http://dx.doi.org/10.21172/ijiet.143.15

Batch Scheduling Method – A Fuzzy Model for Rolling Mill

Majji Ranganath Kumar[1], M. Srinivasa Rao[2], V.V.S. Kesava Rao[3]
[1]Part time research scholar, Department of Mechanical Engineering, College of Engineering(A), Andhra University,Visakhapatnam.
[2]DGM (Maintenance), Department of MMSM, Visakhapatnam Steel Plant.
[3]Professor, Department of Mechanical Engineering, College of Engineering(A), Andhra University,

Abstract– Many uncertain factors in job shop scheduling problems are significant for the scheduling procedures.This paper proposes an orders batch scheduling method for a rolling mill and estimates the production time by means of fuzzy form. A mathematical model is proposed to enhance the average order delivery satisfaction and maximize min satisfaction of fuzzy job shop scheduling model. Each order of a batch is viewed as a fundamental scheduled job.Mixed integer algorithm and genetic algorithm is employed for solving the proposed model. The results of the proposed model arepromising.
Keywords- Rolling mill, Fuzzy schedule, Genetic algorithm.

I. INTRODUCTION

Scheduling is widely defined as the process of assigning aset of jobs to resources over a period of time. Effectivescheduling plays a very important role in today'scompetitive manufacturing environment. Performancecriteria such as machine utilization, manufacturing lead times, inventory costs, meeting due dates, customersatisfaction, and quality of products are all dependent onhow efficiently the jobs are scheduled in the system.Hence, it becomes increasingly important to developeffective scheduling approaches that help in achieving thedesired objective. The scheduling and planning ofa production order have animportant role in the manufacturing system. The diversity of products, increased number of orders, the increasednumber and size of industriesand expansion of factorieshave made the issue of scheduling production ordersmore interesting, hence the traditional methods of optimizationare unable to solve them (Z. Othman,K.Subari and N.Morad, 2007) [9]. Genetic algorithms arestochastic global optimization methods inspired by thebiological mechanisms of evolution and heredity, whichhave been widely used for scheduling problem (Storn 1997) [3].

Rolling mill is an important finishing unitin steel industry, which is a captive industry. Because of tough competition industries are preferring more on made to orderproduction strategy. In rolling mills production takes place on campaign basis .similar product only can be rolled during particular campaign .preparation time is required for changingcampaign as it involves set up time for preparing the rolling lines. Time for calculation of processtime cannot be calculated exactly as it cannot be predicted.

An effort is made in this paper to prepare rolling sequence based on customer orders.Rolling sequence means the sequence of orders to be carried out in a campaign.Customer orders are grouped intolots and later lots into batches again within each batch ordersequences(i.e., rolling sequence) are optimized for customer satisfaction.Integer programming and Heuristic techniquesareappliedto solve theproblem. The paper is organized as follows. Literature survey at section2. Section 3 deals with basic model and calculation of processing time. Section 4 with genetic algorithm and steps followed for calculation of optimization. Results and conclusion in section-5and -6 respectively.

II. LITERATURE REVIEW

The advanced production scheduling techniques are drawing more attentions currently.The production scheduling for tandem cold rolling line had been carried out by many studies, Moon et al.(1999) [5] and Liu et al.(2005) [7] reported the scheduling solutions in a cold rollingline, in which an integer linear programming, anddiscrete event simulation technique were applied for the charging optimization. Wang et al.(2002) [6] proposed a scheduling method for the optimal operational parameters of tandem cold mill, and Zhao et al.(2008) [10] found an optimal rolling sequence for cold mill. With respect to the intermediate storage of cold rolling line, the related scheduling problem was also studied in Leisten (1990) [2]. Verdejoet al.(2009) [13] addressed a sequencing problem in a continuousgalvanizing lineand was solved by a heuristics based tabu search.Tang et al.(2009) [12] studied the scheduling problem of a single crane in annealing process of a cold rolling line,

Although the mentioned studies exhibited a great promotion to the manufacturing of cold rolling line or had been partlyapplied to the production practice, there is a potential structure for the production scheduling of rolling line.

