Scheduling for cellular manufacturing system using Tabu search method

Manoj kumar

Research Scholar, Mechanical engineering,

Green Hills Engineering College, Solan, India

Himachal Pradesh Technical University, Hamirpur

Kmanoj458@gmail.com +918263076128

Abstract— The main contribution of this work is to apply Tabu search based algorithms for solution of scheduling of jobs in CMS environment. An attempt has been made in this work to vary the job sequencing so that optimal sequencing of jobs can be achieved. The idea behind this work is to perturb sequences in the search of better results. More the number of sequences higher will be the degree of the optimization of objective (COF). This algorithm is suitable to explore number of job sequences from a fixed job sequence and its ability to come out from local optima. The main objective, which is the combination of maximizing the machine utilization by keeping penalty cost nil is achieved by this method. A scheduling procedure is developed for a specific FMS to maintain its flexibility and thereby the intended performance measures. The mechanism operates based on Tabu search and optimizes two contradicting objectives simultaneously. The problem in this research is considered as each processing step of job has a processing time with specific operation. Set up times of machines and intercellular movement times can be considered while solving the scheduling problem in future.

Keywords— CMS, Tabu search method, lower penalty cost, combined objective function.

1. INTRODUCTION

Cellular manufacturing is an application of Group Technology in which machines or processes have been aggregated into cells, each of which is dedicated to production of a part or product family or limited group of families. Parts with similar processing requirements are identified; these are then placed into logical groups called part families and the equipment requirements for each part family are subsequently determined. A part family is a collection of parts which are similar either because of geometric shape and size or similar processing steps required in their manufacture. A manufacturing cell consists of several functionally dissimilar machines which are placed in close proximity to one another and dedicated to the manufacture of a part family. It utilizes the concept of divide and conquers i.e. to break up a complex manufacturing facility into several groups of machines (cells), each being dedicated to the processing of a part family. Therefore, each part type is ideally produced in a single cell. Thus, material flow is simplified and scheduling task is made much easier.

CM is a hybrid system (incorporates the flexibility of job shops and the high production rate of flow lines) in which machines are located in close proximity to one another (machine cell) and dedicated to a part family. This, cellular manufacturing is limited to two dimensions being part and machine.

The use of general-purpose machines and equipment in CM allows machines to be changed in order to handle new product designs and product demand with little efforts in terms of cost and time. So it provides great flexibility in producing a variety of products. In conclusion, CM is a manufacturing system that can produce medium volume/medium variety part types more economically than other types of manufacturing systems. In the last several decades, CM has become increasing popular among manufacturers.

1.1. Role of CMS

On one hand we want to be more competitive, we want to excel in terms of quality and value of the goods and services that we offer and we want to be flexible enough to respond quickly to the market needs, and on the other hand are reluctant to adopt new technological innovations. This is more significant when it involves risky investments in labor and capital. There may be many technical details that may constrain the use of CMSs & FMSs. For example, the specifications of the machine tools, the rpm of the machine spindle, the type of material that could be cut and the versatility and power of the control system demanded may all pose problems which may hamper the pace of diffusion of the CMS technology. However, there are other problems which are non-technical in nature and which require a managerial perspective to analyze the problem. Hence, apart from the technical details of the system, a clear understanding of the organizational as well human aspects concerning the acquisition and implementation of FMSs is a crucial input for the decision makers. These issues serves to bring out the various problems that the Indian managers face while implementing the newer manufacturing. These include financial, organizational and personnel issues. Financial issues are those that may generally relate to the economic well being and performance of an organization. Organizational issues relate to the organizational culture, value systems and strategies and the impact of new system on these. Personnel issues address the problems arising out of the human system in an organization consequent to choosing to use newer system.

The advantages derived from cellular manufacturing in comparison with traditional manufacturing system in terms of system performance can be summarized as follows:

1. Setup time is reduced. A manufacturing cell is designed to handle parts having similar shapes and relatively similar sizes. For this reason, many of the parts can employ the same or similar holding devices (fixtures). Generic fixtures for the part family can be developed so that time required for changing fixtures and tools is decreased.

2. Lot sizes are reduced. Once setup times are greatly reduced in CM, small lots are possible and economical. Small lots also smooth production flow.

