

Simulation Analysis of Brake Lining Manufacturing

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Abstract

The Simulation Analysis tools are now widely used in manufacturing industry in order to achieve the desired production efficiency. In this paper, a Simulation model is created to represent the Brake Lining Manufacturing Assembly line. The aim of this paper is to provide a manufacturing plan which will improve the current production capacity, so that it could meet the future demands. Sensitivity analysis was performed in this study by taking the following into consideration such as increasing the manpower and cross skilling the Resources, as a result the output capacity was increased. The results of this Simulation model has been confirming that the production capacity can be increased by applying the improvement Strategies.

Keywords:

Brake Lining Manufacturing, Simulation, Plant Layout, Efficiency.

1. Introduction

Simulation plays an vital role in Automobile industry, right from Design to Development, Production and Cost Analysis. Here in this paper, the simulation study is used for increase in production by identifying the Bottlenecks in an Global Automotive Brake lining Manufacturing Organization situated at South India. Brake Linings play an pivotal role for Deceleration, Emergency Braking in Automobile's and Commercial Trucks/Buses. The Brake Line should be sturdy enough in order to withstand high braking Temperature while working in very high speeds and also not to get worn out easily due to continuous usage. Simulating the Brake Lining Assembly line and resolving the Bottlenecks, and analysing their outcomes on Production.

2. Problem Description

The manufacturing facility in our paper produces brake linings for Tata Vehicles and Ashok Leyland vehicles (7 inch front & rear drum linings). The current production level of brake pads is 30,000 per month and for a day it is only 1,000 per day due to low ongoing demand and effect of Covid-19. Due to the outbreak of Covid-19, many Passengers are now feeling to travel on their own vehicle in order to avoid going in the Public vehicles so that the spread can be reduced. As a result of this many customers started to buy their own Automobile's which in-turn is leading to the increase in production of automobiles and their ancillary industries. The core of this paper is to improve the current production capacity by providing optimal production plan and implementing alternative changes to overcome the bottlenecks and provide the desired output.

3. Literature Review

Many Researcher's have exploited huge benefits by simulation modelling of complex Automobile manufacturing systems. Bae et al. (2015) used computer simulation to improve the current production capacity and to meet the future demands by providing feasible manufacturing solutions and incorporating Sensitivity analysis to find the best alternative approach. Roser et al. (2001) has found a novel method for identifying the bottleneck in a system

by finding the average duration of machine being active for all machines, the machine with average uninterrupted active period is fixed as bottleneck. Duanmu and Taaffee (2007) has performed case study at company that produce two main types of customized products. However, the order of operations in key shared resources highlight that simple takt time calculation is not sufficient to provide adequate information in obtaining achievable throughput. The process consists of several assembly lines that converge to common resources.

Nguyen and Takakuwa (2008) has offered by simulation studies like Resource Utilization, line productivity and manufacturing costs was useful to determine the most suitable manufacturing line in a factory. Taj et al.(1998) have figured that changing an layout may provide benefits, but they were offset by huge investments. Reasons for higher cost might be due to poor cycle time, machine downtime, complex material handling and long changeovers. Gujarathi et al. (2004) have reported that production rate can be obtained without increasing direct labour, there by achieved 32% increase in gross profit in an OEM industry via simulation modeling.

Multiskilling of operators in assembly line can be very much useful for achieving the desired results under dynamic demands, a case study by Kapadia (1998). Production Efficiency can be improved by resource sharing, adding the special equipment to bottleneck point, and merging the production lines, a simulation case study in Semi-trailer production facility by Kongthong et al.(2021). Ladbroke et al.(2001) did a case study on Changes made in Ford's Power Train Operations Simulation environment. Three factors was found to increase the use, they are availability, support and right tools for the job.

From the above simulation papers it has been evident that Simulation modelling will be very much useful for improving the Production capacity and to meet any future market demand. It is also evident that throughput time can be increased by cross skilling the workforce so that they would able to operate on more than one workstation and reduce the production time. Increasing the Machinery would also be considered to reduce the bottleneck and getting high output results.

