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Production Scheduling Model and Machine Assignment to Automotive Parts Manufacturing for Optimum Production

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ABSTRACT

PT. XYZ is a company engaged in the field of Automotive Parts Manufacturer. In carrying out its production this company uses make to order. The company carries out simple planning and scheduling, namely FCFS (First Come First Serve). The company has a problem, namely there is no production scheduling with the appropriate machine assignment. This causes the company to sometimes experience delays in completing the product. The purpose of this study is to overcome scheduling problems in companies to minimize order completion time (makespan). The method used in this study is the Heuristic Pour method, namely the development of a new heuristic algorithm in completing flowshop scheduling with the aim of minimizing makespan based on a combination approach and Genetic Algorithm which will be assisted with the help of MATLAB R2016a software which is a computational algorithm commonly used to solve a search for values in an optimization problem. Based on the data processing that has been done, the results of production scheduling are obtained using the Heuristic Pour method in the order Job 4 (J4) - Job 2 (J2) - Job 7 (J7) - Job 6 (J6) - Job 5 (J5) - Job 3 (J3)) - Job 1 (J1) gets a makespan of 19440 minutes or equal to 16 working days with a total delay of 1 working day. While production scheduling with the selected Genetic Algorithm method gets the order Job 4 (J4) - Job 2 (J2) - Job 7 (J7) - Job 6 (J6) - Job 3 (J3) - Job 1 (J1) - Job 5 (J5) with the best makespan of 18660 minutes or 15 days, and there was no delay in completing requests. The company is expected to consider or review the use of the appropriate production scheduling method because it can provide a more optimum demand completion time (makespan), so the company can reduce delays in fulfilling customer requests.

Key Words: *Genetic Algorithm, Heuristic Pour, Machine Assignment, Production Scheduling.*

1. INTRODUCTION

Production scheduling in the industrial world, both manufacturing and agro-industry has an important role as a form of decision making. The company strives to have the most effective and efficient scheduling so that it can increase the resulting productivity with the minimum total cost and time [1]. Scheduling itself is a design activity in the form of allocating resources, both machines and labor, to carry out a set of tasks according to the process within a certain period of time. The first step in planning a production schedule, which must be considered is the availability of available resources, whether in the form of labor, processing equipment or raw materials. Good scheduling will have a positive impact, namely lower operating costs and delivery times, which can ultimately increase customer satisfaction [2].

A company is currently required to be able to meet the needs of consumers in accordance with the agreed timeframe, so each company will always try to achieve production effectiveness and efficiency in order to achieve optimal results. This is done so that the company can always meet consumer demands and complete orders according to the agreed time. Fulfilling consumer demand according to this time will certainly be a challenge for a company. A company must have an optimal scheduling system for each assignment starting from the assignment of machines, labor and others in order to achieve effectiveness, productivity and efficiency of the production process on the production floor [3].

Scheduling is an activity of planning an activity based on the time that has been arranged to achieve an activity [4]. Scheduling in general can be interpreted as allocating limited resources to do a number of jobs. Scheduling is carried out with the aim that products can be completed on time according to predetermined specifications, maximize productivity, minimize production completion time, increase machine usage, and reduce work-in-progress inventory [5]. To be able to complete the ordered product on time, it is necessary to pay attention to the scheduling arrangements regarding the use of the machine used. Scheduling machine assignments is very useful for knowing which machine needs to be used to complete a job or production process. The assignment model is a special case of the linear programming model. With good scheduling of machine assignments, it can provide the benefits of being able to complete product orders on time, meet specifications that have been set together, maximize throughput, minimize production costs, reduce WIP (Work in Process), increase utilization of production facilities and to maximize revenue.

PT. XYZ is a company engaged in the field of Automotive Parts Manufacturer which produces its main product, Busshing, which is located in Bekasi district, Indonesia. This company produces several types of bushings including Rubber Bushings, Metal Bushings, and Bimetallic Bushings. In carrying out its production, this company uses make to order where the new company will produce products when it receives messages from consumers or customers. This company has a problem, namely there is no production scheduling with the appropriate machine assignment to be able to maximize the effectiveness, productivity and efficiency of the production process. This of course resulted in several consumer orders being completed late by the company because it had a total production time that was less than optimal as a result of inappropriate machine assignments. Based on Table 1.1 it can be seen the processing time for each job on each machine. The data obtained is in the form of processing time data for the manufacture of four types of products on each machine in units of time, namely minutes.

Table 1.1 Production Time Data (Minutes)

Job	M1	M2	M3	M4	M5	M6
***Job* 1 (J1)**	34	35	26	25	35	20
***Job* 2 (J2)**	14	20	35	23	18	15
***Job* 3 (J3)**	26	25	33	27	24	25
***Job* 4 (J4)**	13	27	18	28	37	35
***Job* 5 (J5)**	24	20	34	29	15	13
***Job* 6 (J6)**	31	37	24	33	36	24
***Job* 7 (J7)**	31	21	15	27	36	15

Source : PT XYZ

In Table 1.1 there is data on the production time of each job with the allocation of the machine used. Production time data with each available time is the time when each machine can complete each product batch containing 50 pcs before proceeding to the next machine. In addition to production time data, the data also contains data in the form of seven types of products or jobs with the symbol (J), of which the seven jobs are BMR 246895 SK (J1), BMR 124072 DH32 (J2), BMR 253169 HN 29 (J3), BMR 163366 DH4F (J4), BMR 16 IZ-31 (J5), BMR 164173 T54 (J6), and BMR 184289 RB 235 (J7). The machines used are Pipe Cutting machines, Press Com, Precision, Turret, Sandblasting, and Rubber Hotpress. Based on this data, it is not yet known which allocation or assignment or production scheduling is the most optimal for the company, in its production process. PT. XYZ carries out simple planning and scheduling, namely producing based on orders from consumers by using the rule that orders that have arrived first will be served first (First Come First Serve) and the time period given by consumers for the delivery of this product varies. The company experienced delays in completing the product, therefore the company needs to have a production schedule with the appropriate machine assignment to be able to maximize the effectiveness, productivity and efficiency of the production process.

Genetic algorithm is a heuristic method which is a branch of evolutionary algorithm, which is a technique for solving complex optimization problems by imitating the evolutionary process of living things. Genetic Algorithm is also a method used to find optimal solutions in solving problems by looking for the possibilities of potential solutions [6]. This algorithm also has the advantage of only doing a few mathematical calculations related to the problem to be solved. Due to the nature of natural evolutionary change, this algorithm will seek solutions without regard to processes related to the problem being solved directly. In addition to the genetic algorithm, the heuristic pour algorithm method will also help where [7] developed the heuristic pour algorithm to minimize makespan. The pour heuristic is a search technique that develops accuracy and speed in the search process, but the completeness of what is sought must be sacrificed. The heuristic function is to map from a description of the state of the problem to a measure of needs, generally described in the form of numbers. The advantage of using the heuristic pour method is

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that it shows that the heuristic pour algorithm provides a fairly good performance in solving flowshop scheduling problems with the aim of minimizing makespan and solution search techniques that develop accuracy and speed.

This research is expected to solve problems at the company by obtaining production scheduling with appropriate machine assignments to overcome delay problems and increase the effectiveness, productivity and efficiency of the production process.

2. METHODS

2.1 Place of Research and Time of Research

Research conducted at PT. XYZ which is located on Jl. Base 1A RT.002/RW. 010, BantarGate, Bekasi City, West Java, Indonesia. The research was conducted for 4 months, from March 2023 to June 2023.

