Solving the Scheduling Problem of Stainless Steel and Alloy Factory: A Case Study of Stainless Steel and Alloy Factory in Uttaradit Province

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Abstract

This study addresses production scheduling inefficiency in stainless steel and alloy manufacturing by developing mathematical models and employing Greedy (GdyA) and Genetic Algorithms (GA). A 23-factorial design tested GA efficiency, optimized by ANOVA analysis. Genetic Algorithm (GA) methods are to establish a program for production scheduling. The research found that the small problem would get the appropriate parameter value. Optimal GA parameters varied with problem size: the smaller problems favoured a population of 50 or 200 generations, crossover of 1, and mutation of 0.3, while the larger problems performed best with a population of 200 or 50 generations, crossover of 1, and mutation of 0.3. This study is in line with the objective of giving factories an alternative to use the results of the production scheduling answer values to solve the problem. This approach effectively tackles the NP-Hard nature of production scheduling, with GA consistently finding solutions matching the minimum bound. GdyA also achieved the minimum bound in 50% of the tested cases. It can be implemented in a real-world setting. Optimized GA consistently delivered optimal scheduling solutions over three months, confirming the potential to significantly enhance production efficiency.

Keywords: Production Scheduling Problems, Genetic Algorithms, Stainless Steel and Alloy Production Plants, Programs for Production Scheduling

1. Introduction

Efficiency is crucial in the manufacturing industry to stay competitive. Various factors can impact production efficiency, such as ineffective machine utilization and scheduling. These issues are frequently encountered in manufacturing processes and may stem from inadequate maintenance practices. [1] Incorrect machine settings, intermittent machine use, or machine and workstation scheduling that does not correspond to the production plan. [2] These problems lead to a decrease in production capacity, [3] and an increase in production costs. Lack of effective planning can lead to unbalanced scheduling, resulting in unnecessary disruptions and reduced production continuity. Moreover, delays in the delivery of raw materials and deficiencies in quality management can adversely impact the production process. Addressing these challenges necessitates strategic planning and effective management practices, the adoption of cutting-edge technology and tools, and ongoing training and skill development for personnel. These measures aim to optimize resource utilization, minimize production expenses, and enhance sustainable competitiveness. [4],[5]

In scheduling operations for an organization's production or service systems, the scheduler must interact extensively with various departments to achieve an efficient production schedule. Job Shop Scheduling [5] Production is carried out to ensure timely product delivery to customers. Production scheduling is a common challenge in manufacturing. By employing an effective scheduling method, production time can be reduced, leading to cost savings in various areas. In many industrial plants, scheduling often depends on the expertise of planning personnel to coordinate labor, machines, and workstations. However, this approach may overlook the possibility that the chosen method could extend production time unnecessarily. Computer tools have now been integrated into production scheduling to assist in problem-solving and decision-making within the planning department, helping to minimize risks and losses in various areas. [3] A well-planned and efficient factory controlling the production process can reduce costs, but production scheduling must take into account process time and appropriate allocation of work to machines or workstations. [6] However, there are problems with complex scheduling, such as assigning jobs to machines or workstations that take too long. [4] This can result in resources being unable to complete the process within the designated time frame, impacting production capacity and increasing overall costs. [1]

Information on stainless steel and alloy factory Established in 1982 and expanded under, the name “Vichit Shop”. It has grown and gained a large number of customers. The company has a registered capital of 1 0 million baht. The business operates under the Vichit Shop Group, which has distribution and sales centers in 3 provinces: Uttaradit, Phitsanulok, and Phrae. The factory is considered a leading leader in Uttaradit Province. It consists of a stainless-steel factory and an aluminum alloy casting factory. The production capacity is 20–30 jobs per month. Production is flexible in terms of time, and workstations were used to produce various products according to the form specified by the customer. Different types of machinery are used in the production process and the total working capacity is over 1,600 horsepower. The factory is located in area 30 rai, using modern machinery and selecting good quality raw materials, both stainless steel and alloy. The quality of the production is controlled by the experts. There are products for sale to customers in more than 30 provinces nationwide. In addition, the factory also sells complete materials and equipment used in production. The sales and production value are over 100 million baht per year.

