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DISCRETE EVENT SIMULATION AND RE-ENGINEERING TO IMPROVE PERFORMANCE OF MANUFACTURING SYSTEM

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Abstract

Simulation is a contemporary IT based technology that was raised to minimize risk and speed–up solution of the problems related to the various scenarios. Discrete Event Simulation is one of the tools that have been widely used in several manufacturing areas and organizations. Using a valid simulation model may result in several advantages for creating better manufacturing alternatives in order to improve system performance. This paper presents results of how computer based simulation can be applied into Manufacturing Process Re-engineering in order to improve performance of the existing facility.

A valid computer simulation model of existing gear manufacturing system was prepared using manufacturing oriented simulator WITNESS. The model was used to find out,

- *Maximum throughput of existing facility.*
- *The actual throughput of the existing facility*
- *The bottlenecks in existing setup*

In order to improve performance, a set of feasible modifications to the existing manufacturing system (Manufacturing Process Re-engineering) was prepared. Computer simulation model can accommodate these modifications in the model and simulate it as well as justify the performance. These modifications were included in the model and impact of modifications was studied.

Introduction

Proper utilization of manufacturing resources is of vital importance to any manufacturing industry in today's world of global competition. Discrete Event Simulation (DES) is extremely valuable tool for analyzing complex manufacturing systems. The behavior of a system as it evolves over time is studied by developing a simulation model. This model usually takes the form of a set of assumptions concerning the operation of the system. These assumptions are expressed in mathematical, logical, and symbolic relationships between the entities or objects of interest, of the system. Once developed and validated, a model can be used to investigate a wide variety of "What-if" question about the real world system. Potential changes to the system can first be simulated in order to predict their impact on performance. Thus, simulation modeling can be used both as an analysis tool for predicting the effect of changes to existing systems, and as a design tool to predict the performance of new systems under varying sets of circumstances.

This paper presents a simulation study carried out at gear manufacturing industry for product named crown wheel and pinion (CWP). This manufacturing industry required analysis of its manufacturing process in an attempt to increase its throughput and overall productivity.

The main objective of this study was to simulate the existing gear manufacturing system and to find whether the current facility gives maximum throughput if not to find out the maximum throughput of the facility and to find the current bottlenecks to the throughput. The study provides information about performance of manufacturing system after reengineering.

Manufacturing System Description

The manufacturing system starts form roll punching operation on finished turned blanks of crown and pinion it end at the packing station where one finished crown and finished pinion are packed pair wise.

The total manufacturing process can be best divided in three stages

1) Soft stage

2) Heat treatment

3) Hard stage and packing

In total there are 30 work stations through which the products have to pass. Out of these 10 workstations are common for processing of finished turned blanks of pinion and crown. There are total 32 workers required for operating this facility per shift. The organization works for 25days /month. Out of these 30 work stations at 8 work stations processing of components involve manual work. Rest 22 workstations have traditional as well as CNC machining facilities. Simulation Run length of 29 days with a break of one day after 6days continuous working is considered. In each shift total working hours are 8 with a break of 30minutes.

Soft stage

The finished turned blanks of crown and pinion enters from the store area to the buffer placed before roll punching workstation. At roll punching the identification number and batch number are punched at outer diameter of crown and pinion blanks. These two components separate from each after this operation. Crown blank goes to buffer which is located before crown gear cut rough workstation. Where as pinion blank goes to the buffer located before pinion gear cut rough workstation. There are different manufacturing facilities for crown and pinion manufacturing.

Crown manufacturing

There are 05 operations which are carried out for crown manufacturing once the finished turned blanks of crown enter the crown cell. Each machine has a separate buffer which stores the components once the operation is over. The semi finished product (soft crown) leaves the cell after soft stage inspection. Figure 1 shows general process of entire crown and pinion manufacturing process.

Pinion manufacturing

There are 06 operations which are carried out for pinion manufacturing once the finished turned blanks of pinion enter the pinion cell. The is no buffer between the workstations on which Pinion gear cut rough, pinion gear cut concave and pinion gear cut convex operations are carried out. The semi finished product (soft pinion) leaves the cell after soft stage inspection.