3.Material handling costs and time are reduced. In CM, each part is processed completely within a single

cell (where possible). Thus, part travel time and distance between cells is minimal.

4. A reduction in flow time is obtained**.** Reduced material handling time and reduced setup time greatly reduce flow time.
5. Tool requirements are reduced. Parts produced in a cell are of similar shape, size, and composition. Thus, they often have similar tooling requirements.
6. A reduction in space required**.** Reductions in WIP, finished goods inventories, and lot sizes lead to less space required.
7. Throughout times are reduced. In a job shop, parts are transferred between machines in batches. However, in CM each part is transferred immediately to the next machine after it has been processed. Thus, the waiting time is reduced substantially.

2. DESCRIPTION OF STUDY AREA

Presently, research pertaining to cell formation problem in CMS is in maturity phase of life cycle and the need of hour is that researchers realign their research objectives to the emerging business reality. CMS design research has not been able to adequately satisfy user requirements. There are many areas in which research in CMS can be done. These include developing solution method lies that guarantees product focused cells and the use of more production information in solving the restructuring problems. Adopting a Focused Factory is a powerful approach for today's manufacturing enterprise as a focused factory can provide many benefits including; reduced inventories and cycle times, improved quality and operational efficiencies, better cash flow, greater customer satisfaction / loyalty and a happier more productive work force. The investigation of Stanley D. Stone [1998] introduces the basic concepts of Focused Factories including: Cellular Manufacturing, visual factory techniques in a case study format. It examined a small manufacturer of value added plastic components consisting primarily of control knobs for the aerospace, industrial and consumer markets and suggests one dozen ways to focus the factory to implement CM. This topic can also be extended as a research topic. One of the important research area is Scheduling of Cellular Manufacturing Systems. Initial investment in facilities grouped into CMS is very high so these systems must be scheduled in a manner to realize more utilization of all the facilities while meeting customer delivery schedule. Because of complexity of scheduling there are different views of it Problem Solving Perspective views the scheduling as an optimization problem. It is the formulation of scheduling as a combinatorial optimization problem isolated form the manufacturing planning and control system place. Decision making Perspective is the view that scheduling is a decision that a human must make. Schedulers perform a variety of tasks and use both formal and informal information to accomplish these. Schedulers must address uncertainty, manage bottlenecks, and anticipate the problems that people cause Organizational Perspective. It is a systems-level view that scheduling is part of the complex flow of information and decision-making that forms the manufacturing planning and control system.

3. METHODOLOGY AND RESULTS

3.1. Formulation of problem

The combined objective function constitutes of two functions. These functions are related addresses the problem of scheduling jobs in a flexible job shop with the objective of minimizing total idleness of machine and maximizing the machine utilization. To achieve the objective of maximizing the machine utilization we use the minimization of total machine idle time. So the combined objective function (COF) becomes to minimize the machine idle time by keeping penalty cost zero. To attain our objective of keeping total penalty cost nil and maximizing the machine utilization, we have to minimize our Combined Objective Function (COF).

After every solution move in the TS procedure every solution in the neighborhood of the current solution will be evaluated for a Combined Objective Function (COF) of minimizing machine idle time and keeping penalty cost zero

Our primary objective is to maximize the utilization of the capital-intensive system. Also with the emerging trends towards customer orientation in the world of global market, the system can not afford to ignore objectives that have direct relation to customer satisfactions. So, both of the above objectives (maximizing the system utilization and keeping penalty cost nil) are considered for optimization.

COMBINED OBJECTIVE FUNCTION (COF)

Minimize

$$COF = (W1) * [(Xp * C) \div MPP] + (W2)*(Xq \div TE)$$

Where

W1 = Weight age factor for Customer satisfaction.

TE = Total Elapsed (make span) Time.

Xp= Penalty cost incurred

W2= Weight age factor for machine utilization

C = Function of penalty cost if completion time CTi increases DDi due date for job, C becomes unity which means there will be some penalty cost which is not an acceptable condition. In such condition Tabu search moves will search the neighborhood network to get the required result that is value of Idleness and COF by keeping penalty cost zero.

