International Journal of Engineering, Mathematical and Physical Sciences
ISSN: 2517-9934
Vol:9, No:1, 2015

Optimization of Flexible Job Shop Scheduling Problem with Sequence Dependent Setup Times Using Genetic Algorithm Approach

Sanjay Kumar Parjapati, Ajai Jain

***Abstract*—**This paper presents optimization of makespan for ‘n’ jobs and ‘m’ machines flexible job shop scheduling problem with sequence dependent setup time using genetic algorithm (GA) approach. A restart scheme has also been applied to prevent the premature convergence. Two case studies are taken into consideration. Results are obtained by considering crossover probability (p_c = 0.85) and mutation probability (p_m = 0.15). Five simulation runs for each case study are taken and minimum value among them is taken as optimal makespan. Results indicate that optimal makespan can be achieved with more than one sequence of jobs in a production order.

***Keywords*—**Flexible Job Shop, Genetic Algorithm, Makespan, Sequence Dependent Setup Times.

I. Introduction

SCHEDULING is the process of generating the schedule and schedule is a physical document which generally tells the happening of things and shows a plan for timing of certain activity. Scheduling can also be defined as the process of assigning a set of tasks to resources over a period of time [16]. Scheduling work has considerable significance in manufacturing area. Here resources are called machines and tasks are called jobs. Sometimes, a job may consist of several elementary tasks called operations. The environment of scheduling problem is called the job shop or simply shop. Scheduling is a very complex activity requiring a great amount of computational work. Both exact and approximate methods are available for scheduling but exact methods of scheduling tends to fail due to enormous computational work with the increase in number of jobs and machine. Thus approximate methods such as Simulation Annealing, Tabu Search, Genetic Algorithm are generally used to solve scheduling problems.

Job shop problem have a set of ‘n’ jobs to be processed on a set of ‘m’ machines. Each job has a set of operations to be performed on set of machines in a particular order and each machine can process at most one operation at a time. Flexible job shop problem is an extension of classical job shop problem. In flexible job shop problem an operation can be processed by more than one machine, but in job shop problem one operation can be processed by exactly one machine [24].

Sanjay Kumar Parjapati Assistant Professor, is with the Department of Mechanical Engineering, Stallion College for Engineering and Technology, Saharanpur,(U.P.) (e-mail: sanjay.parjapati.nitkkr@gmail.com)

Ajai Jain Professor, is with the Department of Mechanical Engineering, National Institute of Technology, Kurukshetra,Haryana (e-mail: ajaijain12@gmail.com)

In actual practice, many problems are encountered in a real world whenever some time is spent in bringing a given facility to a desired state for processing the job. The time spent is called set up time. When its magnitude depends upon the job just completed and the job waiting to be processed then the setup time is called the sequence dependent setup time. It has been reported in the literature that sequence dependent set up time (SDST) is one of the most recurrent additional complications in the scheduling problem [7]. As setup times are defined to be the work to arrange the resources, process, or bench for tasks which includes obtaining tools, positioning work in process material, cleaning up, adjusting and returning tools and inspecting material in manufacturing system. In a survey of industrial schedulers, 70% of the schedulers reported that they had to deal with sequence dependent setups [8].

II. Literature Review

Several researchers have addressed the problem of job shop scheduling with sequence dependent setup time. Some important contributions are discussed below.

