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Scheduling of Steel Charges

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Abstract: Present paper studies hybrid flow shop (HFS) scheduling problem with stage skipping and adjustable processing time in steelmaking- continuous casting (SCC) production process. The SCC scheduling problem is solved to determine the machine allocations, starting times and ending times for all operations of all sms charges (jobs). Considering the production objectives and constraints related to stageskipping and adjustable processing time, a new SCC scheduling model is built. Genetic algorithm (GA) is applied to address the scheduling problem.

Keywords: scheduling, hybrid flow shop, stage skipping, adjustable processing time, genetic algorithm

1. Introduction

Production scheduling plays a significant role in many production systems. Solving realistic scheduling problems has aroused more and more attention in recent years.This paper focuses on a scheduling problem arising from the steelmaking- continuouscasting (SCC) production process in steel plants. SCC scheduling is regarded as a problem of determining the continuous casting machine assignments, starting times andending times for all operations of all charges (jobs) under the consideration of regular hybrid flow shop (HFS)scheduling features and some additional technological features in the SCC production process.

2. Literature Review

Tanget al. [2001] reviewed the related works for planning and scheduling systems and methods for integrated steel production. In the above studies, every charge, output of steel converter,which should have a relevant steel grade to beprocessed, is assumed to follow the same process route from the first stage to the last stagewithout skipping any stages. It means that stage skipping is not considered. With the advent of new technologies it is possible to manufacture diverse steel grades in different paths as per technical requirement.Ex:vacuum refining furnace stage can be skipped for non-alloy steel. Therefore, for realistic scheduling in steel plants, stage skipping is a non-negligible additional technologicalfeature.Generally processing time of charges in each stageis considered as non-varying. Sun and Yu [2015] and Jiang et al. [15] considered variable processing times in the last stages. Tang et al. [2014] first considered adjustable processing time of charges in each stage in a SCC dynamic scheduling problem. Lagrangian relaxation, a decomposition and coordination approach, is common method used in SCCscheduling [L.X. Tang et al. 2002.K. Mao, et al. 2014]. K.S. Naphade, [2001], D. Pacciarelli and M. Pranzo (2004), V. Kumar, et al. (2006)], have solved SCC scheduling by heuristic methods,.

Since most of HFS scheduling problems are NP-hard metaheuristic algorithms with the ability of obtaining a high-quality solution within acceptable computationaltimes have gained much attention in SCC scheduling studies. These evolutionary algorithms mainly include evolutionary programming [P. A. Huegler and F. J. Vasko2007], ant colony optimization [A. Atighehchian,2009], and co-evolutionary artificial bee colony algorithm [Q. K. Pan 2016].Jiyanu long etc (2017)applied ga for steel scheduling without considering the due date and compared with many ga techniques.

The rest of the paper is organized as follows. Literature review is described in section 2.The production process and the scheduling problem are described in Section 3. In Section 4, the scheduling problem is formulated as a mathematical model. The details of the proposed GA are introduced in Section 5. In addition, numerical results are reported in Section 6. Finally, Section 6 will conclude this study.

3. Scheduling Problem

The general production process in steel plants consists of four phase: (1) hot metal pretreatment; (2) steelmaking;(3) refining; and (4) continuous casting.

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The hot metal transported from a blast furnace is processed in the hot metal pretreatment phase for desulfuration, desilication, and dephosphorization.

Next, in the steelmaking phase, the pretreated hot metal is poured into abasic oxygen furnace (BOF) called as LD CONVERTOR to melt into crude steel through the addition of scrap and slag flux. The moltensteel from this BOF is then poured into a ladle that is transported by a crane to the refining phase, where the crude steel is refined to the required steel grade of a specific customer order by removing undesired components (e.g. nitrogen, hydrogen, etc.) and adding required alloys. Therefore, the refining phase also has different stages (e.g. ladle furnace, RH furnace, etc.) to satisfy the processing requirements for various steel grades.

