

Performance Improvement using Simulation Tool in a Tiles Production Facility

UROOSA NADIR*, TUFAIL HABIB*, SIKANDAR BILAL KHATTAK*, AND ISHRAT NOOR*

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ABSTRACT

In recent times, the globalization of markets due to the improvement of utilization of resources has significant impact on the manufacturing systems. International competition forced companies to establish efficient and effective production facilities that provide best possible outcome in terms of profitability, throughput and lead time. In this background, every industrial facility is in competition to remain competitive in the market and be flexible for future changes. It is not easy to change the environment of any facility in order to check the results beforehand therefore simulation is a viable option. Simulation tools are used to help analyze performance measures for improvement. This paper presents a case by analyzing a facility in order to improve its production using simulation tool. In this study, simulation model for the production facility of Fort Ceramic Company is developed from its current state and then changes are made to its inter-arrival time. Models for both improved and current systems are developed in the simulation tool. Data analyzed in the simulation tool shows better results that represent a significant improvement in productivity, cycle time and throughput time to optimize the system. It is also observed that by decreasing the inter arrival time there is increase in the throughput which improves the revenue.

Key Words: Simulation, Performance Analysis, Work in Process, Cycle Time, Throughput.

1. INTRODUCTION

Due to the globalization, high competition is emerging in the markets that impact the prevailing manufacturing systems. This competition force companies to establish efficient and effective production facilities that provide best possible outcome in their production facilities. In this situation, every industrial facility is in contention to remain competitive in the market and must be flexible for any future changes. Manufacturing companies are striving to increase their revenues by improving production to provide high quality products to the markets. Therefore,

the competitiveness of manufacturing companies depends on the availability and productivity of their production facilities.

Different organizations involved in manufacturing sector spend a huge amount in establishing their facilities. Therefore, the facilities need to be optimized so that they are flexible for future changes and demands. To increase the efficiency of a real system and to optimize the processes, it is essential to study the performance measures. Simulation is one option to study the

Authors E-Mail: (uroosa@uetpeshawar.edu.pk, tufailh@uetpeshawar.edu.pk, sikandarbilal@uetpeshawar.edu.pk, inoor@uetpeshawar.edu.pk)
* Department of Industrial Engineering, University of Engineering & Technology, Peshawar, Pakistan.

performance of a real system without bringing any change in the real system. With the help of simulation, it is very likely to observe and understand the behavior of the real system.

Main purpose [1] of simulation is that it helps in decision making which means to achieve desired objectives efficiently. Simulation tools are capable of analyzing the shop floor under different scenarios by just changing values and performance measures. Another research [2] used discrete simulation model of transport system to improve variation number and size of vessels in order to get efficient and effective pattern. Simulation is used [3] for shop floor control system that controls current status and information provided by controller. Another approach [4] used simulation to visualize verification of production plans for integration of Enterprise resource planning and scheduling. In the literature; various roles of simulation are emphasized in the effective planning and scheduling of the manufacturing systems. However, it is also essential to conduct a study to investigate the difficulties in efficient flow of material that generates waste in the production process.

After the research gap identification a case study is performed from a local ceramic industry. It has been observed that in the production department, moving the tiles from one machine to another one is not handled properly and big waste is generated during the transportation. It creates difficulties in the efficient flow of material. Furthermore, parts entering the production department are wasted mostly due to cracks and improper check and balance which affects the profitability of the facility. One of the reasons for cracks is that there is much space between each machine which makes the travel time for tiles higher than needed. Thus complete analysis is required in the production facility to measure the production performance.

Therefore, in this study simulation model is developed for the tiles production to analyze the production performance and the ways to reduce the waste generated. In this research simulation is used to measure performance because it is helpful and valuable tool in manufacturing. It allows the system behaviors to be tested and learnt. In addition, simulation modeling provides secure, low cost and fast analysis of the real system. More specifically, in this study, performance measures such as inter-arrival time, cycle time, throughput and WIP (Work in Process) is calculated to identify waste and improve overall production.

The rest of the paper is divided into following sections: next section describes the literature work in this area; then the methodology and data collection of the production system is presented followed by simulation model, results and discussion. Finally, the last section concludes our work and presents recommendations for improvement.

1.1 Literature Review

This research study focuses on process improvement using simulation as a tool. In today's world simulation has gained tremendous popularity because of its extensive use in design and information about process parameters of manufacturing systems under different conditions. Simulation allows pre analysis of system before implementing any technology.

A new application introduced by [5] provides simulation algorithm that is capable of producing all the necessary geometric information about the machining process. Result of simulation helps experts [6] in companies to optimize quality method. A comparison research [7] explores techniques to analyze small samples from large trace files to find their difference using modeling. Simulation models of spherical and polyhedral grains to

analyze railway ballast in design and maintenance used by [8] where the models were compared to give different shear stress. Simulation plays main role in flexible manufacturing for random job arrival where [9] proposed Tardiness estimating method that provided better results. Ribino et. al. [10] used simulation to avoid unproductive bottlenecks in warehouse optimization at design stage to analyze behavior of automatic logistic warehouse. However, the above research has not discussed the difficulty in efficient flow of material that generates waste and its impact on revenues.

