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An Analysis of the Stochastic Behaviour for the Reliability and Cost Benefit Analysis in a Petrochemical Industry

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Abstract

This paper mainly deals with the reliability and cost benefit analysis of Inert Gas units in a petrochemical industry. Network reliability evaluation using probability expressions have been briefly discussed by various authors.In this paper, the stochastic behaviour of the Inert Gas is being analyzed. Methodology for reliability assessment is obtained by using the updated techniques for two Inert Gas units. Reliability study, failure analysis, cost function for starting the new inert gas unit have been discussed. The causes for failure and remedial solutions are suggested along with numerical calculations and graphical representations.
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Key Words and Phrases: Reliability, Maintainability, Failure mode, Effect analysis, Mean time before failure.

1 Introduction

In any petrochemical industry, machinery maintenance and repair is quite costly, however production losses are due to equipment failures. Even if the equipment design is competent and the equipment is operated strictly within the limitations set in the specification, reliability depends on the standards of maintenance. Liquid ammonia from ammonia plant is sent through the tube side of the vapouriser, where it is converted into ammonia vapour by the sensible heat of gas from dissociator in the shell side. Ammonia vapour is then passed through electrically heated furnace of the dissociators, over the catalyst tubes at temperatures between $925^0C - 1000^0C$ and it is cracked down to gaseous hydrogen and nitrogen.

Vijayalakshmi et al. (2005) have analysed the bulk queue G/M/1 in inventory control and discussed about the general bulk queueing system for limited batches Vijayalakshmi et al. (2007). Wei et al.(2012) has discussed about the Globalization, industrial restructuring and Florez et al.(2013) has designed an Optimization model for sustainable materials selection using objective and subjective factors. Infante et al. (2013) has analysed the oil and gas industry with multicriteria decision making. Hou et al. (2014) has derived the Factor analysis and structural equation modelling of sustainable behavior in contaminated land remediation and Ouyang, Wang (2015) made the Resilience assessment of interdependent infrastructure systems: with a focus on joint restoration modeling and analysis. Franchin et al. (2015) has designed a Probabilistic assessment of civil infrastructure resilience to earthquakes.

2 Methodology for Reliability Assessment

Study of the plant process of the Inert Gas units. Data collection on failures from maintenance, planning and operation records, Analysis of collected data to obtain information on the failure rate of each component, Calculation of reliability, Study of the compressor in terms of failure: value failure, packing failure, piston ring failure and bearer ring wear out. Intercooler and after cooler leak Dissociator tube failure, Blower break down, direct contact cooler failure, Improvements to increase the availability, Evaluation of cost economics for the new unit, Calculation of system reliability of third Inert Gas unit which is parallel with the existing units and evaluation of cost economics of the proposed third unit.

2.1 Equipment Details

Ammonia Dissociator,Vapouriser,Nitrogen Generator,Blower Gas-Air Proportionating Valve, Direct Contact Cooler,Impulse Chamber,Reciprocating Compressor / Motor Assembly,Gas Heater, Deoxygenation Unit,Gas After Cooler,Humidrier,Gas Storage Receivers.

2.2 The Concept of Reliability

Reliability engineering is the study of the failure phenomenon of a process or an equipment. All equipments whether mechanical, electrical or any other nature are subjected to undergo failure during their life. Failure rate is the basic reliability parameter. Statistical failure analysis deals with the time dependence of the failure mechanism regardless of its cause. Hence statistical failure analysis plays a vital role as it determines the importance of an equipment or a system, when put into actual operation. Equipment Availability is calculated based on the total time which is defined as the sum of Mean time down(MTD) , Mean time before failure(MTBF) and Uptime ratio(UTR)
$Total\ time = MTBF + MTD$, $UTR = \frac{MTBF}{MTBF+MTD}$,
$MTBF = \frac{Total\ operating\ hours}{Number\ of\ runs}$, $MTD = \frac{Total\ Hours\ Inoperable}{Number\ of\ maintenance\ actions}$

The maintenance time of the equipment may be divided into following classifications and efforts have to be made to minimize them in order to increase the main tenability of an equipment or system. Cool-off, Fault location, Active repair time, Waiting on materials, Administrative, Warm up.