4. Brake Lining Manufacturing Process Layout

In this section, the design and development of the Break Lining Manufacturing assembly process sequences to build a break lining for Tata and Ashok Leyland vehicles is presented. Please refer figure 1. The major process involved in the production lines are Weighing, Mixing, Bagging, Pressing, Oven (Case Hardening Process), Inside Grinding, Outside Grinding, Chamfering, Drilling, Notching, Inspection, Printing & Packing process

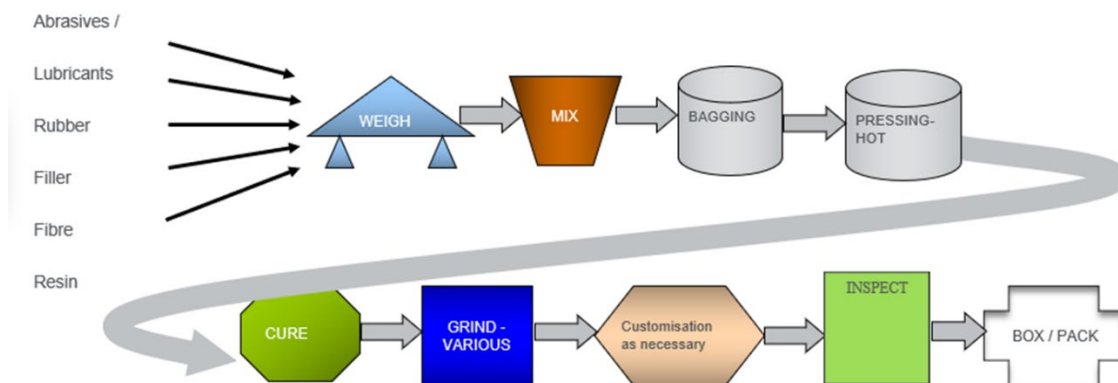


Figure 1. Break lining manufacturing Process Flow.

A 11 Different Raw Materials which are present in Powder form is prepared on depending upon the Batch Requirements for Different Automobile requirements, thus making in quantity of 250 Kg. The Desired raw materials taken in respective Proportions are then mixed using the Mixing Machine. The Mixing Machine thus creates a blend out of 11 different raw materials and with a quantity of 250 kg for each batch.

4.1 Bagging Process

The 250 Kg of Blended variety of Raw material is Fed into the Bagging Machine .The Machine is capable of producing 120 no's of raw material as Bags in 1 Hour. As a result each of the 120 numbers will be weighing 1170 Grams.

4.2 Pressing Process

This Process is done using a Hydraulic Press of 500 Ton Capacity. Each Press has a mould which will be having 9 Cavities, so load up to 9 Bags in the Press. The Hydraulic Press implies 6 Pressure Cycle of 500 Ton, and in 1 Cycle the Press is capable of producing 9 Blanks per 10 minutes. The Cycle time for this Process is 10 minutes.

4.3 Oven (Case Hardening Process)

Once the Press process is over , the 207 nos from hydraulic press is fed into a Oven for the Case Hardening Process. Here the Blanks are heated for upto 160-180°C for 8 Hours. Once the Heat Treatment is over, the Blanks are ready for Finishing.

4.4 Inside Grinding

The Process is also called as Internal Diameter Grinding.Here the Job is loaded into the Grinder by an manual Operator. The Internal diameter of the lining is grinded till the Shining Phase of the job is removed. The inside Grinding is capable of producing only 197 Nos per Hour. Hence the Cycle time for this Process is $197/60$ minutes = 3.28 seconds per piece

4.5 Outside Grinding Process

The outside diameter of the lining is grinded , till the shining is lost and frictional surface is obtained. The Outside Grinding Machine has a capacity of producing 319 nos per hour, but the case is , in the Inside Grinding Process(i.e the previous process) we were able to get a output of only 197. Then the Cycle time of Outside Grinding Machine is $319/60=5.31$ piece.

4.6 Chamfering Process

Once the Brake lining is fitted with the Brake shoe. The Heat and Noise will get produced during operation of the brakes in the vehicle. In order to dissipate the heat & noise produced, a few gaps are made in the job (at both extreme ends of the lining a taper is being done in this process).

4.7 Drilling Process

In this process, the holes are drilled into the break lining , so that it can be fixed to the Brake shoe by Rivetting process. The No.of holes to be drilled , totally depends upon the product specifications , for example the Tata 180 model will require 10 holes , and Ashok Leyland model might vary from 10/14/12 holes respectively.