Performance of manufacturing systems can be efficiently analyzed by using simulation models and tools. Saez et. al. [11] extracted discrete and continuous variable data from machines in real time and inserted in simulation tool to analyze its performance in virtual environment. A case study conducted by Abdul Malik and Rajgopal [12] represent simulation model to show production lead time and work in process inventory differences. Another research study demonstrated [13] simulation results regarding production performance analysis and conducted exception diagnosis in manufacturing processes. Hwang et. al. [14] proposed a model that represented the timestamp data by internet of things and determined the real time performance indicators.

Sproedt et. al. [15] presents decision support for two elements which includes discrete event simulation approach considering all relevant eco-efficiency drivers within a production system. Huang [16] concludes that the capacity of the industry is far more than utilization and productivity improvement using performance measures. Modern approaches like rapid prototyping using virtual models in simulation play vital role in manufacturing systems [17]. In the above research various measures of performance improvement have been discussed. However previous literature has not discussed the performance measures such as inter-arrival time, cycle

time, throughput and WIP to identify and control waste and consequently generate revenues from it.

This paper targets the shop floor area of FORT Ceramics Industry, Industrial State Peshawar, Pakistan and suggests addition of some purposeful process steps in order to increase utilization of cycle time, throughput and WIP as performance measures.

2. RESEARCH METHODOLOGY

Referring to Fig. 1, the research process consists of several steps. First, a detailed study was conducted about the manufacturing processes of the proposed industry to know about the existing issues. It has been observed that the proposed company is using traditional manufacturing processes with no consideration of improving the tiles production. After detailed literature review and problem identification, data was collected about the production process of tiles. Then this data was used to develop a simulation model. This model was created and simulated in SIMIO software of the current production process at different cycle times to analyze the performance measures. The results were analyzed to find the respective processes. Finally, based on these results recommendations were made to the said industry for making necessary improvements.

3. DESCRIPTION OF THE CASE COMPANY

Frontier Forte Ceramics is a private company and is recognized for Tiles manufacturing. Forte Ceramics deals with the manufacturing of tiles of different sizes for homes, offices and other buildings. The company has design and production departments besides other supporting departments. The company is working on the conventional SOPs (Standard Operating Procedures). It consists of the various departments i.e. production

department, WH (Warehouse), administration, maintenance, store, R&P (Research and Development) and HR (Human Resource) department. The process flow layout of different sections of FORTE ceramics is explained in the following section.

3.1 Process Flow Layout of the Tiles Production

Fig. 2 shows the process flow layout of FORTE ceramics. The process starts from raw material and ends at tiles packing. Some of the processes are continuous and some

are discrete. The green color boxes show continuous processes and blue color boxes represent discrete processes.

3.2 Description of Each Section in Production Process

The press molding machines presses the desired powder with high pressure of 200 bars. After pressing the powder, the tile called green biscuit is produced. The tile then transferred through conveyer belts towards brushing section which removes dust from the tiles. The batch of

