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RESEARCH ARTICLE

Effective Maintenance Enabled by the Use of Witness Simulation in a Libyan Cement Factory

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Abstract

This paper presents a new approach using Witness Simulation in combating issues related to maintenance within the existing manufacturing facility. Currently, maintenance is a key issue as many machines breakdown due to every day wear and tear as well as the age of the machine itself. This causes bottlenecks within the entire production system as the schedules of production is disturbed and further backlogs are developed. Also, when machines breakdown there seems to be very little communication from one end to another i.e. parts are needed for the repair of many of the machines, for example, it is very common for the rotary kiln to come to a halt due to increased temperature and different quantities of a mixture of materials. In order to fix the problem and move back on schedule the maintenance team uses certain materials i.e. same materials, all the time. However, due to not having an adequate stock control system and the lack of communication many a times, parts are not readily available and hence the team wait further until parts arrive at the facility. This paper will demonstrate how all of the above problem areas can be adhered to via the use of adopting a simple automated response system using Witness Simulation. The demonstration will be based on a single machine for testing purposes to ensure efficiency that can later be applied to the entire system as a whole.

Keywords: *Corrective maintenance, JIT (just in time), Material Requirement planning, Preventive maintenance, Simulation, Witness.*

Introduction

This paper will look into how maintenance can be controlled using Witness Simulation within the model, currently maintenance is a huge problem as it is combined with the availability of spare parts and warehouse stocks. This happens to be one of the main problem areas the manufacturing facility is facing, as many machines within the facility need preventive maintenance that is carried out on a daily basis and further corrective maintenance when needed [1].

Firstly, a model will be constructed to show how the problem areas can be tackled effectively with the use of "what if" scenarios based on many assumptions within the facility with reference to a single machine i.e. Separator[2]. These scenario subjects will be further tested to verify efficient working order with the use of many timers/counters that will be implemented and be visible in the model joint with an automated response system.
From the above model and scenarios, the user will be able to tell exactly how much material is being used and for what purpose on a daily, weekly and monthly basis, this will enable effective forecasting. Further the automated response systems guarantees effective communication throughout all levels of the organisation to ensure maintenance is carried out affectively and on time with adequate availability of resources [3].

Maintenance Model Building

Fig.1 below is a screen shot of the actual model constructed after running the model for 30 days, the model below represents the initial separator machine from the actual model of the cement factory. The maintenance team with counters to show how many jobs have been carried out and the warehouse to ensure adequate stock is available before work needs to be carried out [4].
The model is based on a single machine for experimental purposes, once satisfied, this solution can be implemented on all machinery and other activities of concern.

The model is based on many assumptions that have been listed under Assumption's below in order for this model to be as accurate as possible and true to life as not all aspects can be replicated exactly but rather to the nearest affect. Please refer to assumptions below whilst reading and following the below in order to gain an accurate understanding of the model constructed [5, 6].

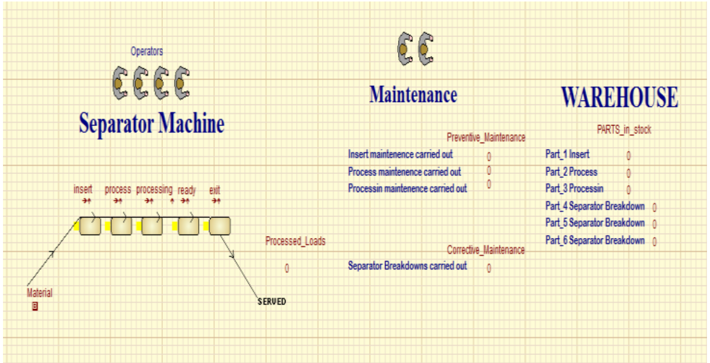


Fig. 1: Screen shot of finished model

Preventive Maintenance

Insert, Process and Processing

These activities are the initial activities that the entity will arrive in, here preventive maintenance is carried out approximately every 12 hours, this requires a maintenance staff, a single part from the warehouse from insert stock and 15mins in time. When this activity stops, a message will appear to show management and call maintenance giving the location, the counters will take in account the number of maintenance carried out and the parts used with reference to the warehouse. Further when the stock for this activity is very low, it will send out a message notifying all for the order of more stock. Once the stock reaches a certain low it will restock automatically to prevent problems i.e. if stock = 5, the system will automatically allocate another 20 to full stock again.

Corrective Maintenance

Processing

This is the only activity that has corrective maintenance, it works exactly the same as the preventive maintenance however, breakdowns occur approximately once every 2 weeks, that takes 4 hours. This also requires maintenance staff and 6 parts in total for the maintenance to be carried out.

When this activity breaks down, a message will appear to show management and call maintenance giving the location, the counters will take in account the number of maintenance carried out and the parts used with reference to the warehouse [7].Further when the stock for this activity is very low, it will send out a message notifying all for the order of more stock. Once the stock reaches a certain low it will restock automatically to prevent problems i.e. if stock = 2, the system will automatically allocate another 8 to full stock again.

Maintenance

Takes into account with the use of counters, the number of preventive and the number of corrective maintenance carried out. This is done by simple plus +1 or minus -1 equation as resources enter or leave activities.

Warehouse

Holds all the stock that is required for the maintenance to be carried out, again used plus +1 and minus -1 equation to control stock according to usage, further automated messages are implemented to show the management when stock has reduced with the use of OPENBOX rule. The warehouse has the ability to restock when stock is very low, this done via the use of further IF rules that have been implemented into the system i.e. IF stock part 1 = 5 (this means that 20 parts have already been used) then, part 1 = part 1 + 20. This will restock the ware to the initial amount of 25 parts.