As for the whole scheduling framework, the scheduling forsingle machine is on the basis of the orders batch scheduling solution, i.e., the results of orders batch scheduling provide thesingle machine scheduling with the input or the boundarycondition. However, the studies in literatures for the ordersbatch scheduling are rather few now. It is worth noting thatsuch practical optimization solution is intensively beingrequired in current steel industry. Although Zhao et al.(2008)[11] presented an order batch scheduling model for rollingline, that model completely viewed the order batch as a basicjob shop scheduling model. To evaluate the order delivery quality of the scheduling, an objective addressed by the delivery satisfaction) is adopted in the paper (Masatoshi et al. 1999 [4].M.Omaret al.2006) [8].A novel objective function for job-shop schedulingproblem with fuzzy processing time and fuzzy due date is solved using differential evolution algorithm(Yanmei Hu et al. 2011) [14]. Batch order processing wasapplied in cold rolling mill by Jun Zhao (2011) [15].An effective genetic algorithm is appliedfor job shopwithfuzzy satisfactionby Akeela M.Al-Atroshi 2013 [16]flexible job-shop scheduling problem as the research object, and constructed mathematical model aimed at minimizing the maximum makespan.The same was solved by genetic algorithm and case study was done in an automobile gear transmission shop byErmingZhou1et al. 2017 [17].

III. SCHEDULING MODEL

Customers place orders on steel mills through marketing management department with due dates and product specifications. Production planning department bunches these orders intobatches in a homogeneous way taking into consideration quality,deliver date, etc.Based on the information after finalizing sequence machine scheduling and subsequent production will take place.The information is shared among various units.(see Figure 1) But in reality often production unit encounters difficulty in following the sequence as time cannot be predicted correctly, inventory builds up on intermediate machines and thereby process delaying.

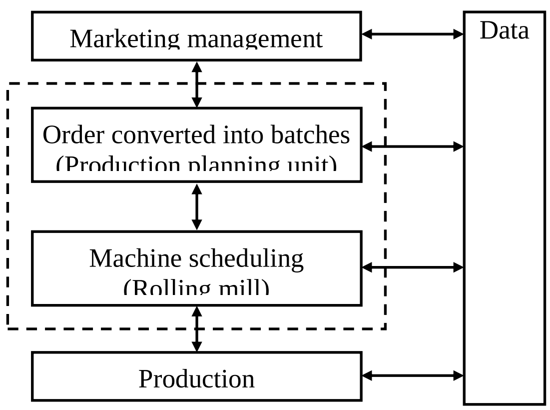


Figure 1.Flow of information

A scheduling model with fuzzy batch manufacturing time and fuzzy due time is proposed herebyconsidering the uncertainty of batch production timeon machines. Thismodel resembles a typicalJob Shop problem, to which a triangular fuzzy number is used to denotethe process of each batch. The ordersareevaluated keeping the objective function asmaximumaverage orderdelivery satisfaction and min satisfactionof the fuzzy job shop scheduling model,mathematical formulation is done and solved by applying heuristicgenetic algorithm.

Since the production requirements of the various products are extremely different, the device parameters or operation pattern has to be changed. In order to maintain the productioncontinuity and reduce the adjustment cost on the machines and the setup time, the order grouping is just to group theorders into some batches based on the product category constraints such as quality,grade,lead time, etc.

Generally such order groupingand scheduling is done manually. However, with the production development, rolling mill adopts generally the week delivery mode tomeet customers' demands, improve the delivery ability. Thus, the manualsscheduling usually exhibits a poor capacity to fulfill thecomplicated requirements

In this paper orders are grouped into homogeneous batchesusing integer linear programming model. Later the orders n each batches are optimized for delivery satisfaction using fuzzy model.

3.1 Integer linear programming –

Based on the weight of order and campaign production target orders are formed into groups, let

Oi = i-th order [i = 1, ….,m]

Bb = b-thlot [b = 1, ….,N]

S = number of lots to be formed
R = maximum number of batches allowed
Max_w, min w= maximumproductweight and minimum product weightallowed in a lot
wi = productweight of i-th order
Objective function(P):minimization of number of lots

MIN(P) $=\sum_{1}^{I} B_I$ (1)

$$\sum_{b=1}^{N} O_i B_b \leq 1$$ for all Orders(i=1 ,…., m) (2)

Constraint satisfies each order is assigned to a particular batch.

$$\sum_{i=1}^{1} O_i B_b \times w_i \leq \max w$$ for all Bb(b=1……n) (3)