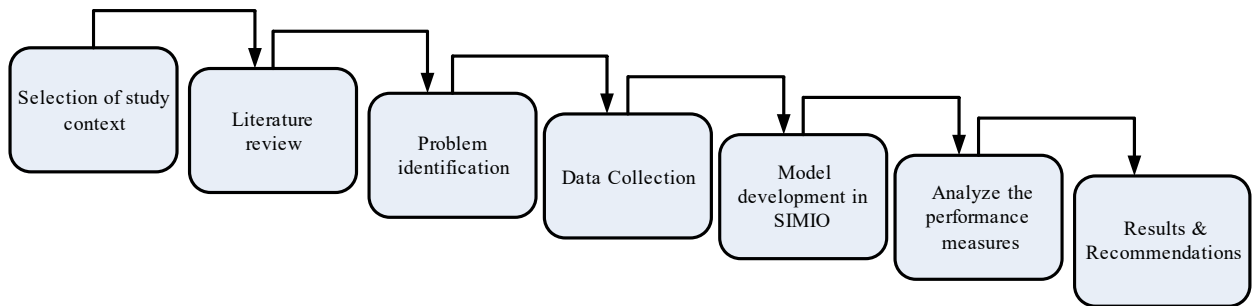


FIG. 1. RESEARCH METHODOLOGY

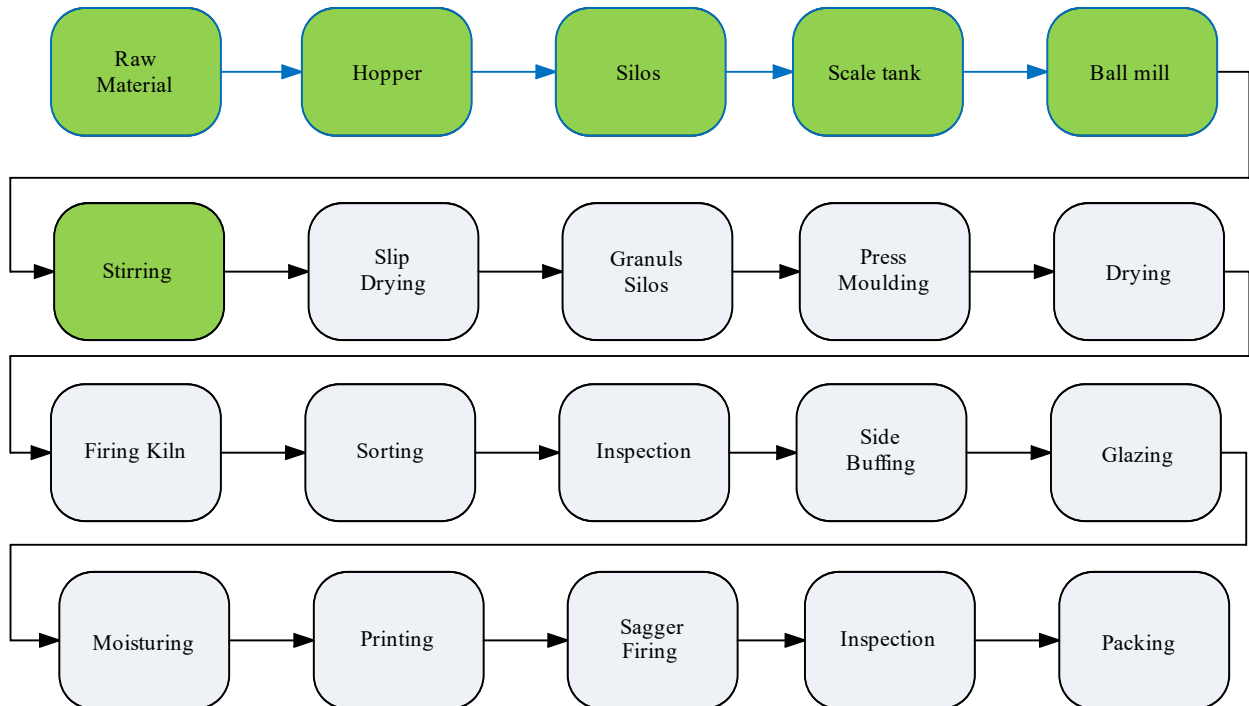


FIG. 2. PROCESS FLOW LAYOUT IN FORTE CERAMICS

nine on one line and batch of eleven on second line is formed with the help of different sensors. After the batch making the control system gives signal and transfers the batches to the kiln. In this section the tile is heated with high temperature to become hard. Then tiles are transferred towards the inspection section. In this section the strength of each tile is checked, the weak tiles fall from the conveyer and the hard tiles pass under the brushes again to remove the moisture. Then these tiles are transferred towards the glazing section, and then they are moved towards the painting section where the tiles are painted by desired colors and designs. Then the tiles are transferred towards the rollers where batches of nine and eleven are made and then the roller transfer the batches towards the second kiln where they again get heated. After this section the tiles are transferred towards sorting section where the experienced workers sort the tiles in five types such as:

- (a) Classic
- (b) Standard
- (c) Commercial
- (d) Sub-standard
- (e) Waste

After sorting the workers pack the different types of tiles in different boxes and then they are transported to the store.

4. DEVELOPMENT OF SIMULATION MODEL IN SIMIO

The data collected from industry is analyzed using Simulation software called SIMIO. A complete simulation model using SIMIO software for current and different versions of the process is developed. Changes are made to system in simulation to see whether the system

improves or deteriorates. Changes that improve the overall results are recorded. Improvements are made according to the wastes generated and actual capacity of industry is calculated using the assumption in case of zero defected parts and utilizing complete capacity of machines. These improvements are made after analyzing the current and improved shop floor model in SIMIO Software.

Simulation is used to imitate the real system in order to study the processes in detail. The machines used in shop floor have already been discussed. Each machine is used as a resource in simulation model where parts are processed and transportation is used to show parts move from one machine to another with the time taken as in real system. The number of tiles damaged or scraped at each machine is added to the sink. Four types of tiles are produced at the end of each shift that are shown in the model.

The data collected is related to:

- (a) Inter arrival time
- (b) Processing times of each station
- (c) Transportation time
- (d) Throughput
- (e) Wastes produced at different sections
- (f) Amount of production of different category tiles

As the production department is automated with some manual works, that is why the exact data was provided by the company.

4.1 INTERARRIVAL TIME, PROCESSING TIMES, TRANSPORTATION TIME

The following data was collected from the tiles production. Table 1 shows the data of inter arrival time, processing times and Transportation times.

4.2 Tiles Pressed by Press Machine (Per Shift)

The amount of tiles which the press machine pressed per shift is taken. The average data is taken from industry for use in simulation model for press machine. Table 2 shows the data of tiles pressed by press machine per shift.

4.3 Throughput

Throughput is defined as the total good parts produced per unit time. So the throughput provided by the forte industry is shown in Table 3.

TABLE 1. INTER ARRIVAL TIME, PROCESSING TIMES, TRANSPORTATION TIME

No.	Description	Time (sec)	
		Line 1	Line 2
1.	Press	7.15	7.15
2.	Conveyor	5.57	5.57
3.	Brushing & drying	1	1
4.	Conveyor	7.4	7.25
5.	Biscuit Kiln	1501.8	1501.8
6.	Conveyor	1	1
7.	Inspection	1	1
8.	Conveyor	2	2
9.	Brushing & buffering	No delay	No delay
10.	Glazing	1	1
11.	Conveyor	3.7	3.7
12.	Moisture	No delay	No delay
13.	Conveyor	1	1
14.	First printing	2.25	2.25
15.	Conveyor	12.06	12.06
16.	Second printing	2.25	2.25
17.	Conveyor	1	1
18.	Glaze kiln	1452.6	1452.6
19.	Conveyor	7	7
20.	Packing	0.3	0.3
21.	Conveyor	10	10

TABLE 2. TILES PRESSED BY PRESS MACHINE (PER SHIFT)

Press Machine	23637 Tiles
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TABLE 3 THROUGHPUT

Item	Total Quantity	Throughput (Good Parts)
Tiles produced	17348	2169

4.4 Wastes Produced at Production Lines

The big issue of Forte Ceramics industry is that the wasted parts are very high. The data collected for this purpose is average data and was collected at specific points. The data also shows the waste produced before entering machines. Table 4 shows the wastes produced before different points and the overall waste parts per shift.

