

## Optimizing Shared Resources in a Batch Production Process using Genetic Algorithm for Small Production Industry

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**Abstract:** The goal of this research is to increase the comprehensive production effectiveness for small production systems. The research is based on the actual demand of the production batch process and provides the ideal solution to the current problems. This approach considers the approach when randomly placed orders are deposited in the form of batches for production, and look for application of intelligent control under realistic conditions. As a result, it is important to develop a new model of production system which takes into account some obstacles. The problem that focuses on the production system is to reduce the time spent by the mathematical model. The optimization problem is solved using intelligent algorithms, which include Genetic Algorithm (GA) while providing some effective improvement strategies based on the lack of application.

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### I. Introduction

Industry plays the most important role in economic development and also has significant impact on people's daily lives. Apart from this, most of the industries are small-medium scale and they have common problems which are poor automated control capability and lack of technology, management skills and techniques in the production process and human resources, high energy consumption etc. These problems are seriously hampering sustainable development of productive forces in the industry. After this, most companies are still using the traditional manpower scheduling method in production plans, which are of less efficiency or are also disabled in complex and dynamic environments. As a result, it is easy to get out of stocks or even out of stock of overstock events. Therefore, there are many issues of industry in relation to improving efficiency for the production system. Zheng, L. (2011) and Zheng (2008) recognize that production is not only a complex batch production system, but requires many barriers and limitations within the process's mobility, for example, delay, reaction Uncertainty non-linearity and different standards production processes have similar characteristics of semi continuous operation in the form of other batch production processes, Based on the sequence of lawn and process conditions. Due to the constant change of products, and the sharing of resources (including time, equipment, raw materials and human resources), it depends on all activities of production and subsequent economic benefit production planning and scheduling; Thus, scheduling of production becomes a very complex problem. At present, research on the mathematical model of production scheduling is still rare, beer companies still rely on artificial scheduling production, and the effect is not ideal. In addition, production scheduling problems are known as NP-hard problems in non-deterministic polynomial time due to batch production environment, dynamic change in customer demand and production scheduling problems (Huang 2002). It has also been recognized that most of these problems can be solved using intelligent control and optimization methods [1].

Their use in industry is increasing, including genetic algorithms (GA), simulate annealing (SA), ant colony optimization (ACO), taboo search (TS) etc. Stark weather, et al. (1992) has implemented a GA for resolving multipurpose JSP in Brewery, these objectives include the minimum average time of the list, the minimum wait time of the customer's orders etc. It has also been implemented for optimization based on GA's dynamic model. In the latter part, GA is used to obtain a series of curves at different temperatures during certain fermentation time to find the optimum temperature curve. This ensures that the ultimate quantity of alcohol in the fermentation process reaches the maximum and also ensures that the concentration of the product is lowest, which protects the quality of beer. It produced mathematical models for product scheduling and showed results that the customized plan has strangeness and practicality. Compared to intelligent control, intelligent optimization technology is still relatively rare in industry, and there are many practical issues that need to be adapted and resolved [2].

The purpose of this research is to achieve significant improvement in efficiency and performance in the breweries production system to meet the different market demands. Based on the development of modeling approach, algorithm analysis, and optimization techniques, which reduce production time and maximize profits.

## **II. Relevant Heuristic Algorithms**

### **Genetic algorithms (GA)**

Genetic algorithms were proposed by John Holland (1975). It is inspired by the biological evolution of random search algorithms based on natural selection and natural genetic mechanisms, to solve both bound and uncontrolled optimization problems, the process of GA is to revise the population of individual solutions repeatedly. In each stage, the current population will be randomly selected to be parents who will produce children for the next generation. In generations continuously, the population develops towards an optimal solution. Similarly, (Michelle 1998; Shaw et al 2000) has defined that GA is a biological simulation in the natural environment of the adaptive genetic and evolutionary process, which is a kind of adaptive capacity and a global search prospect. The probable solution of each problem will be considered as a population (chromosomal) of the population, which will make the cluster of each chromosome in the form of encoding, for each person to provide the assessment according to the predetermined purpose, and also provide a fitness value. The algorithm will be based on the fitness value of its search process. In each stage, the three main types of rules are used to make the next generation from the current population by the selection of three genetic operators, crossover and mutation.