2.2 Research Design

The research conducted is a quantitative research that is descriptive in nature, namely research that emphasizes objective phenomena that are studied quantitatively or carried out using numbers, statistical processing, structure, and controlled experiments. This research begins with identifying and formulating the problems that occur, namely there is no production scheduling with the appropriate machine assignment to be able to maximize the effectiveness, productivity and efficiency of the production process at PT. XYZ. This of course resulted in several consumer orders being completed late by the company because it had a total production time that was less than optimal as a result of inappropriate machine assignments. After the problem is identified and formulated, the next step is to determine the goals to be achieved and study the literature related to production scheduling.

This study aims to provide solutions in scheduling and assignment in the production process to maximize the effectiveness, productivity and efficiency of the production process using the Heuristic Pour algorithm and Genetic algorithm by determining the mapping of production machine time allocation, determining the total production time, scheduling and assigning machines. production with Heuristic Pour Algorithm and Genetic Algorithm. While the analysis that will be carried out is to compare what method is best for production scheduling at PT. XYZ.

2.3 Data analysis techniques

After all the data needed to carry out the calculations have been obtained, then data processing is carried out regarding the calculations to answer the proposed problem formulation, data analysis carried out includes:

1. Master Production Scheduling (MPS)

   A master product schedule (MPS) is a schedule that shows week by week how much product to produce according to customer orders and demand forecasts [8]. The goal is to satisfy the demand for individual products within a product group. This master production schedule will provide output in the form of information on when incoming sales orders can be scheduled into production, and when each shipment can be scheduled for delivery complete with production dates or periods until the product is finished and shipped so that production and delivery schedules become realistic[9].

2. Heuristic Pour Algorithm

   Developed a new heuristic algorithm in solving flowshop scheduling with the aim of minimizing makespan (maximum flow time), which is based on a combination approach [7]. The pour heuristic is a search technique that develops accuracy and speed in the search process, but the completeness of what is sought must be sacrificed. The heuristic function is to map from a description of the state of the problem to a measure of needs, generally described in the form of numbers.

   In this method it is assumed that all jobs are processed separately and independently for each machine. The following is the notation used:

   a. Pi = processing time of job i on machine j.

   b. Cij = time span between when job i on machine j starts (f=0) until that job is finished.

   c. " Ci = sum of completion time for job i on all machines.

   d. Fnmx = time span between when a job is available or can be started until it is done (makespan).

   The steps for working on the Heuristic Pour Algorithm:

   a. Selects job 1 as the first order while in the order of execution so that the processing time of job 1 on all machines is considered zero.

   b. Placing other jobs (besides the job that has been selected as the first order, namely job 1) in the next sequence.

   c. Choose the smallest processing time for each machine.

   d. Perform additional processing time (completion time) for each Pij with the increasing processing time rule, namely by adding processing time cumulatively from the smallest to the largest at each Pij.

   e. Calculating the sum of completion time (∑Ci) for each existing job.

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f. Sort ∑Ci with increasing order rules (ie sorting starting from the smallest to the largest) to be placed in the order after the job that has been selected for the first order temporarily (ie job 1).

g. After obtaining the temporary sequence where job 1 is the first order, then calculate the Fmax from the temporary sequence.

h. Repeat steps 1-7 for each existing job that will be placed as the first order of the job order until the minimum Fmax value is obtained.

i. Repeat steps 1-8 for the job that will occupy the next position, namely in the second, third and so on after the job is selected for the first position with a minimum Fmax value.

3. Genetic Algorithm

A genetic algorithm is a programming technique that mimics biological evolution as a problem solving strategy. This algorithm was first developed by John Holland from the University of Michigan (1975). John Hollan said that every problem in the form of adaptation, whether natural or artificial, can be formulated in genetic terms. The genetic algorithm is a search algorithm that works based on the mechanism of selection and genetics. genetic algorithms are used to optimize parameters with a large scope with a more optimal selection of parameters, namely using genetic algorithms [10]. Genetic algorithms have drawbacks, such as selecting the wrong parameters resulting in weak resulting accuracy. The problem that dominates the genetic algorithm is obtaining the optimal alternative way after a series of repetitions, but this concept can be avoided by choosing the right parameter notation.

4. Genetic Algorithm Scheduling Optimization Steps

Following are the steps for optimizing production scheduling using a genetic algorithm:

a. Parameter setting

Parameter setting needs to be done first. Determination of the parameters in question are population size, probability of crossover (probCR), probability of mutation (probMut).

b. Population Initialization

The purpose of this function is to generate a population that contains a number of chromosomes that contain a number of genes.

c. Individual Evaluation

In a genetic algorithm that aims to calculate the fitness value of several individuals or chromosomes that were previously generated.

d. Roulette Wheel

This Roulette Wheel process is the process of selecting chromosomes that will be maintained in the next population. The roulette wheel is one of the selection methods used in the genetic algorithm. In this selection, individuals or chromosomes will be selected based on fitness values, so it is unlikely that populations with varied fitness values because individuals or chromosomes with small fitness values will most likely die and individuals or chromosomes will die. which has a high fitness value will be selected more than once which causes the individual or chromosome to dominate the population.

e. crossover

The process of crossing over or crossover is one of the most important components in the genetic algorithm. An individual or chromosome that leads to a good solution can be obtained from the process of crossing two individuals or chromosomes selected at the previous stage or it can be said to be a parent to give birth to a new individual or a new chromosome that inherits traits or genes from its parents.

f. Mutation

At this stage, the mutation is an operator in the genetic algorithm that aims to change certain genes of an individual or chromosome. The gene will be changed to a different form than before with this mutation process. For all existing genes, if the generated random number is less than the specified mutation probability then change the gene to its opposite value.

3. RESULT AND DISCUSSION

1. FCFS (First Come First Serve) Production Scheduling

At this stage production scheduling will be carried out using the FCFS (First Come First Serve) method. The company will carry out simple planning and scheduling, namely producing based on orders from consumers using the rule that orders that have arrived first will be served first (First Come First Serve). Based on the FCFS (First Come First Serve) method used by the company, the order of production is obtained, namely J1 – J2 – J3 – J4 – J5 – J6 – J7 and the results and conclusions are as follows:

a. Processing Time Data

Data on the production time of metal rubber bushings based on demand can be seen in Table 3.

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Table 3.1 Production Data

	M1	M2	M3	M4	M5	M6
J1	2040	2100	1560	1500	2100	1200
J2	840	1200	2100	1380	1080	900
J3	1560	1500	1980	1620	1440	1500
J4	780	1620	1080	1680	2220	2100
J5	1440	1200	2040	1740	900	780
J6	1860	2220	1440	1980	2160	1440
J7	1860	1260	900	1620	2160	900

Source: PT. XYZ

It can be seen from Table 3.1 that the turnaround time for each job request is in accordance with the quantity requested by the customer based on the agreed PO (Purchase Order).

b. Calculating total makespan

Based on the FCFS (First Come First Serve) method used by the company, the production sequence J1 – J2 – J3 – J4 – J5 – J6 – J7 is obtained. Production completion time data using the FCFS (First Come First Serve) method can be seen in Table 3.2.