1)

X p= Total Penalty Cost incurred

$$Xp = \sum (CTi - DDi)*UPCi*BSi$$

i= Job number

CTi=Completion Time of job i

DDi =Due Date for job i

UPCi = Unit Penalty Cost for job i

BSi = Batch size of job i

a) Ti = Processing time = (1/60*8) *Batch size = time in days

b) TE= Total elapsed or Actual time= Processing time + Idle time

c) Assuming MPP= 1000

2)

W2 =Weight age factor for Machine Utilization

Xq =Total Machine idle Time of jth machine = ∑ MIjJ

J=machine number

MIj = Machine idle time of Jth machine = TE - ∑ PTji

Processing time of ith job with jth machine

The values of *WI* and *W2* are weight age factors applied as per demand of the business situations such that W1+ W2 =1

In present situation in our problem we want penalty cost to be Nil so we have given weight age factor W1=0.1 and we want machine idle time to be minimized so have given weight age W2=0.9.

3.2. Methodology

Step I.

An initial Job sequence (x_now) is selected at random among the flexible set of job sequence (X). The combined objective function value for the solution (x_now) is computed and defined as best cost. The history record H is initialized with empty record.

Step 2.

A set of neighborhood solutions of x-now is generated: N(x-now) and all the solutions stored in H are identified in N(x_now) and removed to form the set of movable solutions: Candidate-N(x_now).

Step 3.
The COF values of all the solutions in the Candidate (x_now) are calculated and the one (x-next) with the minimum value c (H, x_next) is chosen.

Step 4.

If c (H, x_next)<= best-cost then a move performed, best cost is replaced with c(H, x_next)and the history record H is appended with the swapped pairs of sequence number. Otherwise the history record H is browsed and solution satisfying the aspiration criteria is chosen as(x_next) . The H is also updated.

Step 5.

If the term initiation criteria are not met, step 2 to step 5 is repeated otherwise the procedure is stopped.

3.3. Results

The performance of the algorithm is measured according to an objective function, which is the maximizing the machine utilization by keeping penalty cost nil. The previous work did not explore more number of sequences by perturbing fixed sequences. The strength of Tabu search lies in the generation of random sequences and in large numbers. A large number of sequences are required to get rid of the local minima. In this work we have generated a large number of sequences, so that we can get a global optimal solution. Some of the notable features proposed algorithm on scheduling:

1. Several combinations of job sequencing are to be evaluated by perturbing sequencing obtained from fixed job sequence.
2. Corresponding to each job sequence, the operation-machine-allocation are carried out to achieve the combined objective function of minimizing total tardiness and maximizing the machine utilization by satisfying the system constraints (Available machining time at different machine for each job and penalty after due date).

Special Cases

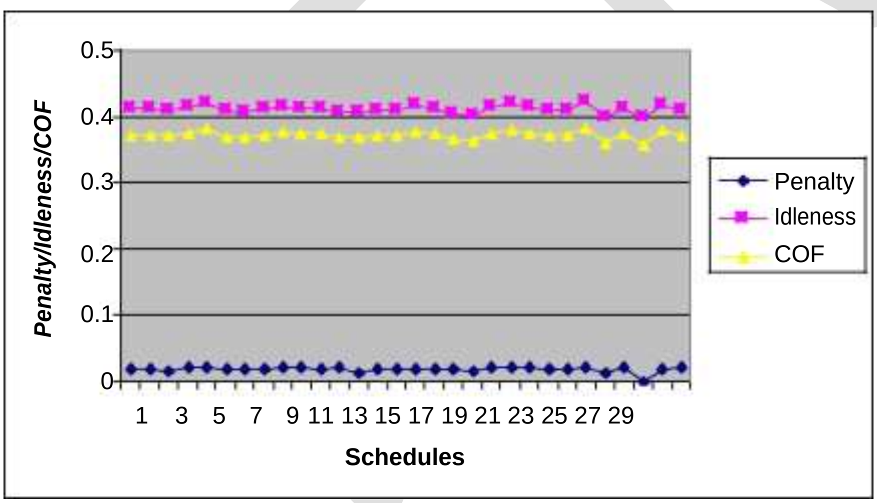
Case Name	Seq.	Penalty	Idleness	COF
Highest Pro Time	21;14;8;30;32;13;12;19;43;3;33;27;42;39;15;37;35;6;29;17;28;	0.2074205	0.7207892	0.4641049
Shortest Pro Time	20;23;38;1;9;26;22;10;34;18;36;11;25;5;16;2;40;4;31;41;7;24;2	0.1683454	0.6090647	0.388705
Highest Batch Size	12;14;30;28;35;8;21;3;31;32;41;16;4;6;13;15;29;36;17;43;33;3	0.1729306	0.7219588	0.4474447
Shortest Batch Size	20;23;38;9;1;5;10;2;22;24;7;11;18;37;40;34;25;27;42;19;26;33	0.2014075	0.60933	0.4053687
Earliest Due Date	9;11;31;28;19;24;29;40;38;35;39;5;20;34;3;23;15;32;43;6;21;1	0.1909506	0.6657351	0.4283428
Highest Due Date	16;26;33;4;7;8;13;18;22;25;14;27;37;41;10;17;36;12;42;30;1;2	0.1857098	0.7003389	0.4430244