In the study of the production data of stainless steel and alloy factories, it was found that the production department has not planned the workstation schedule, and the work assigned to the workstation is by a contractor who comes to receive the work in the factory. Therefore, cooperating with the researcher to solve the work arrangement problem can create appropriate production resources and reduce production costs. The allocation of the product capacity in each period still lacks a clear work schedule for each week and month. In the past, the production schedule was often determined by the expertise of the management staff, which caused many problems such as late delivery, raw material shortages, and excessively long production periods. The production cost of stainless steel and alloy factories is greatly affected by these problems. The main objective of this research is to solve the work schedule problem of stainless steel and alloy factories by developing a mathematical model and using the heuristics method to design and compare the appropriate parameters to arrange the work according to the various problems.

2. Related Research

The research has reviewed literature with related research, in which the method of solving the problem of organizing work or solving problems is shown in **Table 1**.

According to **Table 1**, the related research mentioned above used heuristics to solve problems. However, much research uses heuristics, depending on the suitability of the problem, such as the Gene (GA) method with Tabu Search (TS) and Greedy Algorithm (GDYA). This research focuses on applying these methods as follows:

Table 1 Summary of literature reviews

Authors' names	Year of publication	Research titles
Z. H. Ahmed et al. [7]	2024	Use of Genetic Algorithms (GA) to solve the TSP NP-Hard problem.
R. Ogunsakin and N. Mehandjiev [8]	2022	Using the Meta-Heuristic Approach to solve the problem of reducing time
J. Xie et al. [9]	2024	To use Genetic Algorithms (GA) and Tabu Search (TS) to solve the problem of organizing work.
S. Frisch et al. [10]	2021	Solving the problem of maintaining maintenance by applying various Heuristic methods
C. Destouet et al. [11]	2023	Solving the problem of the JOB Shop schedule for Industry 5.0
F. Liu et al. [12]	2024	Square Scheduling Problem with Tri-Dividual ITERATED GREEDY (TIG) to reduce the time of machinery.
L. Haoran et al. [14]	2024	Solving Job Assignment for machinery using a Greedy Algorithm

2.1 Heuristics

Research and development of genetic algorithm methods [7],[8] Developed by Holland in 1975, it is one of the optimization techniques classified in the estimation method group. The steps of the genetic algorithm are based on Charles Darwin's theory of evolution using the concept of survival of the fittest. [9] The working genetic algorithm is a parallel search method, where the change of answer or member in the population in each generation aims to explore the search space and promote the transmission of good characteristics from the answer in the current generation to the next generation. The method is as follows: [10–13]

1) Chromosome encoding is a part of the major genetic algorithm algorithms. [7] In the encoding of the production scheduling problem, the size of the problem is arranged into bits called chromosomes, which leads to the genetic algorithm as shown in **Figure 1**.

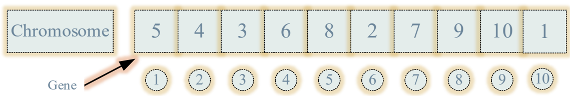

Figure 1 The production scheduling chromosome

2) The operation of the genetic algorithm consists of three operations: reproduction, crossover, and mutation. This process is designed to start with the initial random pop value and each generation of the GA processes to adjust and find the values of the chromosomes to be used. [9]

3) The old population is the string that will be selected, which will be the prototype for creating the new population. [9] The first old population is a random initial population of the scheduling problem with the number of tasks in the bits of the chromosome.

4) The process of crossover and mutation After the entire population has gone through the reproduction process, the members in the breeding pool or the entire population are randomly paired, and the values at the positions are randomly swapped or exchanged. The research Hussain et al. [7] 2024 researched the problem of TSP transportation and compared more than 14 crossover methods and 7 mutations. It was found that sequential constructive crossover (SCX) and exchange mutation (EXCH) gave good results in finding the answer. This research therefore chose the SCX crossover and EXCH mutation methods as well. [7],[9]

5) The new population [7] from all the strings obtained from the genetic algorithm process is called the new population or generation, which will become the old population for the next operation and will continue to be repeated until the generation equals the designed value or the possible answer value is obtained.

6) There are two types of program-stopping procedures: stopping the program when the number of generations has reached the number of designed parameter values, and stopping the program when the answer value meets the lower boundary of this design.

