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Research Paper

APPLICATION OF TAGUCHI METHOD TO ANALYZE THE IMPACT OF COMMON PROCESSES IN MULTISTAGE PRODUCTION SYSTEM

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This paper examines the optimum level of batch size in bottleneck facility and to analyze the effect of common processes on throughput and cycle time in a production system under uncertain situations created by machine breakdown. Few simulation models are carried out by comparing the existing model and proposed model of the production system in the company. The models are verified and validated with the historical data from the company. Taguchi approach for orthogonal array is used in designing experiment. The experimental settings are executed in WITNESS, a simulation package. The delivery performance, average production cycle time and production quantity for both line 1 and line 2 are examined. It is observed that the variation in level of common process in the system has significant impact on the production quantity and cycle time. The main contribution of this paper is determination of the optimal level of batch size in a bottleneck resource. This approach can be generalized to any multistage production system, regardless of the precedence relationships among the various production stages in the system.

Keywords: Batch size, Throughput, Cycle time, Taguchi approach, WITNESS

INTRODUCTION

Multistage production planning is a system which transforms or transfer inventories through a set of connected stages to produce the finished goods. The stages represent the delivery or transformation of raw materials, transfer of work-in progress between production facilities, assembly of component parts, or the distribution of finished goods. The fundamental challenge of multi-stage production is the propagation and accumulation of uncertainties that influences the conformity of the output. The present study is concern with such a multistage system and simulation is chosen to analysis the objectives. A simulation is a surrogate for experimenting with a real manufacturing system. It is often infeasible or not cost-effective to do an

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experiment in a real process. Few simulation models are used to analyze various effects of uncertain factors namely machine breakdown.

Machine breakdown means the failure or stoppage of machines for unknown reasons and a representation of interruption in the process. It yields a reduction of capacity level and delays the release of products or sub assemblies. In this production system there is no alternative machines are available if the existing machines fail and no alternative routing can be executed if an order needs to be expedite.

THE PRODUCTION SYSTEM

The above figure shows the production line of stator core only. There are two different end products, product SA15 (line 1) and A115 (line 2) of this system. Parts are placed in two separate production lines. Each production line contains 7 (seven) different processing namely blanking, riveting, coining, T'Bolt milling, second coining, OD-Turning and slot insulation and ended up with single end products after the assembly operation. Figure 1 is showing the existing production layout of the company. Presently the company use the conventional production processes with known lead time.

EXPERIMENTAL DESIGN

Few simulation models are carried out based on the existing production layout (Figure 1) of the company. The existing layout is modified to introduce common processes in the system.

Figure 2 shows the proposed layout that incorporates commonality dimension. Two models are developed in WITNESS simulation package.

In this paper, two factors are considered and the effects of these factors on the system performance are tested. The levels of common