Method	Seq.	Penalty	Idleness	COF
Tabu Search	23; 38; 35; 36; 31; 26; 42; 40; 16; 3; 11; 1; 7; 34; 25; 24; 15; 41; 19; 28; 37; 12; 18;32; 39; 5; 14; 17; 29; 9; 2; 43;33 21; 30; 4; 20; 13; 22; 27; 6; 10; 8	0.0000	0.3986	0.3587

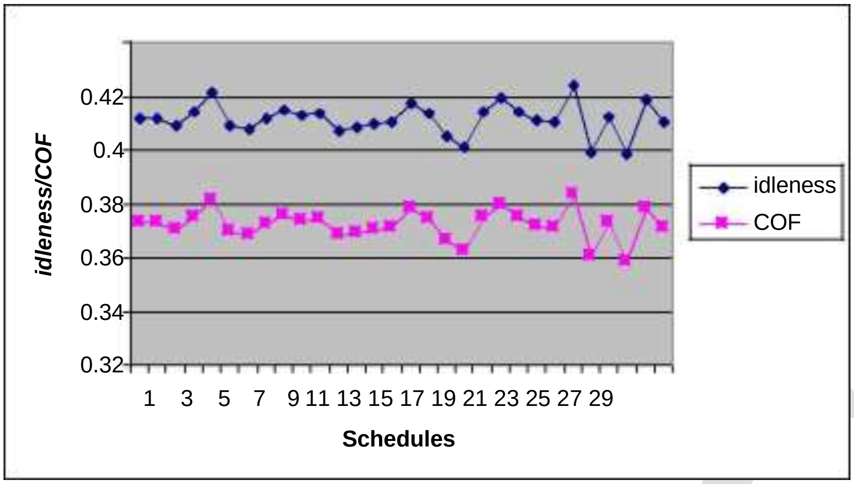
3.4. Comparison of results

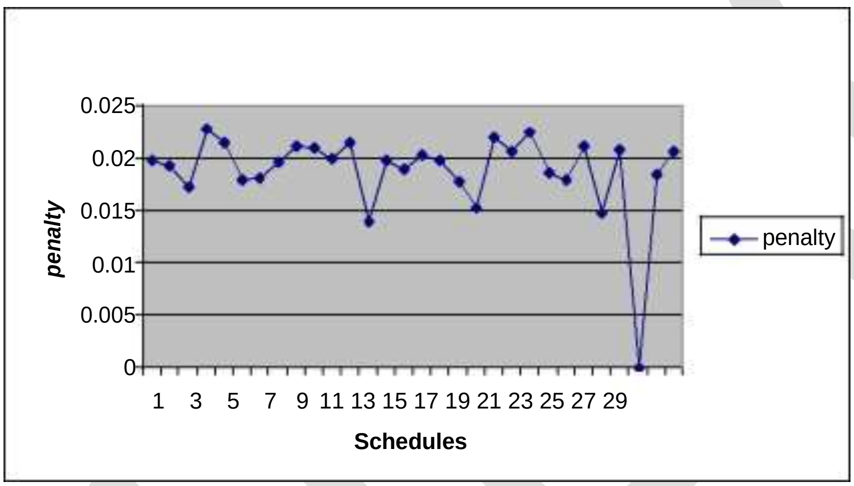
The results show in Tabu search methods the value of penalty is lowest for maximizing machine utilization. Our Combined objective function is also minimum in case of Tabu search method. Hence it can be said that minimizing penalty and maximizing the machine utilization of job sequences are observed here. This corroborates the performance of this algorithm is better as compared to other algorithms.

