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A GPSS MODEL FOR RELIABILITY OF A SIMPLE SUGAR MANUFACTURING SYSTEM

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ABSTRACT

A GPSS model was developed to study the system reliability of a simple sugar production system. Three experiments were conducted to find out the better course of action in improving a sugar mill system performance. The model could be applied to other similar production systems.

INTRODUCTION

Reliability is the probability that an item will perform a defined task satisfactorily for a specified length of time when use for the purpose intended and under the conditions for which it was designed. A typical sugar manufacturing industry consists of large number of operating units working together to produce sugar. Of them cane cutter, crushers, pumps, clarifiers, boiler, evaporators, crystallizer, mixer, centrifuges etc. are considered to be the main operating units. To secure satisfactory sugar production, these operating components must be sufficiently reliable. Since all these units are sequentially interrelated to produce sugar, any break down of a single unit may cause total shut down of the whole system, resulting in inefficient operation and financial loss. Generally two or more units are placed in parallel to improve the system reliability. Another approach may be to install more reliable unit. Thus, there is a trade-off between these two. In connection to these approaches, the objectives of this study is to determine a more reliable system. Selection of more reliable system is closely related to economics. However, this study would be limited only in determination of more reliable system of operation.

Most of the failures of operating units are due to wear out, however some are due to early failure. For a typical unit frequent failure may be observed in the early period or during the wear out period of the equipment. Failure of operating unit may be classified as partial, complete and catastrophic. Partial failure may occur when the unit is still in operation but operating with lower efficiency. Complete failure occurs when there is a total stoppage of the unit. A total failure which occurs suddenly and may result in damage to other units is considered as a catastrophic one. A system down time is a function of the unit itself, the severity of the failure, availability of men and materials and maintenance procedures. If a stand-by/parallel unit is installed, the system down time may only be the time necessary to divert the product and start-up the standby unit. However, for a catastrophic failure there may be insufficient time for recovery and even though a parallel unit is available a total system failure is likely. Reliability of a system may be improved by taking the following measures :

1. Installing better and more reliable unit(s) in the system.
2. Providing parallel/stand-by unit(s).
3. Following better maintenance procedures.

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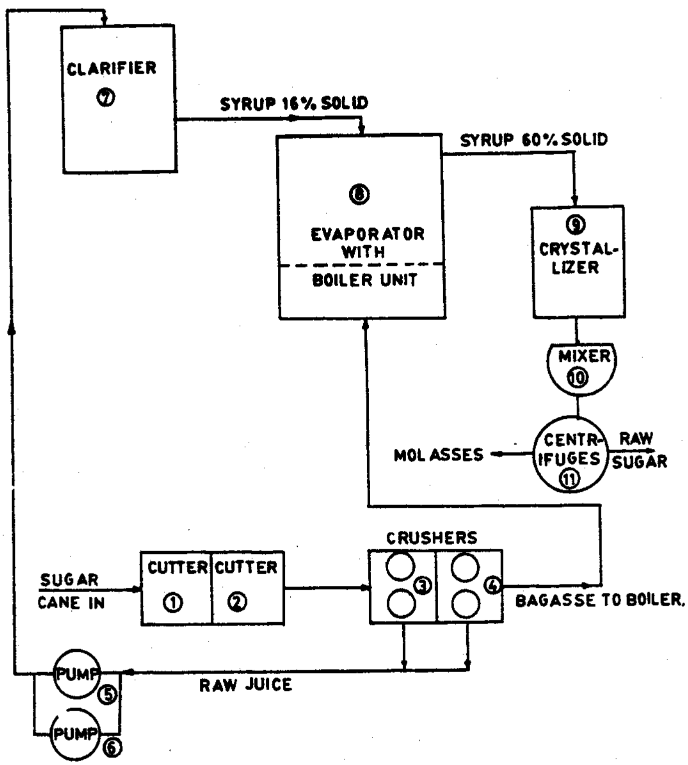

FIG. 1 FLOW DIAGRAM FOR A SIMPLIFIED SUGAR PRODUCTION SYSTEM.

4. Employing skilled man power
5. Maintaining spare parts inventory
6. Providing better workshop facilities

This study includes first two of the above mentioned measures to determine which one would be better to improve reliability of the existing sugar mill system.

THE MODEL

Since sufficiently large numbers of components are involved along with different probabilities of failure, it is too complex to determine the time losses due to failure of units analytically. A GPSS (General Purpose Systems Simulation) model was developed to determine time losses due to a system failure. A simplified sugar production system using Fig. 1 was used to build the model. Fig. 2 shows the conceptual flow diagram of the computer model. The following assumptions were considered in building the model..

1. Mill was operating through out the seasons. It was located in tropical region where farmers can raise sugarcane year round.
2. Mill was operating 16 hours per day in two shifts of 8 hours each. Once a month, mill was stopped for 3 days for monthly maintenance.
3. Once a year, it was shut down for major overhauling for 30 days at the end of the year.
4. For minor damage, no system breakdown time was considered.
5. Time expenditures for all events were exponentially distributed.

The GPSS based computer model (Gordon, 1975) was constructed for a simple system of sugar manufacturing industry as shown in Fig. 1. Local repairmen were considered available to make repairs and to move the equipment to a central workshop for major repair, if required. Transport facilities must be provided to support the system operation. Unit No. 1 and 2; unit no. 3 and 4; and unit no. 5 and 6 are kept in parallel and only one unit need to be in operation for the system. For parallel units different modelling was considered since the system was unaffected only if all units in parallel were down. Severity of failure, using severity functions were also introduced in the model with a view to indicate the need for repairs extending from minor repair to major repairs in the workshop. Only data changes were required for experimentation of the model.