4.8 Notching Process

In this process a notch (a cut) is made at two ends of the lining manufactured. So whenever the brake pad's get worn out till the notch, then it is a indicator for the end user that the pads need to be replaced. Hence Notch is used to indicate the life of the Break pads.

4.9 Inspection Process

The Quality check is done by 3 methods they are Visual Inspection, Tap Test, Using Gauges

4.10 Visual Inspection

Here the Operators , visually inspect the end products one by one with their naked eyes , to check for any defect is present in the product.

4.11 Tap Test

In this check , the operator uses an hammer and manually taps on the end product at 9 points , and identifies whether any air bubbles are formed inside the lining by hearing the Sound.

4.12 Using Gauges

Here the Operator uses equipment's like Vernier caliper, Ball Micrometer, Needle Micrometer, Flat Micrometer, Hole Position Gauges, Plug Gauges etc to check for the Geometric Dimensions and Tolerance.

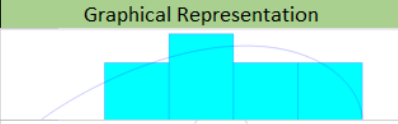
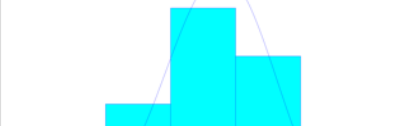
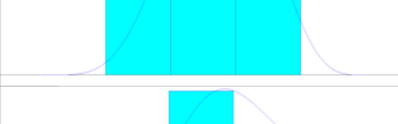

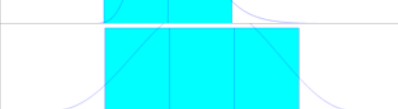
4.13 Printing and Packing Process

This is the last step in the Manufacturing process, once the Quality check has been done, then the Qc Passed products are printed with their respective Barcodes, Packed and then sent for dispatch.

5. Data and Input Distribution Table

The data obtained from the manufacturing facility was fed into the Input analyzer tool in Arena Software, as a result the best possible distribution for each workstation was able to be found. The distribution obtained via input analyzer was then used with model for each workstation. The input data table along with best fit distribution is shown in Table 1.

Table 1. Input Distribution table

S.No	Workstation Name	Distribution	Expression	Graphical Representation
1	Inside Grinding	Beta	$0.29 + 0.04 * \text{BETA}(1.94, 1.54)$	
2	Outside Grinding	Beta	$0.18 + 0.02 * \text{BETA}(6.25, 5.19)$	
3	Chamfering Station	Logonormal	$0.19 + \text{LOGN}(0.0125, 0.00301)$	
4	Drilling Station	Logonormal	$0.16 + \text{LOGN}(0.00846, 0.0019)$	
5	Wear Notch Station	Beta	$0.22 + 0.03 * \text{BETA}(3.96, 3.79)$	

6. Simulation Development & Analysis

A simulation model is developed representing the brake lining manufacturing process layout for one shift operation. The simulation model for the complete Brake lining production process is developed using Arena 16.1 version software, however the particular version has some limitations on the number of modules can be modeled (i.e) <150 modules. The simulation model was developed with a keen knowledge about the various processing stations , their cycle times, the type of distribution needs to be employed, uptime, downtime , warm up period etc. The simulation model of the brake lining production process is shown in Figure 2.