### **Encoding**

Encoding is the primary problem that needs to be solved by GA, the Holland coding method is binary code, but this simple coding method is difficult to describe directly to the nature of problem in many GAS applications, especially in industrial engineering. In the last decade, there are some main encoding methods which have been proposed for special issues (Holland 1975; Gerst 1971; Zhou and Sun 1999):

- Binary encoding
- Gray code
- Real number encoding
- Symbolic coding

### **Initial population and the evaluation of fitness**

First of all, it requires determining the number of people in the population, that is the size of the population (pop size), and then randomly generate the initial population using the fitness function to evaluate the performance of each of the early species. The initial solution that is to calculate the fitness of each initial solution, if the fitness is high, then the individual performance is better, and then it is close to optimal objectives, so the definition of fitness function plays an important role in GA.

In addition, many GA solutions require a significant amount of time to calculate some practical problems, usually its size is large, and for many individuals, especially in calculating and evaluating, more important genetic and evolutionary operations need to be implemented. Large number of fitness can be the reason for low efficiency of this evolutionary calculation process, and fail to meet the requirements of speed calculation. It is believed that GA is likely to have parallel processing, so many parallel GAs have been proposed in the past decades (Tomassini 1995; Concrete 2004). These algorithms have also obtained better customization quality than classical GA.

### **Selection**

On the basis of the size of the selection fitness is to select the better person for the next generation, so it guarantees the population of development. The selection operation is better to choose and reduce the survival of the best of the population is the operation. Individuals have high potential for high fitness for the selection of large groups in the next generation; for lower fitness individuals, there are fewer possibilities to choose for next generation. The task of selecting the operation is to select some individuals from parents according to the following methods:

- **Roulette selection**

Roulette is one of the most commonly used methods among different ways. (Goldberg1998) has explained that if all the people in the population are kept on a roulette wheel according to their fitness value, the higher the person's fitness, the greater the likelihood of selection to produce more offspring, while there is less chance of lower fitness person selection. The following process can be described as follows:

- 1) To compute each fitness of chromosome in the population, the fitness can be denoted  $f_i$ , where  $i=1,2,\dots,M$ ,  $M$  is the size of the population

2) To calculate the sum of all fitness of chromosome, it can be obtained as follows:

$$Sum = \sum_{j=1}^N f_j$$

Where,  $N$  is the number of individuals in the population

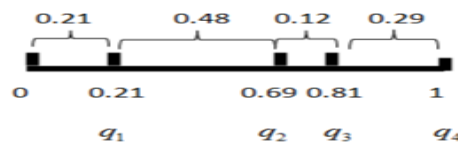
3) To calculate the probability of each individual to be selected for the next generation, the selection probability can be denoted  $p_i$ , then it can be obtained:

$$p_i = \frac{f_i}{Sum}$$

4) To calculate the accumulation probability of each chromosome, it can be obtained:

$$q_i = \sum_{j=1}^i p_j$$

Where, is accumulation probability of chromosome  $i$ , ( $i=1,2,\dots,n$ ). For example:



**Figure no. 1.** Example of the accumulation probability

Figure no.1 is a basic example which is how to calculate the accumulation probability. In this case, 0.21, 0.48, 0.12 and 0.29 are selection probability of each individual;  $q_1, q_2, q_3$  and  $q_4$  are accumulation probability for 0.21, 0.69, 0.81 and 1, separately.

- 5) To generate a pseudo random number, denoted  $r$  of the uniform distribution between 0 and 1, denoted  $[0, 1]$ .
- 6) If  $r \leq q_1$ , select the individual 1; otherwise, to select the individual  $k$ , then it requires to meet  $q_{k-1} \leq r \leq q_k$
- 7) Repeat 4) and 5)  $M$  times

- **Rank selection**

Rank selection sorts the population first according to their fitness value and ranks them. The probability of each individual is selected based on its rank (Baker 1985). The operation process of rank selection can be described as follows:

- 1) All individuals in the population sort descending order according to their fitness value.
- 2) To design a probability distribution table according to the specific problem, and to assign each probability value to each individual according to the above arrangement;
- 3) To apply the selection method of the roulette wheel to generate the next generation population based on the selection probability value of the individuals.

- **Tournament selection**

Tournament selection is also a more commonly used method by which to select a number of individuals randomly from the population to carry on the tournament, then to choose the winner (best fitness of the individual) to be the parent. The operation can be summarised as follows (Ji 2004):

- 1) To select the  $N$  (In general,  $N$  value is 2) individuals randomly in the population to compare their fitness value, and then to select the highest fitness of the individual to the population of the next generation.
- 2) Repeat the above  $M$  times, then the new population can be obtained.