Graphs for results when w1=0.1,w2=0.9



0.44


0.42
0.4
0.38
0.36
0.34
0.32
idleness/COF
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Schedules
idleness
COF

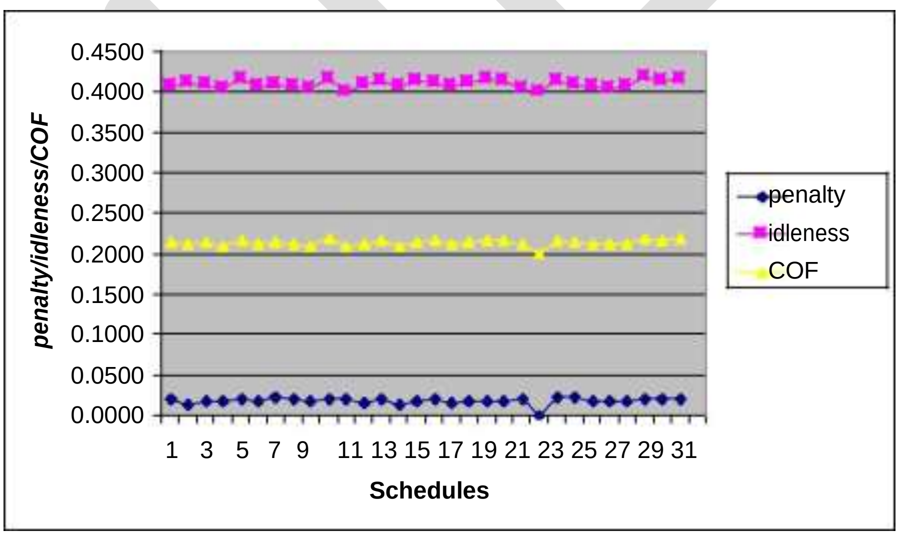

0.025
0.02
0.015
0.01
0.005
0
penalty
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Schedules
penalty

Results when w1=w2=0.5

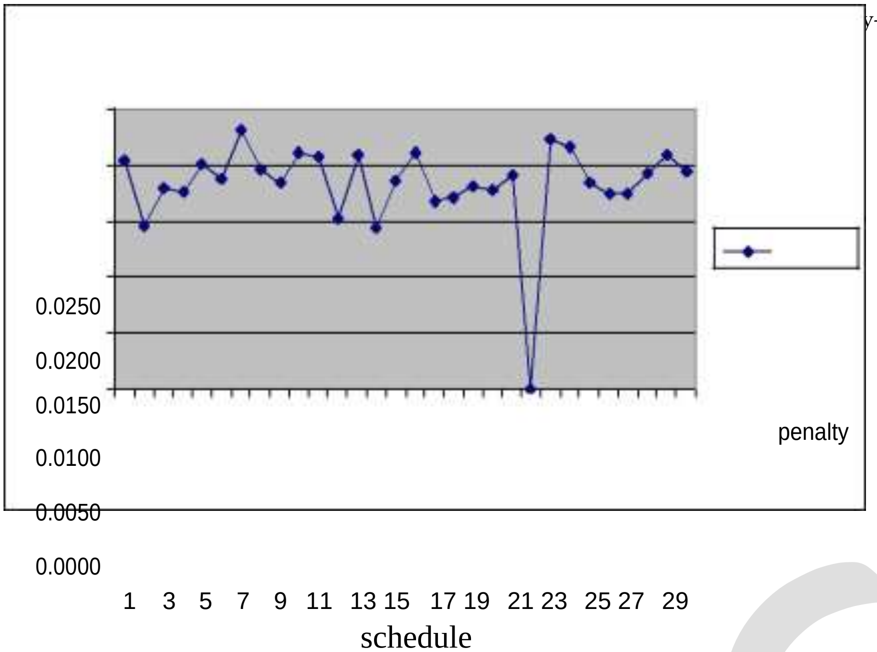
Initial sequence selected	Schedule	Penalty	Idleness	COF
2	1	0.0205	0.4075	0.2140
8	2	0.0145	0.4113	0.2129
12	3	0.0180	0.4108	0.2144
1	4	0.0176	0.4050	0.2111
3	5	0.0202	0.4161	0.2181
4	6	0.0187	0.4078	0.2133
5	7	0.0231	0.4095	0.2155
6	8	0.0197	0.4069	0.2133
20	9	0.0184	0.4043	0.2113
7	10	0.0212	0.4164	0.2188
9	11	0.0208	0.4003	0.2106
10	12	0.0152	0.4164	0.2121
23	13	0.0209	0.4003	0.2174
16	14	0.0144	0.4090	0.2110
11	15	0.0185	0.4139	0.2162
13	16	0.0212	0.4077	0.2160
14	17	0.0167	0.4135	0.2119
15	18	0.0170	0.4112	0.2146
17	19	0.0181	0.4070	0.2178