Figure 1: Existing Production Layout

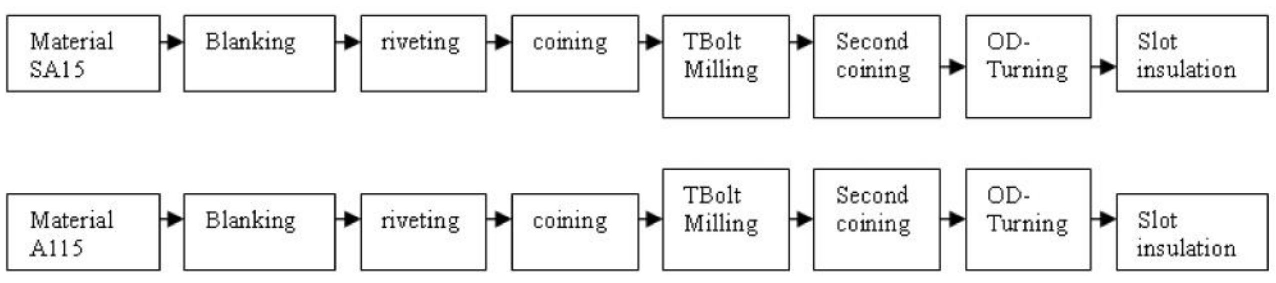


Figure 2: Proposed / Modified Production Layout

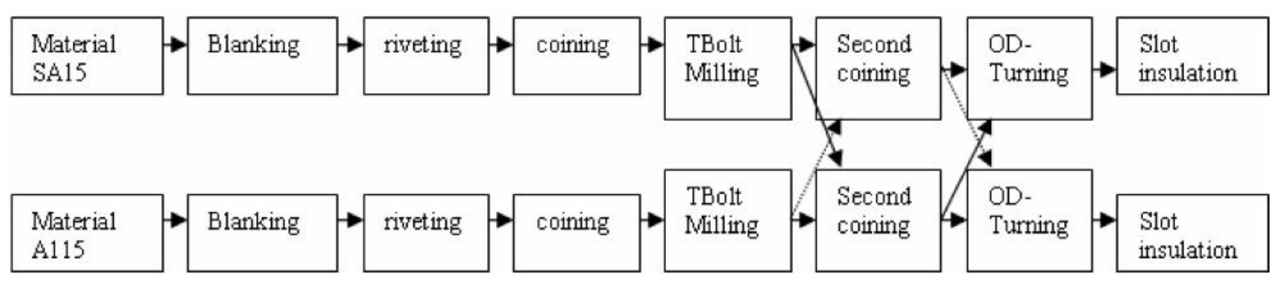


Figure 3: Experimental Design

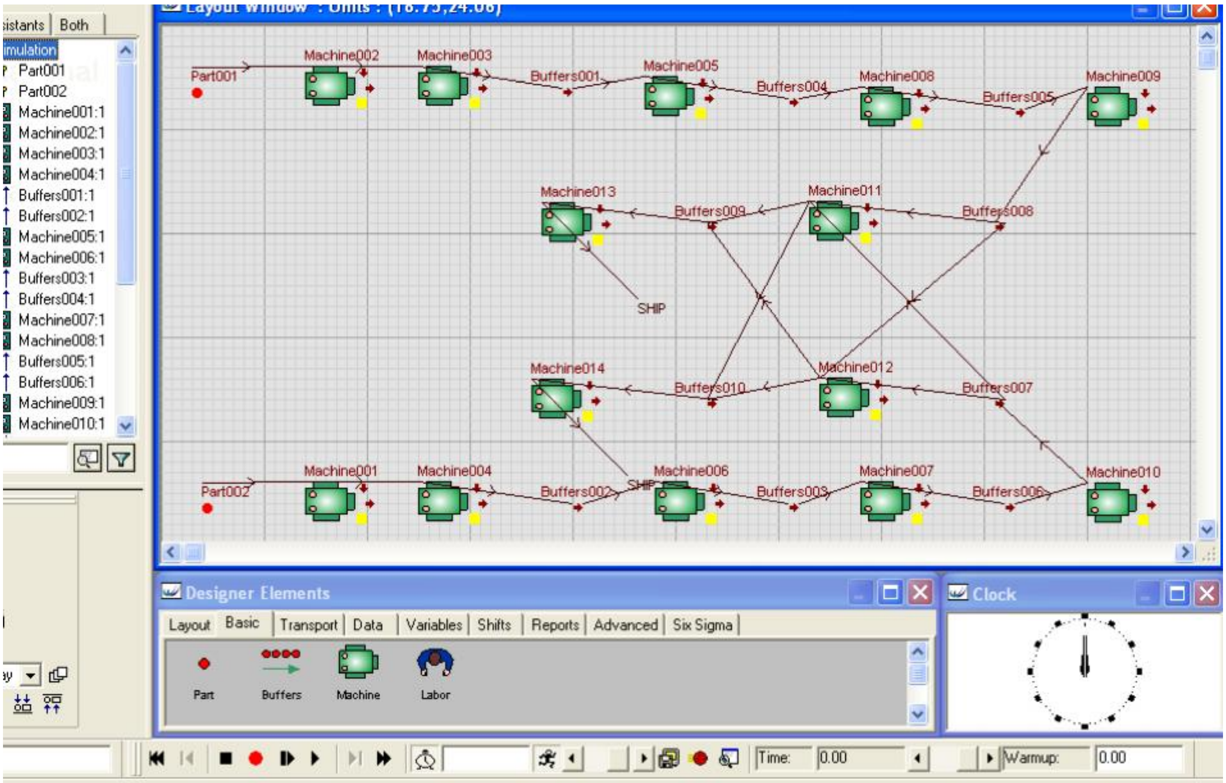


Table 1: Control Factors and Their Levels for Taguchi method			
Control factors	**Level 1**	**Level 2**	**Level 3**
Batch Size at the bottleneck station (that is OD-Turning), A	450	900	1500
Common Process, B	0	2	4

process and production batch size at blockage station are considered as control factor or decision variable is shown in Table 1. The machine breakdown is considered as noise factor. Analyze of mean value, signal to noise ratio and ANOVA are used to analyze the effect of batch size and common process on production cycle time and throughput quantity. Before confirmed the results, interaction effect are observed to make sure that the characteristic of the control factors is additive. The ranges of factor levels are selected based on capacity limitation and in consultation with the engineers in the company. Since this study contains two control factors of three levels.