After refining, the molten steel is transported to continuous casting (CC) phase where the molten steel is cast and cooled to form slabs, billets etc.Most of steel plants follow a hierarchical approach for its production planning and scheduling, whichconsists of three stepsorder batching for consolidating orders into charges, charge batching forgrouping and sequencing charges to form casts and production scheduling. A full furnace or ladle load of molten steel in a BOF is called a charge, which is the basic job unit in production scheduling. A cast is a set of charges that is consecutively processed in a tundish, which is a buffer between the ladle and the continuous caster for continuous casting production.

In order to describe the terms and characteristics of steel scheduling, Fig.1 shows the Gantt chart of a schedule for a specific steelmaking production process consisting of 5 stages, which are desulfuration (DES)stage, BOF stage, ladle furnace (LF) refining stage, RH refining stage and CC stage. The number in the Ganttbar represents the index of charge. However, besides the features of regular HFS scheduling the additional technological features of steel scheduling needed to be considered are summarized as follows.

(1) Caster interruption among the charges in the same cast is prohibited because it will result into cast break and needs lot of time to stream line later.

(2) No setup times are required for processing charges at the stages in hot metal pretreatment,steelmaking and refining phases. However, a setup time is required for processing a new cast in the last stage.

(3) Theassignment of casts to continuous casters is predetermined at planning level. In addition, the casting sequence (processing sequence on the continuous caster) of charges is also predetermined in the charge batchingprocess.

(4) The machines in each non-continuous casting stage are identical. The processing time and itsadjustable range are the same for a charge on each machine in a non-continuous casting stage. However, theprocessing time on a continuous caster is related to the casting speed, number of strands .quality of material and casting surface.Since different continuous casters in the last stage may have different processing times and its adjustable range may be different

(5) Transport times between stages need to be considered as charge temperature is important for casting. In addition, the transport time between different machines may be different according to the layout of shop.

(6) Stage route may be different for different charges. The stage route of each charge is predefined according to its associated steel gradeand the processing requirements, butthe machine allocation in each stage need to be determined in the scheduling process.

(7) The flow chart for the problem is depicted in Fig.2.