- **Elitism selection**

Elitism selection selects the best one or more best individual from the current population to the new population. The individual with the highest fitness in the present population does not participate in the crossover and mutation operation and is used to replace the individual with the lowest fitness of the population after crossing and mutation. This method can guarantee that the optimal individual is not destroyed by the crossover and mutation operation, which is an important guarantee for the convergence of GA. On the other hand, it is also easy to lead to the local optimal and individual is not easy to be eliminated; so that the global search ability of the algorithm is not strong. Therefore, this method is generally used in conjunction with other selection operations, which can have a good effect (Ji 2004).

**Recombination**

Recombination is a new method to generate a new individual (chromosome), then to recombine after the selection, the most common method of the recombination that includes crossover and mutation.

- **Crossover**

Crossover is the operation where two individuals as the parent are chosen by the selection methods to generate, and replace the two new individuals. Crossover operation is the most important feature of GAs, which is different from other evolutionary algorithms. It plays a key role in the convergences of GAs. Chromosome crossover operation is executed in accordance with a certain probability, called  $P_c$ , so that it has  $P_c \times popsize$  individual for crossover operation. More specifically, each individual will generate a random number  $r$  in between 0 and 1, if  $r \leq P_c$ , the individual will be selected for crossover. Then it will randomly match pairs of the chromosome to generate a random number  $pos$  (where  $pos=1..m-1, m$  is the number of genes in the chromosome),  $pos$  is a crossover point which is for crossover and replace of an individual gene. Crossover can be described as following (‘|’ is the crossover point) in Figure .2:

There are also other methods to make the crossover, such as two crossover points, uniform, etc. specific crossover made for a specific problem can improve the performance of the GA. In the GA, it is necessary to pair the individuals in the population before the crossover operation, and the common matching strategy is random matching. Crossover operator is normally designed to include the contents of two aspects: how to determine the position of the cross point? How to carry out the exchange of genes? Here some kinds of crossover operator have been classified that are applicable to binary coding or real number coding as follows (Barros, de Carvalho & Freitas 2015):

```

Before:
Chromosome 1:  11011 | 00100110110
Chromosome 2:  11011 | 11000011110

After:
Offspring 1:   11011 | 11000011110
Offspring 2:   11011 | 00100110110
    
```

**Figure no.2.** Example of crossover operation at the single crossover points

- 1) Single point crossover; also known as the simple crossover, which is to select one crossover point randomly in the individual encoding cluster, and then to exchange a pair of individual parts of the gene at that point.
- 2) Two-point crossover; the specific procedure of implementation is to select two crossover points in the pairing between two individuals of the encoded string, and then to exchange the part of the genes at two crossover points.
- 3) Uniform crossover; this refers to every gene in two pairs of individuals having the same probability to exchange, so as to form two new individuals.
- 4) Arithmetic crossover; it refers to the linear combination of two individuals in order to generate new individuals.

- **Mutation**

The mutation operation is defined when some of the gene values of the individual encoding cluster are randomly rearranged from the crossover operations, so as to mutate, and then to obtain a new individual. Mutation is intended to break one or more individual and to jump out of a local optimum to discover a better minimum or maximum space. It maintains genetic diversity and avoids premature convergence on a local minimum or maximum. A mutation operation can also be described by binary encoding as follows:

```

Before:
Original offspring 1:  1101100100110110
Original offspring 2:  1101111000011110

After:
Mutated offspring 1:  1101110100110110
Mutated offspring 2:  1111111000011010
    
```

**Figure no.3.** Example of a mutation operation

In the example in Figure .3, we have selected one and two random values corresponding to the bit length of the chromosome. In this case, 6 have been selected in the original offspring 1; 3 and 14 have been selected in the original offspring 2. Then simply take the bits from the chromosome and swap them. Chromosome mutation operation is determined by the specified  $P_m$ . The design of mutation operation includes two aspects: how to determine the mutation position? How to process the replacement of gene value? Some types of mutation operators have been classified that are applicable to binary coding or real number coding as follows (Barros, de Carvalho& Freitas 2015): 1) Flip bit; 2) Boundary; 3) Uniform mutation; 4) Non-uniform; 5) Gaussian.

All in all, crossover and mutation have both co-operation and competition (Eiben& Smith 2003). Crossover is explorative that to discover promising areas in the search space, such as gaining information on the problem. It makes a big jump to an area somewhere in between two (parent) areas; mutation is exploitative that to optimize within a promising area, such as using information. It creates random small diversions, thereby staying near the area of the parent.