Each experiment is simulated, the average value and its signal to noise ratio are obtained and analyzed. In order to evaluate the experimental results statistically, analysis of variance (ANOVA) is applied. The same are used to see the effect of the interaction.

Table 2: Cycle Time and Setup Time at Each Stage

SL.NO	OPERATION	CYCLE TIME FOR LINE 1 (Sec)	CYCLE TIME FOR LINE 2 (Sec)	SET UP TIME (Sec)
1.	Blanking	27	27	90
2.	Riveting	24	24	20
3.	Coining	30	28	60
4.	T'Bolt	35	35	15
5.	Sec coining	32	32	60
6.	OD-Turning	44	71	30
7.	Winding	23	18	20

DATA COLLECTION AND VALIDATION

In order to build the simulation models and to set the initial level of various factors in the model, data were collected. The data includes cycle time at each stages and setup time.

The historical data shows that the cycle time and the setup time for OD-Turning station are much higher than the others. It is the bottleneck of the system shown in Table 2. Therefore in this paper different levels of batch size are considered to analyze the effects of production quantity and cycle time.

DATA ANALYSIS AND DISCUSSION

Tables 3 and 4 shows the summary of experimental results for the average production quantity and production cycle time with corresponding S/N ratio for each exercise of Line 1 and Line 2 are observed. The smaller the better characteristic is used for cycle time and in calculating the corresponding S/N ratio. The larger the better principle is adopted for production quantity and for corresponding S/N ratio.

Since the experiment design is orthogonal, the effect of batch size and common process for different levels are separated out. Table 5 shows the response for mean and S/N ratio for production quantity and the same for production cycle time is shown in Table 6 for both of the production lines. Since the characteristic of these factors for production quantities are larger the better, the batch sizes are chosen based on larger mean and S/N ratio for production level and for production cycle time, the smaller the better policy is used. The selection in later case is based on the smaller mean and larger S/N ratio. Because the larger the S/N ratio the smaller the variance are around the desired value.

Table 3: Experimental Results of Production Quantity with Corresponding S/N Ratio

Experiment No	Batch size	Common Process	Production Quantity			
			Line 1		Line 2	
			Mean	S/N ratio Larger	Mean	S/N ratio Larger
1	1500	0	12700	82.07607	20200	86.10702
2	1500	2	13200	82.4115	22600	87.0822
3	1500	4	13500	82.6067	22800	87.1587
4	900	0	12800	82.1442	21900	86.8089
5	900	2	14800	83.4052	23600	87.4582
6	900	4	19900	85.9771	26300	88.3991
7	450	0	14300	83.1067	21900	86.8089
8	450	2	14300	83.1067	23100	87.2722
9	450	4	14800	83.4052	23700	87.4950

Table 4: Experimental Results of Production Cycle Time with Corresponding S/N Ratio

Experiment No	Batch size	Common Process	Production Cycle time (Min)			
			Line 1		Line 2	
			Mean	S/N ratio Smaller	Mean	S/N ratio Smaller
1	1500	0	5498	-74.8041	4591	-73.2381
2	1500	2	4765	-73.5613	4765	-73.5613
3	1500	4	4316	-72.7016	4316	-72.7016
4	900	0	5158	-74.2496	4177	-72.4173
5	900	2	4140	-72.3400	3826	-71.6549
6	900	4	3723	-71.4179	3974	-71.9846
7	450	0	4812	-73.6465	3885	-71.7878
8	450	2	4107	-72.2705	4450	-72.9672
9	450	4	4119	-72.2958	3741	-71.4598

It shows that an increase in batch size yield an increase in production level in the system, but the capacity restrains the further increase in the batch size. Thus, based on response Tables 5 and 6, the batch size and common process are chosen as 900 and 4 respectively.