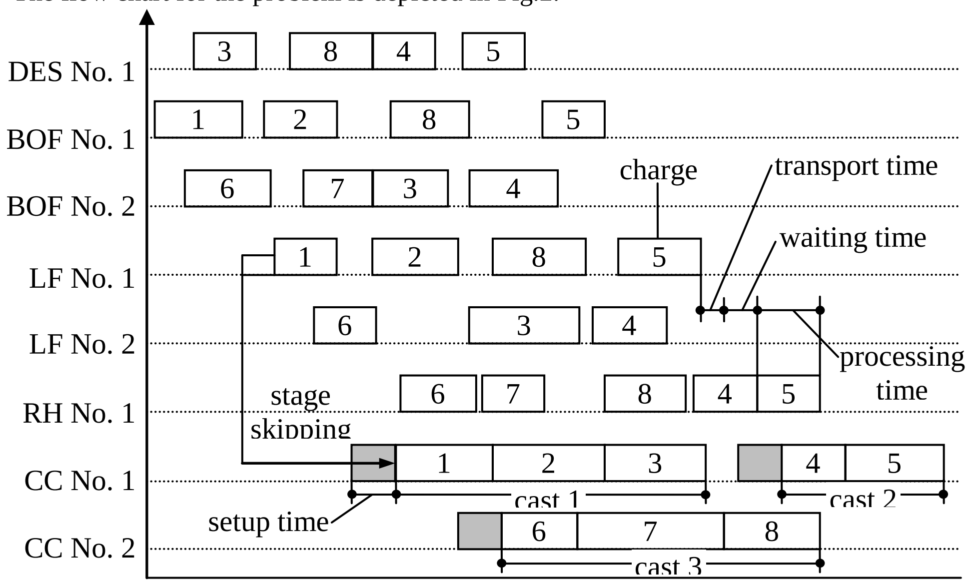

Fig.1: Typical Gantt chart for steel making

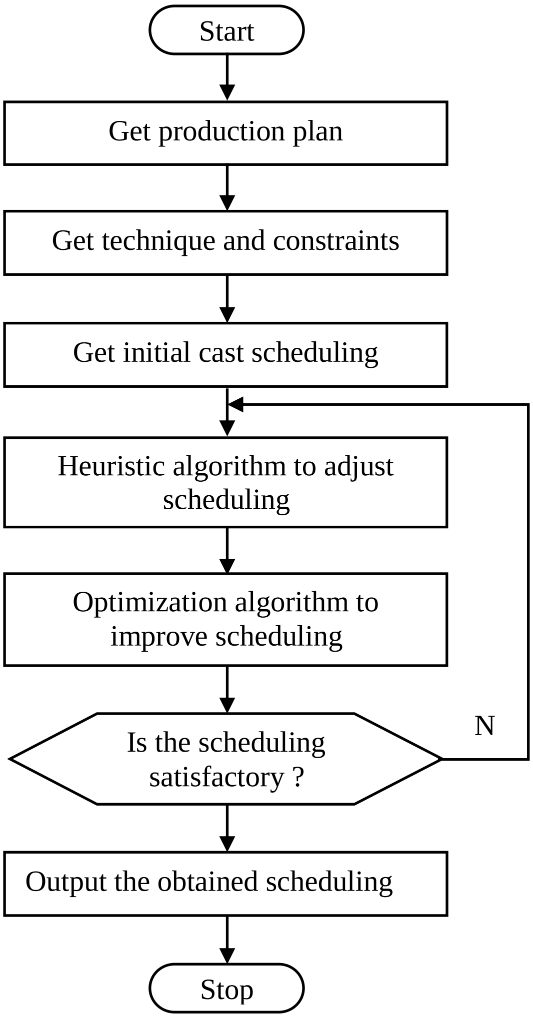

Fig. 2: Flow chart

4. Mathematical Formulation

h : stage index, $h \in \{1,2,...,H\}$;

m : machine index, $m \in \{1,2,....M\}$;

i : charge index, $i \in \{1,2,...,I\}$;

j : cast index, $j \in \{1,2,..., J\}$;

o_i : operation index of charge i, $o_i \in \{1,2,....,O(i)\}$. Since stage skipping is considered, $O(i) \leq H$;

h_{oi} : stage index of the operation o_i of charge i, for each charge, $h_{oi+1} - h_{oi} \geq 1$ and $h_{o(i)} = H$;

W_h : set of indices of all machines in stage h;

Ψ : set of indices of all charges;

Ψ_j : set of indices of all charges in the cast j. $|\Psi_j|$ is the number of charges in set Ψ_j.

$\Psi_{j1} \cap \Psi_{j2} = \varnothing$, for any $j1 \neq j2$. $\sum_{j=1}^{J} |\Psi_j| = I$;

Ω_m : set of indices of all casts allocated on a continuous caster m ($m \in W_H$), $|\Omega_m|$ is the number of casts in set Ω_m. $\sum_{m \in W_H} |\Omega_m| = J$;

*l*i(j) : the last charge in cast j, since the indices of charges are consecutively numbered according to the predetermined casting order on each continuous caster

*l*i(j) : *l*i(j – 1) + $|\Psi_j|$, *l*i(0) = 0 and *l*i(J) = I. Then, $\Psi j = \{li(j-1) + 1, ..., li(j)\}$;

*l*j(m) = the last cast on continuous caster m ($m \in W_H$), since the indices of casts are consecutively numbered according to the index order of the continuous casters in the last stage (*l*j(m) = *l*j(m –

1)+ $|\Omega_m|$ and $lj(M) = J$, where M is the maximum machine index in set W_H. $lj(m-1) = 0$,if $m-1 \notin W_H$. Then,$\Omega_m = \{lj(m-1)+1,...,lj(m)\}$.

$wt_{h,i}^{min}$, $wt_{h,i}^{sta}$, $wt_{h,i}^{max}$: $wt_{h,i}^{min}/wt_{h,i}^{sta}/wt_{h,i}^{max}$ represents the minimum/standard/maximum processing charge I on non-casting machines, $ct_{h,i}^{min}$, $ct_{h,i}^{sta}$, $ct_{h,i}^{max}$: $ct_{h,i}^{min}/ct_{h,i}^{sta}/ct_{h,i}^{max}$ represents the minimum/standard/maximum processing times of charge I on casting machines.

