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Intelligent Approach for Balancing of Workload on Machines for Loading of Machines in Manufacturing

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Abstract

Production planning and control is the managerial activity of a firm to plan, control and meet the targets. Planning is an important activity of any firm. Efficiency and effectiveness of a production house depends on the type of plan and level of control. Production planning has many problems that need to be solved. One of the most critical problem is loading of machines. When the job with some operational requirement is to reach to the shop floor, then the problem is which operation of the job is to be performed on what machine with which tool. Allocation of machines and tools to the required operations of all jobs is the solution to the problem of loading of machines. The present research aims to solve the machine loading problem for the sole objective of balancing of machines for Group Technology manufacturing.

Keywords: Intelligent approach, balancing of machines, FMS, Optimization, Heuristics, Integer Programming

1. INTRODUCTION

Loading of machine is a problem of allocation of tools and machines to operations on the selected job(s) under resource and technological constraints. Loading of machines is the focus of attention for the present research paper. It is complex and multi-objective in nature. None of the available research meets the needs of all manufacturing environments 1. The problem needs to solve with changed variables and environments every time for certain objectives. With the change in machine types, work centers, shop floor types, manufacturing strategies and technologies, the nature and type of problem definition changes. Balancing of machines is one of the major objective to be optimized. Thus the problem of loading of machines need to be solved again for changed parameters of balancing of machines. An intelligent machine loading approach has been proposed for the same in the present research paper. The simulated results of the problem with proposed approach are presented.

2. LITERATURE REVIEW

The problem of loading of machines was first addressed in early 80s by K.E. Stecke. Since then a number of researchers have evaluated the problem of loading of machines by a number of possible approaches. The summary of reviewed literature is tabulated below in table 1.

Table 1 – Literature revealed modeling techniques for loading of machines

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1983 [1]		√																		
1984 [2]						√														
1986 [3]							√													
1986 [4]												√								
1986 [5]																	√			
1986 [6]				√																
1989 [7]		√											√							
1994 [8]																√				
1998 [9]			√																	
1998 [10]											√									
1998 [11]				√						√										
1999 [12]															√					
2000 [13]														√						
2002 [14]	√			√																
2003 [15]																				
2004 [16]																		√		
2005 [17]								√												
2007 [18]					√															

2008 [19]									√											
2009 [20]			√																	
2011 [21]				√																
2012 [22]		√			√															
2012 [23]				√																
2013 [24]																			√	
2013 [25]	√																			
2015 [26]																				√
2015 [27]				√																

Abbreviations used in Table 1 are:

1. Genetic Algorithm (GA)
2. Heuristic Algorithm (HA)
3. Simulated Annealing
4. Mathematical programming
5. Particle Swarm Optimization
6. Queueing Network Model
7. Branch and Bound Algorithms
8. Stochastic Model
9. Modified Immune Algorithm
10. Approx. Lexicographic Approach
11. Iterative Algorithms
12. Hierarchical Approach
13. Branch & Backtrack Procedure
14. Combined Loading Algorithms
15. Dispatching Approach
16. Due-Date Based Methods
17. Dynamic Approach
18. Fuzzy Logic
19. Artificial Neural Network
20. Variable Neighborhood Search

It was found that none of the single modeling technique has yield all time acceptable results for the problem of loading of machines. The exhaustive literature review yields very fruitful results. The computational requirements, complexity, fitness functions for evolutionary techniques, values of correction constants, requirement of number of iterations were all time governing trends for loading of machines. It is revealed in the literature review that problem of machine loading first has been solved for sole objectives. An intelligent approach is proposed for the purpose. The sole objective of balancing of machines has been considered for the present research. Balancing of machines means loading the machines as per their capacity. More capacity machine to be loaded heavily compared to low capacity machines. The present work aimed to develop an intelligent approach for loading of machines for balancing of machines.

3 MODEL DEVELOPMENT

To ensure continuity of the system and for the results to be realistic acceptable some assumptions considered is that job has operation(s) requirements type. Machines are non-identical with different capacity. To complete an operation a cutting tool and a tool slots in the tool magazine of the machine is required. An operation has processing time requirements varying with machine and tool types. Required tool(s) needs to be filled in the tool magazine of the machine, before the production begins.