Xing et al. [22] proposed a multi-objective Genetic Algorithm to solve Fuzzy Job Shop Scheduling Problems, in which the objective functions were conflicting. Two benchmark problems were used to show the effectiveness of the proposed approach. Experimental results demonstrated that the multi-objective Genetic Algorithm does not get stuck at a local optimum easily, and it can solve Job Shop Scheduling problems with Fuzzy processing time and Fuzzy due date effectively. Moon et al. [11] used Genetic Algorithm to solve a general Job Shop Problem with alternative machine routings, they considered four performance measure mean flow time, makespan, maximum lateness, and total absolute deviation from due dates. They first developed Mixed-Integer Linear Programming (MILP) formulation that can be used either to compute optimal solutions for small sized problems or to test the performance of existing heuristic algorithms. In addition, a Genetic Algorithm has been developed for solving large-sized problems. The computational results showed that the Genetic Algorithm outperformed the existing heuristic reported in literature. Authors stated that, developing other kind of meta-heuristic and comparing them with the Genetic Algorithm for same problem would be an interesting research problem. Wang et al. [21] proposed a Novel Genetic Chromosome-encoding Approach. In the encoding method, the operation of crossover and mutation were done in three-dimensional coded space. Authors tried some big benchmark problems with the proposed three dimensional encoding GA for validation. The experimental results indicate that this method is efficient and competitive compared to some existing methods. Xu et al. [23] introduced a time operator depending on the time evolution to solve Job Shop Scheduling Problems. Their purpose was to overcome the defect of adaptive GA whose crossover and mutation probability cannot make a corresponding adjustment with evolutionary process. Their Algorithm's structure was hierarchical and was tested by Muth and Thompson benchmarks. Results showed that the optimized algorithm is highly efficient and improves both the quality of solutions and speed of convergence. Zhang et al. [24] proposed an effective Hybrid Particle Swarm Optimization Algorithm to solve Multi-objective Flexible Job Shop Scheduling Problems. Authors applied their algorithm to solve problems ranging from small scale to large scale. Results showed that the proposed algorithm performed at the same level or better with respect to the three objective functions (minimizing makespan, minimizing total workload and minimizing workload of most loaded machine) in almost all instances, when compared to the result from the other alternative solution method as reported in literature (GA based approach). Further, all result could be got in the reasonable computational time. It proves that this Hybrid Algorithm is efficient and effective. Roshanaei et al. [18] considered the problem of scheduling of a Job Shop (JSS) where setup times are sequence dependent setup time (SDST) to minimize the maximum completion times of operation or makespan. Their problem generally formulated as $J/ST_{sd}/C_{max}$. To tackle such an NP-hard problem, authors employed a recent effective metaheuristic algorithm known as Variable Neighbourhood Search (VNS). An experimental design, based on Taillard's benchmark was conducted to evaluate the efficiency and effectiveness of algorithm proposed by authors, against some effective algorithms available in literature such as GA, HGA, shortest processing time dispatching rule. The obtained results strongly support the high performance of proposed algorithm with respect to other well known heuristic and meta-heuristic algorithms available in literature. Motaghedi et al. [12] solved Flexible Job Shop Scheduling Problem in the case of optimization different contradictory objectives consisting of minimizing makespan, minimizing total workload and minimizing workload of most loaded machine. Authors proposed a new Hybrid Genetic Algorithm to obtain a large set of Pareto-optimal solutions in a reasonable run time. Their algorithm utilized a local search heuristic for improving the chance of obtaining more number of global Pareto-optimal solutions. Computational experiments showed that, the Hybrid Algorithm has superior performance in contrast to previous studies reported in literature that utilized GA based approach. Asadzadeh et al. [3] proposed an Agent-based Parallel Approach for the problems in which creating initial population for parallelizing the Genetic Algorithm was carried out in an agent based manner. Authors used the benchmark instances from OR library to investigate the performance of their approach. The results showed that, proposed algorithm improved the efficiency and the quality of the results obtained i.e. proposed approach not only obtained much shorter schedule lengths, but also has higher convergence speed. Authors stated that, future work will concentrate on improving the performance of their method and applying it to similar problems. Naderi et al. [14] used a high performing metaheuristic for job shop scheduling with sequence dependent setup times for minimization of makespan. Authors proposed an effective neighborhood search structure, based on insertion neighborhoods as well as analyzing the behavior of simulated annealing with different types of operators and parameters by the means of Taguchi method. An experiment based on Taillard benchmark is conducted to evaluate the existing algorithm against some effective algorithms GA, hybrid GA, Immune algorithms and VNS algorithm proposed by various researchers. The result showed that the proposed algorithm outperforms the considered algorithms. Bagheri et al. [4] consider Flexible Job Shop Scheduling Problem (FJSP) with sequence-dependent setup times to minimize makespan and mean tardiness. To solve this problem, a Variable Neighbourhood Search (VNS) Algorithm based on Integrated Approach was proposed by authors. To evaluate the performance of the proposed algorithm, authors generated 20 test problems of different sizes randomly. The results showed that the proposed algorithm performs better than the adapted methods i.e. GA and VNS. Tang et al. [19] used a hybrid algorithm combining the Chaos Particle Swarm Optimization and Genetic Algorithm to solve the FJSP. With the induction of improved Kacem assignments scheme, an initialization mechanism was presented by authors. Authors validated their method on a series of benchmark datasets. The experimental results indicate that this method is efficient and competitive compared to some existing methods (GA and its modification) reported in literature. Chen et al. [5] solved a Flexible Job Shop Scheduling Problem with parallel machines using Genetic Algorithm (GA) and Grouping Genetic Algorithm (GGA). This algorithm consists of two major modules, Machine Selection Module (MSM) and Operation Scheduling Module (OSM). MSM helps an operation to select one of the parallel machines to process it. OSM is then used to arrange the sequences of all operations assigned to each machine. Authors took data from a real weapon production factory for their case study to evaluate the performance of the proposed algorithm. Total tardiness, total machine idle time and makespan were considered performance measures in their study. Authors concluded that, simulation results demonstrate that MSM and OSM respectively using GGA and GA outperforms current method used by the factory. Wang et al. [20] proposed An Effective Pareto-Based Estimation of Distribution Algorithm (P-EDA) to solve the Multi-Objective Flexible Job-Shop Scheduling Problem with the criteria to minimize the makespan, the total workloads of machines and the workload of the critical machine. Simulation tests and comparisons showed that the proposed P-EDA is more effective in solving the MFJSP than both the existing Weighted Approaches and Pareto-Based Approaches. Authors stated that future work should be to design EDA-Based Algorithms for the Lot Sizing Scheduling Problems.