$tt_{m,m'}$: transport time between machines m and m′
st : setup time between two casts
ct_m : earliest available time ofmachine m
λ_1 : penalty coefficient of make span
λ_2 : penalty coefficient of waiting time
λ_3 : penalty coefficient of deviation of processing time from standard time
λ_4 : penalty coefficient of deviation of earliness
U : large integer
$due_{o(li(ij(m)))}$=due date of the charge
$x_{m,oi}$: binary variable that is equal to one if and only if the operation o_i of charge i is processed on machine m;
$y_{m,i,i'}$: binary variable that is equal to one if and only if the operation o_i of charge i′ are both processed on the machine m and i is processed before i′.

Objective function

Following Xuan et al. [2007] and Pan [2013], minimization of the makespan to complete all of the charges as soon as possible, and minimization of the total waiting times to reduce the heat loss of charges etc. can be considered in objective function.Adjustable processing time in steel scheduling will ease the cast break phenomenon , minimization of the deviation of the processing time from its standard processing time is also considered here.The product earliness is to be minimized to prevent the inventory accumulation. The objective function is formulated as follows.

$$\text{minimize } Z = Z_1 + Z_2 + Z_3 + Z_4 \quad (1)$$

with $$Z_1 = \lambda_1 \max_{m \in W_H} \{e_{O(li(lj(m)))}\}$$

$$Z_2 = \lambda_2 \sum_{i=1}^{I} \sum_{O_i=1}^{O(i)-1} \sum_{m=1}^{M} \sum_{m'=1}^{M} x_{m,o_i} x_{m',o_i+1}(s_{o_i+1} - e_{o_i - tt_{m,m'}})$$

$$Z_3 = \lambda_3 \sum_{i=1}^{I} \sum_{o_i=1}^{O(i)-1} (\max\{0, e_{o_i} - s_{o_i} - wt_{h_{o_i},i}^{sta}\} - \min\{0, e_{o_i} - s_{o_i} - wt_{h_{o_i},i}^{sta}\})$$
$$+\lambda_3 \sum_{m \in W_H} \sum_{j \in \Omega_m} \sum_{j \in \Psi j} (\max\{0, e_{O(i)} - S_{O(i)} - ct_{m,i}^{sta}\} - \min\{0, e_{O(i)} - S_{O(i)} - ct_{m,i}^{sta}\})$$

$$Z_4 = \lambda_4 * (e_{o(li(ij(m)))}) - due_{o(li(ij(m)))}$$

Since the charge $li(lj(m))$ is the last charge on continuous caster m, $\max_{m \in W_H} \{e_{O(li(lj(m)))}\}$ is the makespan

$$e_{o_i} - s_{o_i} \geq wt_{h_{o_i},i}^{min}, \quad i \in \Psi,\ o_i \in \{1,2,...,O(i)-1\} \quad (2)$$

$$e_{o_i} - s_{o_i} \leq wt_{h_{o_i},i}^{max}, \quad i \in \Psi,\ o_i \in \{1,2,...,O(i)-1\} \quad (3)$$

$$e_{o(i)} - s_{o(i)} \geq ct_{m,i}^{min}, \quad i \in \Psi_j,\ j \in \Omega_m,\ m \in W_H \quad (4)$$

$$e_{o(i)} - s_{o(i)} \leq ct_{m,i}^{max}, \quad i \in \Psi_j,\ j \in \Omega_m,\ m \in W_H \quad (5)$$

2) For any two consecutive operations of a charge, the later operation must be started after the charge has been transported to the next machine.

$$s_{oi+1} - e_{oi} - tt_{m,m'} + (2 - x_{m,oi} - x_{m',oi+1})\, U \geq 0,$$
$$i \in \Psi,\ o_i \in \{1,2,...,O(i)-1\},\ m \neq m' \in \{1,2,...,M\} \quad (6)$$

3) There exists a precedence relationship on a machine for processing any two charges.