Assumptions

- Maintenance is only based on one single machine i.e. Separator
- Materials represent a single tonne in weight or load just as the actual model represents.
- The separator machine has 3 key areas that preventive maintenance is required i.e. insert, process and processing.
- The separator machine has 1 key area that corrective maintenance is carried out at i.e. processing.
- The separator machine will take approximately the same number of loads as the actual model i.e. 600 plus loads in a single day.
- Each load will arrive every 1 minute and will spend a further 1 minute at every station within the machine.
- Materials will work on a passive basis where they just simply enter the machine, spend the required time in each area and thereafter just leave.
- Preventive maintenance is required approximately every 720 minutes that equates to twice a day for each of the three areas mentioned above.
- Preventive maintenance takes 15 minutes to be carried out.
- Preventive maintenance requires a single part from the warehouse depending on area.
- Warehouse will be fully stocked with adequate number of parts for each area to start with.
- Actual breakdowns will take place

approximately once every 2 weeks.

- Breakdowns require 4 hours of maintenance time.
- Each breakdown requires 2 spare parts from each part i.e. 2 of part 4, 2 of part 5 and 2 of part 6.
- Activities READY & EXIT are dummy activities to aid the process and time required that do not have any maintenance requirements.
- Model will run for a total of 30 days to ensure efficiency.
- Model is based on having a fully computerised system.
- Five Operators for the Separator
- Two technical staff to carry out preventive and corrective maintenance
- Model is further based on J.I.T, Supply Chain management and MRP11.

In the figure 2 below, is the actual separator representation in the model, as can be seen it has 5 stations, of which 3 parts are needed for preventive maintenance i.e. insert, process and processing. The material element is passive and simply flows through the system and represents a single load i.e. 1 tonne. The total output of the separator is a close approximate to the actual in the main facility model to ensure accuracy of use of machine. When preventive maintenance is carried out only 1 part is required at any given time; however there exist 3 parts within the single machine that required preventative maintenance and take 15 minutes. When corrective maintenance is undertaken it requires 6 parts and takes 240 minutes. Processed loads show the number of loads or tonnes that have been processed by the machine.

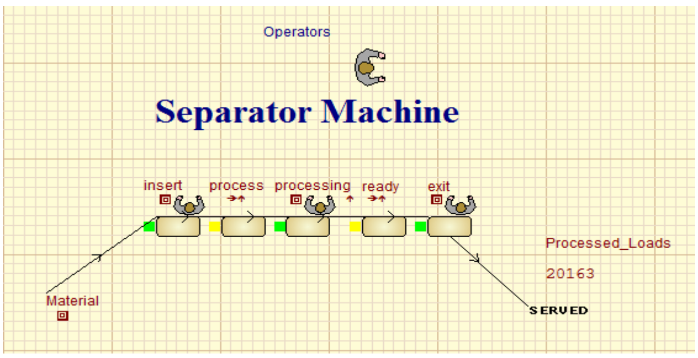


Fig. 2: Separator machine

The maintenance team and the number of maintenance carried out are shown below via the use of the counters and the application of simple equations that will be highlighted later below within certain activities. Furthermore, when maintenance is carried out, depending on area and type, the use of materials to carry out the work is considered and an inventory is kept as can be seen in figure 4 below to show how many parts are available in stock to ensure work can be carried out.