ISSN: 2517-9934
Vol:9, No:1, 2015

Mousakhani et al. [13] studied Flexible Job Shop Problems with sequence-dependent setup times to minimized total tardiness. Authors built an effective Mixed Integer Linear Programming for the problem and compared it with three available models out of that two available models suffered from non-linearity. The other one seemed ineffective due to its large complexity size. To solve large sized problems more efficiently, author developed an effective metaheuristic based on iterated Local Search. The proposed algorithm was compared for performance against some available algorithms, Tabu Search and Variable Neighbourhood Search Algorithm. Finally, results showed that that, the proposed algorithm outperformed the other algorithms. Ziaee et al. [25] investigated the flexible job shop scheduling problem with preventive maintenance constraints. The objective was to minimize the makespan, the total workload of machines and the workload of most loaded machine. The main purpose is to produce reasonable schedules very quickly. A fast heuristic algorithm based on a constructive procedure was developed to solve the problem in very short time. The algorithm was tested on the benchmark instances from the literature in order to evaluate its performance. Computational results show that, the proposed heuristic method was computationally efficient and promising for practical problems.

III. Problem Formulation

Literature review reveals that flexible job shop scheduling problem with consideration of sequence dependent setup times as well as with multiple quantity of each part type has not been attempted by the researchers and this is the first attempt in this direction. In the present work, an attempt is made to optimize flexible job shop scheduling problem with multiple quantity of each part type and with sequence dependent setup times for makespan as performance measure. Thus, the problem considered in the present work is described below:

"There is a order of 'n' jobs/part types to be processed on a set of 'm' machines in flexible job shop. An operation can be performed on more than one machine. The processing time of every operation of each job on machines is known in advance. The setup time of every operation on machines for each job is sequence dependent and is also known in advance. Each part type has multiple quantity of jobs. The objective is to find the optimal schedule for makespan as performance measure."

In accordance with three field notation (α / β / γ), the problem specified can be represented as [1], [2].

$$\mathbf{FJ / ST_{sd}, prec / C_{max}}$$

Following assumptions in line with previous studies are made in the present work [10].

(1) All jobs are available for processing at time zero.
(2) Machines never breakdown and available throughout the scheduling period.
(3) No machine may process more than one operation at the same time.
(4) Infinite buffer exist between stages and before the first and after the last stage.
(5) Job processing cannot be interrupted.
(6) A job cannot be processed on more than one machine at the same time.
(7) No pre-emption is allowed.
(8) Travel time is not taken into consideration.
(9) A job follow precedence constraint of the operation.

