Dist),AP.,India.
E-mail: amara.bhargav@gmail.com.

ARTICLE INFO

Article history:
Received 19 September 2016
Accepted 10 December 2016
Published 31 December 2016

Keywords:
Reconfigurable Manufacturing System (RMS), Production Scheduling, Dedicated Manufacturing Lines (DML), Flexible Manufacturing Systems (FMS).

ABSTRACT

This paper provides a novel approach of production scheduling considering the reconfigurable machine tools. In dedicated Manufacturing lines (DML) and flexible manufacturing systems (FMS) do not meet the challenges up to expected level because of short comings in their implementation procedurals like lack of support for product variation, scalable production capacity and high production cost, RMS provides the solution in designing a new manufacturing system with scalable flexibility and functionality which is needed in the manufacturing industry. This paper studies the problem of Machine tool scheduling of different operations in for the selected product in reconfigurable manufacturing systems (RMS). The objective is to minimize the make span of the product by segregating and scheduling the similar operations of product. To solve the existing problem in the production scheduling different heuristic approaches are developed for simulation, models are evaluated for the performance.

INTRODUCTION

Manufacturing processes is value addition to the raw material which converts low value input parts into high value finished products using available resources such as machines, tools, and energy and manpower. In manufacturing systems, some machines are dedicated for some common machine operations like drilling, boring, milling and treading. This type of manufacturing systems is called dedicated manufacturing lines. For medium scale production this DML systems gives satisfactory profits, to enhance the revenues the flexible manufacturing systems (FMS) are into the manufacturing sector. But, FMS is still not satisfactory due to high cost of production and it also not provide generalized flexibility in the manufacturing setup (Koren, Y., *et al.*, 1999). In the present scenario the main goal of any organization is to earn profit. If the set goal wants to be reached, meeting customer demands completely and in time and offering them high-quality products is must. Production scheduling plays a major key role to achieve the necessary competitiveness and fulfill the given task. But the production scheduling issues are very complex because of the continuous changing needs of customers and the existing constraints in different metal manufacturing industry. Number of researchers has been published, following the appearance of Gantt chart that discusses the models and methods for solving production scheduling problems. In the literature on production scheduling various models and methods are used: mathematical programming (Harjunkoski, I. and I.E. Grossmann, 2002) and artificial intelligence. The models mentioned in the literature can be classified as deterministic and stochastic, and as static and dynamic. The published papers treating the production scheduling problem deal with different types of production. (Erel,

To Cite This Article: A. Bhargav, N. Venkatachalapathi, M.L.S. Deva Kumar., Machine Tool Scheduling Problem for Reconfigurable Manufacturing System (RMS). ***Aust. J. Basic & Appl. Sci.,*** *10(18): 176-180, 2016*

E. and J.B. Ghosh, 2007; He, C., *et al*., 2005) studied a single machine batch scheduling problem, and the objective of established model is to minimize the maximum lateness. In the paper the authors compare various methods for the flow-shop scheduling problem with the late work objective function. (Blazewicz, J., *et al*., 2005; Blazeicz, J., *et al*., 1998) have studied the problem of scheduling a multiprocessor task model with parallel work on several processors that is often used in modern manufacturing system is discussed and they have applied scheduling in time windows for the objective function of maximum lateness and schedule length. Golenko-Ginzburg *et al*., (1997) have discusses the job shop scheduling problem doe flexible manufacturing system. To solve the job-shop scheduling problem a new time and memory efficient representation of the disjunctive graph is given in the paper. T' Kindt *et al*., (2003) discuss the optimization of multiple conflictuous criteria for flow shop scheduling problem. In the literature researchers are elaborated the activities scheduling problem aiming at minimizing the project duration with the possibility to perform the activities in several variants. The project scheduling problem classification is also given. Allahverdi *et al*., (1999) have studied the scheduling problem with the setup time included, in contrast to most models that disregard the machine setup time or consider it as part of the processing time and also studied the family scheduling model which includes the setup times when there are family setup times aimed at minimizing total earliness and total tardiness. Leung *et al*., (2007) have studied the problem of scheduling orders with various priority rules.

EIMaraghy (2005) made an attempt to compare RMS and FMS, concluded that the detailed customized flexibility in RMS is possible. Galan (2008) have studied to group the products into families and to schedule the families using RMS.Meng (2010; Oğuz, C. and M. Fikret Ercan, 1997; Wang, J.-B. and L.-L. Liu, 2009) made an attempt to proposes a model for the RMS by applying colored timed object-oriented Petri nets. Abbasi *et al* ., (2011) have studied to propose a mixed integer nonlinear programming model to determine. Lot of size and corresponding configurations. They have used a genetic algorithm-based procedure is developed to solve the model. Azab *et al*. (2011) have developed and integer model, they have considered operations sequencing in RMS to minimize changeover time while satisfying a number of precedence constraints in their model.

