SIMULATION MODELING OF PRODUCTION LINES: A CASE STUDY OF CEMENT PRODUCTION LINE

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ABSTRACT

Modeling and simulation of production lines is considered to be important for designers who are interested in: Work-load Allocation Problem (WAP), Server Allocation Problem (SAP), and Buffer Allocation Problem (BAP). This paper studies and analyzes a real cement production line as a case study. A simulation model is developed by ARENA software and used to analyze and test several bottlenecks that are causing severe congestions in different areas on the production line and could resolve all of these bottlenecks. Workstation failure data is collected along one year to obtain the machines failure behaviors. This paper searches for the optimum buffer sizes with the increase of the production rate. An actual cement production line is studied and analyzed by the simulation model from stem to stern. After a simulation replication time of 12 days, a simulation results show the line bottlenecks, workstations utilization, buffer capacities and the line production rate. To resolve the bottlenecks, a redesign of allocation of buffers which verify an optimum size could be made and it might be taken into consideration when designers implement this line. Finally modified optimum workstations utilization, buffer capacities and the line production rate with an increase about more than 15% of the production rate and economizing of 34 % of buffer capacities.

Keywords: Production lines; Buffer allocation; Simulation; Cement industry

1. Introduction

A production line is an important class of manufacturing system when large quantities of identical or similar products are to be made (mass production). The performance of a production line is highly influenced by machine failures. When a machine fails, it is then be unavailable during a certain amount of time required to repair it. When a machine is in a failure status, the number of parts in the upstream buffer tempted to be increased while the number of parts in the downstream buffer tempted to be decreased. If this status persists, the upstream buffer may become full and as a consequence the upstream machine may be blocked which of course, would negatively impact on the rate of production. Similarly, the down- stream buffer may become empty and, therefore, the downstream machine may be starved.

Simulation is considered to be the powerful tool to model a production line with unreliable machines and stochastic variable intermediate buffers to identify the line performance. Papadopoulos et al. [1] stated that "Simulation of production lines is a powerful tool in obtaining the performance measures where analytical methods are either difficult or impossible to use". Hosseinpour et al. [2] presented a comprehensive literature review on importance of simulation in manufacturing as a very helpful work tool in industrial field to test the system′s behavior. Simulation is low cost, secure and fast analysis tool with many different system configurations [2]. Hosseinpour et al. [2]

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investigated the application of simulation that used to address in manufacturing which provides this paper with the following:

1. Location and size of inventory buffers,
2. Evaluation of the effect of a new piece of equipment on an existing manufacturing system,
3. Throughput analysis,
4. Bottleneck analysis,
5. Times parts spend in queues,
6. Queue size,
7. Utilization of equipment or personnel.

Kelton et al. [3] presented the concepts of simulation using ARENA to help the modeler reaching the ability to carry out effective simulation modeling. ARENA is based on SIMAN modeling language, and has an object-oriented design to any application area. Many papers have used ARENA software to study production lines and identify the bottlenecks and resolve it in the design phase or in a standing line.

Seraj [4] studied a Rusk production line to increase its capacity using a simulation ARENA model. He simulated the old line to find congestions and bottlenecks then he replaced a machine with a new one and increased the production rate by 50%. Hecker et al. [5] analyzed and optimized a bakery production line using ARENA; a one shift period data was collected, then formulated the model and simulated it, followed by validation of the simulation results with respect to the real data. As equipment utilization affects directly on the line productivity, achieving a possible highly utilization will increase the line productivity, therefore, increase the line performance. This would be achieved based on a perfect preventive and predictive maintenance schedule. Gonca et al. [6] simulated a production line by using an ARENA-based simulation model to select a preventive maintenance schedule which gives the best utility and performance values.

In this research an actual cement production line as a real case study is studied from stem to stern. Actual data is collected about each workstation including production capacities, processing times an d intermediate buffer capacities as mentioned in the following sections. One year failure history data is recorded about each machine from preventive and predictive maintenance department and using ARENA Input Analyzer the most appropriate probability distribution of each unreliable machine is detected. A block diagram of the cement line is established and all needed data is introduced. After a simulation replication time of 12 days, a simulation results are obtained; these results show the line bottlenecks, workstations utilization, buffer capacities and the line production rate. A verification and validation of the model has been done. To resolve the bottlenecks a redesign of allocation of buffers which verify an optimum size could be made, it might be taken into consideration when designers implement this line. Finally modified optimum workstations utilization, buffer capacities and the line production rate with an increase more than 15% of the production rate and economizing of 34 % of buffer capacities.