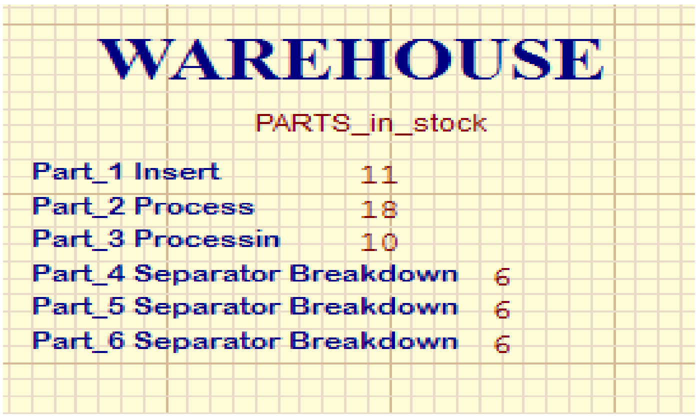


Fig. 3: Maintenance

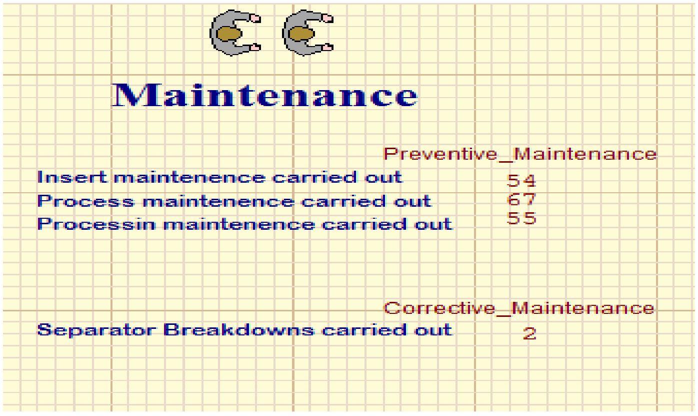
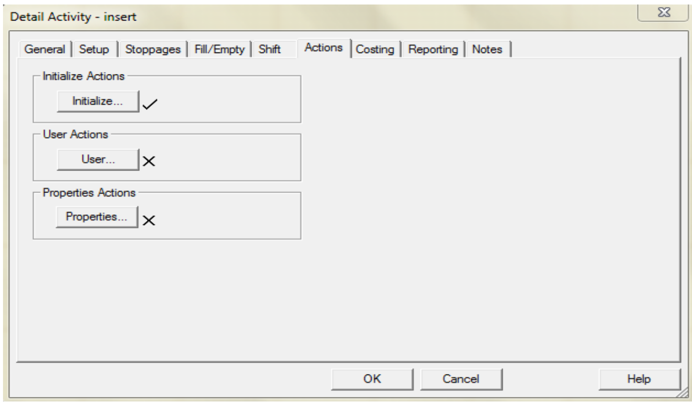
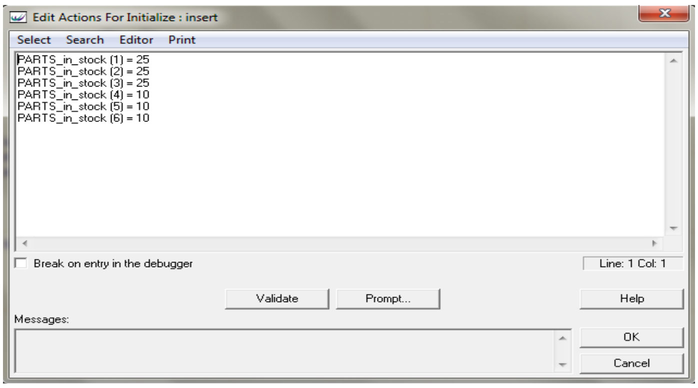


Fig. 4: Warehouse





In fig. 5.a and 5.b it show, how stock levels of all parts in the warehouse start at the adequate level. This was done by adding a simple equation as can be seen in figure 5.b in the first activity inside the initilise action tab.

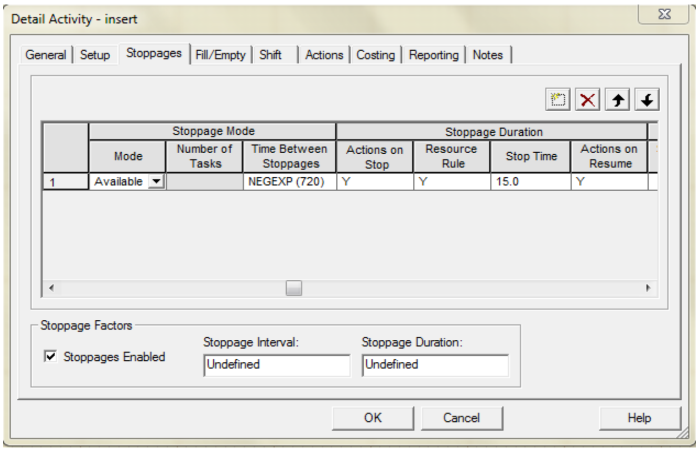


Fig. 6a: below shows how stoppages were added to the system, the timings i.e. when, for how long and further other aspects that needed to be adhered to i.e. who would carry out the maintenance and additional equations/formulas to correlate with work carried out and the parts used i.e. maintenance and warehouse.

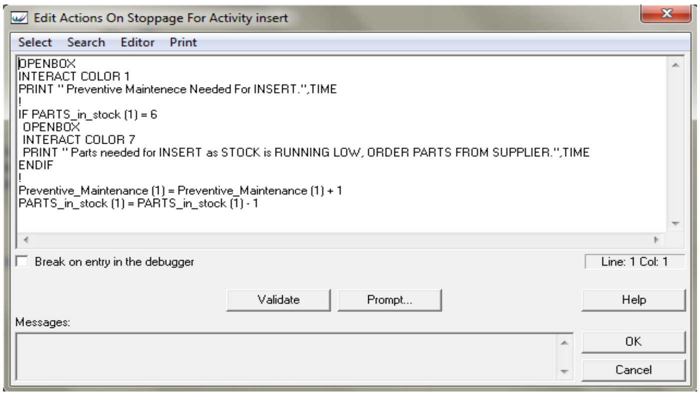


Fig. 6b: Below shows the application of formulas i.e. the first formula, tells the computerised system to report the need for maintenance on the insert area of the machine, this done via a OPENBOX formula. The "interact colours" jus tells it to display the message in different colours. The second formula is an IF Rule with an OPENBOX formula, so "IF" parts in stock equals 6, send out the message to order more stock.

The last two formulas here are simple counts where the number of maintenance and the number of parts used for maintenance are taken into account i.e. these simply add or subtract a number as resources enter and leave activities.

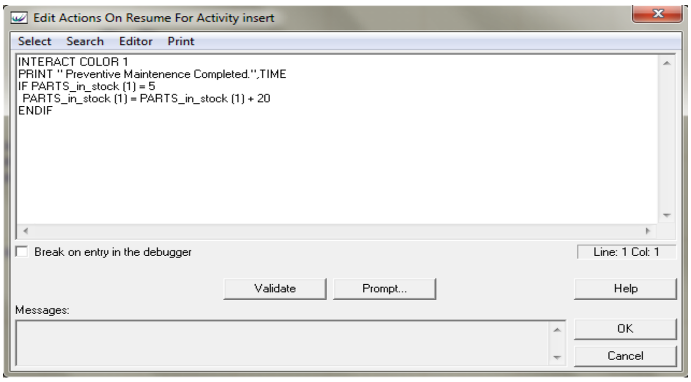


Fig. 6c: Crucial importance as the formula although an IF Rule, works hand in hand with both maintenance and warehouse i.e. this formula restocks the inventory when stock happens to fall low. So here, when there is 5 parts of a certain stock left, this formula automatically orders and stocks up another 20.