All these objects were used to develop the simulation model. The machines were arranged in the SIMIO model as in the real system. After feeding all the collected data in the SIMIO software the final model was developed.

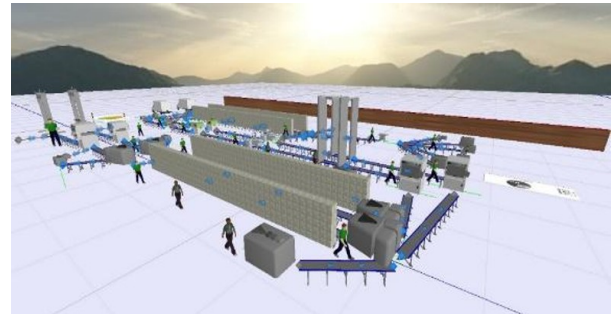
4.5 Modeling of the Production Process in SIMIO Software

SIMIO software was used as a tool to study the current production process and analyzed the cycle time, throughput, work in process, inventory and production rate of tiles. Wastes were identified at different workstations and the reasons behind them. Simulation model of the process is shown in following Fig. 3(a-c). The snapshots were taken after verification and validation.

4.6 Verification

The verification phase involves that whether the collected data was right and the model represents the real system. Since the data was provided by the industry that is why the data is actual and correct. After this the simulation model was developed and checked so many times to verify the sequence of the workstations, the tiles entering

and leaving each machine, wastes produced at each machine, time taken by each batch of tiles to move from one machine to another and quality check of four different types of tiles by the facility.



(a) SCREENSHOT OF SIMIO GRAPHIC MODEL



(b) SCREENSHOT OF SIMIO MODEL IN VERY START OF LINE



(c) TOP VIEW OF MODEL FROM START OF LINE TO PACKAGING

FIG. 3. SIMULATION MODEL OF THE TILES PRODUCTION AREA IN SIMIO

TABLE 4. WASTES PRODUCED AT DIFFERENT POINTS

.Machines	Parts Enter	Wasted Before Entering Machine	Percentage (%)
Dryer	23013	624	2.71
B.Kiln	20807	2206	10.60
G.Kiln	18442	2365	12.82
Packing	17895	-	-

Fig.3(a-c) shows the simulation environment of the facility where each machine is a resource and placed in exact position as in real scenario. The workers are standing with the machines to operate them accordingly. Two production lines represent the processing of tiles. The truck at the end of line shows that after four different tiles have been produced they are loaded onto truck for storing and shipping.

4.7 Validation

In the validation phase the results from simulation model and the real system are checked for any differences. So the simulation results were compared with the real system results.

Fig. 4 shows complete simulation model of the production department while the model is in run mode. The transportation of tiles between the machines is shown with the help of arrows. Pie chart in the figure shows that 60% of the stations are starved and 40% are processing as defined by the color codes.

The status pie in Fig. 5 shows comparison of two or more values at run time. Processing and starved

workstations are compared as shown in status pie. The chart that is divided into 20% for each value where the values consist of starved, processed, blocked, failed and off shift number of parts. During run every 2 highest values are compared.

Fig. 6 shows the throughput of four types of tiles in SIMIO software. The data from here is used in rest of calculations in this study. The number of each type of tile leaving the system is highlighted in Fig.6.

