Multi-objective SDST flow shop scheduling using Genetic Algorithm: An industrial Case study

Ashwani Kumar Dhingra
Department of Mechanical Engineering
University Institute of Engineering & Technology
Maharshi Dayanand University
Rohtak-124001 Haryana INDIA
E-mail: ashwani_dhingra1979@rediff.com

Abstract- In the present work, an industrial case study has been considered for multi-objective flow shop scheduling problem including the sequence dependent set up time. The multi-objectives include the minimization of sum of total weighted squared tardiness, total weighted squared earliness, makespan and number of tardy jobs. Industries can select the optimal sequence with respect to required objectives by changing the weight values of the considered fitness function for achieving organizational and individual goals. The Hybrid Genetic Algorithm developed can easily search the solution in a reasonable time and is also flexible as by changing the weight values and can provide the solutions as per the requirement of the customer and industries.

Keywords – Flow shop scheduling, Genetic Algorithm, SDST, Makespan, tardiness, number of tardy jobs, earliness

I. Introduction

Scheduling in a manufacturing environment is generally considered to be the one of the most significant issue in the planning and operation of manufacturing system. Also Sequence dependent set up time (SDST) is one of the most recurrent additional complications in the scheduling problem. Setup times are defined to be the work to arrange the resources, process, or bench for tasks that includes obtaining tools, positioning work in process material, cleaning up, adjusting and returning tools and inspecting material in manufacturing system. Several researchers disregarded the multi-objective nature of scheduling problems as more than one decision maker is frequently involved in decision making resulting in conflicting objectives. For instance, market manager is involved in maximizing customer satisfaction by minimizing due date related performance measures while production manager is concerned with minimizing makespan and work in process for effective utilization of machines and hence increasing productivity. Several researchers have proposed heuristics and metaheuristics algorithms for $n \times m$ flow shop scheduling problem for optimization several performance measures since the pioneering work of Johnson [1]. Metaheuristics are general methods that guide the search through the solution space, using some form of heuristics and local search. Starting from an initial solution built by some heuristic, metaheuristics improve it iteratively until a stopping criterion is met. The stopping criterion can be elapsed time, number of iterations, and number of evaluations of the objective function and so on. Genetic algorithms are among the widely used metaheuristics for scheduling problems. Present work considers the solution of industrial case study in which the scheduling of n jobs on m machines in a flow shop environment. Also sequence dependent set up time (SDST) has been considered into account while formulating the multi-objective function.

In the recent past, a lot of work has been reported by the researchers in the area of multi-objective flow shop scheduling using GA. One of the earliest GA for the flow shop scheduling problems has been proposed by Chen et al. [2] in which initial population was generated by using several heuristic rules. The first $m - 1$ population members were generated by the $m - 1$ sequence obtained after applying the CDS heuristic of Campbell et al. [3]. Murata et al. [4] considered flow-shop scheduling problem with minimizing the makespan, total tardiness and total flow time. Ponnambalam et al. [5] developed a TSPGA multi-objective algorithm for minimizing weighted sum of makespan, mean flow time and machine idle time in flow shop scheduling problem and concluded that TSPGA was the faster search for obtaining optimal results. Noorul Haq and Radha Ramanan [6] implemented artificial neural network (ANN) approach for minimizing makespan and total flow time in flow shop scheduling environment and concluded that performance of ANN approach was better than constructive heuristics. Fred Choobineh et al. [7] proposed tabu search heuristic including sequence dependent setup for n jobs and single machine problem with minimization of makespan, weighted tardiness and number of tardy jobs simultaneously. They illustrated that the proposed heuristic provides optimal or nearer to optimal solutions in a reasonable time. Eren [8] considered a bi-criteria ***m***-machine SDST flowshop scheduling with minimization of the weighted sum of total completion time and makespan using special heuristics and proved that the special heuristic was more effective than the others for all number of jobs and machines. Sun et al. [9] provides the huge review on different optimization algorithms for the flow shop scheduling problem with different objectives including multi-objectives. Yang [10] proposed hybrid Taguchi based Genetic Algorithm (HTGA) for minimising the makespan and maximum tardiness simultaneously and proved that the HTGA provides better results when compared to others. Pour et al. [11] developed the novel genetic algorithm for optimisation of multi-objective performance measures including weighted sum of the makespan, total waiting time and total tardiness in a flow shop consisting of ***n*** jobs and ***m*** machines. They concluded that the results obtained from proposed novel genetic algorithm are superior to those obtained from the classical genetic algorithm.