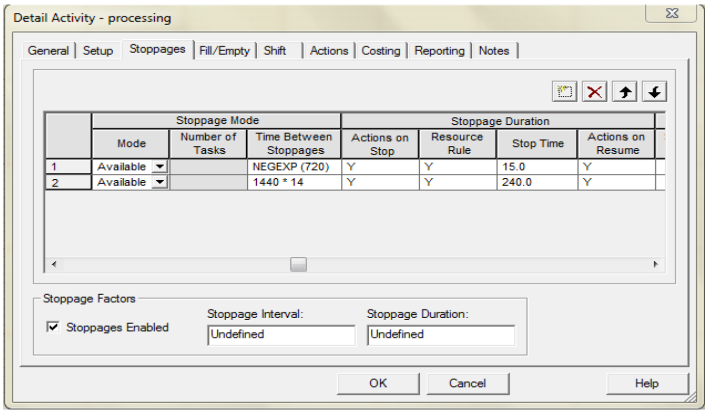


Fig. 7a: The additional stoppage enabled for corrective maintenance to be carried out, please refer to assumptions.

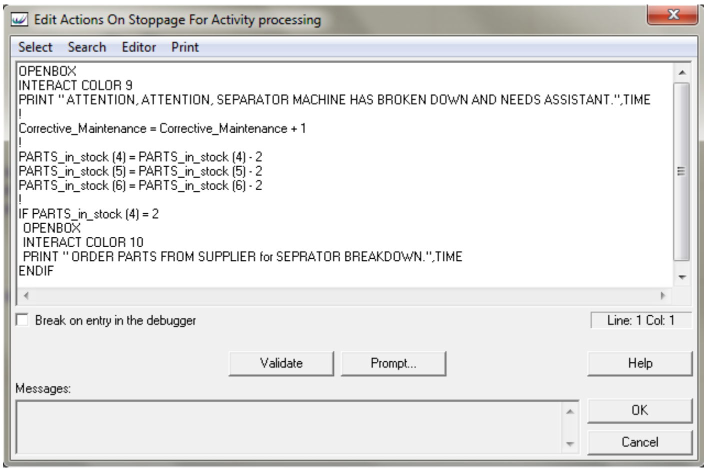


Fig. 7b: below shows the application of formulas to enable adequate correctional maintenance and use of appropriate stock, again this works hand in hand with both maintenance and warehouse with a automated response feature as does the entire system based on computers. Below as mentioned in assumptions, a total of 6 parts are required as can be seen, parts in stock 4, 5 and 6 minus 2 each time a resource responds.

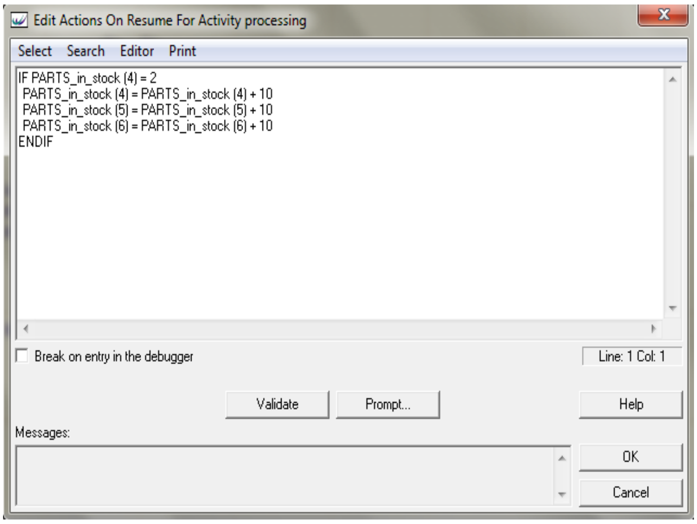


Fig.7c:The IF Rule is also prevalent below in fig. 7c to ensure adequate stock is called upon at the appropriate times as explained previously in figure 6b, however the correctional maintenance happens to be done once every 2 weeks so stock levels are allowed to fall quite low i.e. to the final two part.