$\sum_{1}^{i} o_i\ B_b \times w_i$ ≥minwfor all Bb(b=1……n)

Constraint satisfies that a lotis within the weight limits.
Bi = Integer value. Its value is 1 if at least one order is allotted otherwise its value is 0.

$$B_i + z\left(1-\sum_{i=1}^{M} O_i \bullet B_i\right) \geq 1$$

(4)

$$B_i + z\left(1-\sum_{i=1}^{M} O_i\ B_i\right) \leq 1$$

where z = big value
Eqs.(3 and 4) ensures whether Bi = lot assigned or not.

$$\sum_{i=1}^{N} B_i \leq 25$$

(5)

Bi+1≤Bifor all i = 1, ….,M – 1

$\sum_{1}^{I} B_i > 0$ (6)

Number of lotsare formulated by solving the above equations.

3.2 Fuzzy delivery satisfaction –

Considering the uncertain factors in production, the manufacturing time of each job on a machine is represented by a triangular fuzzy number $\tilde{A}_{ikjl}(a_{ikjl}^{L}, a_{ikjl}^{M}, a_{ikjl}^{U})$ where, i = 1, 2, ..., n denotes the index of jobs; j = 1, 2, …., m denotes the index of machine; k denotes the current sequence number of the whole process of job i, which means the k-th step of job iis processed on machine j; l denotes the current job is the l-th job of machine j. The variables a_{ikjl}^{L} , a_{ikjl}^{M} and a_{ikjl}^{U} , represent the shortest manufacturing time, the possible time and the longest time of a job, respectively. And, the membership curve is illustrated as Figure 2. In addition, we specify the due time of a batch is denoted by trapezoid fuzzy number $\tilde{D}_i(d_i^O, d_i^P)$, where d_i^O and d_i^P denote the optimistic due time and pessimistic time of job i, respectively (seeFigure 3).

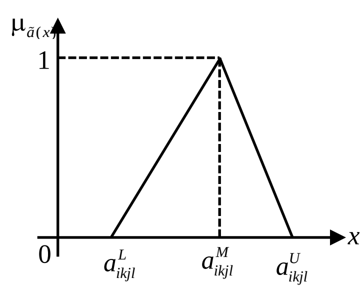


Figure2. Membership function of manufacturing time of an order batch

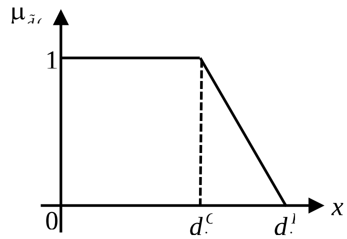


Figure 3. Membership function of due date

The model for batch scheduling of the rolling plant reads as follows. Delivery satisfaction (J) is maximized as follows:
Objective function:
Max J = w1 × Max z1 + w2 × Max z2 (7)

Where

$$z_1 = \frac{1}{n}\sum_{i=1}^{n} K$$

$$z2 = \min[k1, k2, \ldots, ki, \ldots, kn]$$

and

$$K = \frac{area\,\tilde{I} \cap d}{area\,\tilde{I}}$$

w1 and w2 are weight for objective function respectively. Sum of weights is one where $area\,\tilde{I}$ denotes the area of fuzzy completion time of job i; $\tilde{d}$ denotes the area of fuzzy due time of job i; k = delivery satisfaction. z1=average delivery satisfaction and z2= min of delivery of satisfaction.
Subject to:

$\tilde{S}_{ikjl} \geq 0$ l = 1 and k = 1, i = 1, 2, …,n, j = 1, 2, …, m (8)

$\tilde{S}_{ikjl} \geq \tilde{F}_{j(l-1)}$ l≠ 1 and k = 1, i = 1,2,…,n,j=1,2,…,m (9)

$\tilde{F}_{ij} \geq \tilde{S}_{ij} + \tilde{A}_{ij}$ i = 1, 2, …,n,j = 1, 2, …, m (10)