Objective: balancing of workload on machines-

$$Optimize\ F = \min\left(\sum_{i=1}^{I}\sum_{y=1}^{Y}\sum_{z=1}^{Z}(x_{ixyz})(t^{a}_{ixyz} + t_{ix}) - \sum_{i=1}^{I}\sum_{y=1}^{Y}\sum_{z=1}^{Z}(x_{i(x+1)yz})(t^{a}_{i(x+1)yz} + t_{ix})\right) \approx 0 \quad \forall\ \boldsymbol{M}_x, x = 1,2,\dots,(X-1) \tag{1}$$

Subjected to,

$$\textstyle\sum_{y=1}^{Y}\sum_{x=1}^{X}\sum_{z=1}^{Z}(x_{ixyz}) = \sum_{y=1}^{Y}\sum_{x=1}^{X}(M_{ixy})(To_{ixy}),\ \forall\ O_y\ of\ J_i\ and\ i \tag{2}$$

$$\sum_{x=1}^{X}\sum_{z=1}^{Z} x_{ixyz} = \sum_{x=1}^{x}(M_{ixy}) \quad \forall\ O_y \& J_i\ , \quad i = 1,2,\dots,I\ \&\ y = 1,2,\dots,Y \tag{3}$$

$$\sum_{x=1}^{X}(M_{ixy}) = 1 \quad \forall\ O_y\ of\ J_i, and\ i,\ \ i = 1,2,\dots,I\ \&\ y = 1,2,\dots,Y \tag{4}$$

$$M_{xy} = \begin{Bmatrix} 1\ if\ \ machine\ M_x\ can\ perform\ operation\ O_y \\ 0\ otherwise \end{Bmatrix} \tag{5}$$

$$M_{xy} = \begin{Bmatrix} 1\ \ if\ \left[\left(\sum_{i=1}^{I}\sum_{y=1}^{Y}\sum_{z=1}^{Z} x_{ixyz}\right) + To_{ixy}\right] \le Mc_x\ \ \forall\ M_x, \\ 0\ \ otherwise \end{Bmatrix} \tag{6}$$

$$J_{ix} = \begin{Bmatrix} 1 \; if \;\; job \, J_i \; can \; can \; handled \; on \; machine \; M_x \\ 0 \; otherwise \end{Bmatrix} \tag{7}$$

$$To_{yz} = \begin{Bmatrix} 1 \; if \;\; tool \, To_z \; can \; can \; perform \; operation \; O_y \\ 0 \; otherwise \end{Bmatrix} \tag{8}$$

$$To_{yz} = \begin{Bmatrix} 1 \;\; if \left[\left(\sum_{i=1}^{I} \sum_{x=1}^{X} \sum_{y=1}^{Y} x_{ixyz} \right) \right] \leq Av_z \;\; \forall \; To_z \\ 0 \;\; otherwise \end{Bmatrix} \tag{9}$$

$$J_{iz} = \begin{Bmatrix} 1 \; if \;\; job \, J_i \; can \; can \; handled \; on \; machine \; M_x \\ 0 \; otherwise \end{Bmatrix} \tag{10}$$

Where,

F : Unbalancing level

$\boldsymbol{I}$: Total number of jobs

$\boldsymbol{X}$: Total number of machines

$\boldsymbol{Y}$: Total number of operations

$\boldsymbol{Z}$: Total number of tools

$\boldsymbol{J_i}$: Job number, with $\boldsymbol{i}$ as job index $\boldsymbol{i = 1, 2, \ldots, I}$

$\boldsymbol{M_x}$: Machine number with $\boldsymbol{x}$ as machine index $\boldsymbol{x = 1, 2, \ldots, Z}$

$\boldsymbol{O_y}$: Operation number with $\boldsymbol{y}$ as operation index $\boldsymbol{y = 1, 2, \ldots, Y}$

$\boldsymbol{To_z}$: Tool number with $\boldsymbol{z}$ as tool index $\boldsymbol{z = 1, 2, \ldots, Z}$

$\boldsymbol{t}$: Time index $\boldsymbol{t = 1, 2, \ldots, T}$

$\boldsymbol{t_{ixyz}}$: Time requirement by job "$\boldsymbol{J_i}$" on machine "$\boldsymbol{M_x}$" for operation "$\boldsymbol{O_y}$" with tool "$\boldsymbol{To_z}$" (hrs)

$\boldsymbol{t_{ix}}$: Material (Job) handling time for job "$\boldsymbol{J_i}$" on the machine "$\boldsymbol{M_x}$" (min)

$\boldsymbol{Av_z}$: Available number of tool type "$\boldsymbol{To_z}$"