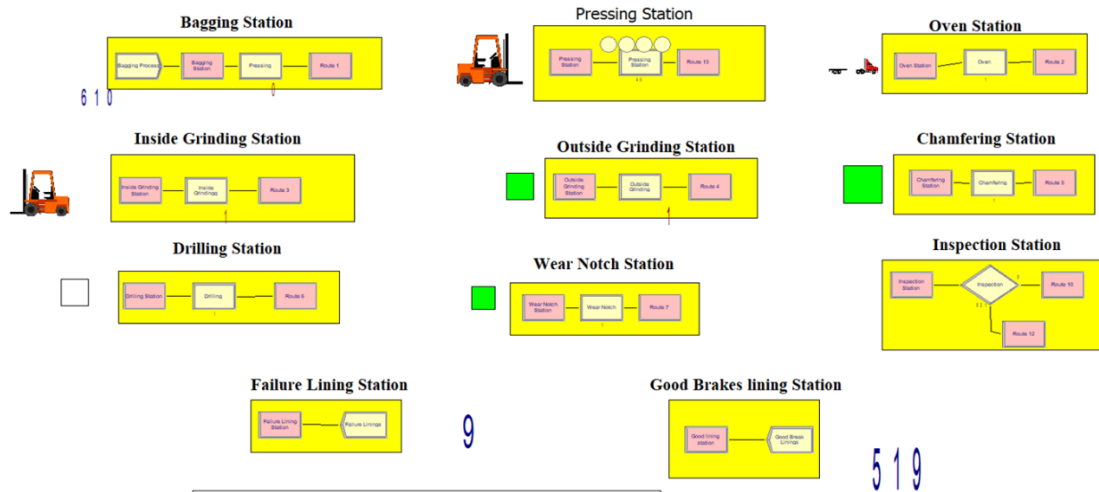


Figure 2. Simulation model design

All the production data per (i.e) the linings produced per hour from each work station is fed into the Input analyzer , and the best possible outcome was found for each workstation is shown in Figure 2. The entities are created with appropriate arrival rates. The distribution obtained from input analyzer was incorporated into each work station in the simulation model. The process stations were modeled with two breaks , each of duration 10 minutes, a lunch break with duration of 30 minutes. The whole model was run for a replication length of 8 hrs with a warm up period of 10 minutes based on the typical plant data. The model station resource data matrix is shown in Figure 3.

	Name	Type	Action	Priority	Resources	Delay Type	Units	Allocation	Expression	Report Statistics
1	Pressing	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Minutes	Value Added	$0.28 + 0.02 * \text{BETA}(2.5, 1.67)$	<input checked="" type="checkbox"/>
2	Oven	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Minutes	Value Added	$0.28 + 0.02 * \text{BETA}(2.5, 1.67)$	<input checked="" type="checkbox"/>
3	Inside Grindingg	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Minutes	Value Added	$0.29 + 0.04 * \text{BETA}(1.94, 1.54)$	<input checked="" type="checkbox"/>
4	Outside Grinding	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Minutes	Value Added	$0.18 + 0.02 * \text{BETA}(6.25, 5.19)$	<input checked="" type="checkbox"/>
5	Chamfering	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Minutes	Value Added	$0.19 + \text{LOGN}(0.0125, 0.00301)$	<input checked="" type="checkbox"/>
6	Drilling	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Minutes	Value Added	$0.16 + \text{LOGN}(0.00846, 0.0019)$	<input checked="" type="checkbox"/>
7	Wear Notch	Standard	Seize Delay Release	Medium(2)	1 rows	Expression	Minutes	Value Added	$0.22 + 0.03 * \text{BETA}(3.96, 3.79)$	<input checked="" type="checkbox"/>

Figure 3. Station data matrix

7. Result Analysis

The simulation model predicted an number out of 1012 Good brake and 11 faulty brake linings for 480 minutes of simulation time. The results produced contained scheduled utilization, instantaneous utilization, number waiting, waiting time, number in, number out, Work in Progress etc. The average WIP was found to be 11.6312 for the whole process. The consolidated results is shown in Table 4.

Table 4. Existing Results	
Number Out	1012
Average Wait Time	3.651
Average Work in Progress	11.6312

7.1.1 Bottlenecks

From the initial model results we were able to find the bottlenecks at 3 workstations, they are Pressing Station, Inside Grinding Station followed by Oven Station. From the graph shown in Figure 4 and Figure 5, we can come to know that, the pressing, inside grinding and oven station has higher number waiting and queue time.