### Convergence

For the selection, crossover and mutation operation, in order to produce new species, the fitness of the new species is requested to be evaluated. The above steps are repeated until the algorithm reaches a pre-determined condition, or the fitness of the population will no longer increase.

### III. Result

Modelling and optimize the use of shared resources in a system, to identify resource deficiencies and improve capacity planning. This is based on a batch production process, where production orders are processed only according to the availability of batch reactors. This represent both the production orders of the manufacturing process, and the batch reactors that are required to process them. Then it will find the optimal resource capacities of the system by applying the Genetic Algorithm solver of MATLAB.

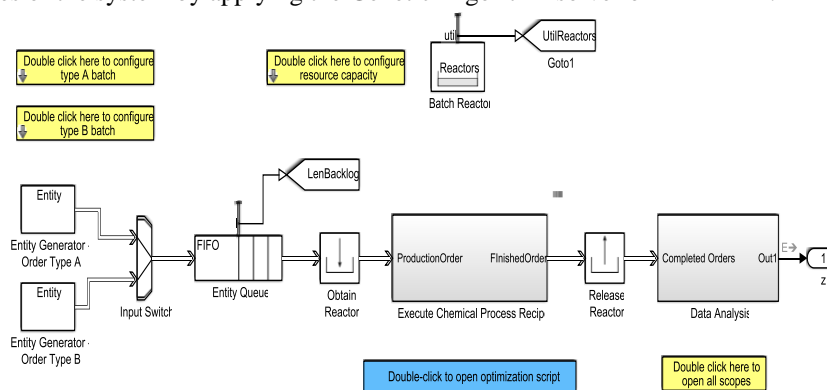


Figure no.4. MATLAB model for Batch Production Process

### Structure of Model

At the top level of the model, the Entity Generators simulate the generation and backlog of production orders by generating entities that represent production orders. When a new entity is generated, the Obtain Reactor block requests a batch reactor to process the order. After the Execute Chemical Process Recipe subsystem completes the order according to a specified chemical process recipe, the block labeled Release Reactor releases the batch reactor back into the pool of resources, where it is now available to process a new order. The Data Analysis subsystem analyzes data related to completion of production orders.

### Shared Resources in the Production Process

The Execute Chemical Process Recipe subsystem simulates the chemical process to produce sol (a type of colloid). A six-step recipe models the main operations in sol production. Execution of these steps requires different resources. A batch reactor provides built-in capabilities to execute steps like adding color, adding particles and stir. Thus the resources required by these steps do not need to be modeled separately. On the other hand, the steps to add water, heat up and drain require extra resources. These resources are shared by all the batch reactors and are limited by the capacity of the production system.

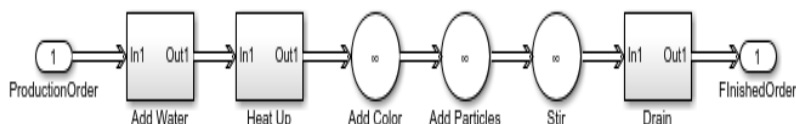


Figure no.5. Block Diagram for process control of water, heat and drain.

For example, when water usage reaches the full capacity, water pressure is too low for another batch reactor to access. In this case, production in that reactor pauses until the water supply becomes available again. In the Execute Chemical Process Recipe subsystem, the example models such a resource sharing process with a Queue block labeled Wait for Water Supply and an Entity Server block labeled Add Water in the Add Water subsystem. The Capacity parameter of the Entity Server block models the capacity of the water supply. During simulation, the number of entities in the Queue block indicates the number of batch reactors waiting for water. The number of entities in the Server block represents the number of batch reactors accessing water.

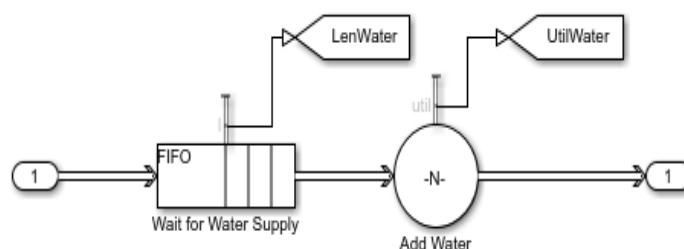


Figure no.6. Water adding and supply system for process

The modeled batch production process is capable of producing two types of batches: type A and type B. Although the main steps required to produce either batch are the same, the chemical process recipes are different. For example, the recipe to produce type B requires more water, so the step to add water takes more time to complete.

Table no.1. Variation in parameter variation of three different conditions of industry.

