Scheduling a Continues Galvanization Line using Genetic Algorithm

H. Fox
Braude College of Engineering
Karmiel, Israel
hila.foxx@gmail.com

S. Ben Alul
Braude College of Engineering
Karmiel, Israel
sbalul20@gmail.com

M. Weiss Cohen
Braude College of Engineering
Karmiel, Israel
miri@braude.ac.il

ABSTRACT

This work deals with a scheduling system for a continuous galvanization line, an important and complex problem for logistic optimization in steel plants. The problem tackled in this work involves several constraints and characteristics inspired by real-life manufacturing plants and literature. Given the complexity of the problem, which belongs to the class of NP-hard problems, a GA methodology was developed. The solution is based on combining a penalty procedure defined for constraints, and assigning various weights for different characteristics of coils. Considering the ability and flexibility of GAs, a set of parameters are analyzed to achieve practical and best results. Our approach achieved satisfying continuous galvanization line sequences with minimum number of coil transitions which improve productivity and reduce costs.

Categories and Subject Descriptors

G.1.6 Optimization- Constrained optimization
I.2.8 ARTIFICIAL INTELLIGENCE - Problem Solving, Control Methods, and Search I.6.3 SIMULATION AND MODELING: Applications

General Terms

Algorithms

Keywords

Genetic algorithms. Continuous Galvanization Line; Optimization Sequencing

INTRODUCTION

Galvanization is a part of the steel manufacturing process. This is a process in which the steel coils are coated with Zinc, to create a protective layer preventing corrosion. Steel making consists of several stages which can be divided into two main stages [4].

ACM ISBN 978-1-4503-4939-0/17/07.
http://dx.doi.org/10.1145/3067695.3076001

First, manufacturing a semi-finished steel product from raw materials. Second, Coil making and the finishing lines. In the first stage, the raw materials are molded into coils.
The second stage consists of a series of processes: Cold coils enter the line, annealing is achieved by heating, galvanizing by Zinc coating and the last stage are special surface treatments Each coil is characterized by a set of characteristics, such as weight, length, width, thickness, chemical composition, furnace time, thermal cycle, roughness and hardness, etc. In addition, [4] there are pre-processing and post-processing requirements which must be met. Before placing the coils onto the processing line, they are separated into clusters as per customers' specifications, these clusters are called Production Campaigns or Batches[3]. This complex procedure of planning a scheduling line, includes objectives such as matching the geometric compatibility of the head of one coil to the tail of another, temperature adjustments according to thickness width of the coil and Zinc thickness. As an example, a thicker coil requires, a high temperature in the furnace and longer heating time, resulting an overall longer processing time for the galvanizing line [1]. Galvanization types change by cooling liquids and air knives, moreover, each liquid/air temperature and type must be suitable to the exact characteristics of a specific coil. There are several types of Galvanization lines, this work deals with the Continuous Galvanization Line (GCL)[14]. In a CGL each cluster of coils are gathered by criteria, such as, due dates and galvanization types. For each cluster, the sequence of the coils needs to be determined. This is a complex task which is derives from the following constraints: a. Each two coils needs to be welded together, so that they do not break during the annealing faze in the furnace. b. Each two coils that are welded together need to have similar characteristics [1], to minimize the adaptation phase of the transition from one coil to the other. This also compels strip speed changes and changes of the process parameters. In cases in which two coils are not sequenced properly, and welding can not be performed, there is a need to add a transition coil [1]. Fernandez et al. [1] proposed a solution using Ant Colony. Tang and Wang [2] propose an approach for solving a sequence in the Continuous Color-Coating line. Kapanoglu and Koc [3] presents a solution using Multi-Population Parallel Genetic Algorithm (MPGA). Valls, et al [4] use Tabu Search (TS) and Tabu Threshold (TT) techniques, to tackle this hard combinatorial problem. In this work we examined four basic characteristic for each coil, and created a penalty system that will assist to evaluate the fitness of each solution (chromosome). The following four basic characteristic are: Steel thickness (ST), Steel width (SW), Steel grade (SG) and Zinc thickness (ZT). We defined each attribute and assigned a weight value in the penalty calculation. The attributes, ranges and weights are described as follows: Steel

thickness (ST) range [20, 80] with penalty weight of 0.1. Steel width (SW) range [4, 10] with penalty weight of 0.2. Steel grade (SG) range [0.1, 10] with penalty weight of 0.2. Zinc thickness (ZT) range [40, 80] with penalty weight of 0.5. Each characteristic and Max penalty will be calculated as follows:

$$ST_{penalty} = (ST\_max - ST\_min) * ST_{weight}$$
$$SW_{penalty} = (SW\_max - SW\_min) * SW_{weight}$$
$$SG_{penalty} = (SG\_max - SG\_min) * SG_{weight}$$
$$ZT_{penalty} = (ZT\_max - ZT\_min) * ZT_{weight}$$
$$max_{penalty} = \sum XX_{penalty}$$

In order to quantify each attributes' penalty for each transition between two coils we used the following equation

$$\frac{abs(FirstCoilValue - SecondCoilValue)}{MaxValue - MinValue} * wieght_{attribute}$$

To create the overall penalty for the transition between two coils, we need to sum up all of the attributes' penalties:

$$\sum_{Each\ attribute} \frac{abs(FirstCoilValue - SecondCoilValue)}{MaxValue - MinValue} * Weight_{attribute}$$

The next step requires calculating the total penalty. In order to do so, we need to quantify the full sequence. The calculation summing up all of the penalties is described as follows:

$$chromosome_{penalty} = \sum_{1}^{seqLength-1} transition_{penalty}(i, i+1)$$

After calculating the penalty, the fitness is derived. The fitness of a solution is proportional to its penalty, resulting the relation of the lower the penalty, the better the fit.