$\boldsymbol{Mc_x}$: Tool Magazine capacity of machine "$\boldsymbol{M_x}$"

$\boldsymbol{To_{ixy}}$: A number of tools required for operation "$\boldsymbol{O_y}$" on machine "$\boldsymbol{M_x}$" of job "$\boldsymbol{J_i}$"

$$x_{ixyz} = \begin{Bmatrix} 1 \; if \; job \, J_i \; is \; loaded \; on \; machine \; M_x \; for \; operation \; O_y \; with \; tool \; To_z \\ 0 \; otherwise \end{Bmatrix}$$

$$M_{ixy} = \begin{Bmatrix} 1 \; if \;\; machine \; M_x \; is \; allocated \; for \; operation \; O_y \; on \; job \; J_i \\ 0 \; otherwise \end{Bmatrix}$$

$$TMC_x = \begin{Bmatrix} 1 \; if \; tool \; magazine \; of \; machine \; M(x) \; is \; full \\ 0 \; otherwise \end{Bmatrix}$$

The shop floor of the industry, the technology adopted, professional skills, machines capacity and size & specifications of the machines possess certain constraints that are required to be taken care of during allocation of machines and tools to the required operations on the jobs. Equation (2) ensures that all operations (y) of individual jobs (i) must be assigned. It is ensured by equation (3) that an operation must be assigned once only. It is required that the job should not split, taken care by equation (4). Equation (5), (6) and (7) ensures that the machine M_x can be allocated only if, the machine can perform the operation O_y [eq. (5)]; tool slot is available in the tool magazine of a machine [eq. (6)]; and, the job geometry (size) can be handled on the machine [eq. (7)]. The tool To_z can be allocated only if, the tool can perform the operation O_y [equation (8)], tool type is available [equation (9)] and, the tool can be used for the job material [equation (10)].

4. SOLUTION METHODOLOGY

A two stage solution methodology is developed for maximization of throughput for loading of machines in FMS. An intelligent solution approach based on all past experiences is proposed. Based on the framed concept of two stage solution approach, Machine Loading Flow Chart for Throughput Optimization (MLFCTO) as shown in Figure 1 is developed for loading of machines in FMS.

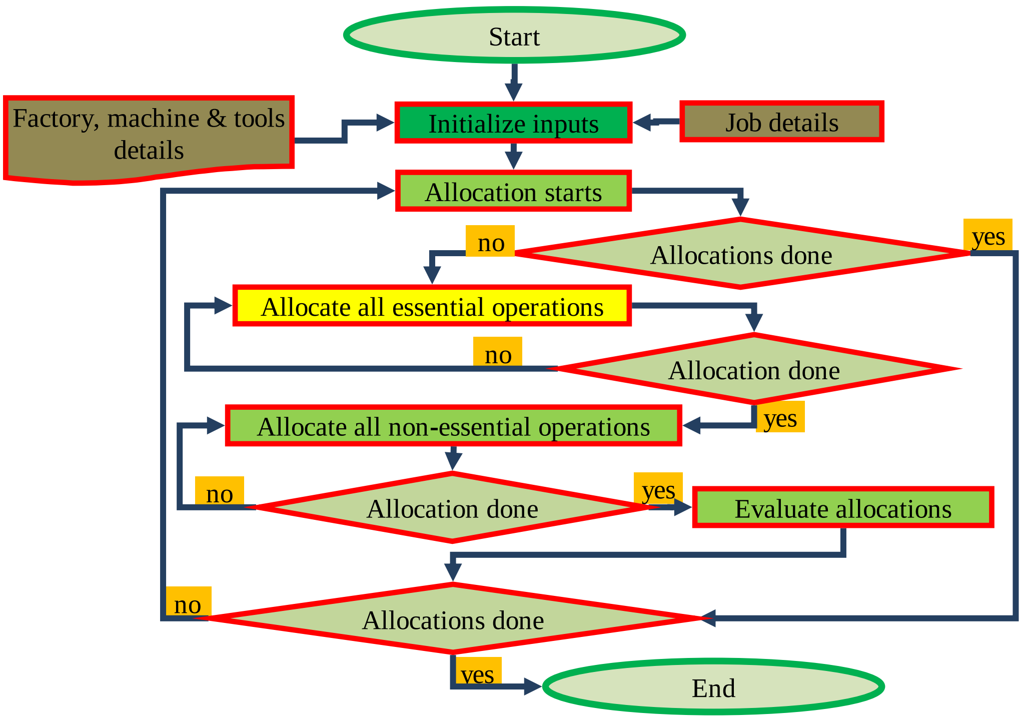
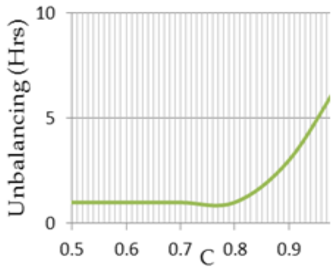