TYPE A BATCH				
S.NO	PARAMETERS	VALUE-1	VALUE-2	VALUE-3
1	Order generation period of type A batch:	10	20	40
2	Time needed to add water:	10	20	40
3	Time needed to heat up:	20	40	80
4	Time needed to add color:	3	6	12
5	Time needed to add particles:	5	10	20
6	Time needed for agitation:	10	20	40
7	Time needed to drain:	10	20	40

RESOURCE CAPACITY				
S.NO	PARAMETERS	VALUE-1	VALUE-2	VALUE-3
1	Number of batch reactors	2	4	8
2	Capacity of water supply (number of reactors that can access simultaneously)	2	4	8
3	Capacity of heat supply (number of reactors that can access simultaneously)	2	4	8
4	Capacity of draining facility (number of reactors that can access simultaneously)	2	4	8

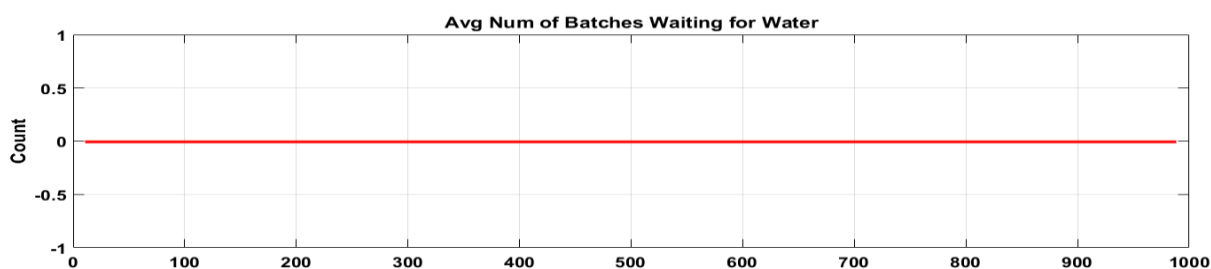


Figure no. 7. Waveform for average number of batches waiting for water

As shown in figure 7. the average number of batches waiting for water is Zero after optimization, so it is clear that the process is at most optimized condition in all stages of parameters.

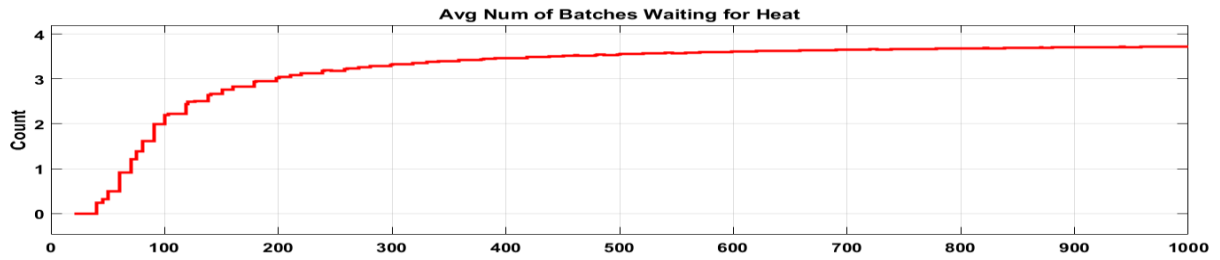


Figure no.8.Waveform for average number of batches waiting for heat

As shown in figure 8. the average number of batches waiting for heat varies, where it is Zero after optimization, so it is clear that the process is at most optimized condition in third stages of parameters.

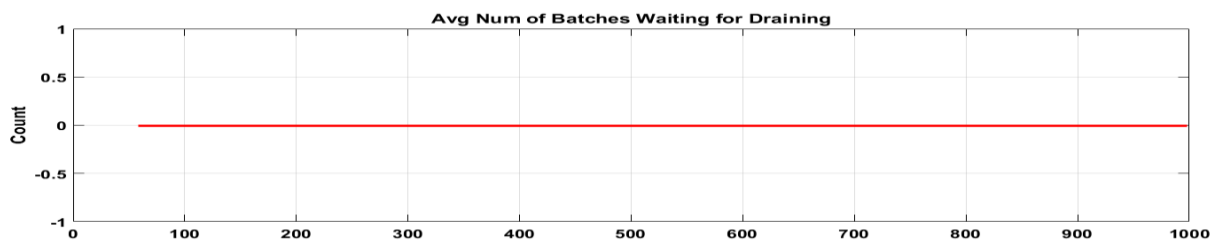


Figure no.9.Waveform for average number of batches waiting for Draining

As shown in figure 9. the average number of batches waiting for Draining is Zero after optimization, so it is clear that the process is at most optimized condition in all three stages of parameters.