Heat treatment

After the soft stage inspection is over the accepted soft crowns and pinion are sent for heat treatment in the batch of 14nos. / batch for crown and 216nos. / batch for pinion if the heat treatment furnace used is continuous gas carburizing furnace (CGCF). Time required for processing of each batch is 20 minutes. The Batch is loaded as per the availability of accepted soft crowns and pinions.

Hard Stage and Packing

In hard section there are total 13 operations carried out. While processing at hard stage crown goes through total 8 workstations, Out of which at 5 workstations processing is carried out on crown and pinion in pair. Where as pinion under goes through total 10 workstations, out of which, 5 are common. There are buffers placed between two successive workstations at this stage for manufacturing of crown and pinion.

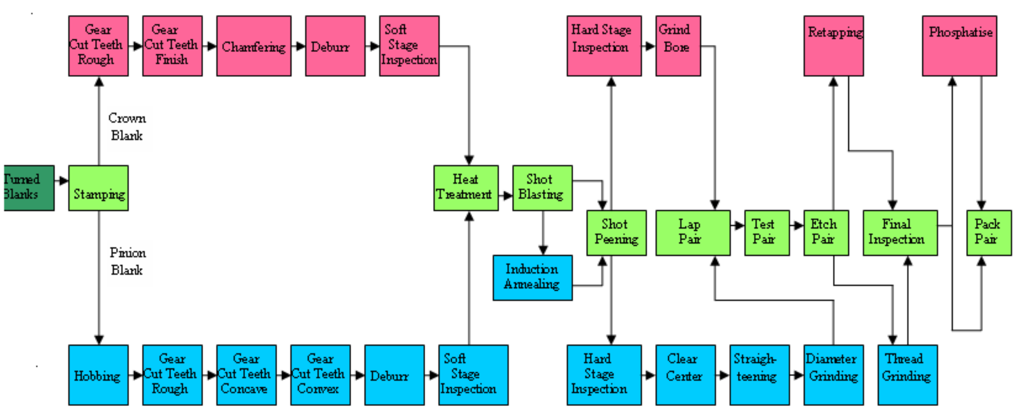

Figure 1. Crown and pinion manufacturing process

Simulation Modeling Tool

The model of crown and pinion manufacturing is built using WITNESS 2007 Manufacturing Performance Edition. It is strongly machine oriented and contains many elements for discrete part manufacturing. Elements may be combined in a designer element module to be reused. The machine element can be single, batch, production, assembly, multi station or multi cycle. The behavior of each element is described on a tabbed detail form in the WITNESS user interface.

Simulation Model

In the first stage the detail study of exiting gear manufacturing process is carried out for better understanding of the manufacturing system. The entities, resources, path network, input, output pattern at each work station is studied and necessary information was obtained. The assumptions made are as below:

- All the machines are well set at the start of simulation time.
- Resources (workers) do not leave the production floor while processing progresses.
- Workstations Crown wheel gear cut rough, Crown wheel gear cut finish and lapping follow lognormal distribution for repair time.

In the second stage warm up time of 1500 minutes was taken. Warm up time ensures that the data collection proceeds only after steady state of the system is reached. With the collected data, necessary information the basic model representing the actual manufacturing system was developed.

In the third phase the developed model is verified and validated. The following process was used for verification/validation.

1. Tracking the routes and flow/process of individual entity in the system.

2. Study the production number as well as throughput number in each work station.

3. Verifying the number of rejected /scrapes parts with the rejection logics.

4. Verifying the flow pattern and storage pattern at each work station.

5. Verifying the overall throughput at the end of each day, each week and at last end of one month.

The model representing actual manufacturing system is Scenario 1.

Manufacturing Process Reengineering

The out come of the simulation study carried out for Scenario 1 confirmed that the actual throughput is quite less compared to maximum throughput (capacity) of facility. The manufacturing process holds large amount of work in process (WIP). This evidence led to proposal of set of feasible modification (Manufacturing Process Reengineering) to the manufacturing system in an attempt to improve overall performance of facility. The manufacturing Process Reengineering is carried as per steps given below.