IV. Adopted Methodology

In order to find the optimal schedule for a flexible job shop with sequence dependent setup times, a genetic algorithm based methodology is adopted in the present work. This section presents the details of the adopted methodology.

A. Representation

Encoding is the first step of GA. Each feasible solution is encoded as a chromosome (string or individual) also called a genotype (encoded solution). Various encoding schemes have been proposed by researchers for job shop scheduling such as binary encoding, permutation encoding, value encoding. The present work utilizes job based representation. In this method, strings (chromosome) are coded as a sequence of numbers (genes) with each gene representing one of the job of each part type involved.

1st gn	2nd gn	3rd gn	4th gn	5th gn	6th gn	7th gn	8th gn	9th gn	
1	4	1	2	3	4	2	1	4	← Part type
1st J	1st j	2nd j	1st j	1st j	2nd j	2nd j	3rd j	3rd j	

Legend: gn = gene; j=job

Fig 1 Chromosome Structure

The length of chromosome depends upon the number of part types and quantity of each part type. Fig. 1 represents the chromosome structure for a production order consisting of four part type to be processed in a flexible job shop with production quantity 3 jobs, 2 jobs, 1 jobs, 3 jobs respectively.

B. Initialization

In this step, initial population is generated having a fixed number of chromosomes and it is called population size. Initial population contains suitable number of solutions for the problem. Generally, initial population is generated randomly [6]. The present work considers a population size equal to 10 and it was generated randomly.

C. Evaluation of Fitness Function

Each chromosome gives a measure of fitness via a fitness function (evaluation or objective). It is performance evaluation of chromosomes. GA is naturally suitable for solving maximization problems [6]. Since objective functions in the present work was minimization of makespan [f(x)], this minimization problem is transformed into maximization problem by following transformation rule [6].

$$F(x) = 1/ [1+f(x)]$$

where f(x) = value of makespan, F(x) = fitness function

D. Selection

Selection operator determines which chromosomes undergo for crossover and mutation. This decision is based on fitness of the chromosomes. During selection, the fitness of chromosomes is compared in order to choose the better chromosomes to drive search in good region of search space. Various selection methods such as Roulette Wheel Selection, Tournament Selection and Rank Selection can be used for selection in Genetic Algorithm. In the present study, Tournament selection was used with a selection pressure of 2.

E. Crossover

Crossover is used as the main Genetic operator and the performance of a GA is heavily dependent on it. A crossover operator is used to recombine two strings to get a better string. In the crossover, new strings are created by exchanging information among strings of the mating pool. A crossover operator is mainly responsible for the search of new strings. In this study, two point crossover with a crossover probability of 0.85 was used. Due to above crossover methodology, some illegal off springs may generate. Then repairing was done to resolve the illegitimacy of off spring after mutation.

F. Mutation

Mutation is regarded as an integral part of a GA. Mutation generates an offspring solution by randomly modifying the parent's feature. It helps to preserve a reasonable level of population diversity, and provides a mechanism to escape from local optima. In the present work, swap mutation with mutation probability of 0.15 was used.

G. Repairing

As discussed earlier, some illegal off springs may generate during crossover. For this, repairing is needed to resolve the illegitimacy of off springs after mutation. A repairing procedure was utilized for this purpose. It checks the string from left to right. If at any point, some genes repeats more than required and some genes are missing, then excess genes at any place are replaced by missing genes randomly.

H. Elitism

After generating offspring's, the parent strings of previous generation may get completely replaced. The best individuals can be lost in two cases (i) if, they are not selected to reproduce and/or (ii) they are destroyed by crossover or mutation [9]. Thus, elitism strategy is used in order to force GA to retain some number of the best individuals at each generation. In the present work, elitism transfers a good individual from previous population to population of next generation with the elitism rate of 0.9 and it means that 10% best population is carried on into the next generation. For example, if, population size is 10, then the total number of best individuals from previous generation to be carried into next generation is equal to one.