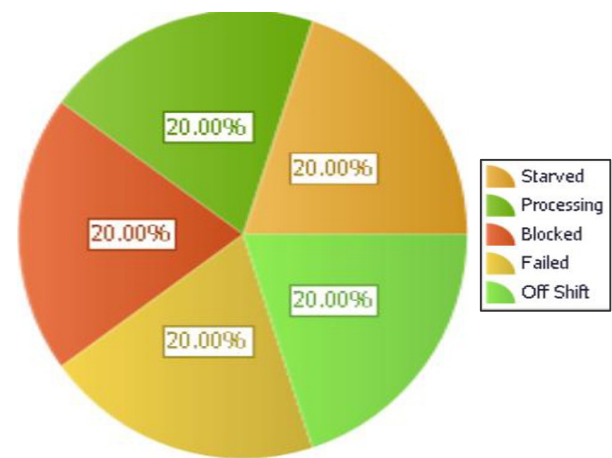


FIG. 5. STATUS PIE CHART OF COMPLETE SIMULATION MODEL

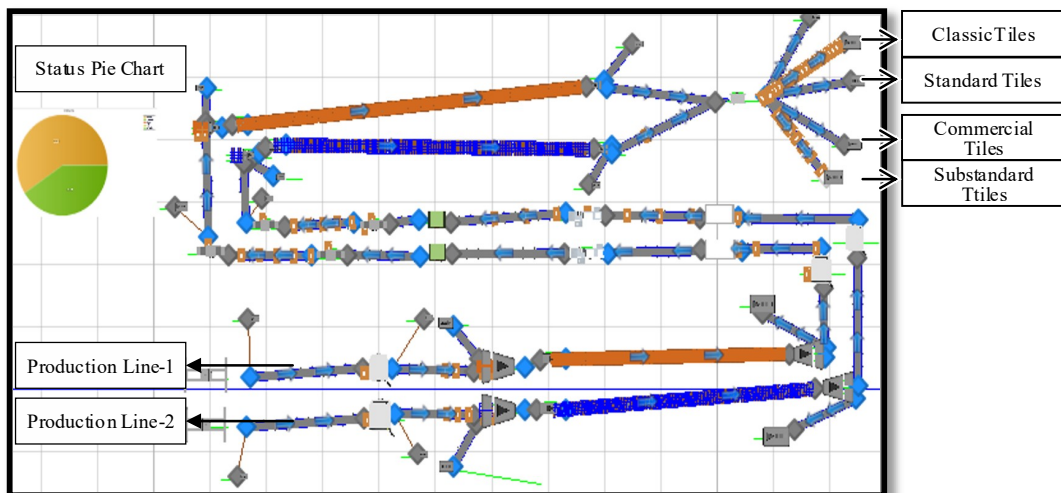


FIG. 4. COMPLETE MODEL IN SIMIO (SCREENSHOT WHILE RUNNING THE MODEL)

The error in the results in Table 5 is due to the wear and tear in the machines in the real system, personal errors and environmental errors. The differences of the results are small in percentage so the model is valid.

Table 6 shows that with inter-arrival time of 7.15sec in real system the wasted ones are 6289 parts which is 26.6% of total parts (17343) entering the system. Wastage of more than 26% is not bearable for any industry. This study focuses on reducing the waste with least changes in production process in order to cope up with the waste that significantly impacts the profit.

4.8 Amount of Production of Different Categories of Tiles

There are four types of tiles such as classics, standard, commercial and sub-standard tiles produced in Fort Ceramics industry. The four types depend on the quality and demand of tiles. Classic being the top quality is 66% of overall production, standard tile is 17.60%, and commercial is 7.4% and sub-standard is 4% of production. The following data about the four types is shown in Table 7.

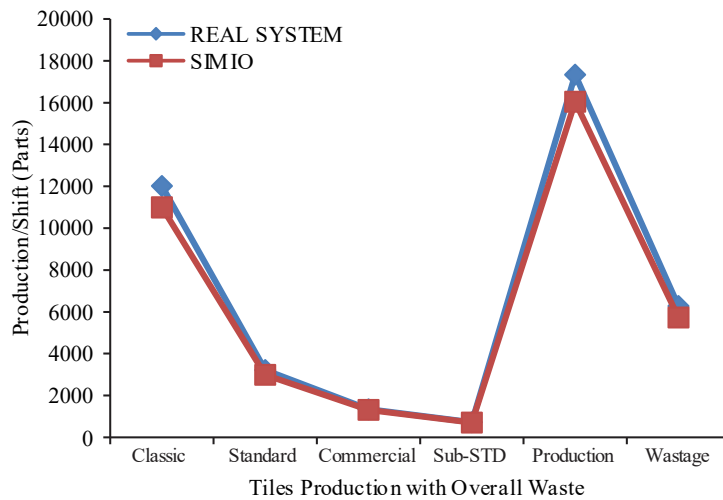


FIG. 6. RESULTS OF THE THROUGHPUT OF FOUR TYPES OF TILES IN SIMIO SOFTWARE

TABLE 5. VALIDATION- FIND DIFFERENCES BY COMPARING THE RESULTS OF REAL SYSTEM AND SIMULATIONS

Items	Real System	SIMIO	Difference	Error (%)
Classic Tiles	12028	11003	1025	8.52
Standard Tiles	3229	3002	227	7.03
Commercial Tiles	1354	1328	26	1.92
Sub-standard Tiles	737	718	19	2.58
Throughput	17348	16051	1297	7.48
Wastage	6289	5737	552	8.78

TABLE 6. OVERALL WASTES PARTS PER SHIFT

	Parts Wasted	Percentage with 17348 Parts	Percentage (%)
Total Wasted Parts	6289	0.266	26.60

5. RESULTS

After the simulation model, the results are analyzed to find the respective processes. These results include the performance measures, comparison of simulation results with real ones, throughput, and work in process and production quantity.

5.1 Performance Measures

Performance measures are quantifiable indicators which show the performance of organization that how the organization is achieving its desired objectives. Different managers in organization routinely review various performance measures and assess such things as production, demand and operating efficiency in order to get a more objective sense of how their business is operating and whether improvement is required. Table 8 shows the performance measures from simulation model results.

Table 8 shows that the work in process of the current system is 2268.25parts/shift and the cycle time is 0.7813sec for each part. The throughput is basically good parts produced per hour that is 2006.4 and the waste produced per shift is 5737parts. The waste produced is too high and it is a big issue in frontier forte ceramics.

5.2 Comparison of Simulation Result with Real System

After completing the simulation model it gives the result so the comparison between real system results and simulation model results are given in Table 9 and also shown in Fig. 6. Where it can clearly be depicted that SIMIO and real system results are almost same with little difference. The graph in Fig. 6 shows two lines red and blue, the blue line represents real system data that is currently being produced at FORT Ceramics industry while the red line represent SIMIO results that has been obtained after putting data in software.