Step 1.Reducing processing time before common stage

One of the possible ways to improve throughput is to decrease the process time or modify the existing equipment to carryout more than one operation without affecting the quality of product. It is observed that the chamfering operation can be carried out on the finish gear cut workstation by attaching a chamfering attachment for finished blank crown at the soft stage. This reduces the process time by 1.5minutes.

Step 2.Reducing processing time after common stage

Shortening the process time could in theory improve throughput. Retapping process time can be reduced from 1.5minutes/crown to 1.0minutes/crown by modifying the tapping attachment.

Step 3.Modify the input pattern

Input pattern at Shot Peening workstation should be increased from 2 Jobs/batch to 4 Jobs / batch keeping the process time same. This could be done by modifying the job holding fixture.

Step 4.Add buffer

We can add buffer between each stage, thus product is available when ever it is required this may result in higher throughput. Considering this a Buffer is added before pinion concave workstation to reduce the blocking effect.

Step 5.Add facility

The number of components at the buffer before final inspection workstation is more at the end of simulation period. This indicates that final inspection facility is to be increased so that buffer before final inspection workstation will remain empty or will have less WIP.

Step 6.Manpower reduction

Simulation study of basic model indicates the scope for manpower reduction without change in throughput

Step 7.Change the sequence of operation

It observed that certain amount of semi finished components is rejected at soft stage inspection. Stamping operation is a value adding operation. If it is carried out after soft stage inspection, only accepted components will go for this operation.

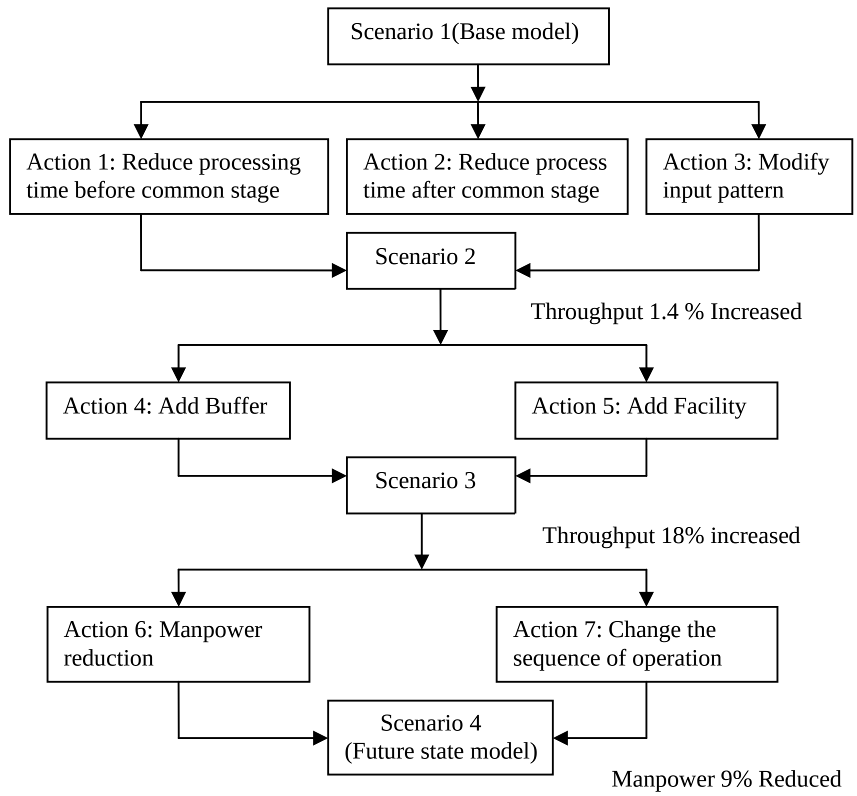

Figure 2: Roadmap of manufacturing process reengineering

Results and Analysis

In the first phase of simulation study the Discrete Event Simulation (DES) model of actual manufacturing system was developed using WITNESS 2007 manufacturing performance edition. The following parameters were specified for simulation.

Length of each simulation run=29 days/month (with one weekly off after 6days of working)

Number of Independent simulation run = 5

Length of warm up period = 1500 minutes.

In addition, the study provided information about performance of manufacturing system if manufacturing process reengineering is carried out.

Each of the objectives is taken into consideration during the process of simulation analysis. The figure against the term Throughput, WIP, in this study means pair of crown and pinion for future discussion. The results of simulation are summarized below in terms of each objective.

