Manufacturing Systems - Problems, Modeling, Analysis and Solutions- A Computational Approach to Real Life Industrial Problem

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Abstract

In this research paper the implications of Total Productivity Measure (TPM) in assessing the operational healthiness of a manufacturing system are discussed. The operational efficiency of a manufacturing unit is computed and compared through several modeling techniques and the results are analyzed scientifically. The impact of operational efficiency of the manufacturing unit on specific consumption norms and consequently on financial results of the system are worked out. Several productivity improvement models are designed and recommended for implementation for improvement in the operational efficiency of the system.

Keywords: *TPM, MTBF, MTD, Reliability, Maintainability, Availability*

1. Introduction

One of the main objectives of any manufacturing organization is to earn profits and the operational healthiness of the enterprise is measured by the index Total Productivity Measure (TPM). The more the TPM, the healthier the enterprise is. A TPM of "one" indicates a situation of no profit no loss. In continuous process production systems the capacity utilization of the organization plays a key role in determining its productivity. If the capacity utilization is more, the consumption efficiency of the input raw materials will be higher and vice versa. Therefore the productivity of the organization depends on the capacity utilization of the enterprise. The capacity utilization, in turn, depends upon the availability of the system for production purposes.

In manufacturing organizations where the selling price of the end product is controlled by the State, it is imperative that the only way for the managements of the organizations to be competitive is to cut down the cost of production. However, cutting down the cost of production below a point may not be feasible for certain given working environment / constraints under which the managements are required to carryout the operations. The technology forced upon these manufacturing units in which there are certain design deficiencies, shortage or poor quality of raw materials supply etc., are some of the constraints under which the managements are required to carry out the operations. Under these circumstances, one of the ways to assess the operational viability of such production units is to go-in for comprehensive modeling of the entire production system, as attempted in the subsequent sections of this research paper.

2. The Problem Setting:

The present case study is undertaken in a fertilizer manufacturing public sector organization, Fertilizer Corporation of India (FCI) Ramagundam Unit, Andhra Pradesh, manufacturing the nitrogenous fertilizer "urea". The organisation adopts coal gasification technology developed by M/s Krupp Koppers of erstwhile West Germany. The technology is yet to be established on large capacity units like the one under study. There are certain problems like poor quality / inadequate supplies of raw materials like coal, power etc., There are also problems pertaining to frequent breakdown of machines due to design deficiencies and equipment mis-match in the unit. All these factors contributed to the low capacity utilization of FCI Ramagundam Unit.

The selling price (i.e consumer price) of the fertilizer " urea " is fixed by the Government at a very low level so as to encourage the farmers to utilize more and more fertilizers, where as the actual cost of production is very high. To protect the manufactures of fertilizers from losses, the Government fixes a price known as "retention price" which depends on the technology employed by the company, capacity utilization of the plant and various other factors. The difference between the retention price and the consumer price is paid as "subsidy" by the Government to the manufacturer.

The retention price (protection price) for FCI Ramagundam Unit (hereafter referred to as "unit" throughout the thesis) is fixed by the Government of India, initially at a production level of 80% of capacity utilization and is gradually de-rated to 66%, 55% and finally to 45% based on the recommendations of various high power committees set-up by the Government. The committees have studied the technology and various problems faced during the operations of the unit and recommended that the retention price should be fixed, based on the attainable capacity of 45% and not at 80% as originally thought of. However even this capacity of 45% is not achieved during the actual operations of the unit. Since the actual operations of the unit is at a production level of less than 45% of the capacity, the retention price fixed by the Government of India is far less than the actual cost of production. The situation is explained as follows. Fertilizer Industry Co-ordination Committee (FICC), an apex body at the Government of India level, has fixed the specific consumption (consumption per one MT of the final product, "urea") norms for the raw materials at a production level of 45% capacity of the unit. The retention price fixed for the production unit is based on these specific consumption norms. Since the capacity utilization of the unit is less than 45%, the actual specific consumption of the raw materials are on much higher side than the norms fixed by FICC. Therefore, the cost of production incurred during actual operations of the unit is more than the retention price set by FICC. As a result, there have been heavy financial losses for the unit and consequently, the unit has been declared "SICK" and referred to BIFR(Board for Industrial and Financial Reconstruction) for studying the viability of operations and to suggest revamping measures. Presently the operations of the unit are suspended by a decision of the Government.