Figure 1: Machine Loading Flow Chart for Throughput Optimization (MLFCTO) for loading of machines in FMS

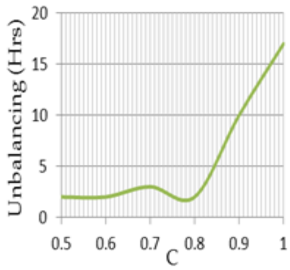
Inputs are initialized at start. First essential operations are allocated. Allocations are checked. After allocation of all essential allocations, allocations of all non-essential operations are done. Allocations are again checked. At last all required allocations on the job(s) or group is analysed. After successful allocations, the program terminates and results are plotted. To execute the developed flow chart MLFCTO, the Machine Loading Algorithm for Throughput Optimization is developed (MLATO). MLATO is executed in practice by developing two separate algorithms, one for essential and other for non-essential operation allocations. MATLAB codes are developed for the simulation of the developed algorithm for proposed flow chart. The codes are executed on a HP Pavilion dv6 Notebook PC, Intel(R) Core(TM)i7 &-2670QM CPU @ 2.20GHz, 4.00 GB RAM, 64 bit windows 10 home premium operating system.

5. RESULTS

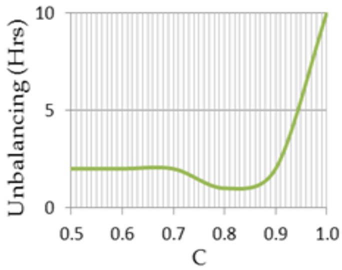
A computational case study is carried out to conduct computational experiments to check the robustness and versatility of the developed algorithms. Ten test problems are examined for result analysis of the developed approach for loading of machines in FMS.Analysing the performance parameters the unbalancing level was reduced to ideally zero i.e. the developed methodology provides 100% balancing of workload on machines. The simulation time is very less lying between, 1.2 to 1.51 seconds. The results data yields 100% results for balancing of workload on machines. The excellent optimum values are achieved with least computational requirements. Figure 2 presents the analysis of throughput as a performance parameters for $0.5 \leq C \leq 1$ for the test problems. Where C is a constant to be calculated by conducting computational experiments.



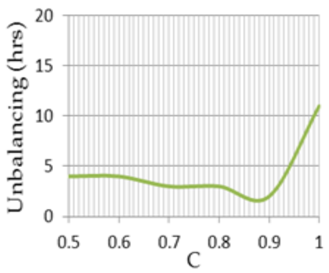
(a) Results of test problem no. 1



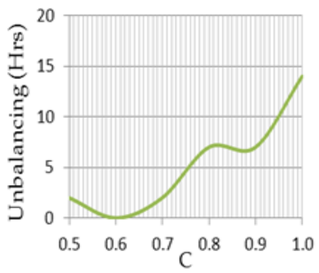
(b) Results of test problem no. 2



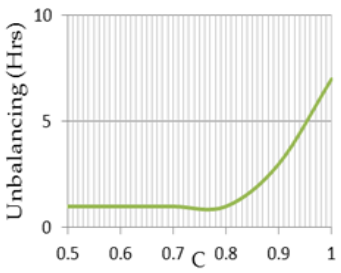
(c) Results of test problem no. 3



(d) Results of test problem no. 4



(e) Results of test problem no. 5



(f) Results of test problem no. 6

Figure 2: Analysis of throughput as a performance parameters for for six test problems

6. CONCLUSION OF THE PRESENT INVESTIGATION

Group technology is a great focus of attention worldwide as a manufacturing technology in present day environment. The proposed intelligent approach yielded 100% balancing of workload on machines for loading of machines. The computational requirements are very less. Accurate, realistic and acceptable results with least computational requirements were yielded. To prove the acceptability of the proposed methodology for higher industrial acceptance, the methodology needs to be tested for other sole objectives of throughput, cost, make span, flow time, machine utilization and job movements.

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