In the present work, the jobs has been scheduled with respect to multi-objective fitness including weighted sum of total weighted squared tardiness, makespan, total weighted squared earliness and makespan and corresponding sequence of the jobs have been given along with completion and idle time of each job on every machines. In the present work, five sets of weights have been considered as four sets of weights to give importance to individual criteria and one for equal importance of the entire criterion in the proposed fitness function. Therefore, results are obtained for five sets of weights value of α, β, γ and δ for proposed multi-objective performance measures (i.e. (0.4,0.3,0.2,0.1), (0.1,0.4,0.3,0.2) (0.2,0.1,0.4,0.3), (0.3,0.2,0.1,0.4) and (0.25,0.25,0.25,0.25)). As the problem belongs to NP hard and hence Hybrid Genetic Algorithm in which seed sequence from the NEH heuristic of Nawaz et al. [12] and EDD rule is combined with remaining randomly generated sequences as per the population size of simple Genetic Algorithm. The parameters fixed for HGA are population size = 50, Elite count = 2, crossover fraction = 0.8, selection function = roulette wheel, mutation fraction = 0.15 and stopping criteria is ***n × m × 0.5 seconds.***

II. PROPOSED ALGORITHM

A. Industrial Case study –

The application of the Hybrid Genetic Algorithm (HGA) for sequencing flow shops in the process industry is being carried out in ABC Industry, which is one of the largest integrated manufacturers of quality automobile components in India.

Division of ABC industry is operational with one Special purpose CNC cutting machine(SPCNCC), Two Special purpose hydraulic operated swaging machine(SPSM), one manual chamfering machine(MCM), Two special purpose hydraulic operated horizontal drilling machines (SPDM), Two Tapping machine and three horizontal manual milling machine. The raw material is cold drawn seamless (CDS) tube and then processed through the process line to get the desired product for automobile industry. The process flow diagram of CDS tube is shown in figure 1.

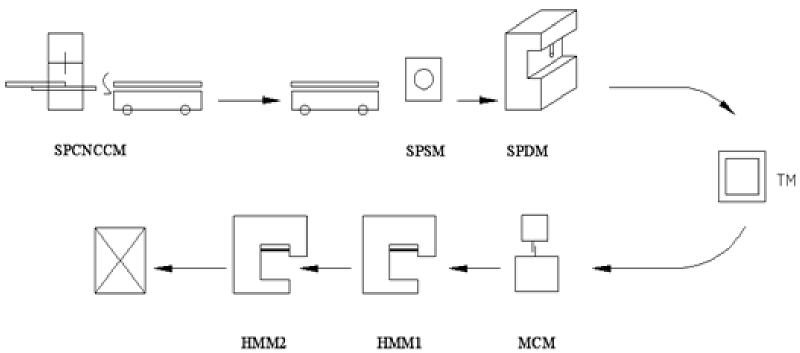

Figure 1. Process diagram of CDS tube

In the process flow production setups are required at every machine and take considerable length of time. Setup on various machines are setting of CNC cutting machine when size of job differs , changing of die and clamp in swaging machine ,change of drill in drilling machine, change of tapping tool in tapping machine , change of chamfering tool and change of milling cutter as per size and operation performed on the CDS tube. The sequence dependent set up time has been noted down for different jobs on different machines when real data was collected from the industry. The data such as processing time, due date, weight of the job with demand and sequence dependent set up time for the 15×7 flow shop scheduling problem have been collected.

III. RESULT AND DISCUSSION

The Hybrid genetic algorithm has been applied to the 15 x 7 industrial problem of SDST flow shop scheduling for all the five sets of weight values considered which results in optimal sequence with corresponding values of all the individual objective of optimized fitness function. The completion time and idle time matrix obtained provides completion time and idle time of each job on each machine with respect to optimal sequence for all the sets of considered weight values.

α = 0.2, β = 0.1, γ = 0.4, δ = 0.3 and α = 0.1, β = 0.4, γ = 0.3, δ = 0.2

Optimal sequence is 7 8 5 6 11 1 10 2 15 9 13 12 3 14 4 and the completion time of the sequence is 105645 minutes

α = 0.4, β = 0.3, γ = 0.2, δ = 0.1 and α = 0.25, β = 0.25, γ = 0.25, δ = 0.25

Optimal sequence is 7 8 5 6 11 10 1 2 15 9 13 12 3 14 4 and the completion time of the sequence is 105645 minutes.