The total system reliability of a process equipment system incorporate the following parameters: R - The Process Reliability, R - The Design Reliability, R - The Inherent Reliability of the process equipment, R - The Construction Reliability.

2.3 Reliability Calculations

Reliability calculations for the Inert Gas units have been done based on following assumptions:(i) The availability of the Inert Gas units have been considered based on the reliability of the units, since the Inert Gas units are used intermittently. (ii)If two or more components of the Inert Gas units have failed at the same time, but in order to calculate the overall reliability based on each individual component's failure rate, the downtime for each failure is considered separately. (iii)The downtime due to preventive maintenance is also considered for failure rate calculation.

Inert Gas UNIT (WEST)

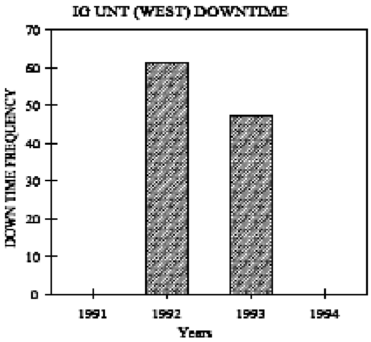
Type of failure	MTBF(in hrs)	Reliability
I suction valve	541.94	0.16
I discharge valve	1443.43	0.50
II suction valve	943.05	0.35
II discharge valve	1233.23	0.44
III suction valve	1021.71	0.38
III discharge valve	1464.00	0.51
IV suction valve	926.67	0.34
IV discharge valve	1363.20	0.48
Packings:LP side	2922.00	0.71
HP side	2898.00	0.70
Piston rings & Bearer rings :LP side	2726.40	0.69
HP side	2898.00	0.70
Cooler leaks :II intercooler	6600.00	0.86
Aftercooler	1290.00	0.46
Liner failure : HP stage	8208.00	0.89
DCC failure	1992.00	0.61
Inert Gas generator leak	3192.00	0.73
Drier	3420.00	0.75
Dissociator	9648.00	0.90
Blower	3768.00	0.77

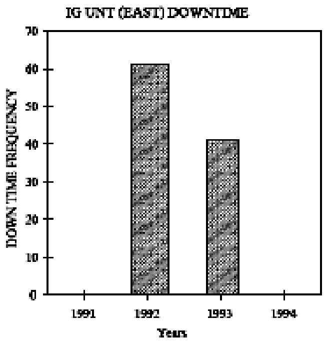
Therefore, the reliability of Inert Gas unit (west) for t = 1000 hrs, $R_2(1000) = 0.00000784$

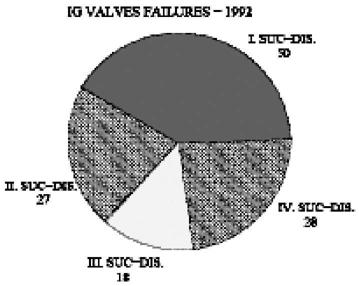
Inert Gas UNIT (EAST)

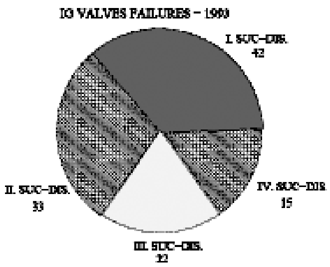
Type of failure	MTBF (in hrs)	Reliability
I suction valve	520.90	0.15
I discharge valve	897.90	0.33
II suction valve	1094.40	0.40
II discharge valve	1017.60	0.38
III suction valve	1274.00	0.46
III discharge valve	1502.40	0.51
IV suction valve	1425.60	0.50
IV discharge valve	1502.40	0.51
Packings : LP side	1689.00	0.55
HP side	2592.00	0.68
Piston rings & Bearer rings :LP side	1689.00	0.55
HP side	2504.00	0.67
Cooler leaks : I intercooler	8196.00	0.89
Aftercooler	960.00	0.35
Blower	4096.00	0.80
Miscellaneous	4884.00	0.82

Therefore, the reliability of Inert Gas unit (east) for t = 1000 hrs, $R_2(1000) = 0.0000124$, Overall system reliability of both the









Inert Gas units in parallel is given by R = 0.0000202

2.4 FMEA (Failure Mode and Effect Analysis)

FMEA is defined as a group of activities which are performed to ensure that all could potentially go wrong with a product, which can be immediately recognized and that actions are taken to prevent things from going wrong. The causes for prevention could help all the existing units and scheduled measures are implemented. Results from FMEA: It identifies the potential and known failure modes, it identifies the causes and the effects of each failure mode, the priorities identified in failure modes are according to frequency of occurrence, severity and defect formation, it allows to plan for problem follow-up and corrective action.