Scenario 1

The simulation study results of Scenario 1 are, Workstations Pinion gear cut rough and pinion gear cut concave are blocked for 9.48% and 2.92 %. Workstation Diameter grinding is under breakdown for 19.75%. Proper preventative maintenance is required. workstation crown gear cut rough and pinion gear cut rough are identified as bottlenecks as the cycle time/process time is more as compared to next workstations in the cells. Many operators are busy for 30% time only, hence can be used to operate other workstation. There is scope for manpower reduction. The current design does not give maximum throughput.

Scenario 2

By combining the first three steps a model was developed which is termed as Scenario 2. This model incorporates the first three steps of manufacturing process reengineering. The first three modifications introduced in model and the outcome shows Increase in the throughput from 6400 pairs packed/month to 6490 pairs packed/month (increase of 1.40%).Buffer at final inspection holds WIP of more than 1000 jobs. Workstations like Pinion gear cut rough and Pinion gear cut concave are blocked of 9.48%and 2.9% of simulation time respectively this is because there is no buffer before and after Pinion gear cut concave workstation. The changes shows that the throughput has increase at the same time there is large amount of WIP at latter stages of manufacturing system as workstation like final inspection is busy for more than 60% of available time.

Above finding motivated to add another final inspection facility as well as buffer before pinion concave workstation. (Step no.4&5 of reengineering process).

Scenario 3

It was developed by combining the first five steps mentioned above. This model includes the first five steps of manufacturing process reengineering. The first five modifications introduced in model and the outcome is analyzed. Increase in the throughput from 6400 pairs packed/month to 7600 pairs packed / month (increase of 18.75%).Workstation pinion gear cut concave is blocked for 2.92% of available time. No WIP at buffer before final inspection workstation. Total WIP is considerably reduced. Additional one operator is required to operate the newly added final inspection workstation. But the operator working on Gratomat workstation is already free as this workstation is removed in manufacturing process reengineering step no. 1. Total workforce required for operating the system remains same.

Scenario 4

It is the combination of all even steps given above for this study. This model is constructed by incorporating all seven steps mentioned in manufacturing process reengineering. The out come of simulation model is analyzed. Throughput remains same even if the sequence of operation is changed. Workstation pinion gear cut concave is blocked for 2.88% of available time. No WIP at buffer before final inspection workstation. Total WIP is considerably reduced. Workforce of 32 operators is required for actual manufacturing system. In this scenario total manpower required is 29. Manpower reduction on 9% is achieved. As many operators are busy only for 35% of simulation time they can be utilized to operate more than one workstation. While doing this care was taken for allocation of workstation. The manufacturing process reengineering has helped in improving the performance of facility.

Scenario 5

The maximum throughput capacity also known as theoretical maximum capacity, of the facility was determined by running the basic model without effect of unscheduled downtime/breakdown. The model was fed with 9000 finished blanks of crown and 9000 finished blanks of pinion. The maximum throughput capacity of the facility found to be 8000 pairs of crown and pinion packed/month. Pinion gear cut rough and pinion gear cut concave machines are blocked for 5.8% and 2.93% as work station next to them is busy and there is no buffer between the work stations.

Table 1: Results of different scenarios

Sr. No.	Description	Scenario				
		1	2	3	4	5
1	Throughput	6400 Nos.	6490 Nos.	7600 Nos.	7600 Nos.	8000 Nos.
2	WIP	1354 Nos.	1264 Nos.	154 Nos.	145 Nos.	737 Nos.
3	Rejection	246 Nos.	246 Nos.	246 Nos.	255 Nos.	263 Nos.
4	Total	8000 Nos.	8000 Nos.	8000 Nos.	8000 Nos.	9000 Nos.

Conclusion

Discrete event simulation is one of the fastest growing tools in manufacturing industry. Adopting this technology can have a profound effect on a company's efficiency and performance.

Efficiency of manufacturing system can be increased by manufacturing process reengineering. Effects of manufacturing process reengineering can be studied with help of simulation model before implementing the reengineering steps on real life system.

The manufacturing system operation is now smoother, workload is now evenly distributed and WIP is considerably reduced.

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