The result in Fig. 7 shows that there are small differences in the real system data and simulation results that might be due to system errors. As the difference is less than 10% that is within the acceptable range therefore, the data is valid.

5.3 Throughput versus Work in Process

After completing the simulation model the actual inter arrival time was 7.15 sec. The performance of the system was then checked by changing the inter arrival time. Table 10 shows the difference in throughput and WIP by changing the inter arrival time.

TABLE 7. AMOUNT OF PRODUCTION OF DIFFERENT CATEGORY TILES

Category	Tiles Produced (Parts/Shift)	Percentages of Types of Tiles with Total Sum	Percentage (%)
Classic	12028	00.66	66.00
Standard	03229	0.176	17.60
Commercial	01354	0.074	7.40
Sub-Standard	00737	00.04	4.00
Reject Parts	00547	0.0297	2.97
Sum of all tiles Produced	17895		

TABLE 8. PERFORMANCE MEASURES (SIMIO RESULTS)

Performance Measures	Values
Work in process (Parts/shift)	2,268.2
Cycle time(Sec)	0.7813
Throughput(Parts/shift)	2006.4
Wastage(Parts/shift)	5737

Similarly, Fig.8 shows the graph between throughput and WIP where critical WIP can be easily estimated by the peak point. The figure shows the effect of change in interval arrival time on WIP and throughput. Similarly, it shows that when decreasing the inter arrival time the throughput increase till inter arrival time of 6.25 sec and after this the throughput is constant. On the other hand, when decreasing the inter arrival time the WIP increasing. The yellow dot shows current and real time data as the inter-arrival time is 7.15 seconds. The grey dot shows 2123 parts as throughput with critical work in process of 3304.6 parts. It is called critical because by decreasing the inter arrival time there is no specific change and throughput remains constant as shown in Fig. 8.

5.4 Cycle Time versus Work in Process

After completing the simulation model, the actual inter arrival time was 7.15 sec. The performance of the system was then checked by changing the inter arrival time. Table 11 and Fig. 9 show the difference in cycle time and WIP level by changing the inter arrival time.

Similarly, Fig. 9 shows the graph between cycle time and WIP. We have to select the point in cycle time where more parts are produced in least time. The Fig. 8 shows the effect of change in interval arrival time on WIP and cycle time. Similarly, it shows that when decreasing the inter arrival time the cycle time shows constant result till

TABLE 9. COMPARISON OF REAL SYSTEM AND SIMIO RESULTS

Performance Measures of Various Tiles	Real System (Parts)	SIMIO (Parts)	Difference (Parts)	Error (%)
Classic	12028	11003	1025	8.52
Standard	3229	3002	227	7.03
Commercial	1354	1328	26	1.92
Sub-standard	737	718	19	2.58
Production per shift	17348	16051	1297	7.48
Wastage	6289	5737	552	8.78

classic	[DestroyedObjects]	FlowTime	TimeInSystem	Average (Ho...	1.0140
				Maximum (Ho...	1.0322
				Minimum (Ho...	1.0024
				Observations	11,003.0000
	InputBuffer	Throughput	NumberEntered	Total	11,003.0000
			NumberExited	Total	11,003.0000
commercial	[DestroyedObjects]	FlowTime	TimeInSystem	Average (Ho...	0.8501
				Maximum (Ho...	0.8648
				Minimum (Ho...	0.8386
				Observations	1,328.0000
	InputBuffer	Throughput	NumberEntered	Total	1,328.0000
			NumberExited	Total	1,328.0000
standard	[DestroyedObjects]	FlowTime	TimeInSystem	Average (Ho...	0.8502
				Maximum (Ho...	0.8683
				Minimum (Ho...	0.8386
				Observations	3,002.0000
	InputBuffer	Throughput	NumberEntered	Total	3,002.0000
			NumberExited	Total	3,002.0000
substandard	[DestroyedObjects]	FlowTime	TimeInSystem	Average (Ho...	1.0140
				Maximum (Ho...	1.0286
				Minimum (Ho...	1.0024
				Observations	718.0000
	InputBuffer	Throughput	NumberEntered	Total	718.0000
			NumberExited	Total	718.0000

FIG. 7. RESULTS OF REAL SYSTEM AND SIMULATIONS IN SIMIO

inter arrival time of 6.25 sec and after this the cycle time increasing. On the other hand, by decreasing the inter arrival time the WIP increases. In Fig. 9 the grey dot shows inter-arrival time of 6.25 sec where the work in process is critical having least cycle time. The yellow dot shows the inter-arrival time of 7.15 sec which gives 2268.2 tiles per shift having cycle time of 0.78 seconds.

Therefore, from Table 11 and Fig 8 illustrate that the critical work-in-process level achieved is 3304.618 on inter arrival time of 6.25 sec.

5.5 Improvements in Production Quantity

After completing the model and finding the critical work in process, the model is checked for the inter-arrival time of 6.25 sec and then the results were compared. Table 12 and Fig. 10 show the improvements between the real time results and the simulated results by reducing the inter arrival times.