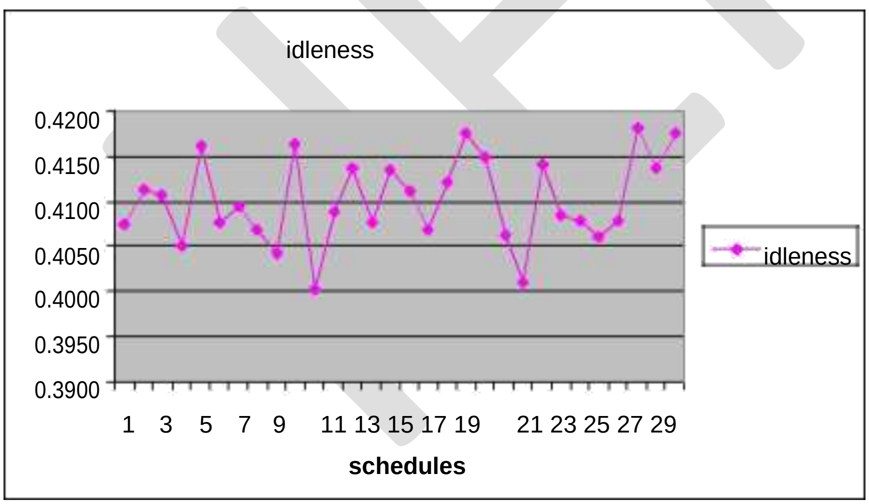
18	20	0.0177	0.4149	0.2163
19	21	0.0191	0.4062	0.2026
21	22	0.0000	0.4010	0.2105
22	23	0.0223	0.4141	0.2182
24	24	0.0217	0.4086	0.2152
25	25	0.0185	0.4079	0.2132
26	26	0.0175	0.4062	0.2119
27	27	0.0175	0.4078	0.2127
28	28	0.0193	0.4181	0.2187
29	29	0.0210	0.4138	0.2174
30	30	0.0495	0.4175	0.2185

Graphs for results when w1=w2=0.5



penalty





4. ACKNOWLEDGEMENT

I express my deep gratitude and respects to my guide Mr. O.S.Bhatia for his keen interest and valuable guidance, strong motivation and constant encouragement during the course of the work. I thank him from the bottom of my heart for introducing me to the welding in vertical milling machine. I thank him for his great patience, constructive criticism and useful suggestions apart from invaluable guidance to me. It gives me immense pleasure to express my special thanks to O.S.Bhatia who always took keen interest in guiding me during my work. I owe my sincere thanks to all the staff members of Green Hills Engineering College Kumarhatti, Solan for their support and encouragement. I would also like to thank my all marvelous friends for extending their whole hearted support. At Last I would like to thank my parents and my brother for their moral support that kept my spirit up during the endeavor.