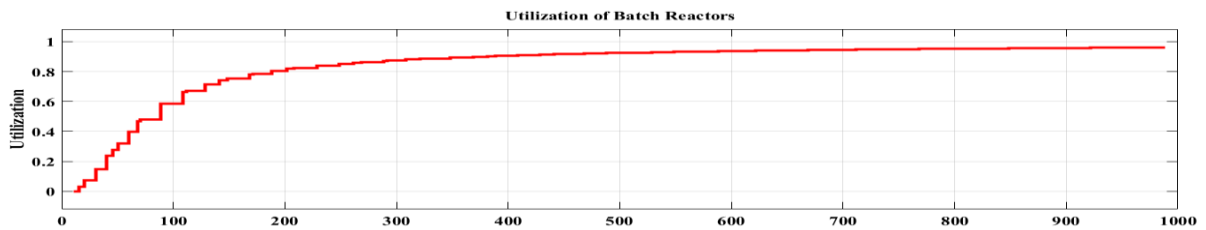


Figure no. 10.Waveform for Utilization of Batch Reactors

As shown in figure 10. the Utilization of Batch Reactors variable between 0 to 0.8

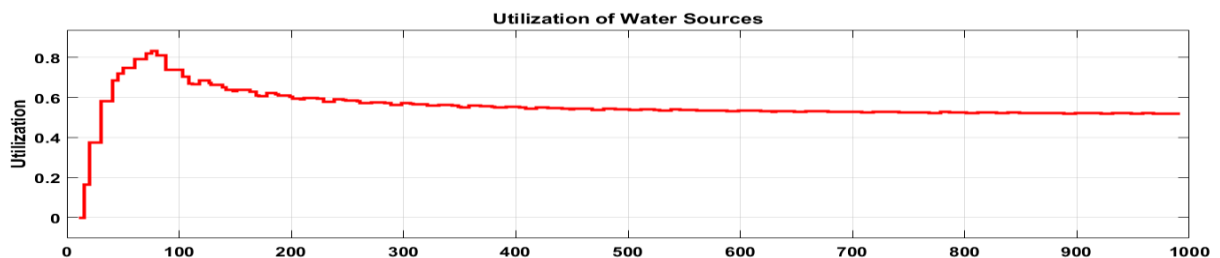


Figure no. 11.Waveform for Utilization of Water Sources

As shown in figure 11. the Utilization of Water Sources variable between 0 to 0.8, 0 to 0.4 and 0 to 0.2

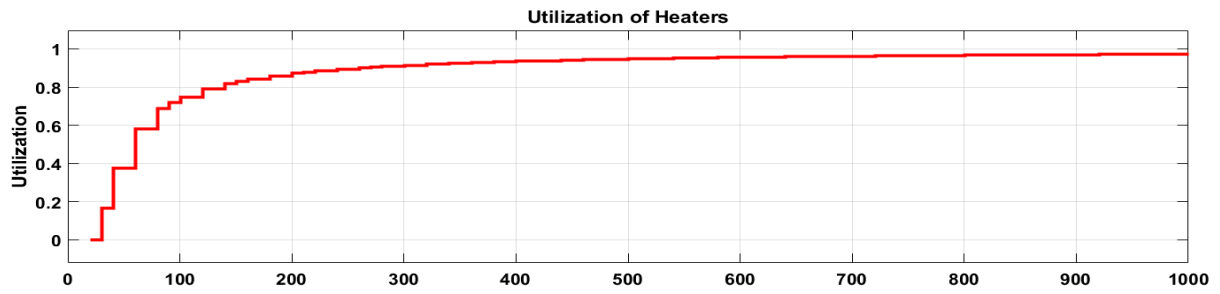


Figure no 12. Waveform for Utilization of Heaters

As shown in figure 12. the Utilization of Heaters variable between 0 to 1, 0 to 0.8 and 0 to 0.3 respectively