Figures 4 and 5 shows the interaction effects of variation in levels of control factors for (a) mean value and (b) S/N ratio of production quantity for Line 1 and Line 2. Figure 4 shows there is an interaction at level 3 (i.e., in level 1500), similarly the interaction

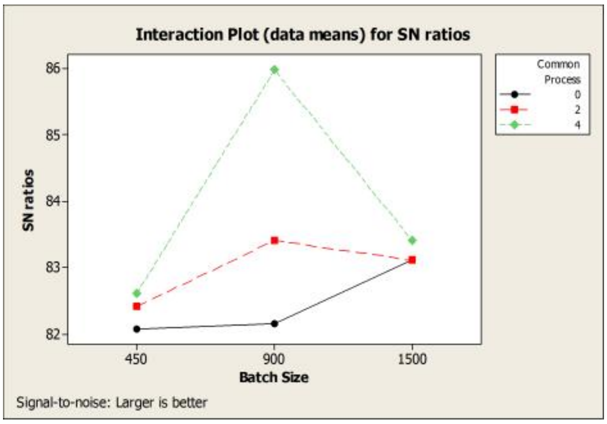
Table 5: Response Table for Production Quantity for Line 1 and 2 (the Larger the Better)

Level	Production Quantity							
	Line 1				Line 2			
	Mean		S/N ratio		Mean		S/N ratio	
	Batch Size	Common Process	Batch Size	Common Process	Batch Size	Common Process	Batch Size	Common Process
Level 1	13133	13267	82.36	82.44	21867	21333	86.78	86.57
Level 2	15833	14100	83.34	82.97	23933	23100	87.56	87.27
Level 3	14467	16067	83.21	84.00	22900	24267	87.19	87.68
Diff	2700	2800	1.48	1.55	2067	2933	0.77	1.11
Rank	2	1	2	1	2	1	2	1
Opt	900	4	900	4	900	4	900	4

Table 6: Response Table for Production Cycle Time for Line 1 and 2 (the Smaller the Better)

Level	Production Cycle Time							
	Line 1				Line 2			
	Mean		S/N ratio		Mean		S/N ratio	
	Batch Size	Common Process	Batch Size	Common Process	Batch Size	Common Process	Batch Size	Common Process
Level 1	4860	5156	-73.69	-74.23	4557	4218	-73.17	-72.48
Level 2	4340	4337	-72.67	-72.72	3992	4347	-72.02	-72.73
Level 3	4346	4053	-72.74	-72.14	4025	4010	-72.07	-72.05
Diff	519	1103	1.02	2.09	565	337	1.15	0.68
Rank	2	1	2	1	1	2	1	2
Opt	900	4	900	4	900	4	900	4

Figure 4: Interaction Plot for (a) Mean Value and (b) S/N Ratio of Production Level for Line 1



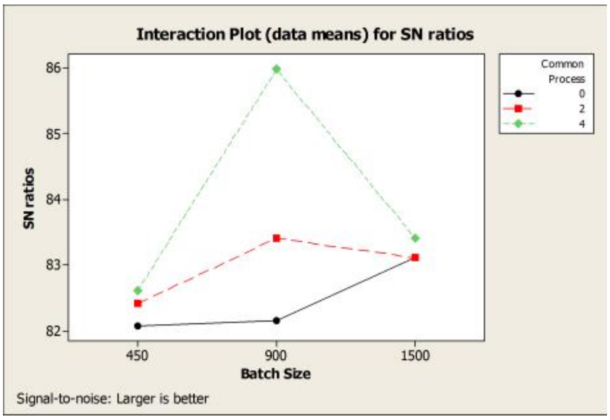


Figure 5: Interaction Plot for (a) Mean Value and (b) S/N Ratio of Production Level for Line 2