$y_{m,i,i'} + y_{m,i',i} - x_{m,oi}x_{m,o'i'} = 0,$ $i \neq i' \in \Psi,\ m \in \{1,2,...,M\} \backslash W_H,$ $o_i' \in \{1,2,...,O(i)-1\} \backslash W_H,$ $o'_{i'} \in \{1,2,...,O(i')-1\}$ (7)

$S_{o'i'} - e_{oi} + (3 - x_{m,o'i'} - x_{m,oi} - y_{m,i,i'})\, U \geq 0,$ (8) $i \neq i' \in \Psi,\ m \in \{1,2,...,M\} \backslash W_H,$ $o'_{i'} \in \{1,2,...,O(i')-1\}$

5) Charges must not be processed on a machine before its earlies

$s_{oi} - et_m + (1 - x_{m,oi})\, U \geq 0,$ $i \in \Psi,\ o_i \in \{1,2,\ldots,O(i)\},\ m \in \{1,2,\ldots,M\}$ (9)

6) Exactly one machine must be allocated for each operation

$$\sum_{m \in W_{h_{o_i}}} x_{m,o_i} = 1 \qquad o_i \in \{1,2,\ldots,O(i)\} \quad (13)$$

$$e_{O(i)} + st \leq s_{o(i+1)}, \qquad i = li(lj(m-1) + \tilde{j}),\ (lj(m-1) + \tilde{j}) \in \Omega_m,$$
$$\tilde{j} \in \{1,2,\ldots,|\Omega_m| - 1\},\ m \in W_H \quad (10)$$

$$e_{O(i)} = s_{O(i+1)}, \qquad i \in \Psi,\ i+1 \in \Psi_j,\ j \in \{1,2,\ldots,J\} \quad (11)$$
$$x_{m,O(i)} = 1 \qquad i \in \Psi_j,\ j \in \Omega_m,\ m \in W_H \quad (12)$$

$$s_{oi \geq 0}, i \in \Psi,\ o_i \in \{1,2,\ldots,O(i)\} \quad (13)$$
$$e_{oi \geq 0}, i \in \Psi,\ o_i \in \{1,2,\ldots,O(i)\} \quad (14)$$

$$x_{m,oi} \in \{0,1\}, \qquad i \in \Psi,\ o_i \in \{1,2,\ldots,O(i)\},\ m \in \{1,2,\ldots,M\} \quad (15)$$
$$y_{m,i,i'} \in \{0,1\}, \qquad i \neq i' \in \Psi,\ m \in \{1,2,\ldots,M\} \quad (16)$$

5. Algorithm

On the basis of the above description we know that the steel scheduling model is a nonlinear and mixed integer optimization problem. GA is an efficient optimization tool which has been extensively used to solve this kind of optimization problems solution. GA begins with a population of stochastically generated chromosomes, and this population evolves through generations. The fitness of each chromosome in the population is first computedin each generation. Then, a selection operator is used to select the chromosomes with higher fitness as parentsto reproduce offspring by employing a crossover operator with a crossover probability (CP). A mutation operator will be used for random alteration of genetic genes in the offspring with a mutation probability (MPA) described in the problem statement, the allocation of casts to continuous casters, the sequence where the casts are processed on each continuous caster, and the casting sequence where the charges in each cast, are all determined at planning level. Therefore, the charge sequence for the last stage is not needed anymore in JBAwas proposed for a three-stage SCC scheduling without considering stage skipping. For ease of description, the current earliest available time of charge i is represented by τ_i. The current earliest available time of machine m is represented by μ_m.

JBA:								
	2	1	3	1	2	3	1	3

Charge sequence in stage 1: charge 2; charge 1; charge 3
Charge sequence in stage 2: charge 1; charge 2; charge 3
Charge sequence in stage 3: charge 1; charge 3