RESULTS

A set of 250 random chromosomes were generated as the initial population. The GA was set to terminate after 1,000 generations. Once completed, the output constructed an Excel file which details the fitted solution. This solution portrays each coil's characteristics and information regarding representation of penalties, and improvements in percentage. The penalty scores range between 100% and decreases with each improvement when compared to the first generations' evaluated solution. 40 coils - threshold of 0.5: Zinc thickness with weight of 0.5, Steel grade with weight of 0.2, Steel width with weight of 0.2 and Steel thickness with weight of 0.1 the sequence:

[30, 3, 37, 34, 19, 32, 16, 20, 39, 35, 13, 29, 23, 28, 31, 15, 40, 38, 22, 26, 2, 1, 14, 17, 27, 8, 18, 4, transition, 24, 12, 25, 9, 36, 33,5,10,11,6,7,21]

Fitness of the best solution in the last generation of 0.756752 was derived and the improvement of the penalty is 12.89584%. As a result of these values, weights and threshold, one transition coil has been inserted in the sequence. Fig. 1 depicts the characteristics and values for each set of coils. Coil number 30 was placed first and has the following values: Zinc thickness of slightly above 50 mg, Steel grade of between5 to 10, Steel width of under 5, and Steel thickness of nearly 50. A transition coil has been added without any value as it requires a coil that does not exist in the given batch. It can be derived that the difference values (delta) between each coil for each characteristic is different: the smallest delta is with the Zinc Thickness, which has the highest weighted characteristics, and the highest deltas are in the Steel Thickness, which is the lowest weighing characteristic. The tendency for each of the characteristic

In this research a novel and efficient flexible system for the CGL scheduling problem is developed. We presented a GA which receives a batch of coils, creates a random initial population and optimizes this solution until reaching 1,000 generations.

Our solution is based on a penalty system. The algorithm optimizes the penalty evaluation, resulting a higher improvement compared to the initial best fitted solution. Due to the connection between fitness and penalties in our solution we expected the fitness to increase throughout the generation while the penalty would decrease. We conducted experiments yielding an improvement of 15.52985%.

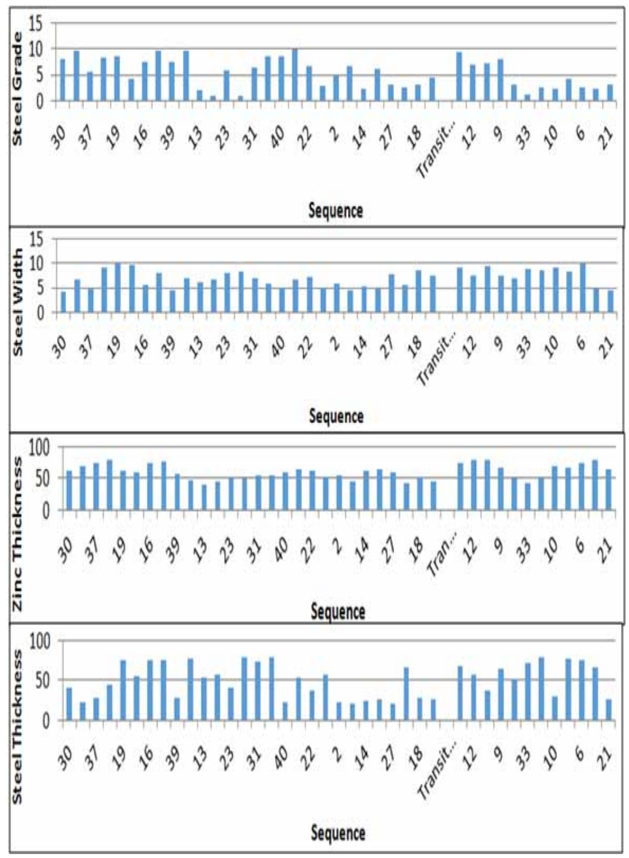

Figure **1**: Galvanization line sequence example

REFERENCES

[1] S. Fernandez, S. Alvarez, D. Diaz, M. Iglesias and B. Ena. 2014. Scheduling a galvanization line by ant colony optimization. International *Conference on Swarm Intelligence*. 146-157

[2] L. Tang and X. Wang. 2008. A predictive reactive scheduling method for color-coating production in steel industry. *The International Journal of Advanced Manufacturing Technology* 35, 633-645, DOI: 10.1007/s00170-006-0740-y

[3] Kapanoglu M., Koc I.O. 2006. A Multi-population Parallel Genetic Algorithm for Highly Constrained Continuous Galvanizing Line Scheduling. In: Almeida F. et al. (eds) Hybrid Metaheuristics. HM 2006. Lecture Notes in Computer Science, vol 4030. Springer, Berlin, Heidelberg. DOI: 10.1007/11890584_3

[4] V. V. Valls, M. A. P. Alarcó, and M. P. L. Sorlí. 2009. Scheduling in a continuous galvanizing line. *Computers & Operations Research.* Volume 36, Issue 1, January 2009, Pages 280-296, ISSN 0305-0548. http://dx.doi.org/10.1016/j.cor.2007.09.006.