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DESIGN AND DEVELOPMENT OF SIMULATION BASED MODEL TO RANK JOB FLOW STRATEGIES

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ABSTRACT

In recent days many business organizations make huge investment in establishing their shop floors, installing most mechanized machines. These mechanized machines ought to operate in tandem with other machines, whose productivity level are usually different, which leads to individual machines working in maximum efficiency and the overall shop floor working in sub-optimal level. A spool shop assembles flanges, valves and nozzles to lengthier pipe, which are used in the construction of power plant, petroleum refinery, and cement plant. Longer cycle time at different work stations, lengthier job queue waiting for processing, high level of work-in-progress are inherent issues in a spool shop. Individual machines operating at maximum efficiency without analysing the flow metrics in a spool shop leads to bottleneck. Current study, aims at spotting and decongesting the bottle neck at various machines, improve the output of the spool shop and optimize individual machine utilization. Four simulation models are developed using ARENA and each one of them are evaluated on the following metrics: output from spool shop per time period, utilization of individual machines per time period, value added time per unit of pipe, average queue length at each machine, average waiting time of a pipe and work-in-progress. First model depicts the data captured in the existing spool shop. In second model, high priority is assigned to the jobs that ought to be further processed in shot blasting machine and heat treatment furnace, thus minimizing the wait time. In third model, a modification is suggested to the existing annealing process, where the job is allowed to cool outside the furnace, thus making the furnace available for the next job. Forth model uses the priority rule in the suggested modified model. In all these models, inter-arrival time of job from storage yard to spool shop is maintained constant. Evaluating each model against performance statistics and queue statistics helps rank models based on each metrics. Models with high priority for further processing make use of single piece flow, a proven lean principle technique that has enhanced the overall efficiency. This eventually motivates practicing shop floor manager to incorporate flow metrics in designing the layout and machine capacity for optimal overall utilization.

Keywords: lean principles, single piece flow; simulation; bottleneck.

1. INTRODUCTION

Business organizations world over are competing for a larger share of market. The information and resources available to them are rather similar. Prices of raw material and commodities are also almost similar because of the advent of commodities market world over. The best option available to business organizations to maximize profit is through minimizing the cost of operations, which is the result of optimum utilization of resources. Resources include men time, machine time, finished goods inventory, work-in-progress (WIP) inventory, working capital and the like. Lean principle advocates for zero or minimum inventory both in finished goods and WIP, which aids clutter free shop floor forcing any problems or undesired issues to surface out quickly. Shop floor implementing lean principles often resort to single piece flow or batches consisting of lower lot size resulting in enhanced productivity [10].

Job flow in shop floor is detrimental to the cost of production and financial health of any business organization. Often, different work stations operate at different speed and with little sync between them. This leads to a situation where each work station produces parts or components at its maximum or near maximum efficiency. But these components ought to be used by its immediate succeeding machine or an assembly line; at the rate these parts or components are produced. Else, these parts or components have to wait for some time to be consumed or used by the succeeding work station or assembly line. Waiting of such parts or components creates bottle neck, and size of bottleneck is directly proportional to the waiting time of parts or components. Bottleneck in any production facility is not desired. Magnitude of bottleneck is high when outputs from more than two machines are to be processed by one. Bottleneck increases the WIP; cluttering the shop floor, warranting high financial commitment and lowering the efficiency of the shop floor.

Spotting a bottleneck in a manufacturing facility is still in the nascent stage. If a work station is waiting for parts (starved), then the bottleneck ought to be in an upstream work station. If the work station is waiting for the processed parts to be transported (blocked) next work station, it signifies the location of bottleneck in the downstream. Level of buffer inventory also helps to spot a bottleneck. If inventory between two workstations are high, then the bottleneck should be in downstream. On the contrary, if inventory between two workstations is low or zero, the bottleneck should be in the upstream. [11]

Bottlenecks in shop floor can be resolved by improving the capacity of the work station or by controlling the job flow rate. First alternate, involves financial outlay, whereas the second minimizes the

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magnitude of bottleneck or shifts the bottleneck to different work station.