$\tilde{S}_{ikjl}$ is the fuzzy start time of job i on machine j; $\tilde{F}_{i(k-1)}$ is the fuzzy completion time of (k – 1)-th step of machine j; $\tilde{F}_{ij}$ is the fuzzy completion time of i on machine j; $\tilde{F}_i$ is the fuzzy completion time of job i; and $\tilde{A}_{ij}$ is the manufacturing time of job i on machine j.
Eq.(7) is the objective to maximize the delivery satisfaction of batch. We define the delivery satisfaction of a batch as the intersection area between the completion time $\tilde{I}$ and the due time of the batch $\tilde{d}$ (see Figure 4). Eq.(8) denotes that the earliest start time of job i is just the initial time of the schedule if it is the first job of the grouped batches and the first work on machine j. Eq.(9) denotes that the earliest start time of job i is the completion time of the previous job on machine j if it is the first step of job i, which means the succeeding job can be started on machine j only if the previous job has been done. Eq.(10) denotes that the completion time of each job is the fuzzy sum of the start time and the manufacturing time of the job.

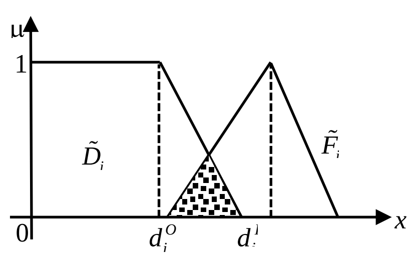


Figure 4.Delivery satisfaction

In general JSSP, the earliest start time of job i on machine j is usually the larger one between the completion time of the previous step of job I and the previous job on machine j.However, to theproposed scheduling model, the calculation has to be redefined since the productmay be continuously transported into the inventory of next machine when the batch of orders is still produced on current machine.

http://dx.doi.org/10.21172/ijiet.143.15

According to the theorem of fuzzy arithmetic definition (Kaufman et al. 1988), the ranking calculation rules can be viewed as a ranking criterion for a triangle fuzzy number(FN).

3.3 Fuzzy ranking adopted in this paper –

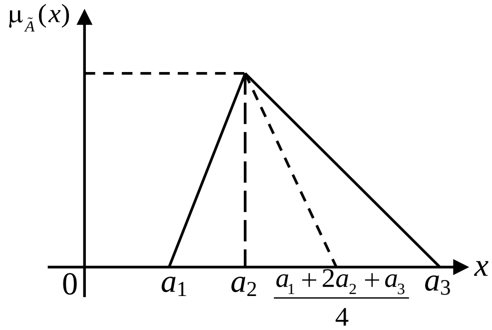
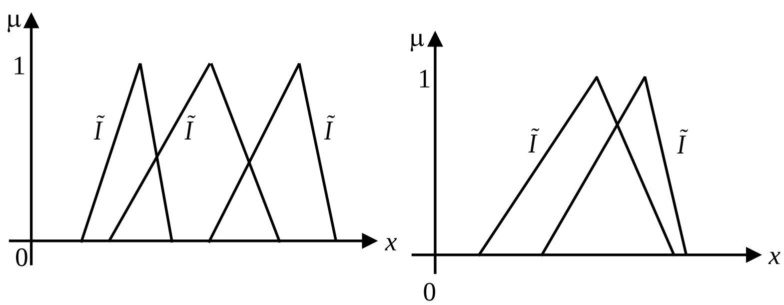
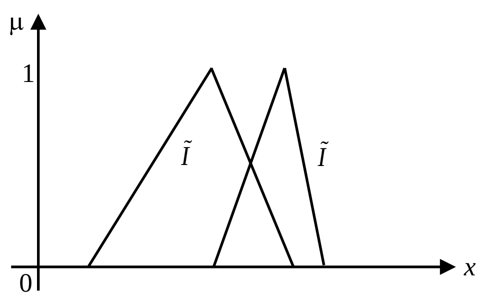