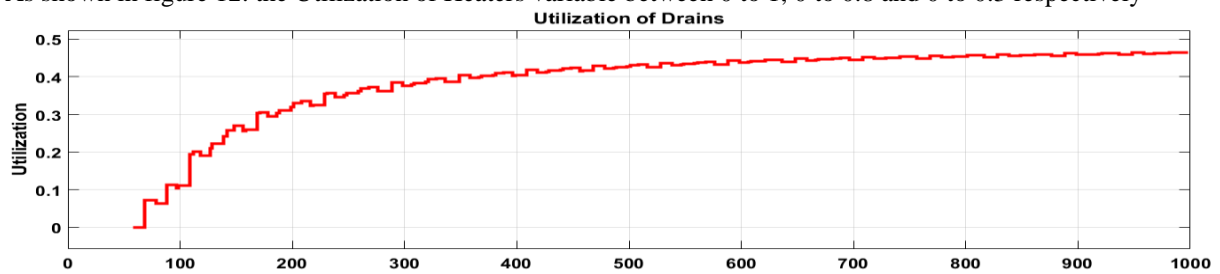


Figure no. 13. Waveform for Utilization of Drains in different conditions

As shown in figure 13. the Utilization of Drains variable between 0 to 0.5, 0 to 0.3 and 0 to 0.12.

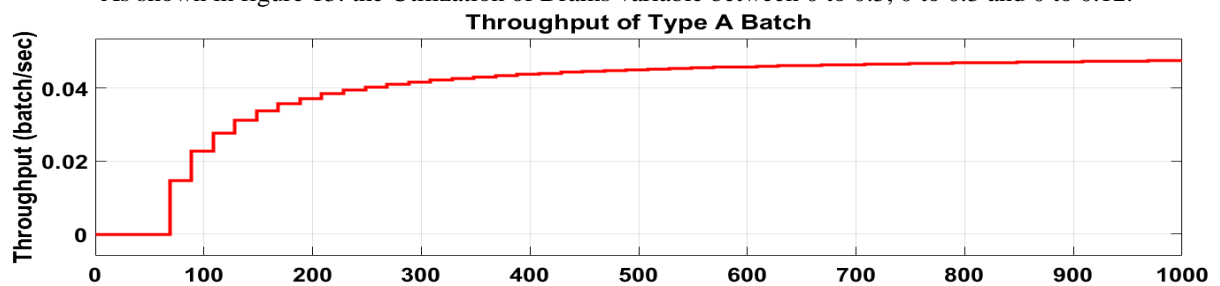


Figure no.14. Waveform for Throughput of Type A Batch in different conditions

As shown in figure 14. the Throughput of Type A Batch variable between 0 to 0.5, 0 to 0.4 and 0 to 0.015

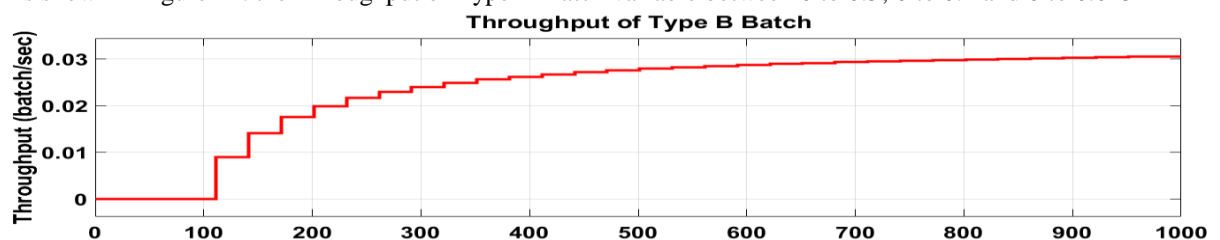


Figure no. 15. Waveform for Utilization of Batch Reactors

As shown in figure 15. the Throughput of Type B Batch variable between 0 to 0.3, 0 to 0.025 and 0 to 0.008

### Optimizing Resource Capacities

Now apply a Genetic Algorithm solver from the MATLAB Global Optimization Toolbox to this Sim Events model to find optimal resource capacities for this system. The genetic algorithm solves optimization problems by repeatedly modifying a population of individual points. Due to its random nature, the genetic algorithm improves your chances of finding a global solution. It does not require the functions to be differentiable or continuous.

The decision variables in this optimization are:

- Number of batch reactors
- Number of water tanks
- Number of heaters



- Number of drains

The genetic algorithm sets these variables as it runs multiple simulations of the model via the variable Resource Capacity. The starting values of resource capacities are shown below:

