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Original Research

Criticality Analysis Using Risk Assessment-Based Maintenance of a Petrochemical Company

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Abstract

To improve maintenance management many evaluations are used to assess the failure risk of hazards in industries. The aim of this study is critical analysis using the risk-based maintenance technique of petrochemical industries. This research is applied in the Fajr Petrochemical Company in southwestern Iran. The assets based on the risk output are prioritized. The criticality analysis showed that 11 failures out of 22 identified failures were at the semi-critical and 11 were at non-critical levels of risk. By this research we can reduce the maintenance cost and prioritize the failures based on their HSE effects and consequence factors.

Keywords: consequence factors, failure, maintenance, Petzone, risk management

Introduction

Analyzing various types of accidental events including fire, explosion, and toxic release has been carried out to evaluate the damage potential of such events. Khan (1999) argues the need for risk assessment in chemical process industries [1]. According to the Health, Safety, and Environemnt (HSE) of the Petzone report (2007), the accidental events in Petzone along the southwest coast of Iran included explosion (49%), toxic release (29%), and accidents (22%). Many assessments are used to evaluate the risk of hazards and damage to equipment and assets to improve maintenance policies and reduce maintenance costs [2, 3]. There is a great deal of attention paid to the concepts of maintainability, reliability, and safety in petrochemical industries [3].

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In recent studies different approaches are proposed for risk assessment in industry [1, 4-7]. In these years varius research for risk-based maintenance were applied [6, 8-16]. Juan and Marquez were presented Adhoc framework for maintenance managemet [6]. Also, risk-based inspection and maintenance [12] and e-maintenance [17, 18] were applied to industries for maintenance management.

The petrochemical industry in most parts of the world is, at last, showing signs of recovery. Petrochemical industries with robust capability to conceptualize sustainable development in terms of industrial management [8, 19, 20], HSE management [21], and oil and petrochemical risk assessment [8, 22-25] have been employed in parts of industries, especially oil and petrochemical. The major equipment failurs in petrochemical industries are related to pumps, compressors, and piping. All types of pumps are using in any phase of petrochemical industries [3].

However, this study will be the one of the earliest study in risk-based maintenance management in the Iran petrochemical company. It can indicate ways in which future related research could be carried out.

Case Study

The Mahshahr Petrochemical Economic Free Zone in Bandar Imam Khomeini is located in southwest Iran along the Persian Gulf coast. It spreads over an area of 1,700 hectares to southwest of Mahshahr. The zone is part of Khouzestan Province and located near large petrochemical companies like Bandar Imam, Razi, and Farabi. It acts as a strategic passageway that facilitates access to oil and gas resources as well as raw materials and feedstock for industrial plants. The Fajr Petrochemcial complex has been constructed in an area covering 54 hectares. Considered as the heart of the zone, it supplies the steam, air, water, nitrogen, and oxygen required by the petrochemical plants in the zone. It also supplies all the electricity requirements for the plants in the zone plus some of the older complexes that are not located in the zone, including Bandar Imam and Razi petrochemical companies. This establishment includes a Gas Power house and steam produce complex, water treatment, air segregation unit, waste water treatment, and collection and distribution networks in the zone. The feeds of this complex supply by raw water and natural gas from Karoon River and gas pipe line. With increasing the pet-zone plans it was nessesery to supply the lack of utility of the Fajr petrochecmial company production by development plan.

Methodology

Hierarchy Structure

Risk assessment is part of the ongoing risk management process that assigns relative priorities for mitigation plans and implementation. In professional risk assessments it combines the probability of an event occurring with the impact that event would cause [8]. Risk assessment techniques can be used to prioritize assets and to align maintenance actions to business targets at any time. By doing so we ensure that maintenance actions are effective, that we reduce indirect maintenance cost, the most important maintenance costs, and those associated with safety, environmental risk, and production losses, and, ultimately, to customer dissatisfaction [8].