5. CONCLUSION

The main contribution of this work is to apply Tabu search based algorithms for solution of scheduling of jobs in CMS environment. An attempt has been made in this work to vary the job sequencing so that optimal sequencing of jobs can be achieved. The idea behind this work is to perturb sequences in the search of better results. More the number of sequences higher will be the degree of the optimization of objective (COF). This algorithm is suitable to explore number of job sequences from a fixed job sequence and its ability to come out from local optima. The main objective, which is the combination of maximizing the machine utilization by keeping penalty cost nil is achieved by this method.A scheduling procedure is developed for a specific FMS to maintain its flexibility and thereby the intended performance measures. The mechanism operates based on Tabu search and optimizes two contradicting objectives simultaneously. The schedule obtained by Tabu search is compared with the solutions obtained by different scheduling rules i.e. SPT, HPT, EDD etc. After comparing the results it can be concluded that Tabu search method is by far superior to other scheduling rules, as it gives optimal value for penalty. idleness and combined objective function (COF). Thus the optimization of scheduling problem can be achieved up to greater degree by utilizing Tabu search method.

REFERENCES:

1. A.Sobhanallahi & E,Shan**,** [1998], Effect of cell based team work in productivity improvement at a manufacturing company, Computers ind. Engng Vol. 35, Nos 3-4, pp. 451-45, IRIS, Swinburne University of Technology, Melbourne, Victoria, Australia.

2. A. J. Vakharia & Y.L. Chang, **[**1997]**,** Cell formation in group technology: a combinatorial search approach .

3. A. Garrido, M. A. Salido, F. Barber & M. A. Lopez, "Heuristic Methods for Solving Job-Shop Scheduling Problems**"** Dpto Sistemas Informáticos Computación, Universidad Politécnica de Valencia, Camino de Vera s/n 46071, Spain.

4. B.Mahadevan, et aI., [2000], Design of cellular manufacturing system for product oriented plant, Third International Conference on Operations & Quantitative Management, Sydney.

5. B.Mahadevan & G Srinivasan, [2000], Software for manufacturing cell formation: issues and experiences, Department of Operations Management, Indian Institute of Management, Bangalore, India.

6. B.Mahadevan, S.Venkataramanaiah, [2003], Re-aligning research objectives in Cellular manufacturing system design, Asian Journal of Operations Management, Department of Production& Operations Management, Indian Institute of Management Bangalore.

7. Charlene A. Yauch & Harold J. Steudel, [2002], Cellular manufacturing for small businesses: key cultural factors that impact the conversion process, Journal of Operations Management 20 (2002) 593-617, Department of Industrial Engineering and Management, Oklahoma State University, USA.

8. Ching- Yuen Chan, et aI., [1996],Considerations for using cellular manufacturing, Journal of Materials Processing Technology,182-187,Hong Kong Polytechnic University, Hung Horn, Hong Kong.

9. Chung-Yang Liu & Shi-Chung Chang, [2000], Scheduling Flexible Flow Shops with Sequence-Dependent Setup Effects .

10. Edward L. Mooney, Ronald L. Rardin, "TABU SEARCH FOR A CLASS OF SCHEDULING PROBLEMS.

11. Eric Molleman, et al.,[2001], The evolution of a cellular manufacturing system a longitudinal case study, Int. .J Production Economics 75 (2002) 305-322, Faculty of Management and Organization, University of Groningen, Netherlands.

12. E.Taillard, [1990], Some efficient heuristic methods for the flow shop sequencing problem," European Journal of Operational Research, vol.47, pp.65-77.

13. Festus Olorunniwoa, Godwin Udo, [2002], The impact of management and employees on cellular manufacturing implementation, Int. J Production Economics, 27-38 College of Business, Tennessee State University, USA.

14. F. Glover, E. Taillard, and D. deWerra, "A user's guide to tabu search," ORSA journal on computing, vol. 41, 1989, pp.3-28.

15. G. Chand & B. Shirvani, [2000],Implementation of TPM in cellular manufacture, Journal of Materials Processing Technology, 149-154, Faculty of Engineering and Computer Technology, University of Central England, Birmingham, UK.
16. Hassan M. Selim, et aI., [1998] Cell formation in group technology: review, evaluation and directions for future research, Computers ind. Engg. Vol 34, No. 1,pp 3-20, College of Engineering & Technology, Cairo, Egypt.
17. J. Grabowski and M. Wodecki, [2004], A very fast Tabu search algorithm for the permutation flow shop problem with make span criterion," Computers and Operations Research, vol.31, no. 11,pp.1891-1909