Table 3.2 Completion Time Data (FCFS Method)

	M1		M2		M3		M4		M5		M6	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
J1	0	2040	2040	4140	4140	5700	5700	7200	7200	9300	9300	10500
J2	2040	2880	4140	5340	5700	7800	7800	9180	9300	10380	10500	11400
J3	2880	4440	5340	6840	7800	9780	9780	11400	11400	12840	12840	14340
J4	4440	5220	6840	8460	9780	10860	11400	13080	13080	15300	15300	17400
J5	5220	6660	8460	9660	10860	12900	13080	14820	15300	16200	17400	18180
J6	6660	8520	9660	11880	12900	14340	14820	16800	16800	18960	18960	20400
J7	8520	10380	11880	13140	14340	15240	16800	18420	18960	21120	21120	22020

Source: Data Processing

Based on Table 3.2, it can be seen that the total makespan using the FCFS method used by the company is 22020 minutes with a total completion of machine 1 of 10380 minutes, machine 2 of 13140 minutes, machine 3 of 15240 minutes, machine 4 of 18420 minutes, machine 5 of 21120 minutes, and machine 6 for 22020 minutes. Following are some of the results obtained from production scheduling calculations using the FCFS (First Come First Serve) method.

a. Job Sequence or Product Worked on

Based on production scheduling using the FCFS (First Come First Serve) method, a job sequence is obtained, namely Job 1 (J1), Job 2 (J2) , Job 3 (J3) , Job4 (J4) , Job 5 (J5) , Job 6 (J6), Job 7 (J7) where the jobs are BMR 246895 SK, BMR 124072 DH32, BMR 253169 HN29, BMR 163366 DH4F, BMR 16 IZ-31, BMR 164173 T54, and BMR 184289 RB235.

b. Assignment of Production Machines

The assignment of production machines used is adjusted to the job order that has been obtained from production scheduling which is carried out using the FCFS (First Come First Serve) method, namely each machine starting from the Pipe Cutting process or machine, Press Com, Precision, Turret, Sandblasting, and Rubber Hotpress will sequentially work on jobs in the order Job 1 (J1) , Job 2 (J2) , Job (J3) , Job 4 (J4) , Job 5 (J5) , Job 6 (J6) , Job 7 (J7) where the job is BMR 246895 SK, BMR 124072 DH32, BMR 253169 HN29, BMR 163366 DH4F, BMR 16 IZ-31, BMR 164173 T54, and BMR 184289 RB235. The total completion time for the Pipe Cut machine was 10380 minutes, Press Com machine was 13140 minutes, Precision machine was 15240 minutes, Turret machine was 18420 minutes, Sandblasting machine was 21120 minutes, and Rubber Hotpress machine was 22020 minutes.

c. Utilization

Based on production scheduling using the FCFS (First Come First Serve) method, utilization in production scheduling is obtained at 7.72%. This utilization is the ability to utilize existing resources in production scheduling when using the FCFS (First Come First Serve) method.

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d. Delay

Production scheduling carried out using the FCFS (First Come First Serve) method has a total makespan of 22020 minutes or equal to 18 working days in accordance with the company's working hours of 7 working hours per shift and the number of shifts is 3 shifts, there is a delay in the agreed completion of 15 working days so that there is a delay of 3 working days.

3. PRODUCTION SCHEDULING HEURISTIC POUR METHOD

Job order using the Heuristic Pour method. Based on the data processing that has been done using the Heuritic Pour method, the best scheduling sequence produced is Job 4 (J4) - Job 2 (J2) - Job 7 (J7) - Job 6 (J6) - Job 5 (J5) - Job 3 (J3) - Job 1 (J1) and the results and conclusions are as follows:

1) Data on production time of metal rubber bushings using the order of the Heuristic Pour method

The following is data on the production time of metal rubber bushings based on requests in September using the Heuristic Pour method.

Table 3.3 Production Time Data (Heuristic Pour Method)

	M1	M2	M3	M4	M5	M6
J4	780	1620	1080	1680	2220	2100
J2	840	1200	2100	1380	1080	900
J7	1860	1260	900	1620	2160	900
J6	1860	2220	1440	1980	2160	1440
J5	1440	1200	2040	1740	900	780
J3	1560	1500	1980	1620	1440	1500
J1	2040	2100	1560	1500	2100	1200

Source: Data Processing

Based on Table 3.3, it can be seen that the job placement order has been based on the order obtained from the production scheduling using the Heuristic Pour method.

2) Calculate the total makespan based on the Heuristic Pour method

Based on the results obtained using the Heuristic Pour method, the production scheduling sequence is Job 4 (J4) - Job 2 (J2) - Job 7 (J7) - Job 6 (J6) - Job 5 (J5) - Job 3 (J3) -Job 1 (J1). The production completion time data table can be seen in Table 3.4.

Table 3.4 Production Completion Time Data (Heuristic Pour Method)

	M1		M2		M3		M4		M5		M6	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
J4	0	780	780	2400	2400	3480	3480	5160	5160	7380	7380	9480
J2	780	1620	2400	3600	3600	5700	5700	7080	7380	8460	9480	10380
J7	1620	3480	3600	4860	5700	6600	7080	8700	8700	10860	10860	11760
J6	3480	5340	5340	7560	7560	9000	9000	10980	10980	13140	13140	14580
J5	5340	6780	7560	8760	9000	11040	11040	12780	13140	14040	14580	15360
J3	6780	8340	8760	10260	11040	13020	13020	14640	14640	16080	16080	17580
J1	8340	10380	10380	12480	13020	14580	14640	16140	16140	18240	18240	19440

Source: Data Processing

Based on Table 3.4, it can be seen that the total makespan using the Heuristic Pour method is 19440 minutes with a total completion of machine 1 of 10380 minutes, machine 2 of 12480 minutes, machine 3 of 14580 minutes, machine 4 of 16140 minutes, machine 5 of 18240 minutes , and machine 6 by 19440 min. In production scheduling using the Heuristic Pour Method, a makespan result of 19440 minutes or equal to 16 working days has been obtained according to the company's working hours of 7 working hours per shift and the number of shifts of 3 shifts. Following are some of the results obtained from the calculation of production scheduling using the Heuristic Pour method.

a. Job Sequence or Product Worked on

Based on production scheduling using the Heuristic Pour method, the job sequence is obtained, namely Job 4 (J4), Job 2 (J2), Job 7 (J7), Job 6 (J6), Job 5 (J5), Job 3 (J3), Job 1 (J1) where the jobs are BMR 163366 DH4F, BMR 124072 DH32, BMR 184289 RB235, BMR 164173 T54, BMR 16 IZ-31, BMR 253169 HN29, and BMR 246895 SK.

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b. Assignment of Production Machines

The assignment of production machines used is adjusted to the job order that has been obtained from production scheduling which is carried out using the Heuristic Pour method, namely each machine starting from the Pipe Cutting process or machine, Press Com, Precision, Turret, Sandblasting, and Rubber Hotpress will sequentially work on jobs with sequence of Job 4 (J4), Job 2 (J2), Job 7 (J7), Job 6 (J6), Job 5 (J5), Job 3 (J3), Job 1 (J1) where the job is BMR 163366 DH4F, BMR 124072 DH32, BMR 184289 RB235, BMR 164173 T54, BMR 16 IZ-31, BMR 253169 HN29, and BMR 246895 SK. The total completion time for the Pipe Cut machine is 10380 minutes, Press Com machine is 12480 minutes, Precision machine is 14580 minutes, Turret machine is 16140 minutes, Sandblasting machine is 18240 minutes, and Rubber Hotpress machine is 19440 minutes.

c. Utilization

Based on production scheduling using the Heuristic Pour method, the utilization in production scheduling is 8.95%. This utilization is the ability to utilize existing resources in production scheduling when using the Heuristic Pour method.

d. Delay

Production scheduling carried out using the Heuristic Pour method has a total makespan of 19440 minutes or equal to 16 working days in accordance with the company's working hours of 7 working hours per shift and the number of shifts is 3 shifts there is a delay in the agreed completion of 15 working days so that there is a delay for 1 working day.