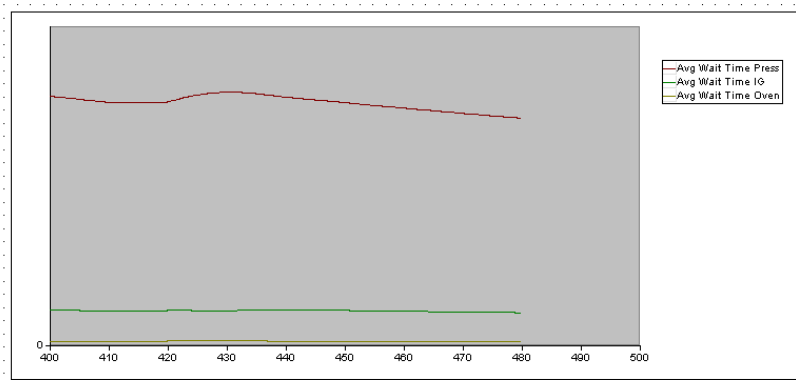


Figure 4. Plot for Average Waiting Time

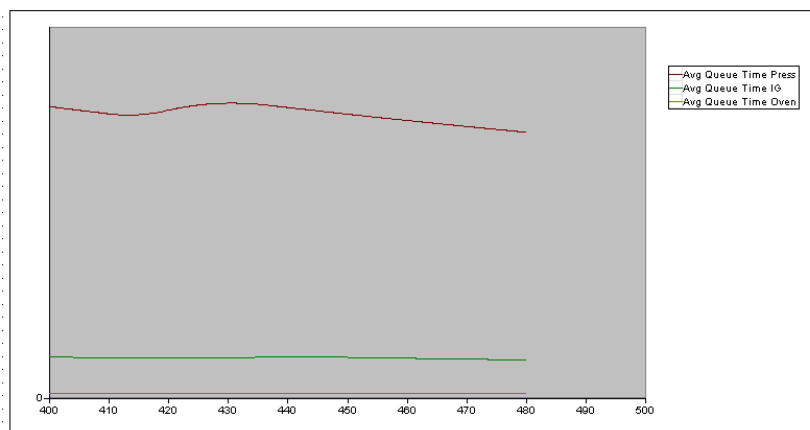


Figure 5. Plot for Average Queue Time

The number waiting, queue time for the simulation model with bottlenecks is shown in Table 5.

Table 5. Results obtained with Bottleneck

Existing Results	
Number Out	1012
Average Wait Time	3.651
Average Work in Progress	11.6312

7.1.2 Improvements

The bottlenecks are eradicated by increasing the capacity of machinery being used for production, mainly the hydraulic press used currently is of 500 Tonnes, this should be increased to either 1000 or 2000 tonnes capacity so that the maximum queue time/waiting time at the particular station will be reduced, followed by increasing the capacity in Inside Grinding workstation and Oven station. As a result of doing this improvements we have increased the number out, Average wait time has been reduced and the average work in progress was reduced considerably. The improved results for the total production process and for the individual bottleneck station is shown in Table 6. and Table 7.

Table 6. Comparison between Existing & Improved Results

Existing Results		Improved Results	
Number Out	1012	Number Out	1023
Average Wait Time	3.651	Average Wait Time	2.5685
Average Work in Progress	11.6312	Average Work in Progress	9.3044

Table 7. Comparison of Existing & Improves Results for bottleneck stations

Bottleneck Areas		
Pressing Station		
	Existing	Improved
Queue time	3.0676	1.6893
Number Waiting	6.6703	3.6876
Busy %	63.55	58.83
Idle %	25.97	30.68
Inactive %	10.48	10.49
Inside Grinding Station		
	Existing	Improved
Queue time	0.4436	0.0906
Number Waiting	0.9646	0.1978
Busy %	41.52	62.71
Idle %	21.45	26.71
Inactive %	10.63	10.58
Oven Station		
	Existing	Improved
Queue time	0.05561	0.05014
Number Waiting	0.1211	0.1095
Busy %	63.55	58.83
Idle %	25.85	30.6
Inactive %	10.59	10.57

7.1.3 Output Analyzer

The Output Analyzer was performed after erradicating the bottlenecls and the output analyzer was performed for 95% confidence interval. The Figure 6. and Figure 7. represents the box plot and result of output analyzer.