Figure 4. The greatest associate ordinary number of A

Criterion 1:If C1(A) = [(a1 + 2a2 + a3)/4] > (<)C1(B) = [(b1 + 2b2 + b3)/4],thenA> (<) B;
Criterion 2:C1(A) = C1(B), then C2(A) = a2 is compared with C2(B) = b2 to rank them;
Criterion 3:If they have the identical C1 and C2, the difference of spreads C3(A) = a3 – a1 is chosen as a third criterion. According to these three criteria, it becomes possible to rank all FNs. Among FNs Ai,i= 1, 2, ...,n. the maximum andminimum FNs are respectively denoted by Amax and Amin. For example, according to these three criteria, determine theorder of FNs of S={A1, A2, A3, A4}, where A1 =(2, 5, 8),A2 = (3, 4, 9), A3=(3, 5, 7),A4 = (4, 5, 8). Using the first criterion C1, C1(A4)= 5.5 and C1(A1)=Cl(A2) = C1(A3)= 5.0. Hence Amax = A4. By the second criterion C2,C2(A3)=C2(A3)=5 and C2(A2)=4. Thus Amin = A2. The third criterion C3 showsC3(A1)=6 and C3(A3)=4. In this way, the decreasing order of FNs of S becomes A4, A1, A3,A2.



(a) Scenario 1 (b) Scenario 2



(c) Scenario 3

Figure 5.Different scenarios

We assume that the manufacturing and setup time of a single steel productcan be neglected. Taking the three scenarios into account, the calculation of the start time of an order batch(job i) on machine j,Sikjl, can be determined by the following rules.

Rule 1: If the Scenario 1 is in the case (all steel production job i have been placed into the inventory of machine j before the previous job on machine j is finished), then Sikjl = Fj(l–1).

Rule 2: If the Scenario 2 is in the case (a part of steel product) in job i have entered into the inventory of machine j before the previous step of job i is totally finished),thenSikjl =Si(k–1)VFj(l–1). The operator [V] is to obtain the larger one of the two values.
Rule 3: If the Scenario 3 is in the case (the previous step of job i just starts after the previous job on machine jhas beentotally finished), then thenSikjl =Si(k–1)VFj(l–1).

3.4 Calculation of fuzzy processing time parameters –
Manufacturing time calculation depended upon the size of steel product
Manufacturing time t = (weightof product* slipcoefficient/(volume of product *density *speed)
+ compensation factor (11)

The time is calculated based on normal situation. Sometimes abnormal situation such as malfunction of equipment and machine maintenance may take place, the mentioned time prediction will be applied to describe the shortest manufacturingtime, a_{ikjl}^{L} .
As for the possible time a_{ikjl}^{M} , it should be determined by the average production capacitypossible time = a_{ikjl}^{M}
= average product weight on that machine till the period
*weight of batchi/accumulated production (12)

Eq.(13) gives the longest manufacturing time a_{ikjl}^{U} calculation considering the machine breakdown,
$a_{ikjl}^{U} = a_{ikjl}^{M}$ + breakdown expected time (13)

IV. Solving for the Order Batch Scheduling

The order batch scheduling model is NP hard. As it was known, it is very hardfor such problem to obtain an optimal solution within an acceptable computation time only by the mathematical programming, even some intelligent optimization.Genetic Algorithm is a class of evolutionalgorithm that eliminates the infeasibility of crossover between two chromosomes organized by ordinal strings. In this study, we encode the scheduling solution by astring of integers, and the sequence of the integer in thestring denotes the manufacturing sequence of thecorresponding order batch for the rolling plant.. Here is an example,(the sequence number is orders in each batch).

Example:Sequence number:	1 2 3 4 5 6 7
Parent:	5 7 3 4 1 2 6
Child:	5 2 3 4 1 7 6
Operator of substring move:	
Substring:	3 4 5
Parent:	1 2 3 4 5 6 7
Child:	1 2 6 7 3 4 5

After creating the new individuals, the roulette wheelselection is applied to establish the new generation as usual. The solving step of order batch scheduling for the rolling plant is as follows.
Step 1: Group the available orders to form a few lotsbased on product tonnages andminimumlots .Which is nothing but order conversion into lotssay for large batches.
Order conversion into lotsdecision – find out which jobs of the same family are to be included in each lots,using integer linear programming as mentioned at section 3.1
Step 2: again the lotsare regrouped into smallbatches based on the orders product category as well as delivery time. Calculate the fuzzy manufacturing time of eachjob ofbatchon the machines, and determine the fuzzy membership function of manufacturing time and due timementioned at section 3.2.1,3.2.3
Step 3: Initiate the status of the machines in the rolling plant, and randomly generate a number of n-bit strings represented as a set of initial solutions. Sequencing decision – determine the order in the jobs within each batch are to be processed,
Step 4: Calculate the fuzzy completion time and the deliverysatisfaction of each batch by the proposed computation principles, and obtain the average satisfaction of eachsolution and the current optimal solution(see section 3.2)
Step 5: Use the evolution operator to create the newindividual, and obtain the best-so-far of the fuzzy scheduling solution.
Step 6: Check whether the iteration number is arrived. If so,output the optimized order batch scheduling solution; otherwise, go back to step 5.
The steps are shown in flow chart (Figure 6).