Step-1: Initialize τ_i for each charge to 0 and μ_m for each machine to the earliest available time et_m. Set h = l.
Step-2: If h < H, go to Step 3, otherwise, go to Step 8.
Step-3: If h = 1, generate a permutation $\zeta = \{\zeta(1), \zeta(2),\ldots, \zeta(n_1)\}$ for all the charges that will be processed in stage h (stage 1) according to the chromosome representation otherwise, calculate the earliest starting time es_{oi} of each charge i that will be processed in stage h and generate a permutation $\zeta = \{\zeta(1), \zeta(2),\ldots, \zeta(n_h)\}$ for these charges according to the non-decreasing sequence of charge's earliest starting time es_{oi}. The starting time of charge i on a machine m ($m \in W_h$) is $s_{oi,m} = \max\{\mu_m, \tau_i + tt_{m'm}\}$, where machine m′ refers to the machine which has been assigned to charge i in stage h_{oi-1}. Then, es_{oi} can be computed as follows: $es_{oi} = \min_{m \in Wh}\{s_{oi,m}\}$.
Step-4: If set ζ is empty, go to Step 7, otherwise, go to Step 5.

Step-5: Take the first charge $\zeta(1)$ from ζ and allocate it to the machine so that charge $\zeta(1)$ has the earliest starting time in stage h. If the number of machines that have the same earliest starting time for processing charge $\zeta(1)$ is greater than 1, a random assignment will be executed to break the tie. The earliest starling time of charge $\zeta(1)$ is computed according to the formula, $es_{o_{\zeta(1)}} = \min_{m\in W_h}\{\max\{\mu_m, \tau_{\zeta(1)} + tt_{m'm}\}\}$, where $\tau_{\zeta(1)}$ and μ_m are the current earliest available times of charge $\zeta(1)$ and machine m, respectively. Note that the transport time $tt_{m'm} = 0$, if h = 1. The machine chosen for charge $\zeta(1)$ is represented as m*. We try to process charge $\zeta(l)$ on machine m* as soon as possible. Thus, the starting time of charge $\zeta(1)$ is$s_{o_{\zeta(1)}} = es_{o_{\zeta(1)}}$. We directly use the standard processing time to compute the ending time of charge, $\zeta(1)$, $e_{o_{\zeta(1)}} = s_{o_{\zeta(1)}} + wt^{sta}_{h,\zeta(1)}$ .The current earliest available time of machine m* should be updated by $\mu_{m^*} = e_{o_{\zeta(1)}}$, and the current earliest available time of charge $\zeta(1)$ should be updated by $\tau_{\zeta(1)} = e_{o_{\zeta(1)}}$.

Step-6: Remove charge $\zeta(1)$ from set ζ, and go to Step 4.

Step-7: h = h + 1, go to Step 2.

Step-8: As described before, the machine allocation for each charge in the last stage and the charge sequence processed by each continuous caster are all predefined. Therefore, we only need to determine the starting time and ending time for each charge on its predefined machine, hi this step, we first determine them without considering the continuity of casting. The schedule of the charges on each continuous caster m ($m \in W_H$) can be computed by the following iterative formulas.

$$s_{O(i)} = \max\{\mu_m, \tau_i + tt_{m'm}\} \quad (17)$$

$$e_{O(i)} = s_{O(i)} + ct^{sta}_{m,i} \quad (18)$$

$$\mu_m = \begin{cases} e_{O(i)} & i \in \{li(j-1)+1, li(j-1)+2, ..., li(j)-1\} \\ e_{O(i)} + st & i = li(j) \end{cases} \quad (19)$$

where $i \in \Psi_j$, $j \in \Omega_m$.

Step-9: In order to ensure the continuous production in each cast, the starting time and ending time for each charge in the cast are adjusted in this Step. For each cast j ($y \in \{1,2,....,J\}$), we first keep the starting time and ending time of its last charge $li(j)$ computed in Step 8 unchanged, and then use the following formulas to adjust the starting times and ending times of the other charges in a reverse direction:

$$e_{O(i)} = s_{O(i+1)} \quad (20)$$

$$s_{O(i)} = e_{O(i)} - ct^{sta}_{m,i} \quad (21)$$

where $i \in \{li(j) - 1, \ldots, li(j-1) + 2, li(j-1) + 1\}$.