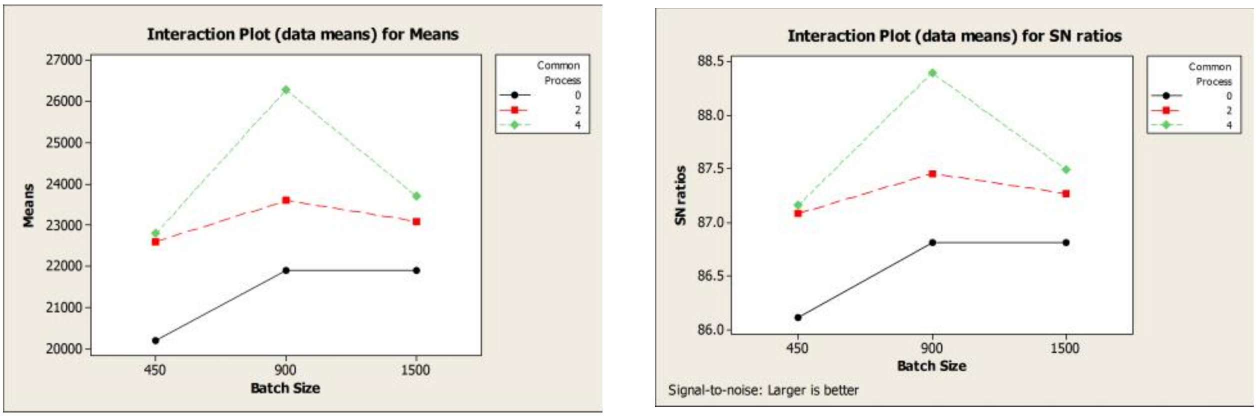


Figure 6: Interaction Plot for (a) Mean Value and (b) S/N Ratio of Production Cycle Time for Line 1

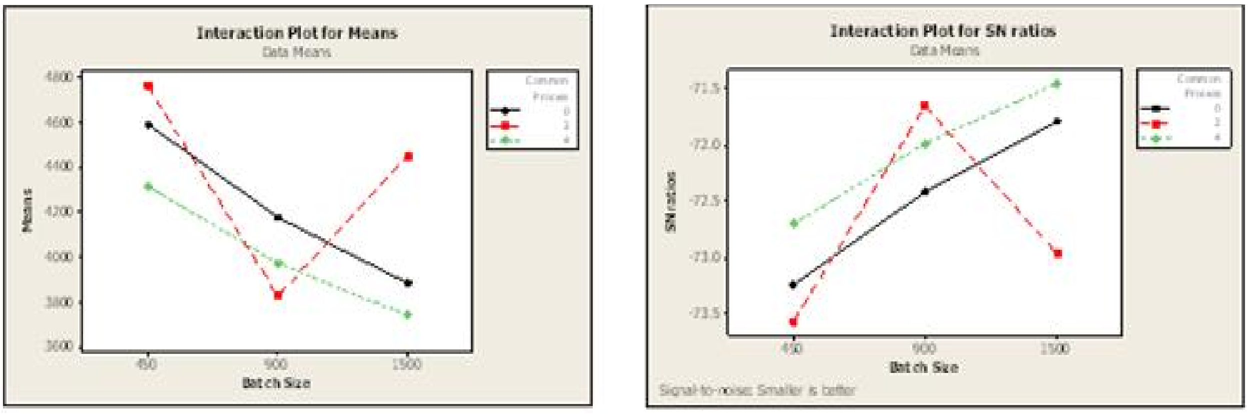
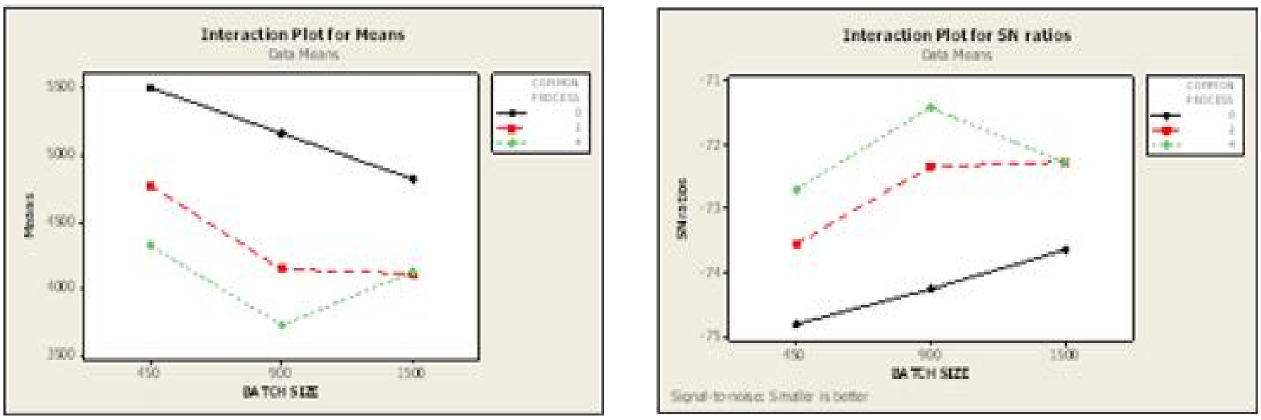


Figure 7: Interaction Plot for (a) Mean Value and (b) S/N Ratio of Production Cycle Time for Line 2



plot for S/N ratio (in level 1500), the interaction is found. There is no interaction is found in Figure 5.