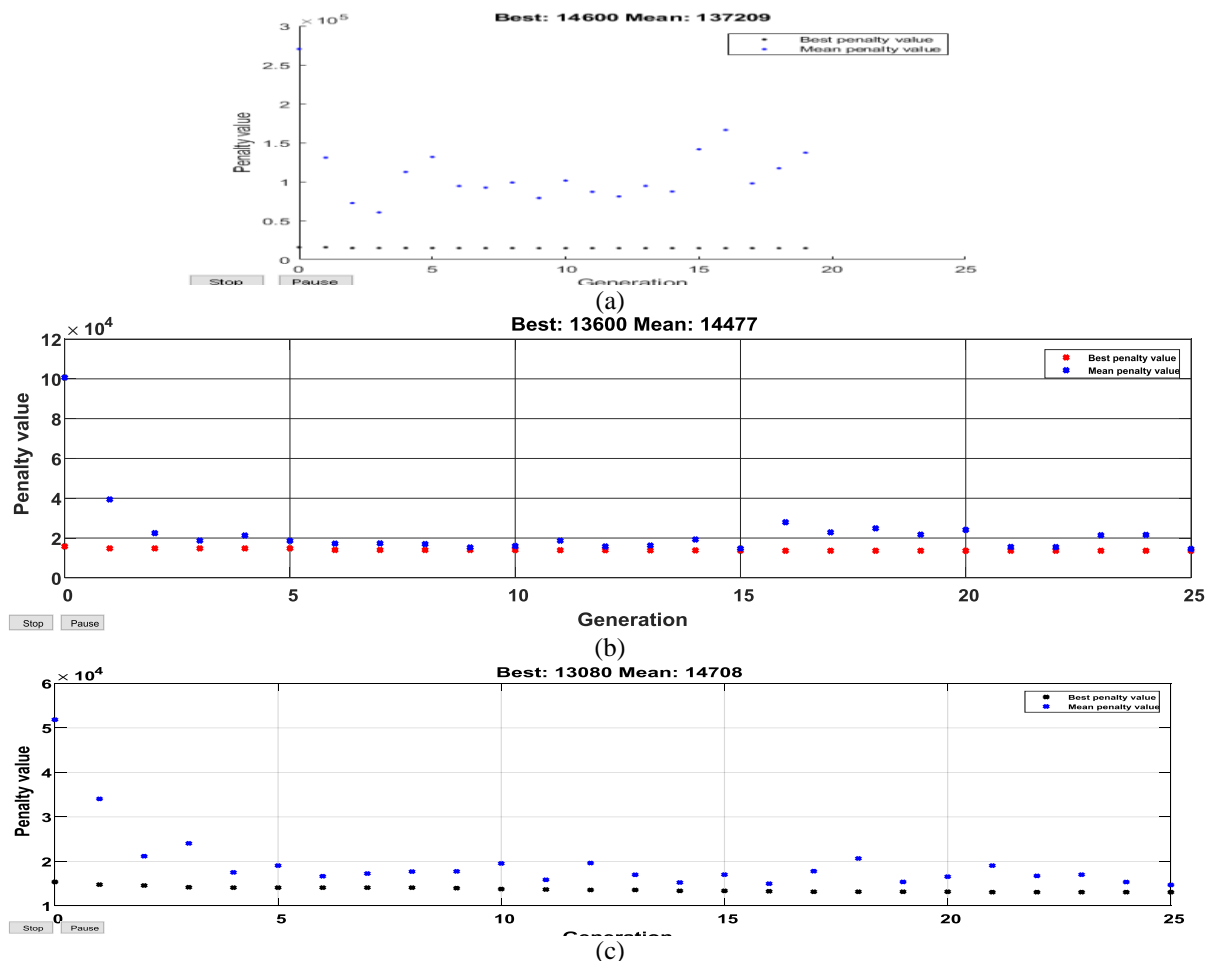


Figure no 16. (a-c) Waveform for penalty values using Genetic Algorithm in different conditions

As shown in figure 16. Waveform for penalty values using Genetic Algorithm in different conditions. The variation in mean and best values of penalty values is shown in below table.

#### IV. Conclusion

This chapter has introduced the traditional and intelligent optimization methods and has given GA algorithms. The basic concept, principles rationales have been discussed. In the development of the application of intelligent optimization algorithms, there are existing contradictions between the optimization results and computational time due to the computational speed and time constraints.

Hence, it is difficult to guarantee the computational results for the global optimum and the optimization effect is not very ideal. It is effective to avoid the local optimal solution, to speed up the convergence and to obtain the better global search ability, etc. Other results of the system include Average number of batches waiting for water, Average number of batches waiting for heat, Average number of batches waiting for draining, Utilization of batch reactors, Utilization of water supply, Utilization of heat supply, Utilization of draining facility, Throughput of type A batch

GA is implemented to improve the total production time as for 12 workers it consumes 47.71 sec, for 2 workers its 252.86 sec and for another system it consumes 179 sec.

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