3 Results

From the failure analysis of numerical calculations and graphical representations, it is clear that Inert Gas compressor is of highly failure prone. Troubles occurring on the compressor may be practically attributed to the special conditions of the plant and utilization of machines in operating conditions differ from those requested during the design stage. As a result of liquid particles entertainment, damages occur on the valves, rings and packings. It would be troublesome and extremely costly to incorporate constructional solutions from designer to curb the harmful effects caused by the entrainment of moisture / extraneous substances along with the gas in the cylinders. Compressor valve behaviour is erratic and from experience it has been observed that valve seats are damaged due to heavy fittings on seating area so that the springs get permanently set. Manufacturing technology up gradation such as induction hardening of valve seats and shot peening of valve springs which are made of high strength precipitation hardened steel may improve valve life. Better material of construction of piston and bearer rings may be considered to improve performance of compressor. Availability coefficient of Inert Gas compressors can be achieved by optimized scheduled maintenance taking into account the major pitfalls from past experience. Prediction of compressor behaviour should be done by making an in-depth study of the operational and mechanical parameters with respect to time.

4 Cost Economy of III Inert Gas Unit

In order to improve the reliability of the existing Inert Gas unit it is proposed to install a third Inert Gas unit. A detailed cost evaluation is made for the startup of the third unit. Third Inert Gas unit on installation will enhance operational flexibility and ensure improved availability. Since, the third Inert Gas unit doesn't directly contribute for production the calculation of the pay-back period may not be appropriate. Hence, a cost benefit analysis based on cost savings due to improved availability during startup and shutdowns can be estimated. The details of the analysis is as follows:

III Inert Gas UNIT

ITEM	COST (Rs.)
Reciprocating compressor	1,11,74,649
Electric Motor	8,65,580
Dissociator spares	22,33,904
Dissociator tubes	30,01,652
Other spares	2,42,199
Ammonia vapouriser	6,02,784
Blower	11,865
Dissociator vapouriser	2,25,895
DCC vessel	96,377
Electrical goods & electrification	2,77,538
Combustion chamber burner	2,87,462
Flame proof control panel	4,35,690
Solenoid valves and control panel	3,36,805
Other instruments	6,18,624
Pipes and fittings	9,00,124
Valves & bolts / nuts	89,102
Structural material	16,778
Total	**1,79,15,538**

During Backend shutdown of Ammonia plant: Consumption of process naphtha:14 tons/hr; fuel naphtha : 4 tons/hr;45 kscg steam :72 tons/hr. Cost estimate of loss due to 1 hr delay in startup because of non-availability of Inert Gas units is as follows:

Cost of process naphtha	Rs. 65,240
Cost of fuel naphtha	Rs. 18,640
Cost of steam	Rs. 25,200
Urea contribution loss	Rs. 1,59,083
Total Loss	Rs. 2,68,163

During full shutdown of Ammonia plant delay of plant startup due to non-availability of Inert Gas units directly leads to loss of urea production. Hence based on the cost benefit analysis it is justified to start the third Inert Gas unit.

5 Conclusion

The reliability analysis carried out on Inert Gas units have brought out the desired results. Failure analysis by FMEA for the possible equipments are obtained to arrive at the root causes and consequences. Based on the above numerical calculations it is proved that the third Inert Gas unit has to be implemented which will lead to high production and increase in cost economy. The recommendations and improvements are suggested based on the design aspects and can be implemented for achieving enhanced availability and reliability of the existing units. The overall reliability calculations and the cost economics of the unit are in favour of the installation of the third ig unit.

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