4. PRODUCTION SCHEDULING OF THE GENETIC ALGORITHM METHOD

At this stage the production scheduling will be carried out using the Genetic Algorithm method. Calculations to complete production scheduling using the Genetic Algorithm method use the help of MATLAB R2016a software which is a programming language with high capabilities in the field of numerical computation. Genetic Algorithm processes that are very long can be completed with the help of MATLAB R2016a software because it can shorten processing time and provide more accurate values or results. The programming that will be made can provide output results in the form of job sequences and the best makespan values as well as the minimum computing or processing time in the production scheduling that is carried out. Following are some stages of production scheduling using the Genetic Algorithm method with the help of MATLAB R2016a software.

a. Determination of Genetic Algorithm Parameters

In scheduling production using Genetic Algorithms, it is necessary to set the required parameters first. Determination of the parameters in question are population size, probability of crossover (probCR), probability of mutation (probMut). According to (Suyanto, 2007) population size usually ranges from 30 to 1000. If the population size is too small the Genetic Algorithm will converge quickly due to the low variation in chromosomes in the population or the few options for crossover and only a few solutions are explored for each generation. . However, a population size that is too large will reduce the performance of the Genetic Algorithm. Based on the recommendations of the AG parameters that have been observed by (Suyanto, 2005) it is recommended that several variations of the parameters of the Genetic Algorithm with a Crossover Probability of 0.8 be selected for a population size of 100 chromosomes and a mutation probability (probMut) of 0.1 because it has the most optimal value. With these parameter values, the Genetic Algorithm can provide an average fitness of 9.9960 which means it will provide the most optimal solution.

b. Input Data and Parameters

At this stage, input data and parameters are used in production scheduling using the Genetic Algorithm. The data in question is the production time data contained in variable m. While the parameters in question are the parameters of population size, crossover probability (probCR), mutation probability (probMut). In more detail, the following is the stage of entering MATLAB programming, input data and parameters used in production scheduling using the Genetic Algorithm.

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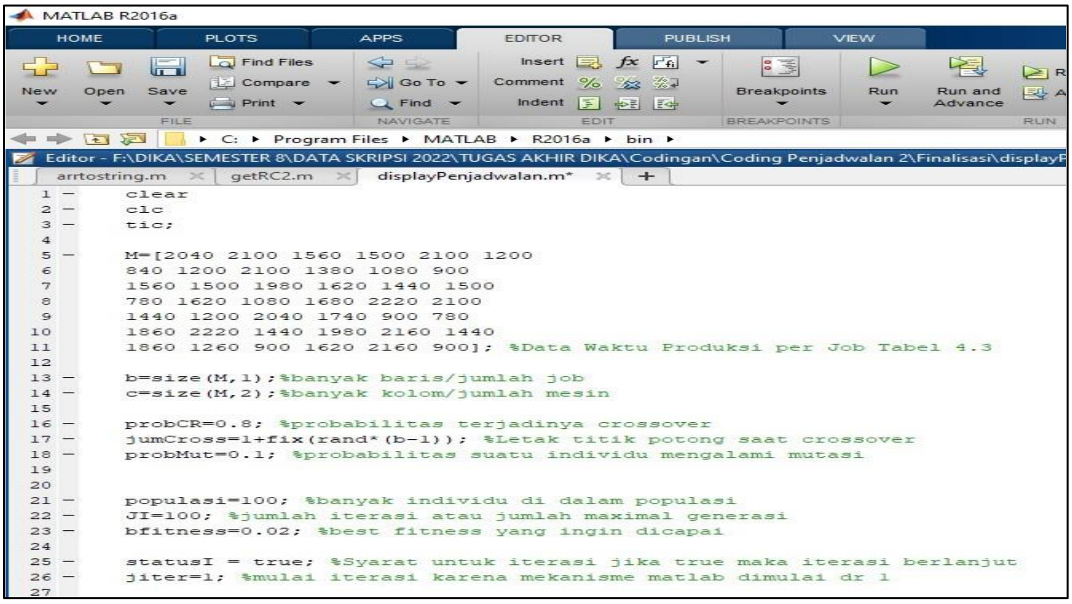

Figure 3.1 Data Input and Parameter Stage in MATLAB Software

Source: Data Processing

c. Population Initialization

At this stage it is necessary to initialize the population as a function in programming in the MATLAB software in the Genetic Algorithm. The purpose of this function is to generate a population that contains a number of chromosomes that contain a number of genes. In this population there are several individuals who have chromosomes that contain a number of genes or in this case, the job sequence. In generating this population, it is formed randomly or randomly where each job will be sorted in a different order where no job is entered more than once in one individual or chromosome, which means that each gene indicates the job contained in that individual or chromosome. The following is the MATLAB programming stage for initializing the population in MATLAB software.

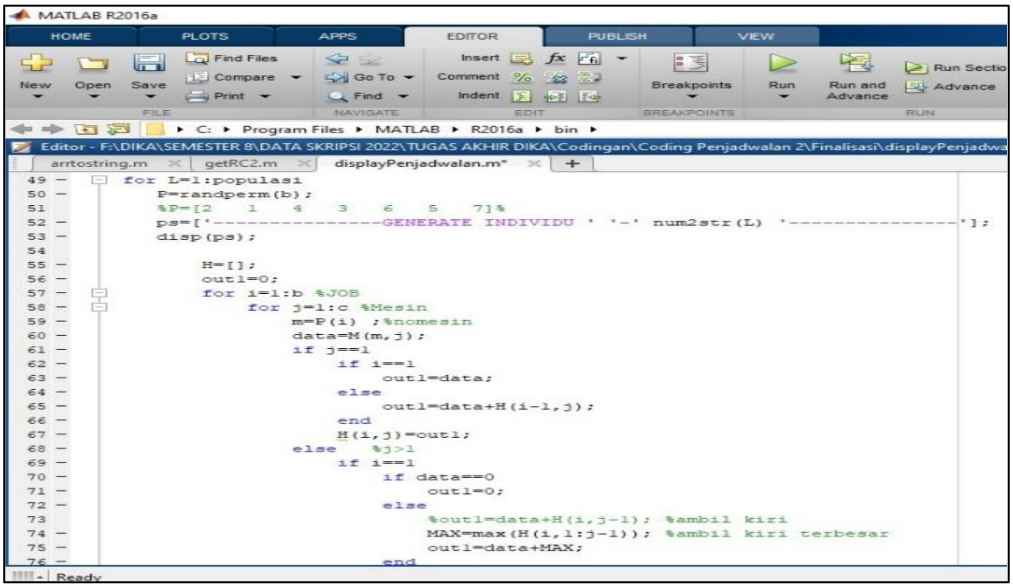

Figure 3.2 Population initialization stage in MATLAB software

Source: Data Processing

Figure 3.2 shows part of the MATLAB programming for initializing the population in the MATLAB software and for more details can be seen in the attached M-file Genetic Algorithm Scheduling source code.

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d. Individual Evaluation

This individual evaluation process is a function of programming in the MATLAB software in the Genetic Algorithm which aims to calculate the fitness value of several individuals or chromosomes that were previously generated. Figure 3.3 is an individual evaluation MATLAB programming stage on MATLAB software.