2.2 Greedy Algorithm (GdyA)

For the scheduling problem of stainless steel and alloy manufacturing plants [13],[14], in the case of multiple workstations, the equations and principles can be described as follows.

There are n jobs and m workstations, each with job j having processing time p_j, and the goal is to distribute the jobs to the workstations in a way that their makespan is minimized. [13–15]

Method 1 is to arrange the tasks in order of longest processing time (LPT) p_j from most to least such that we start with the tasks that take the longest time j = 1,2,3…n.

Method 2 For each job j, select the workstation k that completed the job the fastest at that time, or start selecting any workstation k.

Method 3 Let t_k be the time that workstation k is idle$t_k = \sum_{i=1}^{m} C_i$. When finished, get the sum of all working times.

Method 4 Specify the time when job j is completed on machine k or$C_k = t_k + P_j$.

Method 5 Find the Makespan of the work set that is being scheduled. It is the time when all workstations finish working, which is equal $Makespan = \sum_{k=1}^{m} C_k$to the Makespan of the work set that is being scheduled.

Method 6 Randomly select 1 point in j = 1,2,3…n, then swap the frontmost position to the randomly selected position, and start step 2 again until the set number of programs is complete, and the good answer will be stored.

2.3 Scheduling Problem

Solving the scheduling problem is an important problem in the manufacturing industry, which requires efficient production planning under various constraints and restrictions such as time, machines, and workstations. Proper scheduling helps the production to proceed smoothly and meet the customer's delivery dates. The nature of the scheduling and production planning problem is an NP-hard combinatorial optimization problem. [13] This means that problems take a long time to find an answer, and when the size of the problem increases, the nature of the problem will be exponential. [10],[11] When the problem increases, in the case of N jobs, N production schedules can be arranged with N! jobs. Solving the production scheduling problem can be done mathematically to find the minimum value of the mathematical pattern, such as the linear programming method, the branch, and boundary method, or the heuristic method of finding the best value in various ways, such as the Campbell Dudok and Smith method, the Nawaz Enscore Ham method, etc. In addition, computers are used to help solve problems for accuracy, precision, and convenience. Solve problems according to objectives. However, as the industrial sector develops, it will result in the design of the production schedule becoming more complicated. Solving by calculating using the old method may be difficult and time-consuming.

The research will apply the scheduling method to plan the workstations that have both labor and machines working in the stainless steel and alloy production workstations in the factory to reduce the cost of time and cost in various parts, which is the main issue in this research.

3. Materials and Methods

3.1 Survey of stainless steel and alloy manufacturing plants

The production process of stainless steel and alloy factories in 2023. The production survey is Job Shop production, which is a production system that focuses on production according to customer orders (make-to-order), where each job is different in terms of steps and production time. Machinery and equipment in a Job Shop factory will be arranged according to the type of work or process (process layout), such as cutting, welding, or assembly, where each job may go through a different process.

In production and outside the factory, some technicians come to work at the factory, which will specify the work area, working time, and cost used to produce each job. The survey found that there are more than 7 workstations, with production carried out every day except Sunday throughout the 12 months, with production orders coming from the management. The production time is from 8:00 a.m. to 5:00 p.m. The details of the survey research are as follows:

1) The production uses raw materials such as cylindrical stainless-steel bars and square stainless-steel bars in various sizes such as 1/2, 1, 1½, 2, 2½, and 3 inches. Ready-made stainless-steel components and alloy castings according to the model. Raw material storage uses stock (product stock) in a factory

with an area of more than 64 square meters, and raw material usage is more than 2,000 tons/year.

2) The use of machinery in manufacturing uses both automatic production technology, CNC used in cutting and forming, and machinery with semi-automatic working systems and machinery controlled by human labor. Studies before research on maintenance planning use machinery maintenance will be done after a malfunction, corrective, or breakdown, combined with the use of predictive maintenance. Some machines have maintenance scheduling plans from maintenance personnel together with the production department.

3) Scheduling work for ordering work at workstations. The factory has 2 types of workstations: workstations managed in the factory and workstations that are outsourced to technicians outside the factory. Work has clear working hours. Workstations must be installed at the worksite, and there must be systematic site assessments. The factory has more than 7 workstations in total.