Figures 6 and 7 shows the interaction effects of variation in levels of control factors for (a) mean value and (b) S/N ratio of production cycle time for Line 1 and Line 2. Figure 6 shows the interaction at level in the mean plot. The interaction plot explains, as at batch size level 450 to 1500 there is an interaction with the level of common process 0, 2 and 4. The interaction plot Figure 7 explains, as at batch size level 1500 there is an interaction with the level of common process 2 and 4. The production quantity is peak and cycle time is least when the batch size is 900 and common process is at the highest level.

Tables 7 and 8 shows the ANOVA for production quantity in mean and S/N ratio for Line 1 and Line 2. The same for production cycle time for both of the lines are shown in Tables 9 and Table 10. These tables show the relative importance of the control factors affecting the throughput and cycle time. Both mean and signal to noise ratio ANOVA indicates that batch sizes in OD-Turning station (factor A) and the use of common process (factor B) is statistically significant. The factors have impacts on production quantity and cycle time.

Based on ANOVA (Tables 7, 8, 9 and 10) and response Tables 5 and 6, it is obvious that batch size of 900 in the OD-Turning station and 4 common processes yield the lowest cycle time and maximum throughput in the system.

Table 7: ANOVA for Mean Value and S/N Ratio of Production Quantity of Line 1

Source	Mean value (Line 1)					S/N ratio (Line 1)			
	DF	SS	MS	F	P	SS	MS	F	P
Batch Size	2	10935556	5467778	1.47	0.333	3.2953	1.64764	1.61	0.307
Common Process	2	12402222	6201111	1.66	0.298	3.7422	1.87112	1.83	0.273
Error	4	14897778	3724444			4.0930	1.02325		
Total	8	38235556				11.1305			

Table 8: ANOVA for Mean Value and S/N Ratio of Production Quantity of Line 2

Source	Mean value (Line 2)					S/N ratio (Line 2)			
	DF	SS	MS	F	P	SS	MS	F	P
Batch Size	2	6406667	3203333	4.88	0.085	0.89685	0.448423	5.51	0.071
Common Process	2	13086667	6543333	9.96	0.028	1.88584	0.942920	11.59	0.022
Error	4	2626667	656667			0.32534	0.081335		
Total	8	22120000				3.10802			

Table 9: ANOVA for Mean Value and S/N Ratio of Production Cycle Time of Line 1

Source	Mean value (Line 1)					S/N ratio (Line 1)			
	DF	SS	MS	F	P	SS	MS	F	P
Batch Size	2	533593	266796	6.71	0.053	1.94986	0.97493	6.13	0.060
Common Process	2	1968595	984297	24.76	0.006	7.01025	3.50512	22.05	0.007
Error	4	159029	39757			0.63584	0.15896		
Total	8	2661216				9.59595			

Table 9: ANOVA for Mean Value and S/N Ratio of Production Cycle Time of Line 2

Source	Mean value (Line 2)					S/N ratio (Line 2)			
	DF	SS	MS	F	P	SS	MS	F	P
Batch Size	2	603338	301669	4.43	0.097	2.52084	1.26042	4.14	0.106
Common Process	2	173059	86529	1.27	0.374	0.70909	0.35455	1.16	0.399
Error	4	272427	68107			1.21735	0.30434		
Total	8	1048824				4.44729			

CONCLUSION

The developed simulation models for the manufacturing of the company under consideration are verified and validated as described

- Batch size in the bottleneck (that is, OD-Turning) in combination of common process drastically improves the measured system deliveries. ANOVA for mean and S/N ratio for cycle time and through put indicate that no important factor is omitted from the experiment.
- There is a significant interaction among the common process and the batch size in the bottleneck facility (that is OD-Turning station). It is observed that under the combined effect of common process, the cycle time reduced by 22.6% and 17.40% respectively and throughputs increased by 38% and 28%.
- Based on the least manufacturing cycle time and maximum throughput the optimum batch sizes 900 in the bottleneck (that is OD-Turning) when four common processes ensure the best outcome of the system.
- The mean value and S/N ratio of throughput and cycle time in batch size and common process P-value is less than 1%. Therefore batch size and common process is statistically significant.
- The interaction effect of batch size and common process is statistically significant. Therefore the optimal level yields the lowest cycle time and highest production quantity.

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