2. Description of the cement production process

The production line as shown in Fig. 1 starts at the quarry by loading the limestone to a truck, the truck unloads the limestone to a Crasher, and then the crashed limestone transferred to a Stacker and Reclaimer to make the limestone more homogenous. On the other parallel hand the crashed clay transferred to the Stacker and Reclaimer, also for more homogeneity. Conveyor belts transfer the limestone and clay to the Raw Mill area (two Raw Mills), and then transfer the milled mishmash to the Kiln for making the Clinker after adding some chemical additives. After forty minutes inside the kiln the Clinker cooled in the Cooler and then crashed, after that it is stocked before Cement Mills. The Clinker is milled by three Cement Mills and stocked in Silos, finally it is loaded in customer Vans.

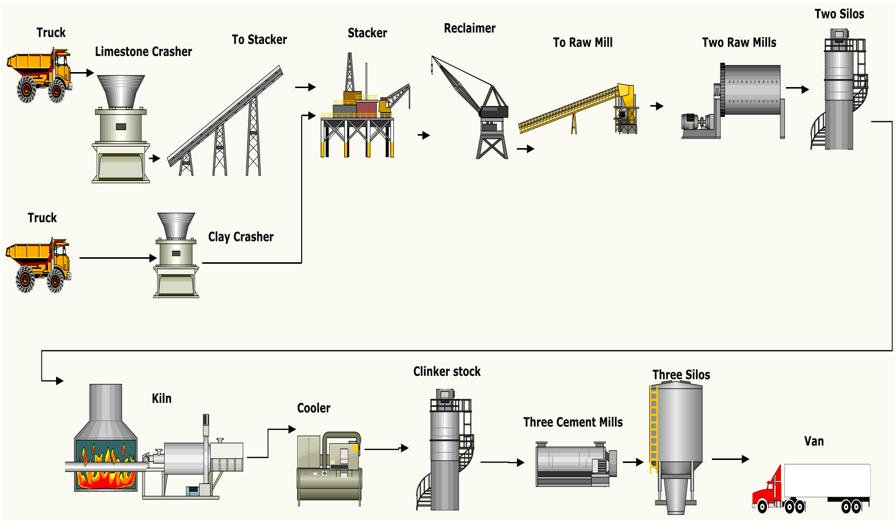

Fig. 1. Layout of the cement production line

3. Proposed approach

In this section the proposed model is explained with its methodology. Assumptions will be stated clearly in the simulation policy then the model steps are performed. This methodology depends on a precise and long time data collection which leads to accurate results. Section 3.3 clarifies the ARENA simulation model. This model simulates the actual cement line. Fig. 2 shows the simulation methodology of the proposed approach.

3.1. Simulation policy

1. The entity which a simulation package ARENA operates on, is the capacity of the arrival truck which, is unloaded to the Crasher both limestone and clay. The two entities are summed as a single entity before the two Raw Mills to complete the cycle.

2. Steady state simulation models are appropriate for the analysis of systems which in theory could run indefinitely
3. It might be appropriate to consider the product as a discrete unit in particular the trucks come in a discrete truck, also the customer van come out the same discrete value.