4) Costs used in operations The research collected data from January 2023 to December 2023. There were, before the research, the total costs were 10 million baht, divided into fixed costs of 3.5 baht, variable costs of 0.6 million baht, semi-variable costs of 0.2 million baht, direct costs of 1.2 million baht, indirect costs of 0.8 million baht, conversion costs of 3.2, and operating costs, machinery maintenance costs, and equipment maintenance costs of 0.5 million baht.

3.2 Development of a mathematical model to solve the scheduling problem

Development of a mathematical model for solving the job scheduling problem [5],[15] with multiple workstations; different mathematical models can be used. Here, we will define n as the job and m as the workstation and create an equation to solve this problem using the following variables.

Indices

i = Index of the jobs to be scheduled at job *i*
j = The index of the jobs to be scheduled at *j*
l = Index of workstation *l*
k = Index of workstation *k*

Conditional equation

C_{max} = Minimum scheduling value of a job set

Parameters

X_{ij} = A binary variable indicating that job *i* is allocated to workstation *j*.
C_j = Total working time of machine j
S_i = Start time of task i
t_i = Working time of job i
Z_{ijkl} = Assigning task i to workstation k and task j to workstation *l*
n = Total number of jobs
m = Total number of workstations
MC = Maximum capacity of each workstation

Precedence Constraints = Restrictions on the work sequence assigned to workstations

Decision Variables

Minimize C_{max}

Subject to

$$C_{max} \geq C_j \ where \ 1 \leq j \leq n \quad (1)$$

$$\sum_{j=1}^{m} X_{ik} = 1 \forall i \in \{1,2,3...n\} \quad (2)$$

$$C_j = \sum_{i=1}^{n} t_i . X_{ij} \forall j \in \{1,2,3...m\} \quad (3)$$

$$\sum_{i=1}^{n} t_i . X_{ij} \approx \frac{\sum_{i=1}^{n} t_i}{m} \quad \forall j \in \{1,2,3...n\}, \{1,2,3...m\} \quad (4)$$

$$X_{ij} \in \{0,1\} \quad \forall i \in \{1,2,3 ... n\}, j \in \{1,2,3 ... m\} \quad (5)$$

$$C_j \leq MC \forall j \in \{1,2,3...m\} \quad (6)$$

$$S_i + t_i \leq S_k \quad \forall (i,k) \in Precedence\ Constraints \quad (7)$$

$$Z_{ijkl} \leq X_{ik} \ where \ 1 \leq i,j \leq n, 1 \leq k,l \leq m \quad (8)$$

$$Z_{ijkl} \leq X_{jl} \ where \ 1 \leq i,j \leq n, 1 \leq k,l \leq m \quad (9)$$

Eq. (1): The working time of the work set that is scheduled in that period must be C_{Max} greater than or equal to C_j

Eq. (2): Constraint on job allocation to workstations. This equation states that every job must be allocated to only one workstation.

Eq. (3): Constraint on the Total Working Time of Workstation This equation states that the total working time of workstation j is the sum of the working times of all jobs allocated to workstation j.

Eq. (4): Balancing Work Time This equation states that the working time of each workstation should be approximately the average of the total working time divided by the number of workstations.

Eq. (5): The constraint on the variable used is binary. This equation states that the variable x must be a binary value (0 or 1).

Eq. (6): The limitation on the workstation's operation shall not exceed the maximum capacity of the specified workstation.

Eq. (7): Balancing the working time of each workstation This equation states that the working time of each workstation should be approximately the average of the total working time divided by the number of machines.

Eqs. (8)–(9): Constraints on the order of operations for workstations. Z_{ijkl} is the assignment of task i to workstation k and assignment of task j to workstation l will be less than or equal to X_{ik} or in the case X_{jl} are under their conditions.

3.3 Development of work scheduling in stainless steel and alloy manufacturing plants

Problems in scheduling production in stainless steel and alloy factories. The researcher found the problem of scheduling production for employees who work in groups or workstations. Generally, production scheduling uses the expertise of production planning staff to organize the production schedule and assign work to workstations. Therefore, the operation in the production process found problems of work being delayed, not being on time for customer delivery, or using a long production period, which caused unnecessary costs in production. In the production process in the factory, most of them are cutting, forming, welding, grinding, and installation at the work site, such as alloy door work, stainless steel frame assembly work, steel molding assembly work, and maintenance work for general old customers, which will have a clear working period (processing time) and delivery date to customers, as shown in the example in **Table 2**.