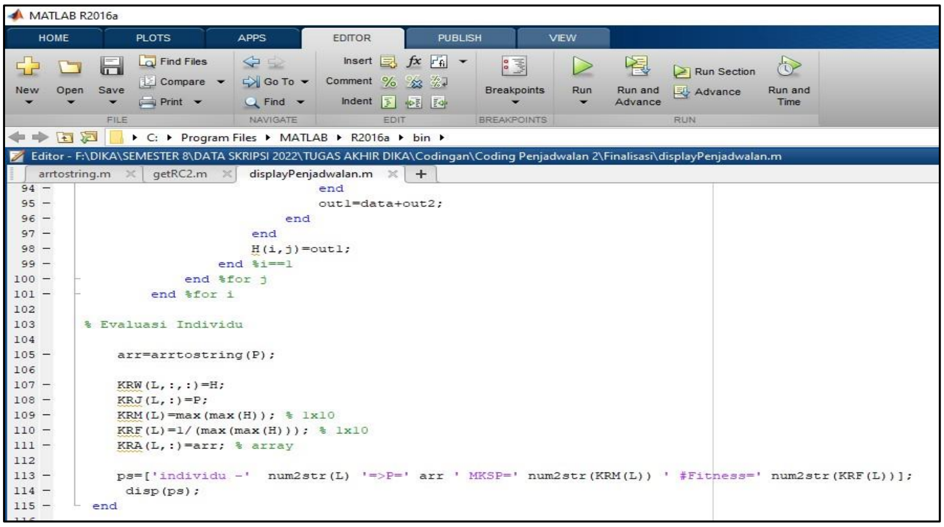

Figure 3.3 Individual Evaluation Stage on MATLAB software

Source: Data Processing

e. Roulette Wheel

This Roulette Wheel process is the process of selecting chromosomes that will be maintained in the next population. The roulette wheel is one of the selection methods used in the genetic algorithm. In this selection, individuals or chromosomes will be selected based on fitness values, so it is unlikely that populations with varied fitness values because individuals or chromosomes with small fitness values will most likely die and individuals or chromosomes will die. which has a high fitness value will be selected more than once which causes the individual or chromosome to dominate the population. Figure 3.4 is the MATLAB Roulette wheel programming stage in the MATLAB software.

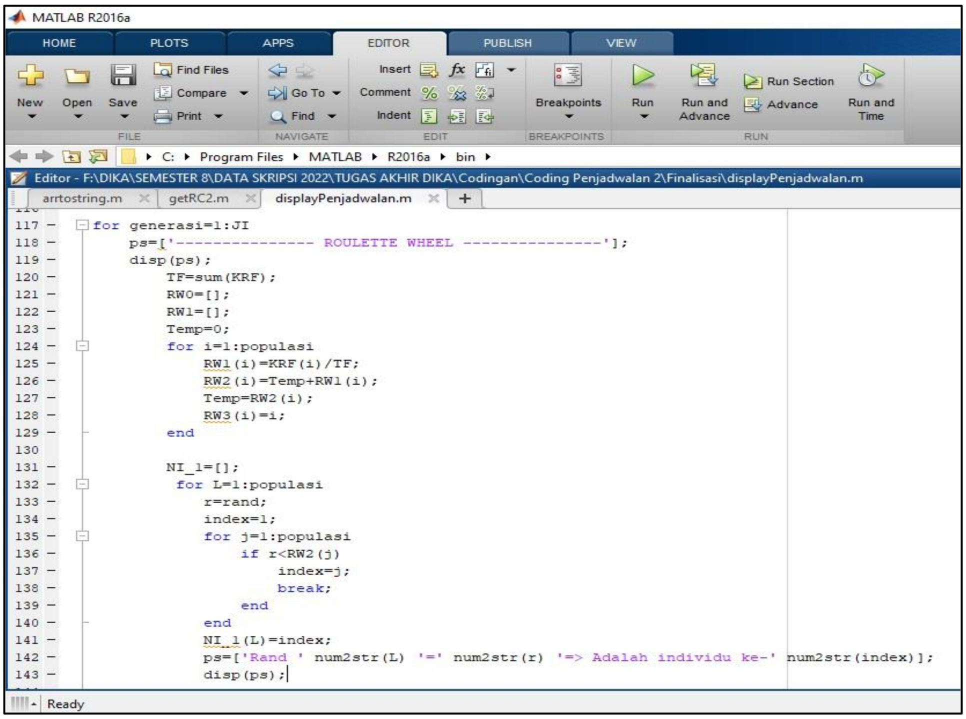

Figure 3.4 Roulette wheel selection stages in MATLAB software

Source: Data Processing

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f. crossover

At this stage is the process of crossing over contained in the genetic algorithm. The process of crossing over or crossover is one of the most important components in the genetic algorithm. An individual or chromosome that leads to a good solution can be obtained from the process of crossing two individuals or chromosomes selected at the previous stage or it can be said to be a parent (parent) to give birth to a new individual or a new chromosome that inherits traits or genes from its parents. (parents). This process of crossing over or crossover is based on predetermined parameters, namely with a crossover probability (probCR) of 0.8 to get better fitness results from new individuals or new chromosomes being born. Figure 3.5 is the MATLAB programming process of crossing over or crossover in MATLAB software.

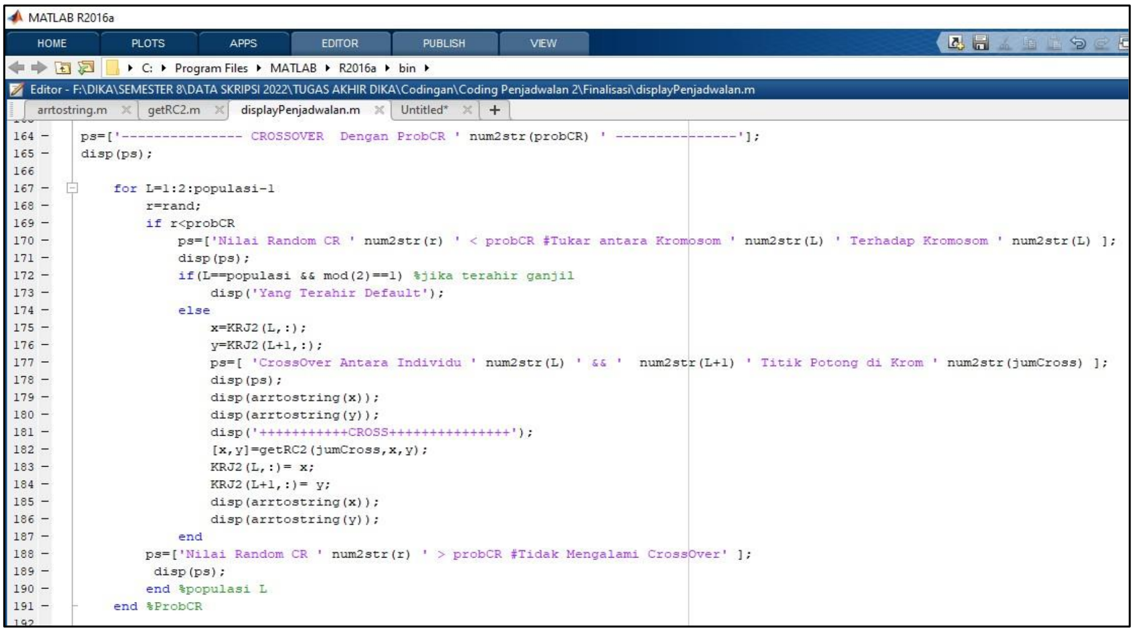

Figure 3.5 Crossover or Crossover Stages in the MATLAB software

Source: Data Processing

g. Mutation

At this stage, the mutation is an operator in the genetic algorithm that aims to change certain genes of an individual or chromosome. What is meant by genes here is the job sequence that exists in an individual or chromosome. The gene will be changed to a different form than before with this mutation process. The mutation process has parameters that have been set, namely the probability of mutation (probMut) of 0.1. The following is the MATLAB programming for the mutation process in the MATLAB software.