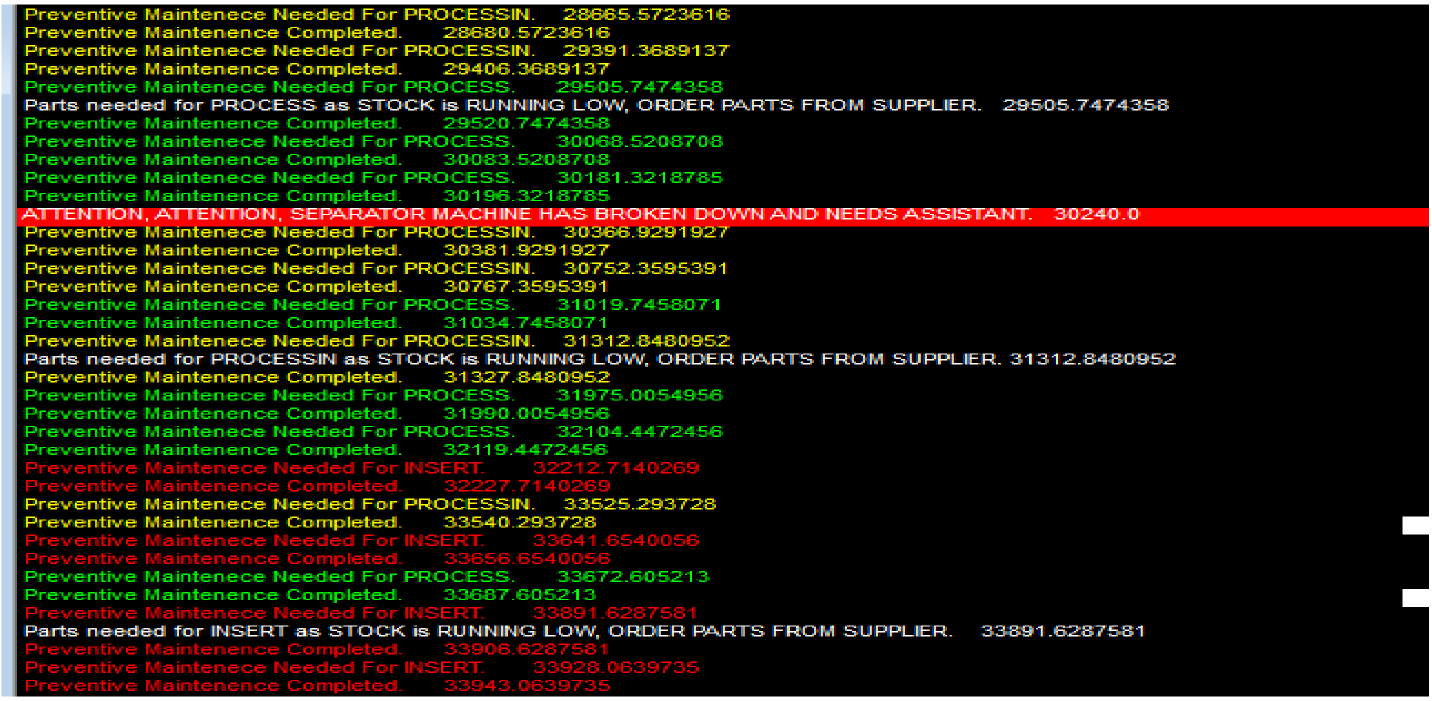


Fig. 8: Represents the computerised automated system that flags all aspects of maintenance and stock level issues.

Fig. 8 represents the computerised automated system that flags all aspects of maintenance and stock level issues. Different colours represent different aspects of the model as follows:

- Yellow writing represents preventive maintenance for PROCESSING
- Green writing represents preventive maintenance for PROCESS
- RED writing represents preventive maintenance for INSERT
- WHITE writing represents different stock levels running low
- WHITE writing with RED represents corrective maintenance

The above constructed model ensures all work is carried out adequately with adequate parts and ensures stock never falls below a certain levels. This ensures any future maintenance backlogs and problem areas by affective communication methodology adopted via the use of Witness Simulation.

Scenario 1 = 1 DAY

Below is a screen shot of scenario 1 where, after all the above mentioned assumptions and techniques have been implemented and the model has been run for a total of 1440 minutes i.e. 1 single day, the following results can be seen.

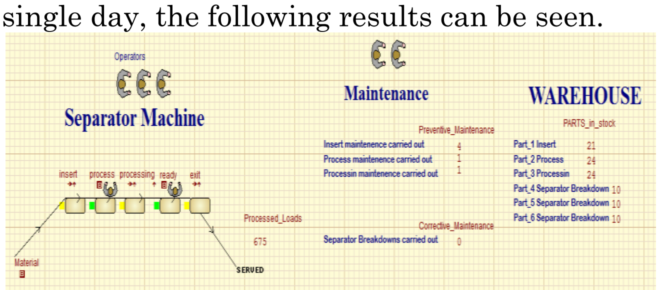
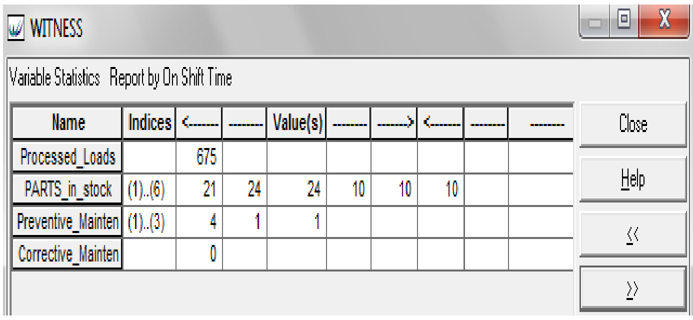


Fig. 9: Scenario 1 = 1 DAY

Fig. 10a below shows the variables statistics, this shows the number of loads processed, the amount of stock and the number of maintenance duties carried out. Therefore, total number of loads processed in 1 day is 675 tonnes, total number of preventive maintenance has been carried out is 6, 4 on insert and 1 each on process and processing. Further with reference to the maintenance, the number of stock that remain after each maintenance is tallied up as work is carried out i.e. 21 parts for insert remains, 24 parts for both process and processing still remains, whilst 10 parts each for the breakdown remain as no corrective maintenance has been carried out yet. This can also be seen clear above in figure 9 in the Warehouse area under parts in stock.


WITNESS

Variable Statistics Report by On Shift Time

Name	Indices	<-------	-------	Value(s)	-------	------>	<-------	-------	-------
Processed_Loads		675							
PARTS_in_stock	(1)..(6)	21	24	24	10	10	10		
Preventive_Mainten	(1)..(3)	4	1	1					
Corrective_Mainten		0							

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Fig. 10a below shows the variables statistics, this shows the number of loads processed, the amount of stock and the number of maintenance duties carried out.

Fig. 10b below shows the resource statistics i.e. the number of operators and maintenance staff; it also shows how busy or free the resources are, and the average times a task takes. The number of staff is also visible in the model however the time is not as this is implemented within the activity as well as mentioned in the assumptions. Here it can be seen that the operators take exactly 1 minute at each activity and exactly 15 minutes on maintenance. Further, both resources seem to be free for a large proportion of the time especially the maintenance.