The research data found that the work schedule of the workstation with 2 to 3 workers in the workstation, including the workstation of the external contractor with more than 3 workers, and the staff scheduling plan will consider the production order data of the customers each month. It includes the delivery schedule and the different working periods of each job, such as the sliding stainless steel door, pattern 064. There is a working period of 8 days, and it is due within 15 days. It is installation at the worksite and inspection, etc. The workstation scheduling is capable of the work on more than 1 job but must complete 1 job at a time and deliver the work according to the delivery schedule every time, showing the efficiency of the workstation of the stainless steel and alloy factory.

Table 2 An example of a production schedule includes production orders, working hours, and delivery dates for the factory

Jobs	Job no:	Working hours (days)	Delivery date
Stainless steel sliding door separated on 2 sides B012	1	13	16
Stainless steel and alloy sliding balcony	2	6	8
Alloy door work by pattern	3	4	8
Stainless steel sliding door JNC – 029 model	4	30	40
Sliding alloy door, right opening, size 4.3 × 2.10 m.	5	12	16
Front-of-house stainless steel windows and doors	6	24	32
Sliding stainless steel door, pattern 053, sliding door	7	8	15
Stainless steel balcony A 137 model	8	6	8
Stainless steel polycarbonate roof, TNPC 107 model	9	3	8
Stainless steel balcony, swing doors, and stair railings	10	3	8

3.4 Design and development of production scheduling programs

This method has applied the best solution heuristic methods, the Greedy algorithm (GdyA) and the Genetic algorithm (GA) method. This program is designed based on the principles of job scheduling with the GdyA and the GA methods by using the program for calculation. The program will input data according to the number of jobs and workstations, such as scheduling production for 10 jobs and 3 workstations (10 × 3), etc. The processing will be performed according to the values specified by the user through the program window, as shown in **Figure 2**. The user can set the basic values or parameters for the methods GdyA and GA. The next step is to process and analyze the results, which will show the results as makespan values, completion time of the work batch in each month, or C_{max} by the program design steps in **Figure 3**.

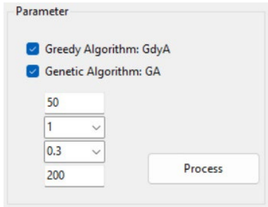

Figure 2 Selection of models for analysis of results

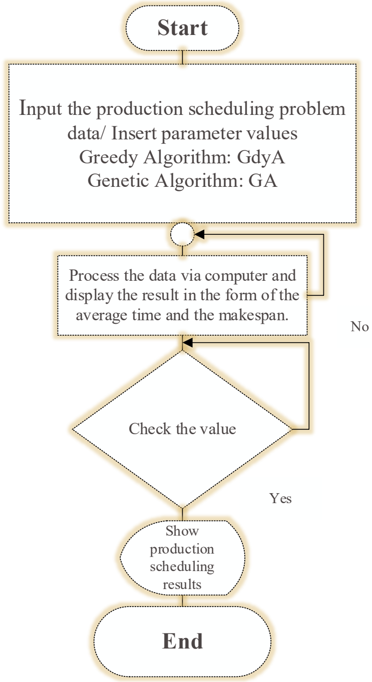

Figure 3 Design of the GdyA and GA algorithms

Figure 3 shows the steps of program development to solve the production scheduling problem. It is implemented with C# coding to design the program and to select the import of the production scheduling problem data. Select the production scheduling method with GdyA and GA with the design of parameter settings using the initial population and the number of Gen cycles. The crossover value is the sequential constructive crossover (SCX). The mutation is an exchange mutation (EXCH), which is the result of Z. H. Ahmed et al. The best answers to crossover and mutation. The steps of selecting the production scheduling method by the user. The program processes all scheduling, including the Cmax or the makespan values. The user will compare the results of the production scheduling. The program works on Windows as shown in **Figure 2**, and the analysis of the factory's production scheduling problem is shown in **Figure 4**.