Since the charge sequences for all stages are contained in chromosome, generate a permutation for each stage h according to the chromosome representation rather than the charge's earliest starting times in Step-3. Generate a permutation for each stage h according to the chromosome representation rather than the charge's earliest starting times in Step-3, and we also do not need to allocate machines for charges in each stage according to the earliest starting time rule in Step-5.

$$e_{i,m} - s_{i,m} \geq wt^{min}_{m,i}, \quad i \in \Psi, m \in W(i) \quad (22)$$

$$e_{i,m} - s_{i,m} \leq wt^{max}_{m,i}, \quad i \in \Psi, m \in W(i) \quad (23)$$

$$s_{i,SM(i,m)} - e_{i,m} \geq tt_{m,SM(i,m)}, \quad i \in \Psi, m \in W(i), SM(i,m) \in W(i) \quad (24)$$

$$s_{SI(i,m),m} - e_{i,m} \geq 0, \quad m \in W(i), SI(i,m) \in \Psi \quad (25)$$

$$s_{i,m} \geq et_m, \quad i \in \Psi, m \in W(i) \quad (26)$$

$$s_{SI(i,m),m} - e_{i,m} \geq st, \quad i \in \Psi_{j1}, SI(i,m) \in \Psi_{j2}, m = m_{O(i)} \in W_H, j1 < j2 \in \Omega_{mO(i)} \quad (27)$$

$$s_{SI(i,m),m} - e_{i,m} = 0, \quad i \in \Psi_j, SI(i,m) \in \Psi_j, m = m_{O(i)} \in W_H, j \in \{1,2,\ldots,J\} \quad (28)$$

$$s_{i,m} \geq 0 \quad i \in \Psi, m \in W(i) \quad (29)$$

$$e_{i,m} \geq 0 \quad i \in \Psi, m \in W(i) \quad (30)$$

We can find that Pl is still not a LP model because its objective (24) and (27) are nonlinear. However, it can be reformulated as a LP model by employing three sets of new variables:

$$C_{max} = \max_{m \in W_H} \{e_{li(lj(m)),m}\} \quad (31)$$

$$Z_{i,m} = -\min(0, e_{i,m} - s_{i,m} - wt^{sta}_{m,i}, \quad i \in \Psi,\ m \in W(i) \quad (32)$$

$$Y_{i,m} = \max(0, e_{i,m} - s_{i,m} - wt^{sta}_{m,i}, \quad i \in \Psi,\ m \in W(i) \quad (33)$$

Note that C_{max}, $Z_{i,m}$ and $Y_{i,m}$ are nonnegative. We also have the following relations: $s_{i,m} = Z_{i,m} - Y_{i,m} + e_{i,m} - wt^{sta}_{m,i}$, $e_{i,m} = Y_{i,m} - Z_{i,m} + s_{i,m} - wt^{sta}_{m,i}$. Therefore a LP model can be obtained by employing C_{max}, $Z_{i,m}$ and $Y_{i,m}$ in the model P1.

(P2)

minimize $Z = Z_1 + Z_2 + Z_{3+}Z_4$, (34)

with $Z_1 = \lambda_1 C_{max}$

$$Z_2 = \lambda_2 \sum_{i=1}^{I} \sum_{\substack{m \in W(i) \\ SM(i,m) \in W(i)}} (s_{i,SM(i,m)} - e_{i,m} - tt_{m,SM(i,m)})$$

$$Z_3 = \lambda_3 \sum_{i=1}^{I} \sum_{m \in W(i)} (Y_{i,m} + Z_{i,m})$$

$Z_4 = \lambda_4 * (e_{o(li(ij(m)))}) - due_{o(li(ij(m)))}$

subject to (27)-(35) and

$Cmax \geq e_{li(lj(m)),m}$, $\quad m \in W_H$ (35)

$$s_{i,m} = Z_{i,m} - Y_{i,m} + e_{i,m} - wt^{sta}_{m,i}, \quad i \in \Psi,\ m \in W(i) \quad (36)$$

$$e_{i,m} = Y_{i,m} - Z_{i,m} + s_{i,m} + wt^{sta}_{m,i}, \quad i \in \Psi,\ m \in W(i)$$

$C_{max} \geq 0$

$Z_{i,m} \geq 0$, $\quad i \in \Psi,\ m \in W(i)$

$Y_{i,m} \geq 0$, $\quad i \in \Psi,\ m \in W(i)$

6. Experimental Results

The results of preliminary experiments show that within a reasonable time period the algorithm convergesthe relative percentage improvement in objective function value is calculated as