Result in Fig. 10 illustrate that the production per shift is increased by 933 tiles. It means that by changing the inter arrival time from 7.15-6.25 sec increases the overall

TABLE 10. RESULTS OF THROUGHPUT VS. WORK IN PROCESS

No.	Inter-Arrival Time (Sec)	Work in Process (Parts)	Production/Shift (Parts)	Throughput (8 Hours/Shift)
1.	9.15	1777.7	12794	01599.3
2.	8.15	1997.3	14072	001759
3.	7.15	2268.25	16051	2006.40
4.	6.25	3304.6	16984	002123
5.	6.15	3492.2	16929	2116.12
6.	5.15	5875	17003	2125.43
7.	4.15	9438.17	17066	02133.3
8.	3.50	12805.54	17098	2137.23
9.	3.30	14132.5	17103	02137.9
10.	3.15	15228	17123	2140.33
11.	3.00	16433.32	17163	2145.32
12.	2.90	17300	17185	2148.09
13.	2.70	19547.1	17196	2149.55
14.	2.50	21937.4	17216	002152
15.	2.15	27457.7	17245	2155.6

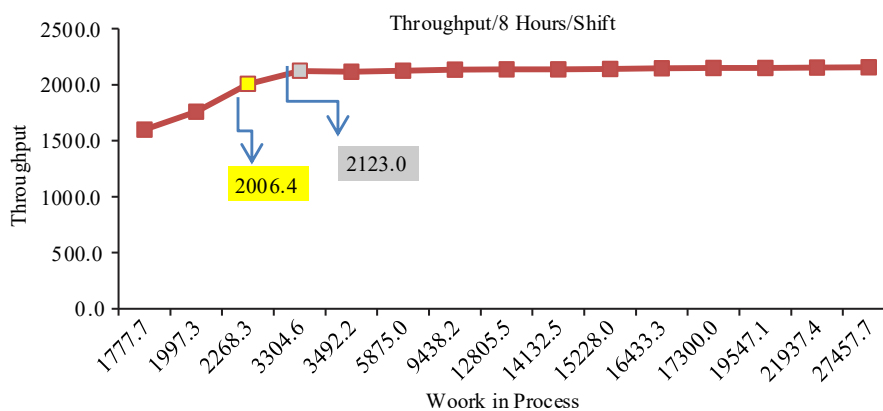


FIG.8 THROUGHPUT VS. WORK IN PROCESS

production while the WIP is not increasing from critical WIP level.

The following significant results are achieved that impact the overall production using simulation tool shown in Table 13. It can be seen that by decreasing the inter

arrival time from 7.15-6.25 seconds, the throughput increases which results an increase of revenue by PAK RS. 35402.00 So when applied with 25% of sale price gives a profit of PAK RS 26551.50. This results in a substantial improvement in tiles production to generate higher revenues.

TABLE 11. RESULTS OF CYCLE TIME VS. WIP

No.	Inter-Arrival Time (sec)	Work in Process (Parts)	Cycle Time (sec)
1.	9.15	1777.7	0.7652
2.	8.15	1997.3	0.7743
3.	7.15	2268.25	0.7813
4.	6.25	3304.6	0.9987
5.	6.15	3492.2	1.3394
6.	5.15	5875	1.4437
7.	4.15	9438.17	1.8107
8.	3.50	12805.54	2.0069
9.	3.30	14132.5	2.0625
10.	3.15	15228	2.0943
11.	3.00	16433.32	2.129
12.	2.90	17300	2.1529
13.	2.70	19547.1	2.2946
14.	2.50	21937.4	2.3981
15.	2.15	27457.7	2.6069

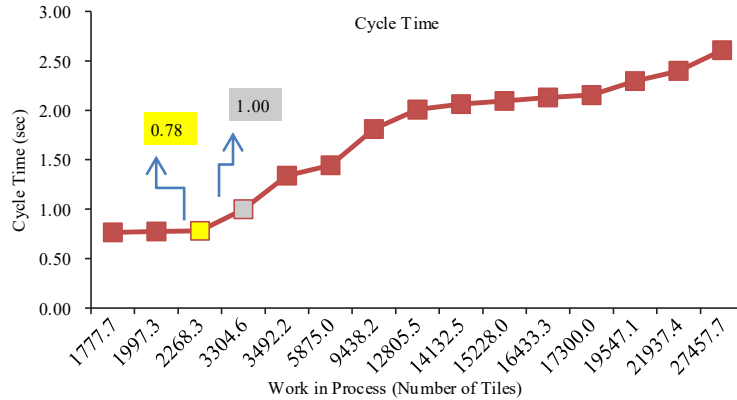


FIG. 9. CYCLE TIME VS. WORK IN PROCESS

TABLE 12. RESULTS OF INTER ARRIVAL TIME

Items	Inter-Arrival Time (sec)	
	SIMIO 7.15	SIMIO 6.25
Classic	11003	11,649
Standard	3002	3,210
Commercial	1328	1,363
Sub-Standard	718	762
Production Shift	16051	16,984
Throughput	2006.375	2123

6. DISCUSSION

In this study the tiles production of the forte ceramics is conducted. From the Inter Arrival Time, Processing Times and Transportation Time it is found that the big issue of Forte Ceramics industry is that waste is produced in tiles production. That impact their overall production and loss of revenue. SIMIO software was used as a tool to study the current production process and analyzed the cycle time, throughput; work in process, inventory and production rate of tiles. Model was created and simulated in SIMIO of the current production department at different cycle times. The results were analyzed to find the respective processes which improve the production rate to a greater extent as discussed in the following section.