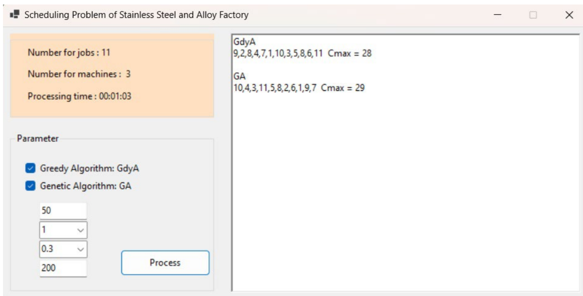

Figure 4 Production scheduling program model and shows the analysis of the results

3.5 The appropriate test of the parameters of the method of angel algorithm

The objective is to find the appropriate value of starting the parameters for the program [16] and to analyze the production schedule. The program will calculate the random sizes of the population size and the number of generations. The crossover percentage of mutation [17],[18] by showing the factors and factors for testing from the experiment are shown in **Table 3**.

Table 3 Level of factors and factors in the test

Factor	Levels	
	low (-)	high (+)
Initiative population	50/200	200/50
Percentage of Crossover	0.5	1.00
Percentage of Mutation	0.1	0.3

The experiment from **Table 3** is a test for the optimization of the parameters [19–21]. There will be appropriate production at 9 works with 3 workstations and 30 works with 6 workstations. Due to the small random problems and large problems with a 2-factorial design, the testing designs are 8 tests with 100 testing times to find an average percentage and choose the best answer in the test that the minimum make span must be collected [22]. The comparison is the processing time and the lowest scope. The test will use a report to analyze the results using ANOVA [23],[24] by finding the variation in the parameters of the genetic algorithm [25]. Finding a parameter with ANOVA will make it easy to find the answer, and access to the answer that is faster is shown in **Table 4**.

Table 4 Analysis of the appropriate value of the parameters of the genetic algorithm method

Problems	Pop/Gen	% of Crossover	% of Mutation
9 × 3	50/200	1.0	0.3
30 × 5	200/50	1.0	0.3

4. Results

In this study, the methods of schedule used by the GDYA and the GA to solve the problem of the manufacturing schedule of the stainless-steel factory and alloy work that brought the problem in the production process, namely the use of the production period of the work set of customers, such as the problem of 25 × 5, which is the work to be scheduled for the 25 events. There are 5 workstations in program development to compare and find the best answer before making a production order, and the research uses Gen Intel (R) Core (TM) i7-1165G7 @ 2.80GHz. 2.70GHz. 8.00 GB. to analyze the production schedule.

4.1 Production schedule of stainless-steel factory and alloy work

The researcher brought up the problem of work that has been produced by customers and the production department to test 100 tests of each problem, which shows the results of the answer. To compare the values of each method, measure the make span or C_{MAX} of that work as shown in problems in **Table 5**.

Table 5 Production schedule of the factory

Job item	Number of jobs in a month	Numbers of workstations
1	9	3
2	10	3
3	25	5
4	30	6

Table 5 shows the problem of the production schedule of the production factory, stainless steel, and 4 alloy work, in which each work set has an unequal number and number of workstations. Because some workstations are external contractors. In some months, the contractor may receive a similar job or equal to the factory workstation. The workstation within the factory has 2 – 3 stations. The work is a group of employees in the factory that works as well as the external workstation and the workstation in the factory must also have machinery maintenance work in the case of the cycle of maintenance.

The researcher has analyzed the problem using the production schedule program. For the work of the stainless-steel plant and alloy work, problems the work to find the lowest boundary using the analysis program to compare the production schedule, and show the analysis of the production schedule as shown in **Table 6**.

Table 6 Results of the testing of the production schedule of 9 work 3 stations (9 × 3)

Scheduling methods	Lower bound	Makespan (days)	Work processing time (seconds)
GdyA	14	16	00.29.05
GA	14	14*	00.54.01

Table 6 shows the analysis of the production schedule 9 × 3, the results of the best value work are the methods of GA, and the best time of the work set

is equal to. 14 days. The program takes 0.54 minutes to get the lowest boundary and shows the test of 13 problems, 3 stations, as shown in **Table 7**

Table 7 Results of the testing of the production schedule 13 work 3 stations (13 × 3)

Scheduling methods	Lower bound	Makespan (days)	Work processing time (seconds)
GdyA	21	21	00.37.02
GA	21	21*	01.00.04

Table 7 shows the analysis of the production schedule 10 × 3, the results of the best-value work are the methods of heuristics and GDYA. The best is 21 days and the method of GA has the best time of the work set that is equal to 21 days. The program takes 1 minute and both methods get the lowest boundaries equal to 21 days and the problem of 25 works with 5 stations, as shown in **Table 8**.