α = 0.3, β = 0.2, γ = 0.1, δ = 0.4

Optimal sequence is 11 8 7 5 6 10 1 2 15 9 13 12 3 14 and the completion time of the sequence is 105355 minutes

Table -1 Values of objective functions for different weights for the industrial case study

Weight values (α, β, γ, δ)	Total weighted squared tardiness	Makespan	Total weighted squared earliness	No. of tardy jobs	Weighted sum (multi-objective)
(02,0.1,0.4,0.3)	1.4454×10^{10}	105645	5953600	14	2.8933×10^{9}
(0.4,0.3,0.2,0.1)	59638529	105645	1.4374×10^{10}	13	5.7617×10^{9}
(0.3,0.2,0.1,0.4)	1.4259×10^{10}	105355	234202201	13	4.3011×10^{9}
(0.25,0.25,0.25,0.25)	59638529	105645	1.4374×10^{10}	13	5.7617×10^{9}
(0.1,0.4,0.3,0.2)	1.4454×10^{10}	105645	5953600	14	2.8933×10^{9}

Table 1 provides the value of different performance measures obtained with minimization of the multi-objective fitness functions for different sets of considered weight values. Also the completion time and idle time for each job on each machine for the optimal sequence with any subsets of considered weight values for minimized multi-objective fitness function has been obtained.

IV.CONCLUSION

As multiple decisions are frequently involved in the present fluctuating, dynamic and competitive environment of markets and proposed multi-objective fitness function proves to be viable and flexible for scheduling the jobs with respect to any criteria. Industries can select the optimal sequence with respect to required criteria by changing the weight values of the considered fitness function for achieving organizational and individual goals. The Hybrid

Genetic Algorithm developed can easily search the solution in a reasonable time and is also flexible as by changing the weight values, it can provide the solutions per the requirement of the customer and industries. As the industries are concern to the profit and also good will of the customers but in the industrial problem considered, the maximum number of jobs are tardy which cause penalty to the industries and consequently profit and good will is reduced. So for efficient project management the efficiency of the machines should be enhanced with minimising the handling time of the jobs. So, there is a scope of some more machines to be employed in parallel so that number of tardy jobs and other criteria can be minimised.

V. REFERENCES

[1] Johnson, S.M., "Optimal two-and three-stage production schedules with setup times included" Naval Research Logistics Quarterly, Vol. 1, pp. 61-68,1954.

[2] Chen, C.L., Vempati, V.S. and Aljaber, N., "An application of genetic algorithms for flow shop problems", European Journal of Operational Research, Vol. 80, pp.389-396,1995.

[3] Campbell, H.G., Dudek, R.A. & Smith M.L., "A heuristic algorithm for n job m machine sequencing problem", Management Science, Vol. 16, No.10, pp. 630-637,1970.

[4] Murata, T., Ishibuchi, H. and Tanaka H., "Genetic algorithms for flow shop scheduling problems", Computers &Industrial Engineering, Vol. 30, No.4, pp.1061–71,1996.

[5] Ponnambalam, S. G., Jagannathan, H., Kataria, M. and Gadicherla, A., "A TSP-GA multi-objective algorithm for flow shop scheduling", International Journal of Advanced Manufacturing Technology, Vol. 23, pp. 909–915,2004.

[6] Noorul Haq, A. and Radha Ramanan, T., " A bicriterian flow shops scheduling using artificial neural network", International Journal of Advanced Manufacturing Technology, Vol. 30, pp. 1132–1138, 2006.

[7] Fred Choobineh, F., Mohebbi , E. and Khoo, H., "A multi-objective tabu search for a single-machine scheduling problem with sequence dependent set up times", European Journal of Operational Research, Vol. 175, pp. 318–337,2006.

[8] Eren, T., "A Bi-criteria M-Machine Flow shop Scheduling with Sequence-Dependent Setup Times", Applied Mathematical Modelling, Vol. 34, No. 2, pp. 284 – 29, 2010.

[9] Sun, Y., Zhang, C., Gao,L., Wang X., "Multi-objective optimization algorithms for flow shop scheduling problem: a review and prospects", International Journal of Advance Manufacturing Technology, Vol. 55, pp. 723 – 739, 2011.

[10] Yang, C.I., Chou, J.H. and Chang, C.K., "Hybrid Taguchi-Based Genetic Algorithm for Flow shop Scheduling problem", International Journal of Innovative Computing, Information and Control, Vol. 9, No. 3, pp. 1045-1063, 2012.

[11] Poura, N.S., Moghaddamb, R.T. and Asadi, H., Optimizing a multi-objectives flow shop scheduling problem by a novel genetic algorithm", International Journal of Industrial Engineering Computations, Vol. 4, pp.345–354, 2013.

[12] Nawaz, M., Enscore. E. and Ham, I., "A heuristic algorithm for the m-machine n-job flow shop sequencing problem", Omega, Vol. 11, pp. 91–95,1983.