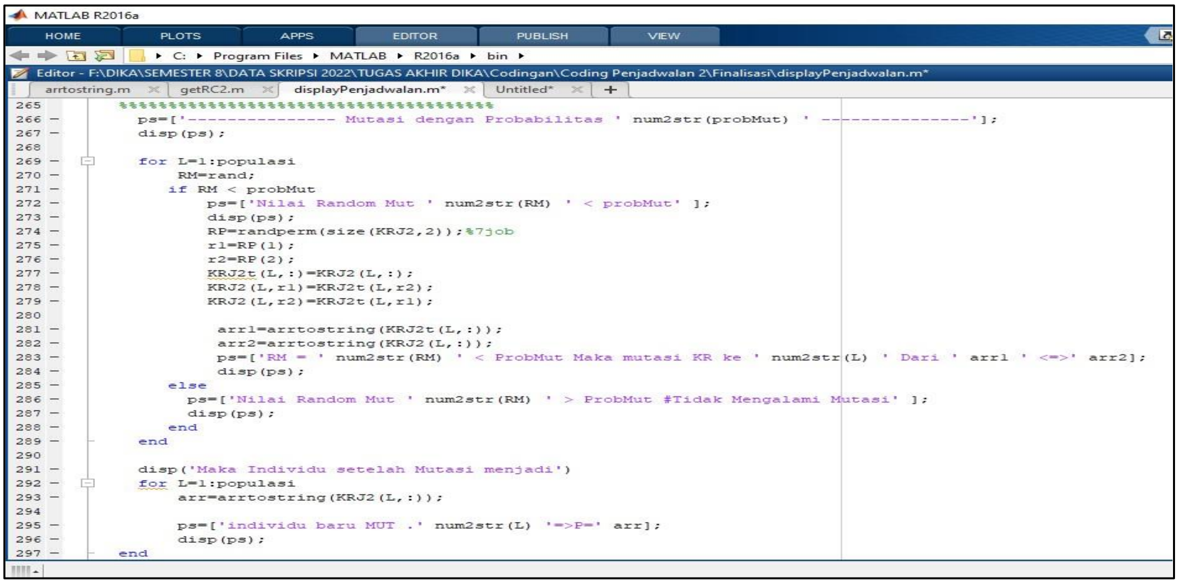

Figure 3.6 Mutation Stage in MATLAB software

Source: Data Processing

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h. Population Replacement

Population replacement or generational replacement is replacing all individuals from a population in one generation at once with the results of crossing or crossover and mutation. Thus new individuals or new chromosomes will appear to replace the previous generation. In this case the new sequence resulting from the crossover and mutation will replace the previous sequence that was generated. The following is MATLAB population replacement programming in MATLAB software.

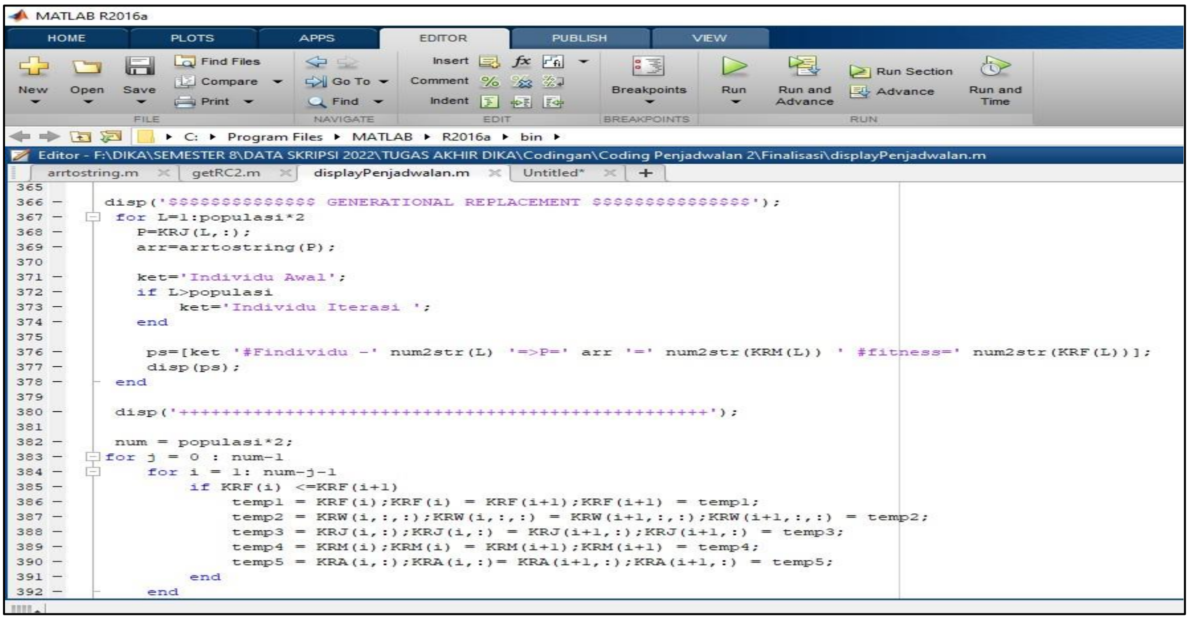

Figure 3.7 Stages of Population Replacement or Generational Replacement in MATLAB software
Source: Data Processing

i. Running Programming

At this stage is the stage to get a solution from the genetic algorithm programming that has been made. After completing the MATLAB programming of each stage of the genetic algorithm, the programming needs to be run by clicking the Run command on the toolbar contained in the MATLAB R2016a software. The graph genetic algorithm that is created will display the progress in finding the best makespan and the average makespan that has been generated.

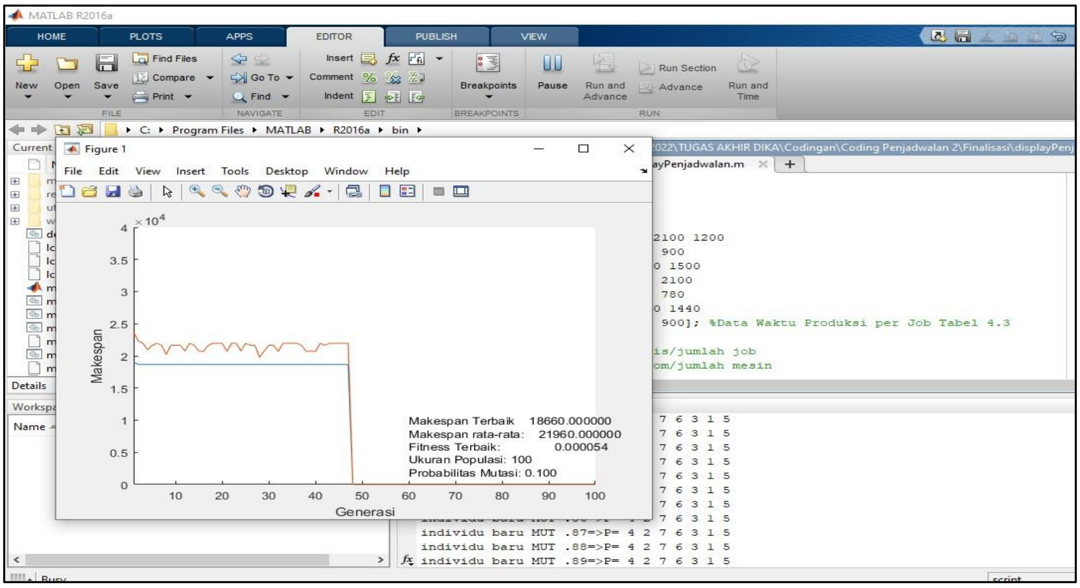

Figure 3.8 Running progress on the MATLAB R2016a software
Source: Data Processing

The results or output of the genetic algorithm programming in the MATLAB software will stop based on 2 choices, namely the iteration stops because the best fitness is achieved or the iteration stops because it has reached a maximum iteration of 100

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generations. Until you get between the two choices, the progress of running the programming will continue. Figure 3.9 is the result obtained after running the genetic algorithm programming in the MATLAB R2016a software has been completed.