RPI= Z – Z*/Z *100 (37)

where z = the value of existing sequence

Z* =the value obtained through algorithm

Table-1:RPI values

Convertor *Lh*ccm	Z*	RPI
3*2*6	7500	1.83
3*2*4	12728	2.05
4*2*5	13280	2.5

The proposed algorithm improves the objective function in terms of relative percentage

7. Conclusion

This paper studied a realistic SCC scheduling problem with stage skipping and adjustable processing time, which can be found in many practical applications in the steel plants.The objective for this problem is minimization of the makespan, the waiting time and the deviation of the processing time. GA method is applied.A weighted sum method isused in this application for converting the multiple objectives into a single objective.in future maintenance time also can be added in the model

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References

[1] L. X. Tang, J. Y. Liu, A. Y. Rong and Z. H. Yang, "A review of planning and scheduling systems and methods for integrated steel production", Eur. J. Oper. Res., vol. 133, no. 1, pp. 1-20, Aug. 2001.

[2] L. X. Tang, P. B. Luh, J. Y. Liu and L. Fang, "Steel-making process scheduling using lagrangian relaxation", Int.J. Prod. Res., vol. 40, no. 1, pp. 55-70, Jan. 2002.

[3] K. Mao, Q. K. Pan, X. F. Pang and T. Y. Chai, "A novel lagrangian relaxation approach for a hybrid flowshop scheduling problem in the steelmaking-continuous casting process", Eur. J. Oper. Res., vol. 236, no. 1, pp.51-60, Jul. 2014.

[4] H. Xuan and L. X. Tang, "Scheduling a hybrid flowshop with batch production at the last stage",Comput. Oper.Res., vol. 34, no. 9, pp. 2718-2733, Sep. 2007.

[5] L. L. Sun and S. P. Yu, "Scheduling a real-world hybrid flow shop with variable processing times using lagrangian relaxation", Int. J. Adv. Manuf. Tech., vol. 78, no.9-12, pp. 1961-1970, Jun. 2015.

[6] K. S. Naphade, S. D. Wu, R. H. Storer and B. J. Doshi, "Melt scheduling to trade off material waste and shipping performance",Oper. Res., vol. 49, no. 5, pp. 629-645, Sep. 2001.

[7] D. Pacciarelli and M. Pranzo, "Production scheduling in a steelmaking-continuous casting plant",Comput. Chem. Eng., vol. 28, no. 12, pp. 2823-2835, Nov. 2004.

[8] V. Kumar, S. Kumar, M. K. Tiwari and F. T. S. Chan, "Auction-based approach to resolve the scheduling problem in the steel making process", Int. J. Prod. Res., vol. 44, no. 8, pp. 1503-1522, Apr. 2006.

[9] P. A. Huegler and F. J. Vasko, "Metaheuristics for melt shop scheduling in the steel industry", J. Oper. Res. Soc., vol. 58, no. 6, pp. 791-796, Jun. 2007.

[10] A. Atighehchian, M. Bijari and H. Tarkesh, "A novel hybrid algorithm for scheduling steel-making continuous casting production", Comput. Oper. Res., vol. 36, no. 8, pp. 2450-2461, Aug. 2009. 34

[11] Q. K. Pan, L. Wang, K. Mao, J. H. Zhao and M. Zhang, "An effective artificial bee colony algorithm for a real-world hybrid flowshop problem in steelmaking process", IEEE T. Autom. Sci. Eng., vol. 10, no. 2, pp.307-322, Apr. 2013.

[12] Q. K. Pan, "An effective co-evolutionary artificial bee colony algorithm for steelmaking-continuous castingscheduling", Eur. J. Oper. Res., vol. 250, no. 3, pp. 702-714, May. 2016.

[13] S. L. Jiang, M. Liu, J. H. Hao and W. P. Qian, "A bi-layer optimization approach for a hybrid flowshop scheduling problem involving controllable processing times in the steelmaking industry", Comput. Ind. Eng., vol.87, no. pp. 518-531, Sep. 2015.