Table 8 Results of the testing of the production schedule of the problem 25 work with 5 stations (25 × 5)

Scheduling methods	Lower bound	Makespan (days)	Work processing time (seconds)
GdyA	25	28	00.49.10
GA	25	25*	01.20.12

Table 8 shows the analysis of the production schedule 25 × 5, the results of the best value work are the methods of GA, and the best time of the work set is equal to 25 days, the program takes 1.20 seconds to work and shows 30 problems with 6 stations as shown in **Table 9**.

Table 9 Results of the production schedule of 30 works with 6 stations (30 × 6)

Scheduling methods	Lower bound	Makespan (days)	Work processing time(seconds)
GdyA	29	29*	00.48.14
GA	29	29*	02.00.42

Table 9 shows the analysis of the production scheduling results 30 × 6. The work solution with the best work value is the heuristic method of GdyA, which has the best work set time equal to 29 days, and the GA method, which has the best work set time equal to 29 days. The program takes 2 minutes to run and has the lowest boundary value equal to 29 days.

4.2 Results of 3-month work schedule

The research used production data from 3 months of customer orders, from March to May 2024, to record the work orders, time, and delivery dates in the program, and to create a work schedule. The same data was given to a group of factory employees to create a schedule as shown in **Table 10**.

From the table, the application of the scheduling program to schedule the work of the stainless steel and alloy factory found that in March 2024, there were 18 jobs to be produced and delivered to customers and there were 6 workstations. The scheduling resulted in a total work set time of 29 days, which was the lowest boundary value. In April 2024, there were 20 jobs to be produced and delivered to customers and there were 5 workstations. The scheduling resulted in a total work set time of 24 days, which was the lowest boundary value. In May 2024, there were 25 jobs to be produced and delivered to customers and there were 7 workstations. The scheduling resulted in a total work set time of 32 days, which was the lowest boundary value.

Table 10 Results of 3-month work schedule

Months (2024)	Working hours/number of workstations in month	Lower bound	Makespan
March	18 × 6	29	29*
April	20 × 5	24	24*
May	25 × 7	32	32*

Table 10 presents the solutions for work span optimization in the factory, highlighting how different problems are addressed using various methods, each requiring different amounts of time. The researcher has developed a comprehensive plan that includes strategies for data storage, work data import, determination of the number of workstations, scheduling of working periods, and integration of big data techniques. These have been implemented through a developed program within an online database, designed for versatile applications across multiple operational areas.

5. Discussion and Conclusion

A study of solving the production scheduling problem of a stainless steel and alloy factory designed and developed a mathematical model to solve the scheduling problem, together with the application of heuristics, greedy algorithm: GdyA and GA to establish a program for use in production scheduling, to compare the results of production scheduling in the form of a computer program using the genetic algorithm. The design was to find the appropriate value of the appropriate parameter values. It was found that in a small problem, the appropriate value of the random population size is 50, the number of generations is 200, the crossover percentage is 1, and the mutation percentage is 0.3. For a large problem, the appropriate value of the random population size is 200, the number of generations is 50, the crossover percentage is 1, and the mutation percentage is 0.3. Therefore, it will give a good answer value of the genetic algorithm for small and large problems. The results of the test of the production scheduling problem of a stainless steel and alloy factory, 4 problems, found that the developed program can schedule the production. To compare the use of the GdyA method and the GA method for scheduling production, the results of the analysis obtained the lowest boundary values for all 4 problems. The method that found the best answer was the GA method and the GdyA method was also able to obtain the lowest boundary values for 1 problem. The research used 3 months of scheduling data, from March to May 2024, with different work problems, in which the program could find the time values according to the lowest boundary values. This research is, therefore, in line with the objectives and can be used as a good guideline for managing the work of stainless steel and alloy factories.

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