2. LITERATURE REVIEW

Taichii Ohno and Shigeo Shingo of Toyota Motor Company were the forerunners of Toyota Production System(TPS), who analysed Ford's shortcomings and proposed the new concept of single piece flow [1] [2] [3]. Eventually these lead to improve the efficiency of the production system as a whole, contradicting Ford's practice of improving local efficiency at each work station. Noteworthy advantages of single piece flow is its ability to handle highly diversified range of products, at the lowest cost, with high levels of productivity, speed of delivery, minimum stock levels, minimize or eliminate waste and achieve optimum quality [4].

Commonly adopted measurable performance indicators of organizations are rejects and scrap, reworking, labour and machine productivity, product quality, inventory levels and turnover, manufacturing cycle time, unit manufacturing cost, delivery speed and reliability [5]. Demeter and Matyusz emphasize on inventory turnover as performance indicator because the business organization needs to maintain only low levels of raw material, WIP and finished goods, which involves limited working capital. In their study, authors found direct relationship between processes and level of inventory, whereas, they observed no relationship between products and level of inventory. Moreover dedicated production lines or cellular manufacturing had higher inventory turnover, contrasting to job shops[6].

Hinckeldeyn et al in their study discovers that bottleneck is addressed usually in manufacturing facilities, neglecting the fact that it could as well be handled from product design and process design stages. Three design driven business organizations were chosen based on the degree of novelty of their development work. Result of the study revealed a significant improvement in performance indicators [7].

Allwood *et al* in their research work titled 'Manufacturing at double the speed' conclude that not all of the opportunities to double the speed of manufacturing will be a desirable goal, though it be achieved by the invent of technology. It is just not the productivity, but rather it is a balancing of multiple objectives such as operational cost, initial capital outlay, market demand, demand fluctuation and price fluctuation [8].

Bottleneck could be well handled by decreasing the machine downtime. Pascual *et al* proposed a model that protects production system with buffer stock and facility redundancy, during maintenance. This model could as well be extended to situation of bottleneck, where job flow is stopped either from upstream or to downstream machines [9].

Eliminating non-value added activities brings the cost of operation and also reduces the occurrence of bottleneck. Non-value added activities do not add value to the end product and eventually the customer also not willing to pay for. Such activities are often identified with magnified observation and its elimination requires a attitude change among employees. Magnitude of bottleneck could further reduced by minimizing machine setup time, by implementing the powerful lean tool 'Single Minute Exchange of Die' (SMED).

Shin and Pfeffer, describe a comprehensive value stream evaluation consisting of KPIs from monetary and non-monetary streams. It is highlighted that monetary KPIs include lead time, expenses, savings, process cost, whereas non-monetary includes overall equipment effectiveness (OEE), every part every interval (EPEI), and space. EPEI is a flexibility indicator, which describes the overall time in which all product variants can be produced on one defined resource, whereas, OEE evaluates the effectiveness of a manufacturing operation. All the KPIs are measured in the current state, and three levels of target fixed for non-monetary KPIs. At each level of target, the non-monetary KPIs are maintained at a specific value and the system is simulated to obtain the monetary KPIs. Each level of variation is stiffer and moves closer to ideal situation [10].

3. PIPE SPOOLING PROCESS

A pipe spool is a prefabricated assembly of pipes, flanges, nozzles, valve and the like, which are pre-mounted in an offsite fabrication facility and later transported to the assembly or construction site. First process in pipe spooling is shot blasting, where dirt and surface impurities are removed. It is a surface treatment process using high velocity steel abrasive, which is possible to obtain excellent cleaning and surface preparation for secondary finishing operations. The shot blasting turbine delivers abrasive shot by centrifugal force in a specific and controlled direction, speed and quantity. Second process is the bending of pipes, done by localized heating by induction, which makes use of the capability of the magnetic field to transmit energy without direct contact. Thus the outer bend has strain with lower wall thickness and the inner bend is compressed with greater wall thickness. The established thermal gradient causes loss of structural integrity. The third process is Post Bend Heat Treatment (PBHT), where the stresses are relieved and the pipe regains structural integrity. The purpose is to regain the spheroid like structure from the needle like structure which comes into being due to the localized heating of the pipes during bending. The pipe is heated above its upper critical temperature of 1080^0C and held for 35 hours in a controlled temperature. The pipes are brought out of the furnace at 760^0C and allowed to cool to room temperature. In the Fourth process, the scales that have formed on the pipe during heat treatment process is cleaned (Shot Blast Post Bend Heat Treatment). Fifth process is the radiographic testing; the part to be inspected is placed between the radiation source and radiation sensitive film. The variation in the image intensity can be used to determine thickness or composition of material and it would also reveal the presence of any flaws or discontinuities inside the pipe. The lengthy pipes are marked and cut according to the design requirement. Standard fitting have pre-machined bevelled edges, the pipes end that is to be fitted to these fittings have to be