2.1 Problem Definition:

This paper deals with production scheduling issues in machining shop. The machining of engine blocks (Milling, Drilling, Boring, Threading and honing) is a combined continuous discrete production with processes: loading and unloading the job, changing tools, shifting job into different machines measuring and checking the features generated. Fig.1 gives a scheme of production lines in the machining shop. The production process consists of five production lines with ten different machines for production of engine blocks.

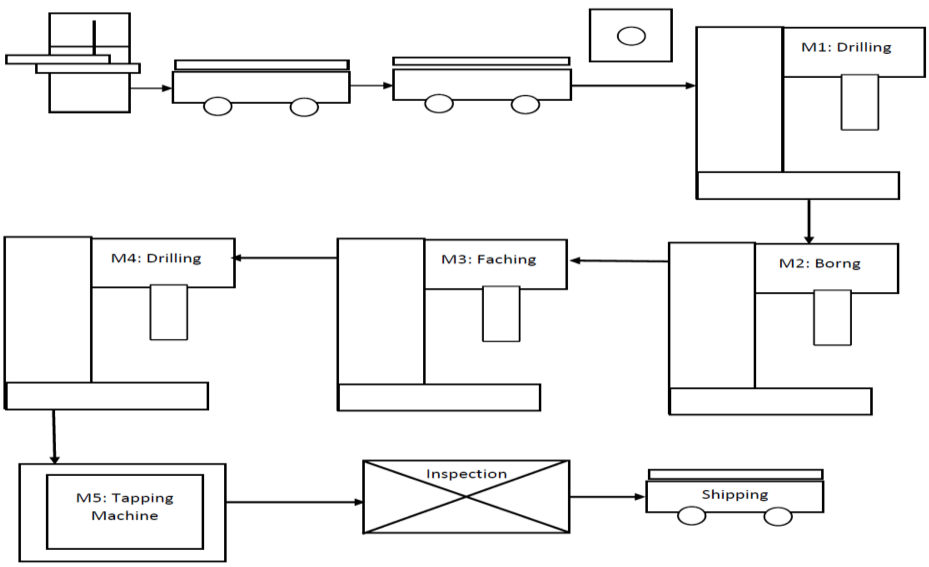

Fig. 1: Engine Block Production line in Machine Shop

Tasks set to the production of engine blocks scheduling system are:

- To calculate the available machining capacity for the total of 24 hours,
- To group products according to similar features
- To group products according to dimensions of features
- To open production order with the similar features grouped as mentioned above
- To create daily plan for production based on work shifts

To schedule daily production for the lines and available capacities of machines

Machine shops cause bottlenecks. Bottlenecks are identified as critical manufacturing resources and scheduled first. The mathematical model and algorithm for engine block machining scheduling is developed based on algorithm with adjustment to the specific problem of scheduling machine shop.

The objective is to find feasible production schedule

Let $F_o = \{i_a | \, i \in a\}$

be a set of features which can be produced by the same machine and

$$D_o = \{m_i | \, i \in F\}$$

Be a set of items with similar dimensions. Thus the items are grouped to production order *O.*

The following notation is used

2.2 Indices:

i = 1… I	Items
j = 1… J	Operations
l = 1… L	Production lines
m = 1… M	Machines
O = 1… O	Production Orders
t = 1….T	Periods

2.3 Parameters:

$dd_{i,o}$ = delivery date for item i and order o

K_i = tardiness of item i [day]

$k_{l,f}$ = utilization factor of machine m on production line l

$K^{R}_{l,f,t}$ = avalable capacity of machine m in a day t [$hours$]

$K^{cap}_{l,f}$ = capacity of machine on production line per hour [$no. of\ items\ /hour$]

N^{R}_{m} = available number of machines type

n^{h}_{s} = number of hours in shift s

$\delta_{s,t}$ = number of shifts in a day

O^{h} = numberof overtime hours

$\Pr(i)$ = priority of item i

$q_{i,m}$ = quantity of items i from one machine [$number$]

$q_{i,o}$ = quantity of items i per production order o [$number$]

$q_{i,t}$ = quantity of produced items i in period t [$number$]

$q^{n}_{i,t}$ = $orderd\ quantity\ of\ item\ i\ [number]$

$q^{z}_{i,t}$ = $inventory\ of\ item\ i\ in\ period\ t\ [number]$

Q_{tot} = $total\ quantity\ of\ engine\ blocks\ machined$

Q_{l} = $quantity\ of\ engine\ blocks\ machined\ for\ line\ l$

$Q_{l,f,m}$ = $quantity\ of\ items\ machined\ for\ one\ feature\ in\ machine\ m\ on\ line\ l$