I. Termination Criterion

It refers to the stopping criterion for further exploration in the search space. In the present work, if the fitness value did not change for 100 iterations, GA terminates and algorithm reaches to the optimum value of makespan.

J. Restart Scheme

The population evolves as the GA proceeds. Sometimes, the population has a low diversity for the process to avoid becoming trapped in a local optimum. In order to avoid premature convergence, a restart scheme was utilized [17]. If the best seen fitness value is not promoted for more than a pre specified number of generations (no change), the restart phase commences to regenerate the population. In the present work, restart scheme was applied if there is no improvement in the fitness value for 10 successive iterations.

The above methodology is coded in MATLAB® and executed on Windows platform on Intel(R) Pentium(R) Dual CPU E2140 @ 1.60 GHz 1.60 GHz, 1 GB RAM.

V. Results and Discussions

In the paper presented, two case studies are taken into consideration. The optimization is carried out for each case study with crossover probability of 0.85 and mutation probability of 0.15. Five simulation runs are taken for each case study and minimum makespan among five runs is taken as optimal makespan. The details of these case studies are described below.

TABLE I
SHOP CONFIGURATION AND PRODUCTION ORDER DATA (CASE STUDY 1)

No. of part types	10
No. of machines	05
Maximum no. of operations	05
Setup time	U [20-60]
Processing time	U [20-100]
Quantity of each part type	U[10-30]

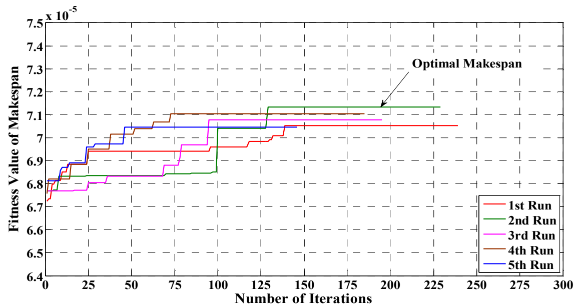

Fig. 2 Convergence Curve for Case Study 1

A. Case Study 1

Table I summarizes details of flexible job shop configuration and production order received. Further details of case study are not presented here for want of space and are available at Parjapati, S. K. [15].

In this case study, each part type does not require all operations. For this case study, optimization is carried out using adopted methodology as described in section IV and optimal makespan is 14017 minutes. Fig. 2 shows the convergence curve between fitness value of makespan and number of iterations.

For case study 1, job sequence for optimal makespan is:

[2 7 2 2 3 3 1 3 3 1 3 4 2 3 2 2 4 2 2 2 3 1 2 2 2 1 3 3 3 4 3 3 3 3 3 3 4 4 4 4 3 3 3 4 4 3 4 4 4 7 4 7 7 3 9 9 9 4 1 7 1 3 4 4 9 2 4 4 7 7 8 1 4 10 8 3 4 7 3 10 10 10 10 3 7 2 3 10 9 10 7 4 9 4 8 10 10 8 8 8 2 2 8 9 5 9 10 5 9 10 10 4 5 2 10 10 10 1 8 8 5 9 7 7 8 10 7 1 8 8 10 8 2 10 2 2 1 5 8 8 9 8 8 10 8 1 10 5 10 8 7 10 8 8 5 2 6 10 10 5 8 9 5 6 8 6 9 6 5 3 3 5 9 5 9 5 7 8 4 5 7 6 1 3 5 8 5 8 8 4 8 9 6 9 5 4 8 7 1 7 6 6 7 5 1 3 6 6 10 1 7]

B. Case Study 2

Table II summarizes details of flexible job shop configuration and production order received. Further details of case study are not presented here for want of space and are available at Parjapati, S. K. [15].

In this case study, each part type requires all operations. For this case study, optimization is carried out using adopted methodology as described in section IV and optimal makespan is 3560 minutes. Fig. 3 shows the convergence curve between fitness value of makespan and number of iterations.