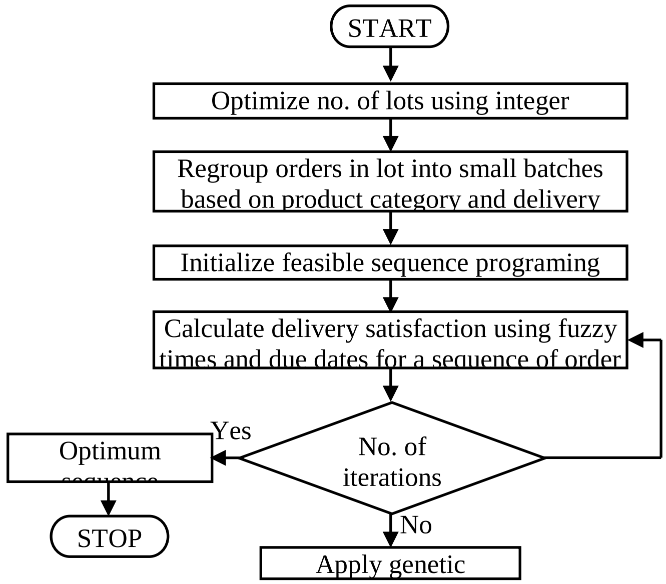


Figure 6. Flow chart indicating methodology adopted

V. DATA ANALYSIS AND RESULTS

To verify the effect of the proposed fuzzy scheduling model, a study was conducted for order delivery satisfaction with data obtained from a rolling mill and compared to the manual scheduling.

1 Data is obtained for product category,delivery period of the item,quantity of products in the order,weight of products in the order.Each rolling milltries to optimize the productivity using minimum batches and maximum productionas far as possible in order to minimize set up time, tool wear outs, integer linear programming is used to selectminimum lotswith orders placed.

2 The data isagain regrouped in terms of product category and within product category deliveryperiodare target is taken to form arolling batch and the algorithm is applied.Sample data is shown in Table 1. Such data is obtained fromstep 5.1.

Table 1: The data is calculated from a rolling mill

Order Sl. No.	Product category	Delivery period(in week) (from current date)	Orderqty. (Nos.)
1	1	1	14
2	2	2	13
3	3	3	15
4	3	4	16
5	2	1	18
6	2	2	14
7	3	3	10
8	4	3	14
9	4	2	15
10	4	3	16
11	1	2	14
12	2	4	15
13	3	2	13
14	1	1	14
15	1	3	12

3 w2 value is taken as 0.2 in delivery satisfaction objective function.

The statistic comparisons arelisted in Table 2, where four groups of real data from rolling mills is presented.

In the statistics, we make 10 timesindependent experiments for each algorithm, and obtain theaverage values of the solution. From the table, the intelligentsearch algorithms, whose delivery satisfaction(objective function) fundamentally exceed 70%, get the fairly better solutionsthan that by the manual scheduling. Furthermore, manual schedulingalways takes more time even forthe experienced worker. As for the order delivery satisfaction, theproposed GA gets the best scheduling solution.

Table 2: The results for delivery satisfaction in each batch is follows

Batch qty.	Manual schedule (objective function)	GA (objective function)
54	0.78	0.8
60	0.75	0.76
12	0.64	0.70

VI. CONCLUSION

The product lots (largebatches) are formed for maximumcampaign production for optimum number of ordersthat can be planned. To optimize thisinteger programming is used as the processing times cannot be accurately determined fuzzy processing times are calculated. Finding out the order sequence in a regrouped batch for scheduling when such fuzzy processing time appearis a complicated task when it is done manually. Hence a model is prosed to verify the effect of the proposed fuzzy scheduling model and comparedthe study for order delivery satisfaction withthe manual scheduling.