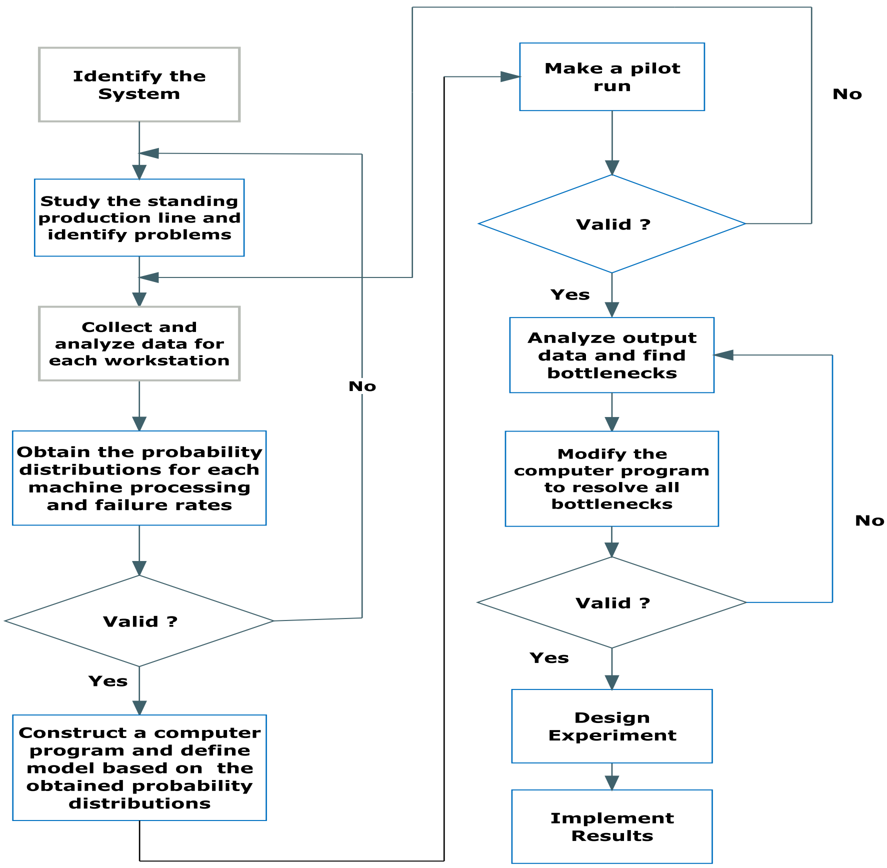

Fig. 2. Simulation methodology of the proposed approach

3.2. Methodology

The production line should be studied in details which given by Seraj [4]:

1. All workstations should be analyzed; processes, resources, material, and timings should be identified and documented.
2. All data related to activities and resources should be identified and collected.
3. A simulation model that truly represent the real production line and simulate its behavior, should be developed, and validated.

4. Once, a valid model is built, a simulation experiment should be conducted to search for a feasible solution to maximize the capacity of the production line and optimize the buffer allocation within the existing constraints.
5. The simulation model

The simulation model begins with two arrivals of limestone and clay, each in a separate line until the stacking process, then the two entities are directed in parallel to the milling process where the two entities are matched to one entity. This entity is transferred between the other processes in serial mode until the disposal process. Fig. 3 depicts the ARENA simulation model.

3.3. The collected input data

The probability distributions with their parameters of major activities are collected from the actual production line for a complete year. These data include the failure of each machine during this year which is entered to ARENA Input Analyzer to produce the best distribution of failure. The failure data includes the predictive and preventive maintenance schedule. The probability distributions with their parameters are scheduled in Table1, Where:-

EXPO (7) =Exponential distribution with mean 7
LOGN=Lognormal distribution
GAMM=Gamma distribution

Table 1.
Processing and failure time distribution according to ARENA Input Analyzer

Truck arrival	EXPO (7) min.	Raw Mill Capacity	9000 ton/day
Crasher processing time	EXPO (6) min.	Raw Mill 1 Failure	EXPO(7.4)
Packing machine	EXPO(8) min.	Raw Mill 2 Failure	EXPO(7.18)
Crasher failure	LOGN (1.04, 2.26) hrs.	Kiln Capacity	7000 ton/day
Stacker processing time	EXPO (7) min.	Kiln Failure	GAMM(15.8, 0.718)
Reclaimer processing time	EXPO (8) min.	Cement Mill Capacity	8000 ton/day
Cooler processing time	EXPO(6) min.	Cement Mill 1 Failure	LOGN(3.72, 8.12)
Cooler failure	EXPO (10) hrs.	Cement Mill 2 Failure	LOGN(4.69, 10.1)
Disposal truck arrival	EXPO(10) min.	Cement Mill 3 Failure	LOGN(4.23, 9.1)

3.4. Verification and validation

The animation method is used to show the movement of entities inside the model and to insure that the movement is similar to what the designer think which called Face Validity [7]. Face Validity means that animation should be in accordance with the flow of the raw material and clinker in the real production line; and this verifies the model.

Validation of the ARENA model is done by comparing the model output with the real system output which called statistical validation or Walk through validation [7]. The number of cement trucks produced per day from the model is compared with the number of cement trucks produced per day from the real system. The number of cement trucks produced per day from the model is 143 trucks, while the real system production rate per day is 134 which are equal 6667 ton per day, which is considered to be valid. The nature of this production system is a steady state because it works continuously for 24 hours a day and 7 days a week.