TABLE II
SHOP CONFIGURATION AND PRODUCTION ORDER DATA (CASE STUDY 2)

No. of part types	05
No. of machines	05
Maximum no. of operations	05
Setup time	U [20-60]
Processing time	U [20-100]
Quantity of each part type	U[10-20]

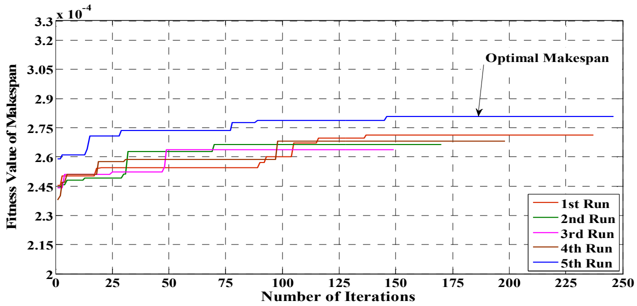

Fig. 3 Convergence Curve for Case Study 2

For case study 2, job sequences for optimal makespan are:

First Sequence: [4 3 3 3 4 4 4 4 3 4 4 3 4 5 3 3 5 3 5 3 4 4 4 3 5 4 5 4 5 1 5 4 3 5 1 5 5 1 1 5 5 5 4 1 1 5 1 5 1 3 1 5 2 2 5 4 5 1 2 2 5 4 2 2 1 5 2 2 3 2 1 2]

Second Sequence: [4 3 3 3 4 3 4 4 3 4 4 3 4 5 3 3 5 3 5 3 4 4 4 3 5 4 5 4 5 1 3 4 5 5 1 5 5 1 1 5 5 5 4 1 1 5 1 5 1 3 1 5 2 2 5 4 5 1 2 2 5 4 2 2 1 5 2 2 3 2 1 2]

Thus, there are two job sequences that result is same optimal makespan.

VI. CONCLUSION

In the present work, an attempt has been made to solve Flexible Job Shop Scheduling Problem with Sequence Dependent Setup Times. A Genetic Algorithm based methodology is developed and two case studies are taken into consideration. Results are obtained by considering crossover probability (p_c = 0.85) and mutation probability (p_m = 0.15) and makespan as performance measure. Results indicate that optimal makespan can be achieved with more than one sequence of jobs in a production order.