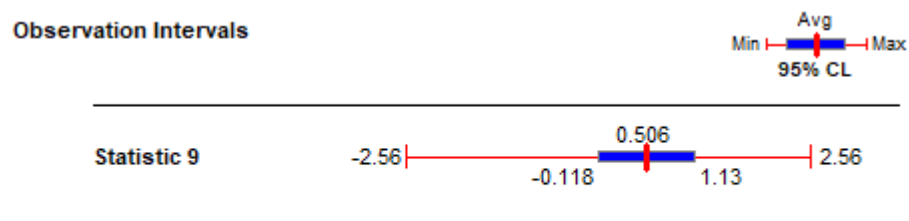


Figure 6. Box Plot

Classical C.I. Intervals Summary						
IDENTIFIER	AVERAGE	STANDARD DEVIATION	0.950 C.I. HALF-WIDTH	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBS.
Statistic 9	0.506	1.95	0.625	-2.56	2.56	40

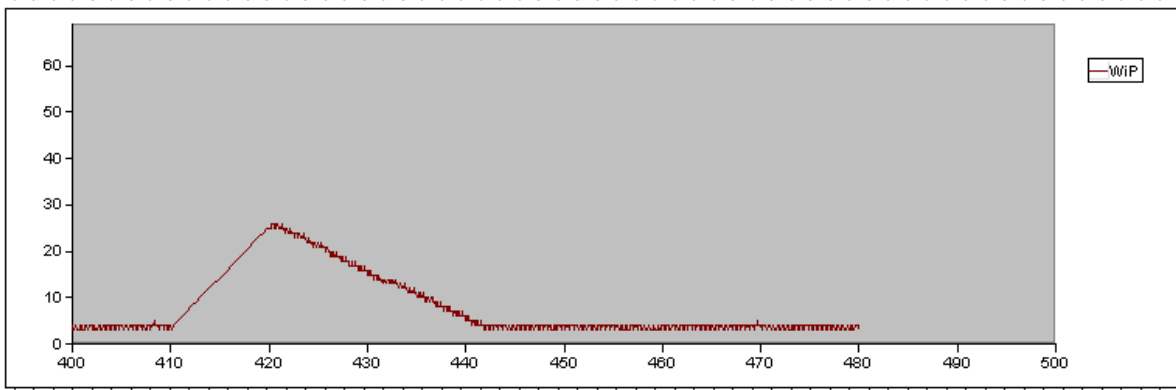
Figure 7. Output Analyzer Result

Futhermore we should multi skill the operators so that 1 particular operator can handle 2 workstation simultaneously also it will reduce the labour cost. Finally the Quality control is currently done by manual intervention , hence the company should focus on establishing a Automated quality checking machine so that the human error/time consumed can be reduced.

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Appendix



The Figure 6. shown displays the Work in progress of the brake lining manufacturing plant with the bottlenecks