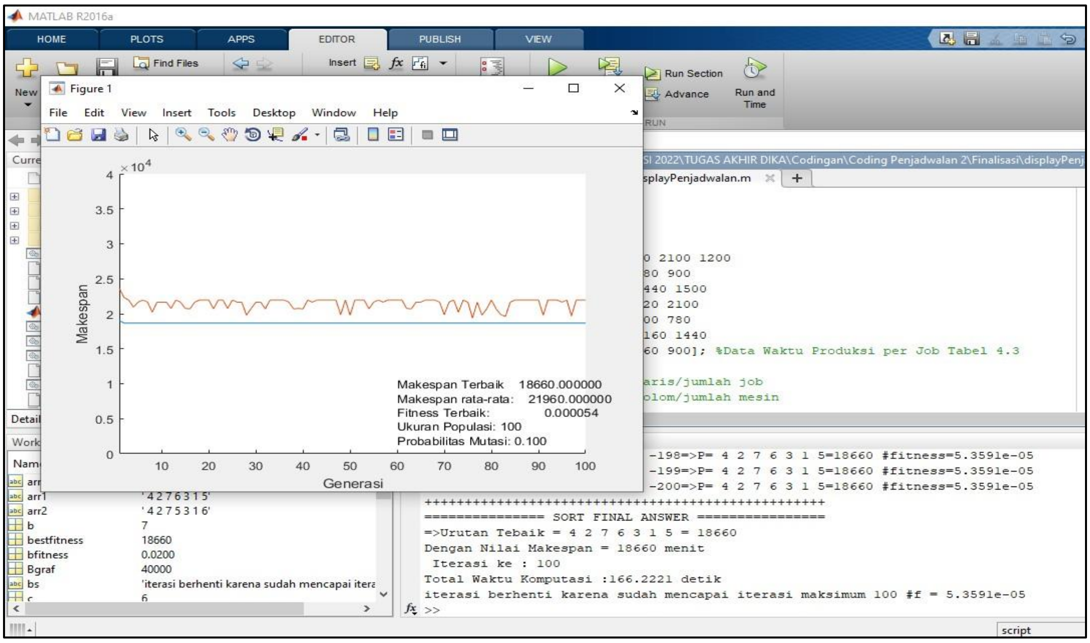

Figure 3.9 Running on the MATLAB R2016a software Stop

Source: Data Processing

From Figure 3.10 it is known that the running of the genetic algorithm programming has been completed with the statement that the iteration stops because it has reached the maximum iteration of 100 generations.

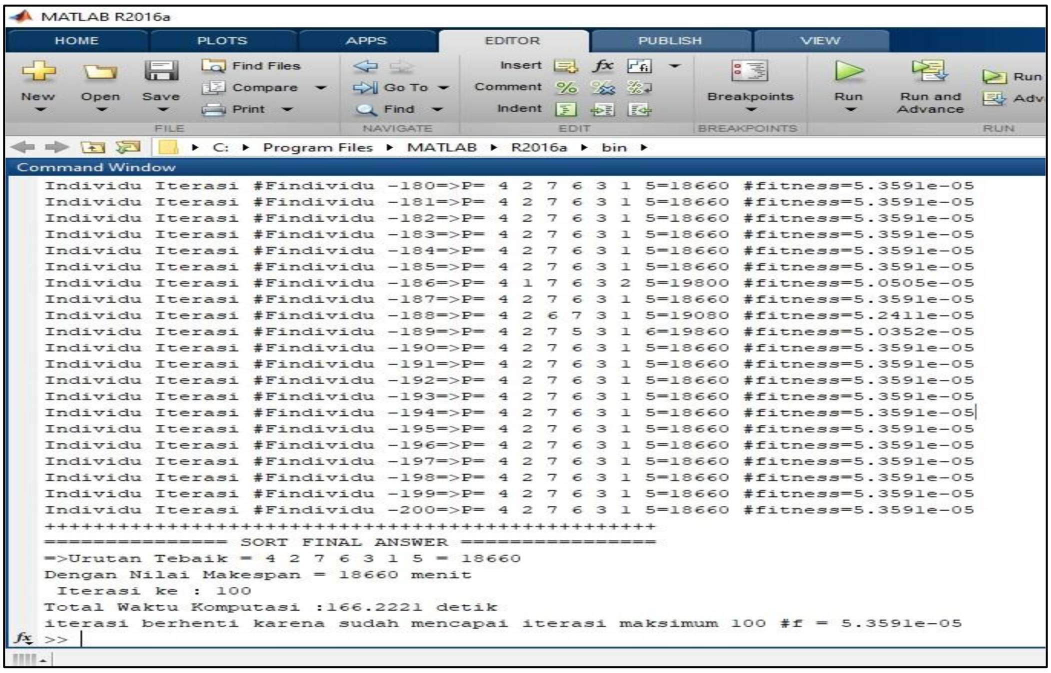

Figure 3.10 *Output* Genetic Algorithm Program in MATLAB R2016a

Source: Data Processin

Results The output is in the form of a graph that displays the search for the best makespan and the resulting average makespan which will stop when the genetic algorithm programming is finished. Figure 3.11 is a makespan.

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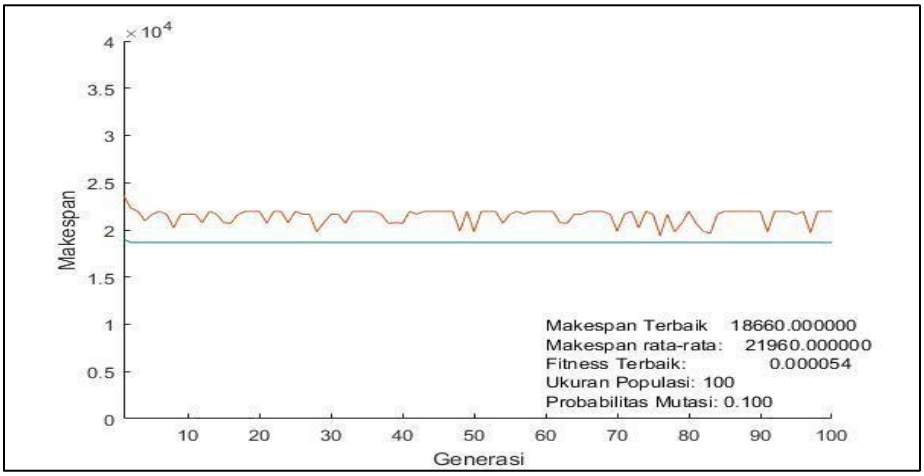

Figure 3.11 Output Graph of Genetic Algorithm Programming in MATLAB R2016a

Source: Data Processing

In the graph shown in Figure 3.11 the blue line is the graph generated by the search for the best makespan while the red line is the graph produced by the average makespan during the running programming process.

j. Scheduling using Genetic Algorithm

Scheduling can be done after getting the best sequence from the genetic algorithm programmer with the help of MATLAB R2016a software. The sequence obtained from the parameters previously set, namely the population size of 100, the probability of crossover (probCR) of 0.8 and the probability of mutation (probMut) of 0.1 is Job 4 (J4) - Job 2 (J2) - Job 7 (J7)) - Job6 (J6) - Job 3 (J3) - Job 1 (J1) - Job 5 (J5) with a makespan result of 18660 minutes with a programming computation time of 166.2221 seconds and a fitness result of 0.000054. The following is a summary of the results obtained from programming using MATLAB R2016a software. From these results, the results of scheduling using the Genetic Algorithm are presented.

1) Data on the production time of metal rubber bushings uses the order of the Genetic Algorithm method.

The following is data on the production time of metal rubber bushings based on requests in September using the Heuristic Pour method.