The model as coded in the GPSS language has the following program logic and entities. The complete computer program may be obtained from the author.

Program Logic

1. Transaction represents operating units.
2. The whole system is considered as storage of capacity to equal number of units in the system.
3. Facilities represent the unit location.
4. Unit no. represents different types of unit and also provides linkages to the failure patterns.
5. When a unit fails, it does not leave the storage until either a replacement has been found or the original unit has been repaired and is ready for service.

GPSS Entities

1. Transactions	machine units
2. Time Unit	hour
3. Queues :	
a. LINE 1	queue for crew
b. LINE 2	queue for transport facilities
c. LINE 3	queue for workshop facilities
4. Facilities	unit positions, truck, crew and workshop
5. Half word matrix 1:	
Rows	unit index no.
Column 1	mean time to failure
Column 2	mean time to repair in the workshop
Column 3	mean time to remove/ install or repair by local repairmen
Column 4	mean transport time to/from workshop

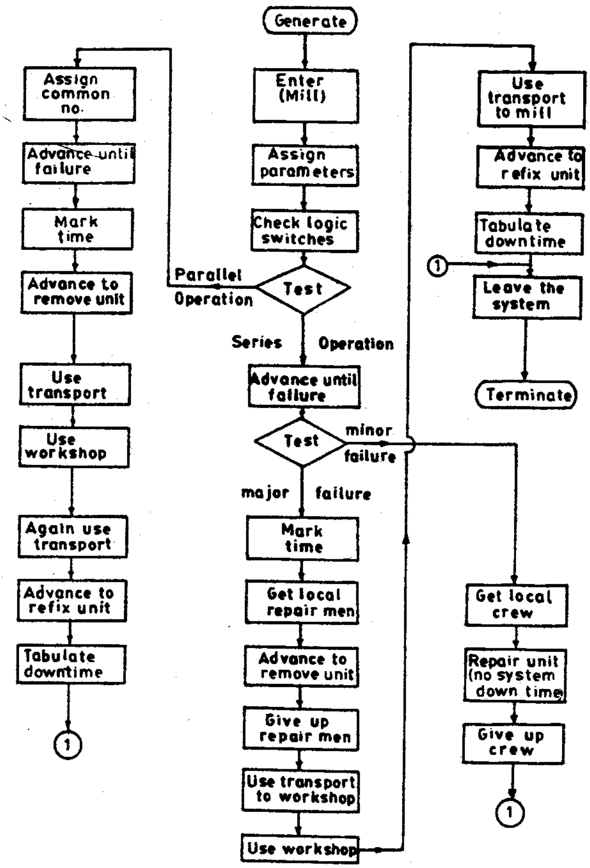

Fig. 2 Conceptual Flow Diagram of the computer model

DESIGN OF EXPERIMENT AND RESULTS

The necessary data for the experimentation were collected directly from the literature (Cane Sugar Handbook, 1977). The mean failure time of individual unit was computed from historical data on the failure of individual unit into a distribution. Failure severity functions for units were also used in this model as defined by Thomas and Zanakis (1974). A basic experiment using computer was performed on the operating units (Table 1) of a sugar mill with a view to determine the system mean down time.

Table 1 Experimental design and mean time of failure of the machines

Experiment 1		Experiment 2		Experiment 3		
Unit name	Unit index	Mean time of failure (hr)	Mean time of failure (hr)	Unit name	New unit index	Mean time of failure (hr)
Knife	1	400	400	Knife	1	400
Knife	2	200	200	Crusher	2	1900
Crusher	3	1900	1900	Crusher	3	1800
Crusher	4	1800	1800	Pump	4	500
Pump	5	500	500	Pump	5	500
Pump	6	500	500	Clarifier	6	800
Clarifier	7	800	800	Boiler and evaporator	7	2800
Boiler and evaporator	8	2800	2800	Crystallizer	8	2500
Crystallizer	9	2500	2500	Mixer	9	300
Mixer	10	300	300	Centrifuge	10	300
Centrifuge	11	300	600	Centrifuge	11	200

Table 2 The summary results of the experiments

Experiment 1			Experiment 2			Experiment 3		
Failure frequency within 0-8000 (hr)	Mean system down time (hr)	Standard deviation	Failure frequency within 0-8000 (hr)	Mean system down time (hr)	Standard deviation	Failure frequenc y within 0-8000 (hr)	Mean system down time (hr)	Standar d deviation
19	2436.68	2842	17	2304.53	3004	9	1456.55	1832

This down time was used as a datum to compare with any changed pattern of the systems. Second experiment was conducted by installing a more reliable centrifuge and replacing presently used one. Since the centrifuge was an important unit in the system and was more sensitive to failure (Table 1), this study was concentrated mainly on this particular unit. The mean system down time was recorded. Third and last experiment was performed by introducing an extra unit of centrifuge as a parallel unit and decreasing one unit of knife (unit 2) from the model. Mean system down time from all the experiments were compared. Based on the comparison, improved system was chosen with higher reliability of operation. The summary of the design of experiment is shown in Table 1.

The experimental key results were gathered from computer outputs and are presented in Table 2. Table 2 reveals the fact that the best policy to improve the reliability of the system is to provide an extra unit of centrifuge in parallel and reducing a unit of less reliable knife.

CONCLUSIONS

The GPSS model could be successfully applied to study and improve the system reliability of any industry like sugar industry. It could help in decision making process of the industrial management. The model is flexible enough to handle and analyze any industrial system of more complex in nature. Only minor modification and/or addition of subprogram to the model could serve the purpose. The model could be further improved by introducing cost-benefit analysis into the model.

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