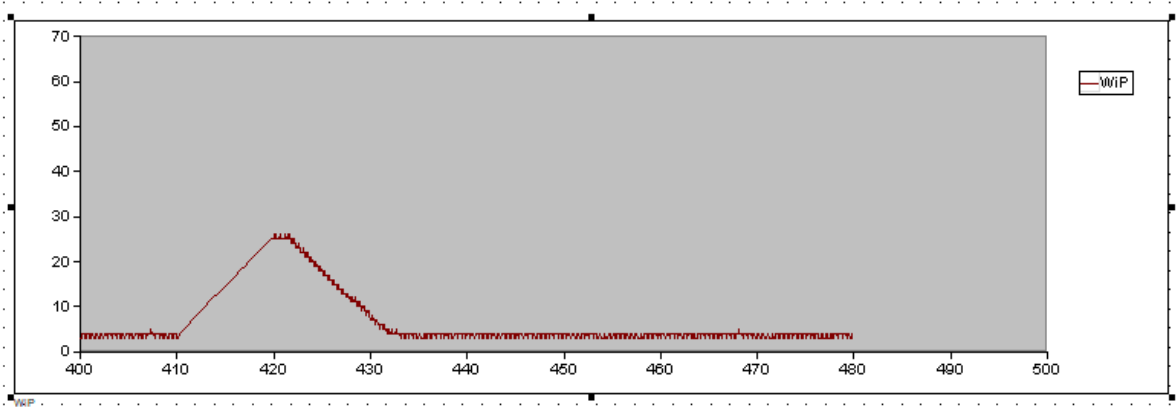


Figure 7. Depicting Work in Progress after improvements

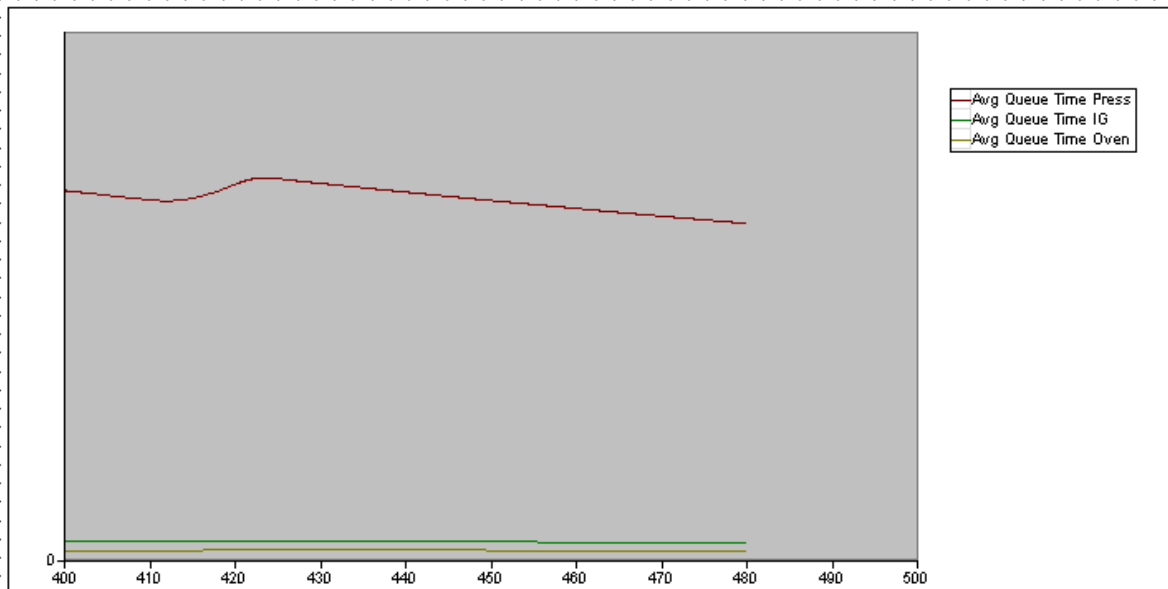
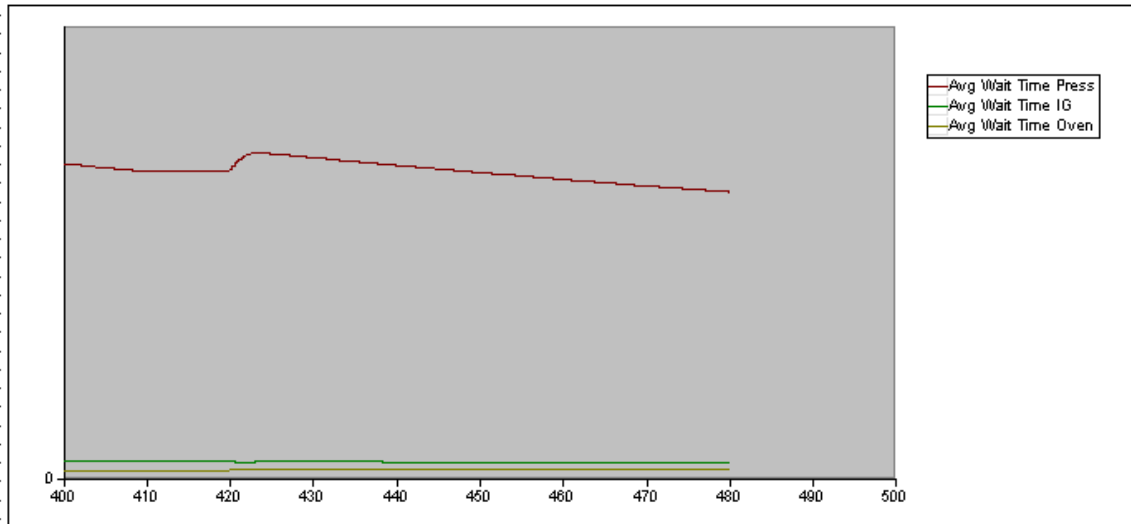


Figure 8. Depicting Waiting time & Queue time for Bottleneck areas (Pressing Station, Inside grinding, Oven station)