Table 1 illustrates a group of four-week production data in detail. Using theproposed method, the result of the instance has been confirmed to be effective by the experienced scheduling rule-based JSSP model with fuzzy manufacturing time is established for the order batch scheduling problem in the rolling plant. And evolution algorithm is designed to solve the fuzzy schedulingmodel.

The average delivery satisfaction of orders reaches above 70%, which greatly meets the customer timing demands in the market.It is better than manual method.

Future research plans to extend this model to solvethe problem using different programming method underdifferent uncertain environments.

VII. REFERENCES

[1] Kaufman A., M. Gupta. Fuzzy mathematical models inengineering and management science, North-Holland, Amsterdam, 1988.

[2] Leisten R. (1990) Flow-shop sequencing problems withlimited buffer storage, International Journal of Production Research, Vol.28, pp. 2085-2100.

[3] Storn R., K. Price (1997). Differential evolution - a simpleand efficient heuristic for global optimization over continuous spaces, Journal of Global Optimization, Vol.11, pp. 341-359.

[4] Masatoshi S., M. Testuya (1999). An efficient geneticalgorithm for job-shop scheduling problems with fuzzy processing time and fuzzy duedate. Computers &Industrial Engineering, Vol.36, No.2, pp. 325-341.

[5] Moon S., A. N. Hrymak (1999). Scheduling of the batchannealing process-deterministic case. Computers & Chemical Engineering, Vol.23, No.9, pp. 1193-1208.

[6] Wang D., A. K. Tieu, F. G. Boer, et al. (2002). Toward aheuristic optimum design of rolling schedules for tandem cold rolling mills. Engineering Application of Artificial Intelligence, Vol.13, No, 4, pp. 397-406.

[7] Liu Q., W. Wang, H. Zhan, et al (2005). Optimal schedulingmethod for a bell-type batch annealing shop and its application. Control Engineering Practice, Vol.13, No.10, pp. 1315-1325.

[8] M. Omar, A. Baharum, Y. Hasan, “A job-shop scheduling problem (JSSP) using genetic algorithm (GA)”. Proceedings of the 2nd IMT-GT Regional Conference on Mathematics, Statistics and Applications. Vol. IV: Computer Sciences & Applications. 13–15 June 2006, Penang, Malaysia. Pp. 39-45.

[9] Z.Othman, K. Subari, And N. Morad, “Job Shop Scheduling With Alternative Machines Using Genetic Algorithms”, Journal Teknologi, 41(D), 2007, pp. 67-78.

[10] Zhao J., Q. Liu, W. Wang (2008). Models and algorithms ofproduction scheduling in tandem cold rolling, ActaAutomaticaSinica, Vol.34, No.5, pp. 565-573.

[11] Zhao J., W. Wang, Q. Liu (2008). Model and algorithm ofgrouping batch scheduling for cold rolling sheet production line, Computer Integrated Manufacturing Systems, Vol.14, No.10, pp. 1957-1965.

[12] Tang L., X. Xie, and J. Liu (2009). Scheduling of a singlecrane in batch annealing process. Computers & Operations Research, Vol.36, pp. 2853-2865.

[13] Verdejo V., M. P. Alarco, and M. LinoSorli (2009).Scheduling in a continuous galvanizing line, Computers & Operations Research, Vol.36, pp. 280-296.

[14] BY Yanmei Hu, Minghao Yin and Xiangtao Li (2011) A novel objective function for job-shop scheduling problem with fuzzy processing time and fuzzy due date is solved using differential evolution algorithm, Int. J. Adv. Manuf. Technol. (2011) 56: 1125-1138.

[15] Jun Zhao1, Ying Liu, Wei Wang, Liqun Cong, Yisha Liu, An order batch scheduling method based on fuzzy model for cold rolling plant, 18th IFAC World Congress, 2011.

[16] Akeela M. Al-Atroshi, Dr. Sama T. Azez, Baydaa S. Bhnam, An Effective Genetic Algorithm for Job Shop Scheduling with Fuzzy Degree of Satisfaction IJCSI International Journal of Computer Science Issues, Vol. 10, Issue 5, No 1, September 2013.

[17] Erming Zhou1,Jin Zhu1 and Ling Deng, Flexible job-shop scheduling based on genetic algorithm and simulation validation, MATEC Web conferences 100, 02047 (2017), DOI: 10, 1051/matecconf/201710002047.