WITNESS

Resource Statistics Report by On Shift Time

Name	Maintenanc	Operators
% Busy	3.13	46.93
% Free	96.88	53.07
Quantity	2	5
No. Of Tasks Started	6	3385
No. Of Tasks Ended	6	3383
No. Of Tasks Now	0	2
No. Of Tasks Pre-empt	0	0
Avg Task Time	15.00	1.00

Fig. 10b: below shows the resource statistics

Figure 10c below shows the activity statistics, the highlighted black indicates where the activity has been blocked, this will indicate preventive maintenance that is being carried out as mentioned above. As based on assumptions, it can be seen that dummy ACTIVTY ready and exit remain at zero.

Fig. 10c: Below shows the activity statistics, the highlighted black indicates where the activity has been blocked

Scenario 1 Findings

WITNESS

Activity Statistics Report by On Shift Time

Name	insert	process	processing	ready	exit
% Free	46.94	51.04	52.01	53.13	53.13
% Busy	47.01	46.94	46.94	46.88	46.88
% Filling	0.00	0.00	0.00	0.00	0.00
% Emptying	0.00	0.00	0.00	0.00	0.00
% Blocked	1.88	0.97	0.00	0.00	0.00
% Task Wait Resource	0.00	0.00	0.00	0.00	0.00
% Setup	0.00	0.00	0.00	0.00	0.00
% Setup Wait Resource	0.00	0.00	0.00	0.00	0.00
% Stopped	4.17	1.04	1.04	0.00	0.00
% Resuming Wait Resource	0.00	0.00	0.00	0.00	0.00
No. Of Tasks	677	676	676	675	675

By running the model for a single day and evaluating the statistics, it was very clear that the counters were in working order with regards to using the stock for maintenance needs as 6 preventive maintenances were carried out and the total numbers of loads were taken into account.

However, it was also clear that, currently the existing resources had too much free time or too many resources were on duty at once, further the average time was not realistic as it was always exactly 1 minute or 15 minutes to carry out tasks. Further scenarios need to be developed to take into account the above, corrective maintenance and the task of stock replenishment associated with low stock levels in warehouse.

Scenario 2 = 1 Week

Below is a screen shot of scenario 2, where the model is run for 1 week, this scenario has the following changes applied to it according to the findings of scenario 1 to make the model more realistic and efficient.

- Operators have been reduced to 4
- Maintenance staff now only consists of 1 individual
- Process time for entities within the activities has been changed to NEGEXP 1 for INSERT, NEGEXP 1.1 for PROCESS AND NEGEXP 1.2 for PROCESSING.
- The time taken for preventive maintenance to be carried out has been changed to NEGEXP 15 for INSERT, NEGEXP 16 for PROCESS and NEGEXP 17 for PROCESSING.

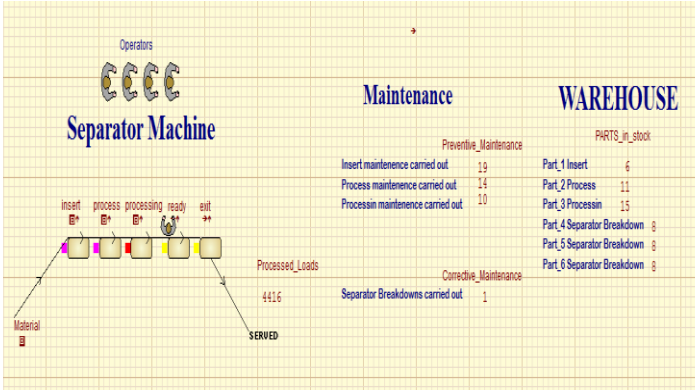

Fig.11: Scenario 2 = 1 Week

Below is the variable statistics after running the model for one single day just like scenario 1. All the number of parts remain the same other than the processed loads i.e. before the changes were applied, the total number of processed loads as can be seen in fig. 10a above was 675, now due to the changes applied in process time and maintenance time it has been reduced to 595 loads.

WITNESS

Variable Statistics Report by On Shift Time

Name	Indices	<-----	-----	Value(s)	-----	----->	<-----	-----	-----
Processed_Loads		595							
PARTS_in_stock	(1)..(6)	21	24	24	10	10	10		
Preventive_Mainten	(1)..(3)	4	1	1					
Corrective_Mainten		0							

Fig. 11a: variable statistics after running the model for one single day just like scenario 1

Below in fig. 11b is the actual scenario variable statistics after being run for 1 week, total number of processed loads is 4416, preventive maintenance has been carried out an increased amount of time as well as 1 corrective maintenance. According to the assumptions it can be seen as 1 corrective maintenance is carried out it requires 2 of each part, this is where the number has changes from 10 to now 8 in the 3 right hand columns below. The following is also visible within the model by the use of counters as can be seen in fig. 11.

WITNESS

Variable Statistics Report by On Shift Time

Name	Indices	<------	-------	Value(s)	-------	------>	<------	-------	-------
Processed_Loads		4416							
PARTS_in_stock	(1)..(6)	6	11	15	8	8	8		
Preventive_Mainten	(1)..(3)	19	14	10					
Corrective_Mainten		1							

Fig. 11b: The actual scenario variable statistics

Figure 11c below shows, some of the changes that have been applied and mentioned above i.e. operators = 4, maintenance staff = 1. Here we can see the effect the changes in process time have had on the model and the difference in time. Firstly it can be seen that the time taken has decreased for maintenance, this was not the desired effect that was wanted as it seems to be too low, and however the time for processing entities has increased very slightly as planned. Maintenance staff has been halved and even though seem to be free majority of the time but has really increased in busyness slightly when compared to figure 10b, the operators are more busy now than in scenario 1 when there is 5 operators.