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prepared for proper fixing of fitting like flanges, T-joints, nozzles or valves. Fittings are welded to pipes using shielded metal arc welding (SMAW) and the weld quality is checked using 'Dye Penetration test' which is a non-destructive test performed to check for laminations. The pipe is initially cleaned with acetone, after which the dye is applied. The pipe is further cleaned leaving the remains of the dye occupy the cracks. The developer is then applied to pipes and the cracks are indicated by color regions. The time for drying of these dyes varies with ambient temperature and humidity. Next process is the Post Weld Heat Treatment (PWHT), where the heat affected zone loses its structural integrity due to the localized action of heating, which results in variation of properties at the welded area. PWHT eliminates residual stresses by heating, soaking, and cooling the weld area in a controlled manner to temperatures below the transformation point, giving sufficient time to readjust to its original state and removing the residual stress. The pipe should be post weld heat treated to ensure expulsion of hydrogen from heat affected zone. The process involves soaking the pipes at 750^0 C for two hours and maintaining it at that temperature for 8 hours followed by cooling. The scales that have formed on the pipe during heat treatment process are removed by shot blasting (Shot Blast Post Weld Heat Treatment). Finally the pipes are painted manually as per the requirements of customer.

4. SIMULATION AND ANALYSIS OF JOB FLOW

Time taken at each process in the spool shop is recorded and it was observed that the time is rather stochastic, so a simulation model is used. Four simulation models are developed according to the existing production process; first model (LOWOP) represents the data captured from the spool shop. Second model (LOWP) has a priority rule that, jobs for shot blasting and heat treatment furnace coming from the upstream workstations are given high priority when compared to the ones coming from lower stream workstations. In the third model (SPWOP), concept of single price flow is incorporated, where the pipes from the storage yard would not enter the shop floor if the shot blasting machine is occupied by previous lot or jobs from upstream process. Fourth model (SPWP) consists of single piece flow with the priority rule mentioned in the second model.

The spool shop has only one shot blasting machine and heat treatment furnace. Jobs from upstream processes use shot blasting thrice and heat treatment furnace twice. The lot size for shot blasting is three and for that of heat treatment is five.

The pipes ought to cool in the furnace for eight hours to reach room temperature. A rail system is proposed, where the hot pipes are allowed to cool in the rail, making the furnace available for the next charge. In this proposed model also has four models as mentioned above in the existing model.

Eight Arena models were simulated and the results of job waiting time (minutes) according to each model is depicted below Figure-1.

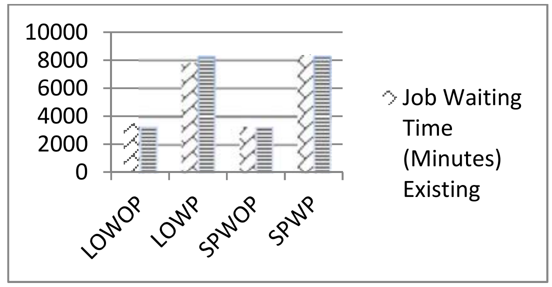

Figure-1. Job waiting time in minutes.

Compare to all the models, single piece flow without priority rule (SPWOP) has the least job waiting time, the reason being the pipes enter the spool shop if only the shot blasting machine is free. Thus freeing up the shop floor and the avoid accumulating WIP at each work station.

Average number of WIP in the spool shop is depicted in the Figure-2.

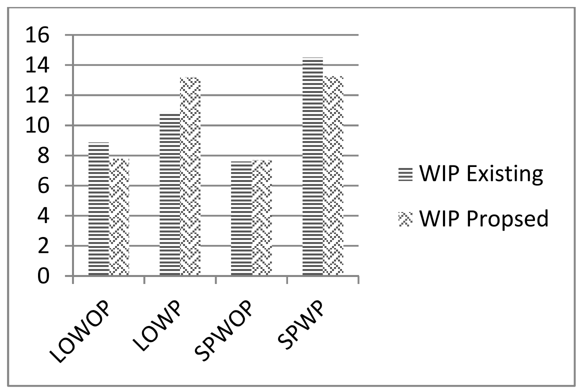

Figure-2. Average number of jobs in the spool shop.