Table 3.5 Production Time Data (Genetic Algorithm Method)

	M1	M2	M3	M4	M5	M6
J4	780	1620	1080	1680	2220	2100
J2	840	1200	2100	1380	1080	900
J7	1860	1260	900	1620	2160	900
J6	1860	2220	1440	1980	2160	1440
J3	1560	1500	1980	1620	1440	1500
J1	2040	2100	1560	1500	2100	1200
J5	1440	1200	2040	1740	900	780

Source: Data Processing

Based on Table 3.5, it can be seen that the job placement order has been based on the order obtained from the production scheduling using the Genetic Algorithm method.

2) Calculating the total makespan using the Genetic Algorithm method Based on the results obtained using the Heuristic Pour method, the production scheduling sequence is Job 4 (J4) - Job 2 (J2) - Job 7 (J7) - Job 6 (J6) - Job 3 (J3) – Job 1 (J1) - Job 5 (J5).

Table 3.6 Production Completion Time Data (Genetic Algorithm Method)

	M1		M2		M3		M4		M5		M6	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
J4	0	780	780	2400	2400	3480	3480	5160	5160	7380	7380	9480
J2	780	1620	2400	3600	3600	5700	5700	7080	7380	8460	9480	10380
J7	1620	3480	3600	4860	5700	6600	7080	8700	8700	10860	10860	11760

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J6	3480	5340	5340	7560	7560	9000	9000	10980	10980	13140	13140	14580
J3	5340	6900	7560	9060	9060	11040	11040	12660	13140	14580	14580	16080
J1	6900	8940	9060	11160	11160	12720	12720	14220	14580	16680	16680	17880
J5	8940	10380	11160	12360	12720	14760	14760	16500	16680	17580	17880	18660

Based on Table 3.6, it can be seen that the total makespan using the Genetic Algorithm method is 18660 minutes with a total completion of machine 1 of 10380 minutes, machine 2 of 12360 minutes, machine 3 of 14760 minutes, machine 4 of 16500 minutes, machine 5 of 17580 minutes , and machine 6 by 18660 min.

4. Comparison of Production Scheduling Methods

Based on the results of data processing in the production scheduling process that has been obtained using the FCFS (First Come First Serve), Heuristic Pour, and Genetic Algorithm methods, the following comparison results are obtained.

Table 3.7 Comparison of Production Scheduling Methods

Method	Scheduling Sequence	Makespan (Days)	Utilization (%)	Late (Days)
First Come First Serves	J1 – J2 – J3 – J4 – J5 – J6 – J7	22020 minute = 18 days	7,72	3
Heurestic Pour	J4-J2-J7-J6- J5-J3-J1	19440 minute = 16 days	8,95	1
Genetic Algorithm	J4-J2-J7-J6- J3-J1-J5	18660 minute = 15 days	8,93	0

Based on Table 3.7 it can be seen that of the three methods used for production scheduling that have been compared to get the result that the Genetic Algorithm method can be chosen as the best method among the other two methods because it has the best makespan of 18660 minutes or 15 days, and in completing requests did not experience delays with a total completion time of 15 working days in accordance with the company's working hours of 7 working hours per shift and the number of shifts of 3 shifts.

IV. CONCLUSION

Based on the results of research that has been conducted at PT. Madya Putera then it can be concluded as follows.

1. Based on the scheduling carried out by the previous company, namely by using the FCFS (First Come First Serve) method, the job sequence was obtained, namely Job 1 (BMR 246895 SK), Job 2 (BMR 124072 DH32), Job 3 (BMR 253169 HN29), Job 4 (BMR 163366 DH4F) , Job 5 (BMR 16 IZ-31) , Job 6 (BMR 164173T54) , Job 7 (BMR 184289 RB235) produces a makespan of 22020 minutes or equal to 18 working days. Based on scheduling using the Heuristic Pour method, the job order is obtained, namely Job 4 (BMR 163366 DH4F), Job 2 (BMR 124072 DH32), Job 7 (BMR 184289 RB235), Job 6 (BMR 164173 T54), Job 5 (BMR 16) IZ-31), Job 3 (BMR 253169 HN29) , Job 1 (BMR 246895 SK) produces a makespan of 19440 minutes or equal to 16 working days. Based on scheduling using the Genetic Algorithm method, the job sequence is obtained, namely Job 4 (BMR 163366 DH4F), Job 2 (BMR 124072 DH32) , Job 7 (BMR 184289190 RB235) , Job 6 (BMR 164173 T54) , Job 3 (BMR 253169 HN 29), Job 1 (BMR 246895 SK) , Job 5 (BMR 16 IZ-31) produces a makespan of 18660 minutes or equal to 15 working days.
2. The assignment of production machines used is adjusted to the job order that has been obtained from the production scheduling carried out with the flowshop model, the following results are obtained.

   a. Based on the FCFS (First Come First Serve) method or what was done by the previous company, that is, every machine starting from the Pipe Cutting process or machine, Press Com, Precision, Turret, Sandblasting, and Rubber Hotpress will sequentially work on jobs in the order of Job 1 (BMR 246895 SK) , Job 2 (BMR 124072 DH32) , Job 3 (BMR 253169 HN29), Job 4 (BMR 163366 DH4F) , Job 5 (BMR 16 IZ-31) , Job 6 (BMR 164173 T54) , Job 7 (BMR 184289 RB235). The total completion time for the Pipe Cut machine was 10380 minutes, Press Com machine was 13140 minutes, Precision machine was 15240 minutes, Turret machine was 18420 minutes, Sandblasting machine was 21120 minutes, and Rubber Hotpress machine was 22020 minutes.

   b. Based on the Heuristic Pour method, that is, each machine starting from the Pipe Cutting process or machine, Press Com, Precision, Turret, Sandblasting, and Rubber Hotpress will sequentially work on jobs in the order Job 4 (BMR 163366 DH4F), Job 2 (BMR 124072 DH32), Job 7 (BMR 184289 RB235) , Job 6 (BMR 164173 T54) , Job 5 (BMR 16 IZ-31) , Job 3 (BMR 253169 HN29) , Job 1 (BMR 246895 SK). The total completion time for the Pipe Cut machine is 10380 minutes, Press Com machine is 12480 minutes, Precision machine is 14580 minutes, Turret machine is 16140 minutes, Sandblasting machine is 18240 minutes, and Rubber Hotpress machine is 19440 minutes.

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c. Based on the Genetic Algorithm method, that is, each machine starting from the Pipe Cutting process or machine, Press Com, Precision, Turret, Sandblasting, and Rubber Hotpress will sequentially work on jobs in the order of Job 4 (BMR 163366 DH4F), Job 2 (BMR 124072 DH32), Job 7 (BMR 184289 RB235) , Job 6 (BMR 164173 T54) , Job 3 (BMR 253169 HN 29) , Job 1 (BMR 246895 SK) , Job 5 (BMR 16 IZ-31). The total completion time for the Pipe Cut machine is 10380 minutes, Press Com machine is 12360 minutes, Precision machine is 14760 minutes, Turret machine is 16500 minutes, Sandblasting machine is 17580 minutes, and Rubber Hotpress machine is 18660 minutes.

3. Based on the production scheduling that has been carried out, the Genetic Algorithm method can be chosen as the best method among the other two methods because it has the best makespan of 18660 minutes or 15 days, and in the completion of requests there are no delays with a total turnaround time of 15 working days in accordance with company working hours of 7 working hours per shift and the number of shifts is 3 shifts. While the results of makespan using the Heuristic Pour method, you get a makespan value of 19440 minutes or 16 working days with a delay in completion of 1 working day, if you use the FCFS (First Come First Serve) method used by the previous company, you get a makespan value of 22020 minutes or 18 working days with a delay of 3 working days.

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