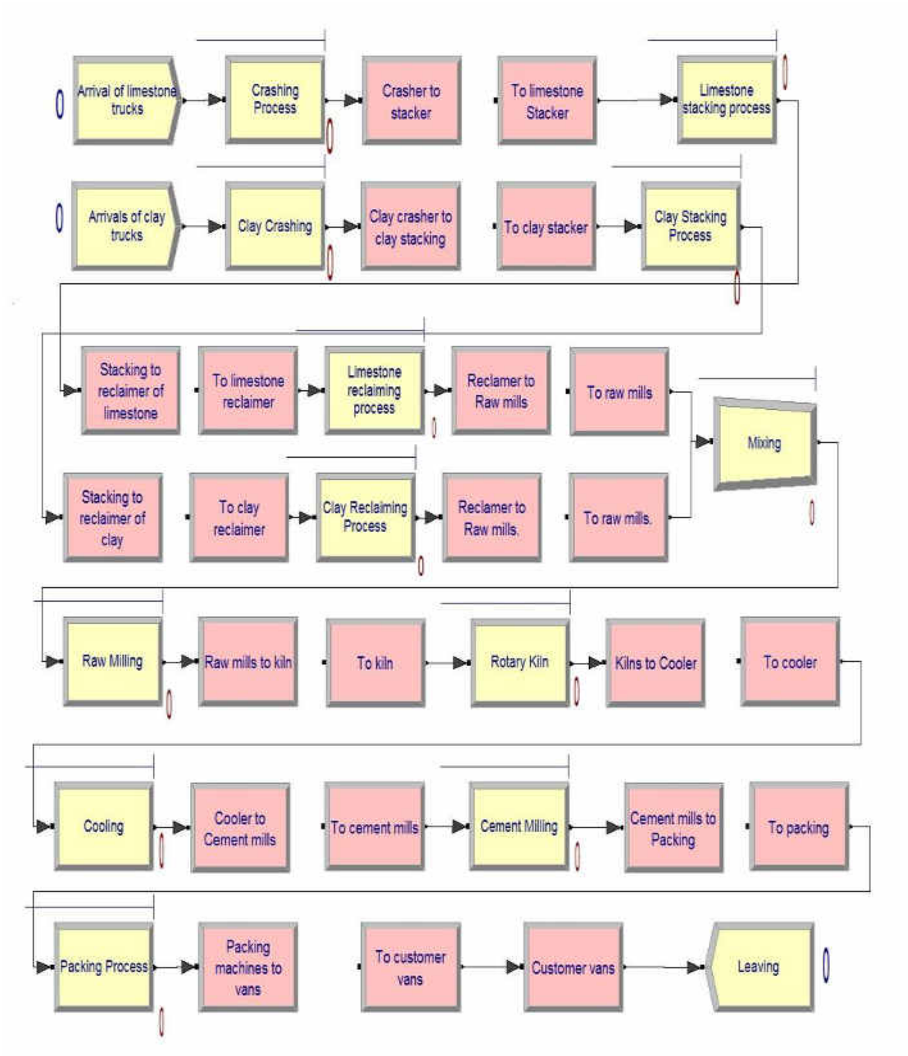

Fig. 3. ARENA simulation model for the cement production line

3.5. Performance measures and results

The simulation run results after 12 days simulation time and 8 replications are summarized in Tables 2, 3 and 4 which is considered medium and real because of scheduled preventive, predictive and corrective maintenance of workstation components. Table 2 depicts the utilization percent for each workstation .Table 3 shows the intermediate buffer stocks which clarifies that the largest buffer is before the kiln with average capacity of 9 entities which equals 450 tons, whereas the maximum capacity is 124 entities and equivalent to 6200 tons. The actual buffer capacity is 10,000 ton which seems to be large space. The kiln buffer should be large because the kiln area is the heart of cement production and production managers should make the kiln not to be stopped. At the moment the kiln stops; the company's profit will decrease. This storage is called silo in the area. The average Work In Progress (WIP) is 26.2589 trucks which equivalent to1313 tons. The maximum WIP is 140 trucks which equivalent to 7000 tons.

Table 2.
The utilization percent of each workstation

Work station	Limestone Crasher	Clay Crasher	Limestone stacker	Clay Stacker	Limestone Reclaimer	Clay Reclaimer	Raw mill	Kiln	Cooler	Cement mill	Packing
Utili zation %	71.21	70.06	70.99	69.77	84.17	83.84	60	85	60	50	80

Table 3.
The average simulated buffer storages for each workstation

Work station	Limestone Crasher	Clay Crasher	Limestone stacker	Clay Stacker	Limestone Reclaimer	Clay Reclaimer	Raw mill	Kiln	Cooler	Cement mill	Packing
Number of trucks	2.8192	1.7619	2.0194	1.7468	5.6977	4.5616	1.07	8.97	4.93	3.71	1.73
Tons	140.96	88.095	100.97	87.34	284.885	228.08	53.5	448.5	246.5	185.5	86.5

Table 4.
The maximum value of intermediate buffer capacities

Work station	Limestone Crasher	Clay Crasher	Limestone stacker	Clay Stacker	Limestone Reclaimer	Clay Reclaimer	Raw mill	Kiln	Cooler	Cement mill	Packing
Trucks	79.0000	22.0000	44.0000	23.0000	56.0000	55.0000	132	124	62	51	49
Tons	3950	1100	2200	1150	2800	2750	6600	6200	3100	2550	2450