REFERENCES

[1] Al-Hinai, N. and ELMekkawy, T.Y.; (2011) "Robust and stable flexible job shop scheduling with random machine breakdowns using a hybrid genetic algorithm", International Journal of Production Economics, Vol. 132, pp 279-291.
[2] Allahverdi, A., Ng, C.T., Cheng, T.C.E. and Kovalyov Y. M. (2008), A survey of scheduling problems with setup times or costs, European journal of Operational Research, Vol. 187, pp 985-1032.
[3] Asadzadeh, L. and Zamanifar, K.; (2010) "An Agent Based Parallel Approach for the Job Shop Scheduling Problem with Genetic Algorithm". Mathematical and Computer Modelling, Vol. 52, pp 1957-1965.
[4] Bagheri, A. and Zandieh, M. (2011) "Bi-criteria flexible job shop scheduling with sequence-dependent setup times-Variable neighborhood search approach" Journal of Manufacturing Systems, Vol. 30, pp 8-15.
[5] Chen, J.C., Wu, C.C., Chen, C.W. and Chen, K.H. (2012) "Flexible Job Shop Scheduling with Parallel Machines using Genetic Algorithm and Grouping Genetic Algorithm". Expert System with Applications, Vol. 39, pp 10016-10021.
[6] Deb, K. (2003), Optimization for Engineering Design, Algorithm and Examples, Prentice Hall, New Delhi, India.
[7] Dhingra, A. (2010), "Multi objective flow shop scheduling using metaheuristics", unpublished Ph.D. dissertation, N.I.T. Kurukshetra.
[8] Luh P.B., Gou, L., Zhang, Y., Nagahora, T., Tsuji, M., Yoneda, K., Hasegawa, T., Kyoya, Y., and Kano, T. (1998), "Job shop scheduling with group dependent setup, finite buffers and long time horizon", Journal of Annals of Operation Research, Vol. 76, pp233-259
[9] Mitchell, M. (2002), An introduction to genetic algorithm, Prentice Hall, New Delhi, India.
[10] Moghaddas, R. and Houshmand, M. "Job Shop Scheduling Problem with Sequence Dependent Setup Times". Multi Conference of Engineers and Computer Scientists, March 19-21, 2008, Hong Kong.
[11] Moon, I., Lee, S. and Bae, H. (2008) "Genetic Algorithms for Job Shop Scheduling Problems with Alternate Routings". International Journal of Production Research, Vol. 46, pp 2695-2705.
[12] Motaghedi, A., Sabri-laghaie, K. and Heydari, M. (2010) "Solving Flexible Job Shop Scheduling with Multi Objective Approach". International Journal of Industrial Engineering & Production Research, Vol. 21, pp 197-209.
[13] Mousakhani, M. (2013), "Sequence Dependent Setup Times Flexible Job Shop Scheduling Problem to Minimize Total Tardiness". International Journal of Production Research available online: http://dx.doi.org/10.1080/00207543.2012.746480
[14] Naderi, B., Ghomi S.M.T.F. and Aminnayeri, M. (2010) "A high performing metaheuristic for job shop scheduling with sequence dependent setup times", Applied Soft Computing 10 (2010) pp 703-710
[15] Parjapati, S.K. (2013), "Flexible job shop scheduling optimization with sequence dependent set up times using genetic algorithm approach", unpublished M.Tech. dissertation, N.I.T., Kurukshetra.
[16] Pinedo, M. (2001), Scheduling: Theory, Algorithm, and Systems, Prentice Hall, New York.
[17] Ruiz, R. and Maroto, C. (2006), "A genetic algorithm for hybrid flow shops with sequence dependent setup times and machine eligibility", European Journal of Operational Research, Vol. 169, pp 781-800.
[18] Roshanaei, V., Esfehani, M.M.S. and Zandieh, M. (2010) " Integrating non-preemptive open shop scheduling with sequence-dependent setup times using advanced metaheuristics", Expert Systems with Applications, Vol. 37, pp 259-266
[19] Tang, J., Zhang, G., Lin, B. and Zhang B. (2011) "A Hybrid Algorithm for Flexible Job-Shop Scheduling Problem". Advanced in Control Engineering and Information Science, Vol. 15, pp 3678-3683.
[20] Wang, L., Wang, S. and Liu, M. (2013) "A Pareto Based Estimation of Distribution Algorithm for the Multi Objective Flexible Job Shop

Scheduling Problem". International Journal of Production Research, available online: http://dx.doi.org/10.1080/00207543.2012.752588
[21] Wang, Y.M., Li, H.Y. and Wang, J. (2009), "Genetic Algorithm with New Encoding Scheme for Job Shop Scheduling". International Journal of Advanced Manufacturing Technology. Vol. 44, pp 977-984.
[22] Xing, Y.J., Wang, Z. Q., Sun, J. and Meng, J.J. (2006), "A Multi Objective Fuzzy Genetic Algorithm for Job Shop Scheduling Problems", Journal of Achievements in Material and Engineering, Vol. 17, Issue 1-2, pp 297-300.
[23] Xu, L., Shuang, W. and Ming, H. (2009), "Application on Job Shop Scheduling with Genetic Algorithm based on Mixed Strategy". IEEE International Conference on Chinese Control and Decision 2009, pp 2007-2009 Guilin.
[24] Zhang G., Shao X., Li P. and Gao L. (2009) "An effective hybrid particle swarm optimization algorithm for multi-objective flexible job-shop scheduling problem", Computer and industrial engineering, Vol. 56, pp 1309-1318.
[25] Ziaee, M. (2014) " An Efficient Heuristic Algorithm for Flexible Job Shop Scheduling with maintenance Constrain" Applied Mathematics and Sciences, Vol. 1, No. 1, May 2014

Parjapati, S.K. did his B.Tech.in Mechanical Engineering in 2008 and M.Tech. in Industrial and Production Engineering in 2013 from NIT Kurukshetra. He is recipient of Gold Medal in M.Tech. for securing highest marks. His areas of interest are scheduling of manufacturing systems.

Jain, A. is professor in Department of Mechanical Engineering In NIT Kurukshetra. He did his Ph.D. from Kurukshetra University. His research interests are in the area of planning scheduling and control of manufacturing systems.