$t_{i,j}$ = $processing\ time\ of\ operation\ j\ of\ item\ i\ [hours]$

$t_{l,f,c}$ = $processing\ time\ of\ feature\ in\ machine\ m\ on\ production\ line\ l\ [hours]$

$t^{m}_{l,f,i}$ = $duration\ of\ machining\ of\ item\ i\ form\ machine\ m\ on\ production\ line\ l$

tm_{m} = $time\ of\ assuring\ necessary\ quantity\ of\ machining\ type$

$tm^{m}_{l,f,i}$ = $start\ time\ of\ machining\ operation\ of\ item\ i$

$tm_{l,m}$ = $start\ time\ of\ feature\ maching\ in\ machine\ m\ on\ production\ line\ l$

$tz_{i,o}$ = $finish\ time\ of\ item\ i\ on\ production\ order\ o$

$tz^{m}_{l,f}$ = $finish\ time\ of\ machining$

ε = $transportation\ time\ between\ one\ work\ station\ and\ another\ workstation$

$\tau_{l,f,m,m+1}$ = $time\ between\ feature\ machning$

2.4 Decision Variables:

$x_{i,m}$ binary variable, $x_{i,m} = 1$ if item i is produced in machine m, *otherwise* $x_{i,m} = 0$

$y_{f,m}$ binary variable, $y_{f,,m} = 1$ if operation f, is produced in machine m, *otherwise* $y_{f,m} = 0$

$y_{i\,l}$ binary variable, $y_{i,,l} = 1$ if operation i, is produced in line l, *otherwise* $y_{i,l} = 0$

The Mathematical Model is formulated as follows.

Minimize

$$T = \sum_i K_i \quad (1)$$

Subject to:

$$K_i = \begin{cases} 0 & \text{if } dd_{i,o} \geq tz_{i,o} \ ; \\ tz_{i,o} & \text{otherwise} \end{cases} \quad (2)$$

$$q_{i,o} \geq \max\left(0,\ q_{i,t}^{n} - q_{i,t}^{z}\right) \quad (3)$$

$$\sum_t q_{i,t} \geq q_{i,t}^{n} \qquad \forall i \quad (4)$$

$$\sum_m q_{i,f} = q_{i,o} \qquad \forall o \quad (5)$$

$$q_{i,m} \leq min\left\{q_{i,o}, \frac{q_{l,f,m}}{b_i} - q_{g,o}.b_g\right\}. \quad (6)$$

$$\sum_a n_{a,t}.Q_{l,f,m} \leq K_{l,f,t}^{R} \ .K_{l,f}^{cap} \quad (7)$$

$$b_i \ .N_m^R \leq \ Q_{l,f,m} \quad (8)$$

$$K_{l,f,t}^{R} = \left[\sum \delta_{s,t} \ .n_s^h + O^h\right].k_{l,f} \quad (9)$$

$$\sum_l Q_l \leq Q_{raw} \quad (10)$$

$$\sum_i x_{i,m} \cdot q_{i,o} \leq N_{m,t}^{R} \quad (11)$$

$$tm_{l,f,i}^{m} \geq max\left(y_{a,c} \ .\left(tm_{l,f,m} + t_{l,f,m}\right),\ \ \sum_i x_{i,m} \ .tm_m \ .tz_{l,f}^{m}\right). \quad (12)$$

3.1 Model Evaluation:

In this section briefly explains the evaluation of the developed model for minimizing the make span of the machining of engine block. This model need to be evaluated using advanced software's like CIPLEX for both similar features in size and complexities in producing them. In the present paper only considered for the study of the production scheduling problem in flow shop scheduling using RMS.

3.2 Data Collection:

The real data have been collected from the production head that is responsible for production planning for the flow shop scheduling problem. The data such as processing time, Due date, weight of the job with demand and sequence dependent set up time for execution of developed model. Using this collected data the developed model is going to evaluate in the next step and the same considered in the next paper.

Conclusion:

The study has been done on the problem of scheduling of different operations in reconfigurable manufacturing systems (RMS). The assumptions which has been made that a manufacturing system is available with set of machines. This manufacturing system is designed to manufacture variety of features in any selected component. Here the system requires reconfiguration to switch from one feature of operation to another feature, which needs some changes in the system. This changes are highly depends on the sequence of two consecutive features machining. An attempt has been made on studying this problem, by formulation of mathematical model by considering the sequence of operations.

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