To resolve the kiln bottleneck, its processing time modified from EXPO (10) to EXPO (8) by increasing its capacity to reach 9000 ton/day without any change in the other equipment parameters merely increasing the third shift of Crashers, Stackers and

Reclaimer to work all day like the other equipment of line because they works only two shifts in the standing line. If it is done, the daily production capacity will increase to 158 trucks per day instead of 134 trucks per day which equivalent to 7883.3 tons per day with an increase of 1216.3 tons per day. And that represents more than 15 % extra production which would lead to a profit covers the kiln extension cost after one month production, but it may need an extra cement mill. Also the line performance would increase by improving the preventive maintenance schedule which minimize the failure time.

4. Conclusions

The goal of this study was achieved by measuring the performance of a cement production line. The production line was thoroughly analyzed and found to have bottlenecks that were causing congestion in the kiln area on the line. Simulation was used to analyze this bottleneck and resolve it, so Simulation is the best tool that can be used in such a study because one can search for a good feasible solution without disrupting its operation. The production capacity could be increased by 15.4 % if an extension is added to the kiln and it may need an extra cement mill. The line performance would be increased by improving the preventive maintenance schedule to increase the machines utilization which leads to extra productivity increase.

5. References

[1] D. Papadopoulos, H.T. O'kelly, M. E. J. Vidalis and J. Spinellis, Analysis and Design of Discrete Part Production Lines, First Edit. Springer Science+Business Media, LLC, 2009.

[2] F. Hosseinpour and H. Hajihosseini, "Importance of Simulation in Manufacturing", World Academy of Science, Engineering and Technology, pp. 285–288, 2009.

[3] W. D. Kelton and D. T. Sadowski, RP, Sturrock, Simulation with ARENA, Fourth Edi. McGraw-Hill New York, 2007.

[4] S. Y. Abed, "A Simulation Study To Increase The Capacity Of A Rusk Production Line," Wseas Transactions on Information Science & Applications, vol. 5, no. 9, pp. 1395–1404, 2008.

[5] F. Hecker, W. Hussein, and T. Becker, "Analysis and optimization of a bakery production line using ARENA," International Journal of Simulation Modeling, vol. 9, no. 4, pp. 208–216, Dec. 2010.

[6] G. Altuger, C. Chassapis, "Multi Criteria Preventive Maintenance Scheduling Through Arena Based Simulation Modeling," IEEE, pp. 2123–2134, Winter Simulation Conference 2009.

[7] C.A. Chung, Simulation Modeling Handbook: A practical Approach, CRC Press LLc, 2004

محاكاة خطوط الإنتاج: دراسة حالة لخط إنتاج الأسمنت

الملخص:

تعتبر النمذجة والمحاكاة لخطوط الإنتاج مهمة للمصممين المهتمين بمشكلة توزيع عبء العمل (WAP) ومشكلة تخصيص الخادم (SAP) ومشكلة تخصيص المخزن المؤقت (BAP). هذا البحث يدرس ويحلل خطاً موجوداً على أرض الواقع لإنتاج الأسمنت. ببناء نموذج محاكاة باستخدام أحد برامج المحاكاة (ARENA) يتم تحليل واختبار العديد من الاختناقات التي تتسبب في الازدحام الشديد في مناطق مختلفة على خط الإنتاج ويمكن حل جميع هذه الاختناقات. يتم جمع البيانات اللازمة للحصول على سلوك كل عطل من أعطال الماكينات على امتداد سنة كاملة. فى هذا البحث يتم الحصول على الأحجام المثلى للمخازن البينية مع زيادة معدل الإنتاج. بدراسة وتحليل خط الإنتاج من البداية للنهاية وتشغيل نموذج المحاكاة لمدة 12 يوماً تظهر نتائج محاكاة الاختناقات الموجودة بالخط وكذلك طبوغرافية محطات العمل وقدرات المخزن المؤقت ومعدل الإنتاج. يمكن أن يتم إعادة تصميم لحجم المخازن المؤقتة التي تحقق حجماً أمثل لحل الاختناقات، وقد تؤخذ هذه الاعتبارات عند مصممى مثل هذه الأنواع من الخطوط أو إجراء تعديلات على خط الإنتاج للاستفادة المثلى من محطات العمل وقدرات المخزن المؤقت. وأخيراً تم الحصول على زيادة فى الإنتاجية أكثر من 15% وترشيد 34 % من مساحة المخزن المؤقت.

كلمات البحث: خطوط الإنتاج ، تخصيص الموازنات ، المحاكاة ، صناعة الأسمنت