It is under these circumstances the present study is undertaken to scientifically evaluate the practicable attainable capacity utilization of the unit and consequent revision required in the retention price. The financial impact on the unit, in case of continuation of the operations is also examined in this study.

3. The Methodology:

The heart of the entire fertilizer unit is the "gasification plant" where the coal gasification technology, developed by M/S. Krupp Koppers of erst- while West Germany, is employed. The plant is laid down in three identical streams with one gasifier in each stream and this is defined as the "Production system" for the present study purpose. The production process of this plant has been modelled as a Markov chain and a detailed analysis has been carried out. The state- space for the process of the production system has been defined. There are three distinct states for the process viz., the run state, the idle state and the down state. The one- step staionary transition probability matrix, n- step conditional probabilities, n-step unconditional probabilities, the steady-state probabilities, the first passage time and recurrence time of the state of the system are computed. This analysis gives the complete description of the behavior of the process of the production system. The average availability of the production system has been computed to be 0.6265.

The field- failure data of the production system has been collected. Frequency distributions for failure and downtimes of the system have been developed. A detailed reliability-maintainability-availability analysis of the production system has been carried out. Various observed functions viz., failure density, failure rate, reliability etc., have been worked out. It has been established that the inter-arrival rate of failures follows exponential distribution and chi-square goodness of fit test has also been carried out. The Mean Time Between Failures(MTBF) of the gasifiers has been computed to be 73.65 hours. It has been established that the downtimes of the gasifiers follow log – normal distribution and the chi – square goodness of fit test has also been carried out. The observed and theoretical values for the maintainability function have been worked out to be 44.99 hours. It implies that the production system on an average, fails after every 73.65 hours and whenever it fails it will be down for 44.99 hours for carrying out necessary repairs and maintenance in order to put it back into operable condition. Subsequently the availability of the production system, through reliability-maintainability analysis, has been computed to be 0.6208.

The simulation experiment has been carried out both for inter arrival rate of failure as well as downtimes of the gasifiers of the production system. The MTBF and MDT values obtained are 54.13 hours and 46.87 hours respectively. The availability of the production system, using simulation modelling has been subsequently computed to be is 0.5359.

4. Analysis

The values of the availability of the production system computed through different models discussed earlier are compatible and are in agreement with each other. However, the value obtained from Markov chain modelling, which is a mathematical model, has been utilized to compute the expected gasifier run hours of the production system and subsequent analysis.

Correlation analysis has been carried out to assess the degree of association between "gasifier run hours" of the production system and the "actual urea production". The correlation coefficient 'r' was found to be 0.9625, which indicates a very high degree of association between the two variables. A mathematical model has been formulated depicting the relationship between the two variables under study. The appropriateness and adequacy of the model has been discussed in detail. The co-efficient of determination has been computed to be 0.9264. It would mean that 92.64% of the total variation in urea production is explained by gasifier run hours. This is highly significant. The tests like t-test for determining the significance of regression co-efficient, F-test for determining the significance of co-efficient of determination and d-statistic for determining the auto-correlation between the two variables have been carried out to test the appropriateness and adequacy of the regression model developed. The estimated monthly urea production has been computed from this regression model. Subsequently, the practicable attainable capacity of the Ramagundam Unit has been worked out to be 36.55, say 37%. Thus, the attainable capacity of FCI Ramagundam Unit is much less than the capacity taken (45%) for the purposes of computing the existing retention price of urea. Thus, the need for revising the retention price has been established.