WITNESS

Resource Statistics Report by On Shift Time

Name	Maintenanc	Operators
% Busy	5.55	57.71
% Free	94.45	42.29
Quantity	1	4
No. Of Tasks Started	44	22109
No. Of Tasks Ended	43	22109
No. Of Tasks Now	1	0
No. Of Tasks Pre-empt	0	0
Avg Task Time	13.01	1.05

Fig. 11c: shows, some of the changes that have been applied and mentioned above i.e. operators = 4, maintenance staff = 1.

Figure 11d is the activity statistics of scenario 2, when compared to scenario 1 figure 10c, it can be seen firstly at the top column, the amount of time activities are free has been reduced almost by half, the busy still remains approximately the same with slight variations. However the percentage of time the 3 key activities seem to be blocked has increased dramatically. This is due to having only a single maintenance staff, as he carries out both preventive and corrective maintenance and when both are need at once it causes a blockade. Further stopped time has increased slightly for process and processing where as insert has decreased, this is die to time, the first scenario was just for 1 single day where only 6 preventive measures took place whereas this scenario a total of 43 preventive and 1 corrective took place. The resuming wait for resource has hence also increased slightly due to reduction on employees.

WITNESS

Activity Statistics Report by On Shift Time

Name	insert	process	processing	ready	exit
% Free	22.28	27.43	38.85	56.19	56.19
% Busy	44.46	46.73	52.05	43.81	43.81
% Filling	0.00	0.00	0.00	0.00	0.00
% Emptying	0.00	0.00	0.00	0.00	0.00
% Blocked	29.31	23.54	8.24	0.00	0.00
% Task Wait Resource	0.80	0.00	0.00	0.00	0.00
% Setup	0.00	0.00	0.00	0.00	0.00
% Setup Wait Resource	0.00	0.00	0.00	0.00	0.00
% Stopped	2.68	2.01	0.86	0.00	0.00
% Resuming Wait Resource	0.47	0.29	0.00	0.00	0.00
No. Of Tasks	4419	4418	4416	4416	4416

Fig. 11d: The activity statistics of scenario 2

Scenario 2 Finding

By running the model for 1 week and evaluating the changes applied and statistics, it is very clear that the counters are in working order with regards to using the stock for maintenance needs, as 43 preventive and 1 corrective maintenance were carried out and the total numbers of loads were taken into account. Further testing need to be applied to see how stock replenishment works, as the stock level has yet been reduced to a very low level where more stock is required.Currently although the existing resources have too much free time they do not have too many staff as work at times needs to be carried out simultaneously, the average time was more realistic as it did not take exactly 1 minute, however the time taken for preventive maintenance seen to decrease. Further scenarios need to be developed to take into account the above, corrective maintenance and the task of stock replenishment associated with low stock levels in warehouse.

Scenario 3 = 1 Month

Below is fig. 12, a screen shot of scenario 3, where the model is run for 1 month and guarantees the need of stock replenishment, this scenario has the following changes applied to it according to the findings of scenario 1 and 2 to make the model more realistic and efficient.

- Maintenance staff has been changed back to 2
- The time taken for preventive maintenance to be carried out has been changed to NEGEXP 15 for INSERT, PROCESS and PROCESSING.

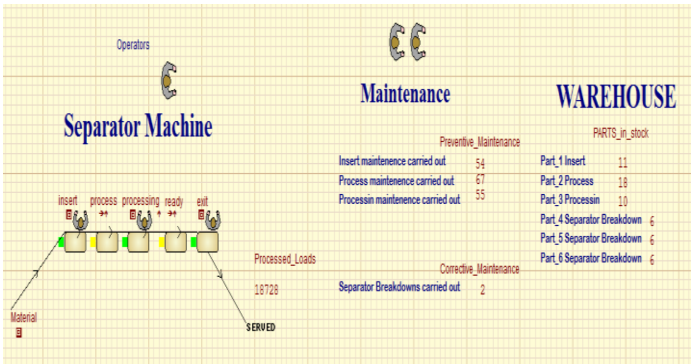

Fig.12a: Screen shot of scenario 3

Below in figure 12a is the variable statistics; here it is clearly visible as is when running the actual model that, when stock falls to a certain low, the stock is replenished automatically i.e. according to the assumptions we start with full stock i.e. 25 parts of each for preventive, however it can be seen below that, although 54, 67 and 55 maintenance has been carried out, parts still remain in the system i.e. warehouse, further 2 corrective maintenance has now been carried out and parts have reduced by 2 every time as mentioned in assumptions. At the end of the month total number of loads processed = 18728.

WITNESS

Variable Statistics Report by On Shift Time

Name	Indices	<-----	-------	Value(s)	-------	------>	<------	-------	-------
Processed_Loads		18728							
PARTS_in_stock	(1)..(6)	11	18	10	6	6	6		
Preventive_Mainten	(1)..(3)	54	67	55					
Corrective_Mainten		2							

Fig. :12a is the variable statistics

Below is the resource statistics at the end of running the model for 30 days, firstly average task time has now been reduced to a more realistic figure of slightly above the 15 minutes rather than scenario 2 where it had increased quite a bit for maintenance, the operators time has also jumped up a second which shows how they are working together. Maintenance now has decreased busy time as there exist 2 rather than the initial change of 1 and operators are busy as usual,

WITNESS

Resource Statistics Report by On Shift Time

Name	Maintenanc	Operators
% Busy	3.49	57.43
% Free	96.51	42.57
Quantity	2	4
No. Of Tasks Started	178	93736
No. Of Tasks Ended	178	93733
No. Of Tasks Now	0	3
No. Of Tasks Pre-empt	0	0
Avg Task Time	16.96	1.06

Fig. 12b: resource statistics at the end of running the model for 30 days

Below figure 12c shows the activity statistics of scenario 3, busyness remains quite stable for all activities when compared to scenario 2, however activity INSERT and PROCESS seem to be blocked for increased amounts of time. This has to be combated to ensure greater efficiency. Stopped time for INSERT has reduced but increased for both PROCESS and PROCESSING however, resuming wait resource has diminished all together.