The results in Table 8 show that the work in process of the current system is 2268.25 parts/shift and the cycle time is 0.7813sec for each part. The throughput is basically good parts produced per hour that is 2006.4 and the waste produced per shift is 5737 parts. The waste produced is too high and it is a big issue in frontier forte ceramics. After completing the model and finding the critical work in process, the model is checked for the inter-arrival time of 6.25 sec and then the results were compared. Table 12 and Fig. 10 show the improvements between the real time results and the simulated results by reducing the inter arrival times. These improvements are related to increase in production quantity of all types of tiles. In addition to that an increase in the production

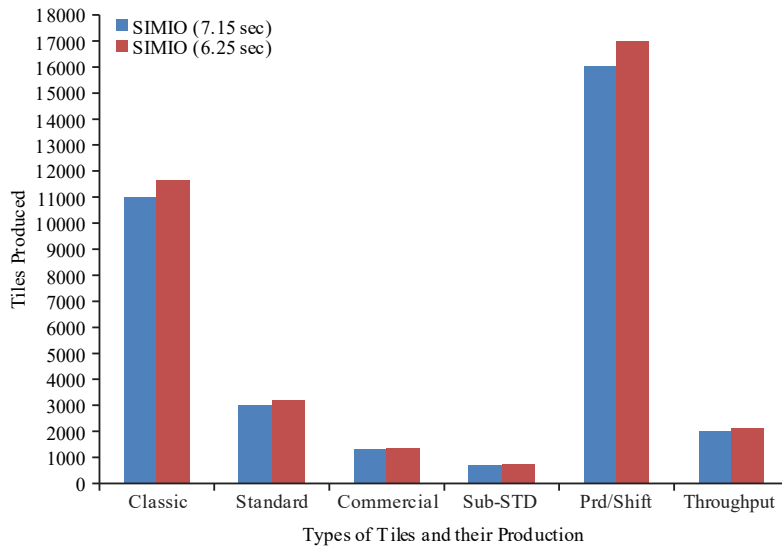


FIG. 10. RESULTS OF COMPARISON OF NUMBER OF TILES PRODUCED FOR INTER ARRIVAL TIME OF 7.15 AND 6.25 SEC.

TABLE 13. INCREASE IN PRODUCTION OF TILES ALONG WITH SALE PRICE

Items	Current Production in SIMIO (7.15 sec)	Simulated Production in SIMIO (6.25 sec)	Increase in Production of Good Parts	Price/Tile (PAK RS.)	Total Price (PAK RS.)
Classic	11003	11,649	646	40/-	25840/-
Standard	3002	3,210	208	35/-	7280/-
Commercial	1328	1,363	35	30/-	1050/-
Sub-standard	718	762	44	28/-	1232/-
Production/shift	16051	16,984	933	Not Applicable	
Throughput	2006.37	2123	117	Not Applicable	
				Total Sale Price	3540/-

shift and WIP could also be achieved with reduced inter arrival time. The impact of the overall production using simulation tool is shown in Table 13. It can be seen in the results that by decreasing the inter arrival time, the throughput increases which results an increase of revenue. So when applied with 25% of sale price gives a substantial profit that is a big improvement in the process.

One of the limitations of this study is that the design changes and especially the layout changes are not analyzed in the simulation model. The design changes will have an impact on the overall production of the tiles.

7. CONCLUSION

In this study simulation model for the production facility of Ceramic Company is developed. The results represent a significant improvement of the production process in productivity, cycle time and throughput time to optimize the system. There is a substantial increase in production of each type of tile by changing the inter-arrival time from 7.15-6.25 seconds. In addition, significant results obtained are summarized here:

- (a) The critical work in process is achieved at throughput 2123 parts with WIP 3304 parts which almost remains constant after increasing the throughput.
- (b) Cycle time of 1.00 sec is achieved at WIP of 3304 parts.
- (c) Simulation results show an increase of 646 classic tiles as each piece price is PAK RS. 40.00 which could gives total of PAK RS. 25840.00 increase in sales.
- (d) Standard tiles are increased by 208 and each tiles price is 35 Rs that could give total of PAK RS. 7280.00 increase in sales.
- (e) Similarly, the increase in sales of commercial and Sub-standard tiles are PAKRS. 1050.00 and PAK RS. 1232.00 respectively.

It is concluded that by decreasing the inter arrival time, throughput can be increased, therefore the real time of 7.15sec is reduced to 6.25sec in SIMIO software. By decreasing the inter arrival time there is an increase in the throughput which improves the revenue. Therefore, data analyzed in the simulation tool shows better results that represent a substantial improvement in the production process.

FORTE Ceramics Company can gain from this study if they act on the following recommendations,

- the production facility should change the conveyer's type to reduce the number of wasted tiles on the line,
- the company must employ Push pull interface,
- must apply design changes in production line to reduce the number of wasted tiles,
- reduce their raw material inventory by placing order on specific time period.

We have not described the design layout in the simulation model, so future research could focus on models of designing the production process, changes in production line to reduce the number of wasted tiles, methods to reduce their raw material inventory and develop models to reduce the transportation time between the machines etc. Repeat studies on other models of the same process in order to enhance the reliability of the findings would be beneficial.

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