The actual specific consumption of the raw materials for three months pertaining to the past period at a monthly production level of around 37% of the installed capacity has been taken and the average specific consumptions are worked out. These specific consumptions are proposed as norms for retention price computation since it is established that the attainable capacity of the production unit is only 37% by the scientific analysis carried out as discussed in preceding sections. It is also proposed that the actual fixed expenses incurred during the latest financial year of the operations of the production unit should be taken into consideration for the retention price computation. The estimated retention price of urea has been calculated based on these proposals. The proposed retention price, thus, worked out to be Rs.14178 per MT as against the existing retention price of Rs. 8032 per MT of urea. Thus an increase of 76.52% is proposed. The financial impact on the unit has also been worked out based on the new retention price proposed. It is estimated that the contribution (i.e. sales revenue less variable cost) turns out to be positive (Rs. 57.88 crores) from the existing negative contribution of Rs. 9.76 crores during the financial year. (The operations of the unit were suspended by a decision of the Government of India and the viability of operations of the unit are under examination by the Board for industrial and Financial Reconstruction, BIFR). Thus, the estimated revenue from the operations of the unit is more than the estimated variable cost incurred during the operations. However, this positive contribution is not fully adequate to absorb all the fixed expenses. These costs are sunk costs and have to be incurred irrespective of the decision whether to continue with the operations of the unit or to suspend the operations. Since the contribution is positive and is covering more than 50% of the fixed expenses, the operations of the unit are recommended to be continued.

It is also observed that the actual specific consumptions achieved during the financial year are more than the specific consumptions computed from the scientific modeling and analysis carried out during the course of this research work. Therefore, certain short- term measures are proposed to improve upon the specific consumptions. However, a long term strategy of conversion of feedstock from coal to naphtha has been proposed. Since it is established that naphtha technology is more economical than the coal gasification technology on large capacity plants like FCI Ramagundam Unit. The proposal is expected to result in a net profit of Rs.61.83 crores per annum. This proposal involves a capital outlay of Rs.511.77 crores, which needs the approval of the Government of India. However, till such time the proposal is approved by the Government, it is recommended that the operations of the unit may be allowed to be continued.

5. Application of Other Evaluation Models

A model known as "Inter Plant Productivity Model (IPPM)" has been developed to evaluate the operational efficiency of all process plants of the production unit. Various sub-factors of the model viz., the specific consumption efficiency factor, minimum loss factor and overtime minimization factor are recommended to be computed every month. Then the plant productivity factor is obtained by integrating all the sub-factors through a relation suggested. The computational procedure of the model is illustrated with actual data. It is recommended that, the plant scoring the highest average plant productivity factor, during the period of operation of 12 months in a financial year, be declared the best operating plant of the year. Certain awards are also proposed to be presented to the best operating plant of the financial year. This model is expected to create a sense of competitiveness amongst the process plants of the unit, which leads to improvement in overall productivity of the organization.

A multi-factor group incentive scheme is designed specifically for the production unit under study. The scheme is expected to increase the production level in the organization, to improve the manpower efficiency and to improve the consumption norms of the major process raw materials. The scheme developed is based on two indices viz., the productivity index and the material utilization index. The procedure for computing the above mentioned indices and arriving at the incentive earnings has been discussed at length. It is expected that the implementation of this scheme will motivate the employees in achieving the higher production and productivity.

The modern trend in many continuous production systems is to offload the "routine repair and maintenance" jobs to contracting agencies. In choosing qualified and reputed contracting agencies inorder to minimize the execution time and the associated costs involved. At the same time, care has to be taken to maintain the quality of the work done inorder to prevent frequent failures of the plant and equipment. A scientific method of evaluating the contracting agencies before the work order is placed, is expected to achieve this objective by eliminating/ black-listing the inefficient contracting agencies from getting the work orders awarded. A multi–factor evaluation scheme comprising of three factors viz., time taken for execution of the work, actual cost of the work executed and the quality of the work executed is designed for the production unit under study. A detailed discussion has been carried out on the methodology proposed.

6. Conclusion

Thus in this research work, the present problems faced by the production unit have been discussed in detail and an extensive modeling and analysis work has been carried out to understand the behavior of the production system. Based on the results of the study, a change in the retention price of the product has been discussed. Certain short-term and long-term measures are also proposed to bring in efficiency into the system. Some motivation and evaluation models are also designed and proposed for implementation in order to improve the overall productivity of the organization.

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