JIT (Just In Time)

Findings

From the very start the importance of maintenance is highlighted within the

WITNESS

Activity Statistics Report by On Shift Time

Name	insert	process	processing	ready	exit
% Free	22.03	24.65	36.83	56.65	56.65
% Busy	43.35	47.51	52.16	43.35	43.35
% Filling	0.00	0.00	0.00	0.00	0.00
% Emptying	0.00	0.00	0.00	0.00	0.00
% Blocked	32.10	25.55	8.07	0.00	0.00
% Task Wait Resource	0.79	0.00	0.00	0.00	0.00
% Setup	0.00	0.00	0.00	0.00	0.00
% Setup Wait Resource	0.00	0.00	0.00	0.00	0.00
% Stopped	1.73	2.29	2.94	0.00	0.00
% Resuming Wait Resource	0.00	0.00	0.00	0.00	0.00
No. Of Tasks	18730	18730	18729	18729	18728

Fig. 12c: shows the activity statistics of scenario 3

above philosophy indirectly although it may not use the word maintenance, the core being Flow, Flexibility and Developing the chain of supply. In order for any type of manufacture or production that uses machinery, maintenance is combined to the facets of total output and efficiency, maintenance allows the flow of materials, enables value to be added to products, flexibility and adequate requisite of supply to ensure fully working order to meet targets and produce appropriate output and quality. Further, the J.I.T philosophy recognises the needs and the trouble maintenance can cause in any industry and hence has maintenance as the first hurdle of enabling J.I.T [8]. Affective maintenance abolishes many problem areas and backlogs that can result in huge deficits for organisation, especially in the cement industry. The Simulation model developed demonstrates a very effective approach in maintaining affective maintenance as a whole that will enable the facility to move forward at a far greater pace. The model further takes into account other aspects of the philosophy as mentioned previously in the J.I.T report.

Materials Management

Findings

The objectives of materials management as described above are of utmost importance to the facility, as this correlate to the three questions as to which, when and how much materials are required. These problem areas are solved via use of Witness Simulations automated response system aided by implicated equations. The systems notifies all management at all levels, regarding, how much materials have been used with regards to maintenance, how much materials are available and when new materials should be ordered from suppliers. The development of "what if" scenarios enable the user to see the types of problems that may arise by running time effective scenes i.e. the model developed can be run for any amount of time; this will show how much materials have been used with the number of maintenance carried out.[9,10]

Dependent versus Independent Demand

Findings

From the above, it is clear that inventory products related to the maintenance falls under independent demand as these materials are not directly related to the end product manufactured at the facility. However, further reading proves this matter to be dependent demand as well as this use or amount of materials can be forecasted. For example, the facility plans to manufacture 1000 tonnes of cement, from this production schedule that will highlight the use of machinery, one can forecast the amount of preventive maintenance as well as corrective maintenance. Therefore, maintenance is both independent at times as well as dependent in other times.

Material Requirements Planning (MRP)

Findings

The above Material Management and Demand sections of the report, when combined together allow and cater for MRP and MRP11. These strategies have to work side by side in order to achieve strategic results. MRP and MRP11 is more about the actual production of the end product with little reference to maintenance as such, however, it is all about allocating the right resources, to the right place, at the right time, in the right quantity and staying ahead of schedule. None of this is achievable without the use of affective maintenance to the facility flowing forward with production schedules. The schedules listed above only work well, when there are very few if not any disturbances within the facility[11]. This strategy also makes aware the need to plan and control systems, it highlights the need to work with many other areas producing affective communication and using software as a strategy to move forwards.
The final paragraph where it states "MRP11 is by definition fully integrated or at least fully interfaced" is of great importance, this applies pressure on the importance of working as part of a team with affective communication and moving forward towards better systems i.e. software, to achieve total control. [12,13].The model developed, although for only a single machine demonstrates the ability to stay ahead of forecasts and problem areas by the use of a new computerised automated system that enables affective communication at all levels [14, 15].

Conclusion

After testing the model for 30 days, it proves to be very affective taking all the above into account aided by mathematical equations, however as mentioned previously, this has only be done for a single machine, this has to be done for the entire system so those at managerial levels within the facility can communicate effectively. Further contemplation with regards to the model, shows there may be in fact a problem area i.e. the amount of time it takes supply of certain materials to get to the desired location, however, this can easily be sorted out via the use of forecasts. For example, currently the separator machine needs approximately 6 preventive maintenance in a single day, if delivery from supplier takes 5 working day for example, make sure stock does not fall below that level i.e. 6 preventive maintenance X 5 working days = 30. Therefore a minimum total of 30 parts must be available at the last resort when ordering stock.
Currently, in the developed model, with the use of equations, stock levels are allowed to fall down to the last remaining 5 parts for the preventative and 2 parts for the corrective, all that really needs to be done now is a forecast and actual data with regards to parts to be implemented for accuracy.
The model constructed using Witness Simulation, caters to all the needs of the above mentioned philosophies and the needs of the existing facility. It tells you how much of different stock is used, how much is remaining and when stock is low, it categorises the location where work is being taken out, complex equations aid the efficiency and provide excellent communication and teamwork throughout all levels of the facility.

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