According to number of jobs in the spool shop single piece flow without priority rule (SPWOP) has the least value signifying a clutter free shop floor.

Value added time signifies the time job is processed, it always lower the better. The following figure depicts the value added time of all the 8 models.

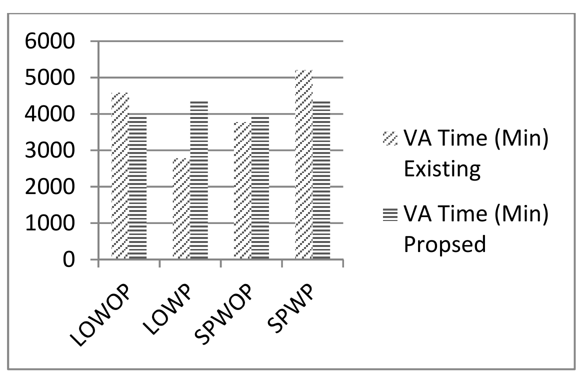

Figure-3. Average value added time.

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It could be observed from Figure-3, value added time for all the proposed models is lower when compared to its corresponding existing models. Reason being: pipes after annealing process are allowed to cool down to room temperature in a rail system outside the furnace. Thus making the furnace available for the next charge immediately.

Table-1 lists the job waiting time in individual workstations for all existing models. It could be observed that the job waiting time is low for single piece flow without priority. Single piece flow with priority rule delays the job, because of the high priority to the batch coming from lower stream workstations. Thus, eventually increases the job waiting time in shot blasting machine and heat treatment furnace.

Table-1. Job waiting time for existing models.

Process	**Job waiting time (Existing) in min**			
	LOWOP	**LOWP**	**SPWOP**	**SPWP**
Shot Blasting	5.24	76.75	13.58	52
Bending	228.35	223.17	88.97	148.75
Heat Treatment	192.5	183.25	182	168.32
Radiography	223.5	209.86	79.48	211.5
Marking	235.23	219.45	106.72	219.71
Edge preparation	0	0	0	0
Fit-up	0	0	0	0
Weld	285.36	307.31	154.96	306.87
Dye Penetrant	0	0	0	0
Inspection	120.36	119.67	65.86	119.7

Table-2 lists the job waiting time of all the proposed models. It is observed that single piece flow without priority model has the least job waiting time.

Table-2. Job waiting time for proposed models.

Process	**Job waiting time (Proposed) in min**			
	LOWOP	**LOWP**	**SPWOP**	**SPWP**
Shot Blasting	13.98	50.82	12.34	63.62
Bending	226.35	224.29	67.75	148.43
Heat Treatment	190.25	182.56	172.56	165.35
Radiography	230.32	210.99	77.34	213.61
Marking	265.25	219.98	89.45	217.28
Edge preparation	0	0	0	0
Fit-up	0	0	0	0
Weld	260.65	225.35	135.36	240.25
Dye Penetrant	0	0	0	0
Inspection	116.35	118.34	57.66	119.78

From all the above models, it was found that, proposed single piece flow without priority rule (SPWOP) has the best results in comparing performance and queue statistics in the spool shop.

5. CONCLUSION

Pipes spooling process has lengthier cycle time. Resulting in high job waiting time and cluttering the shop floor. In the current study, eight simulation models were developed, with four depicting the current practice and rest incorporating a rail system to cool the hot annealed pipes (proposed). Each of the models in two broad groups had four models under each. First model depicts current state of the spool shop; second model incorporates a priority rule of assigning high priority to jobs from downstream workstations. Third model has a single piece flow system without priority rule, which reduces the WIP and the fourth model is the single piece flow with the priority rule.

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Eight models are simulated and the results favor the proposed single piece flow model without priority rule. Single piece flow help maintain clutter free shop floor and priority rule increase the job wait time at shot blasting station and heat treatment furnace. These two work stations are used by jobs from downstream which are assigned high priority, and jobs from upstream workstations carry low priority, increasing the overall average waiting time.

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