In general, risk is a conventional way of conveying uncertainty in the life-cycle of a system. These definitions may be modified or changed on the basis of recommendations by expert panel or carrying out surveys grounded on the Delphi method [28].

The decision-making process behind determination of asset priority has a hierarchical structure and associated mathematics to derive weights and priorities [8]. In this study, the steps to follow in order to approach the problem would be as follows:

1. State the goal
2. Define the criteria
3. Define the sub-criteria
4. Identify alternatives

In this research the goal is hierarchy process of risk assessment and identification of the failures. The consequences and frequencies of the failures are the two main criteria. The sub criteria for consequence are operational impact factor, operational flexibility factor, maintenance cost fctor, impact on safety, and environment factor.

In this research the alternatives are the identified failures determined by the experts group. Failures such as turbine trip, boiler refractory, brick damage, and blow-down pump performance problems are identified.

It should be highlighted that defining the scale for each criterion may require a search for certain equipment historical data. Information in the first four steps can be arranged in a hierarchical tree as in Fig. 1.

Notice that assessing criticality will be specific to each individual system, plant, or business unit. For instance, criticality of two similar plants in the same industry may be different since risk factors for both plants may vary or have different relative importance.

In this study the team was composed of seven members, including the facilitator and people from the following departments: research and development management, maintenance management, operations management, process engineering, maintenance engineering, and operations planning, health, and safety, and environment engineering and management.

Criticality Analysis

For maintenance purposes the analysis level was decided to be the plant sub-systems level. Risk factors considered in the analysis were: employee safety, environmental affection, operational downtime, maintenance and direct and indirect costs of operations, and failure frequency and mean time to repair. The assessment of risk for each asset considered was based on equation 1 [8].

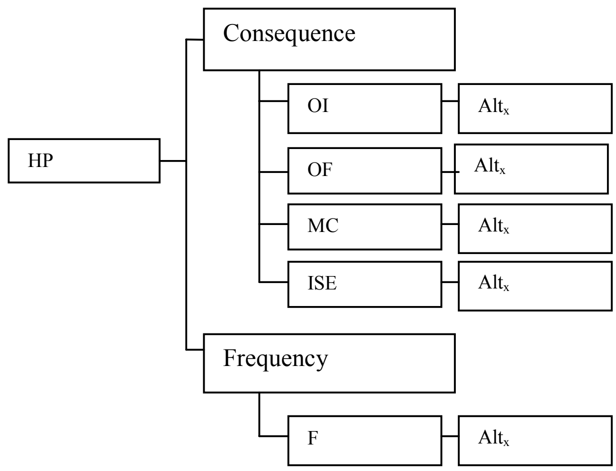

Fig. 1. Hierarchical structures for failures.

Table 1. Frequency classification and scale.

Failure frequency (F)	Failure per year	Model value
Poor	> 4	4
Average	3-4	3
Good	1-2	2
Excellent	<1	1

Source: [8]

$$R = F \times C \quad (1)$$

...where F is the frequency factor or number of failures in a certain time period (year) and C is the consequence of the failure measured as follows:

$$(OI \times OF) + MC + ISE \quad (2)$$

...where:
OI – operational impact factor
OF – operational flexibility factor
MC – maintenance cost factor
ISE – impact on safety and environment factor

Concerning the frequency of failures (F), the team decided to establish the classification and scale (as explained in Table 1) to rank the different assets.

On the other side, the different consequence factors, defining C in Tables 2 to 5, was classified and scaled. The consequence (C) factors considered in the analysis were operational impact factor (OI), operational flexibility factor (OF), maintenance cost factor (MC), and impact on safety and environment factor (ISE).

Result and Discussion

As a result of the above-mentioned classifications, the maximum value for an asset risk was set to 200 risk dimensionless units, when substituting in equations 1 and 2. The team established three levels of asset criticality as shown in Table 6.

This method was applied to the Fajr petrochemical company. Once the overall criteria for the criticality analysis of the plant were established, a list of the plant systems and sub-systems was obtained, data was conveniently gathered for analysis, and a document similar to the one presented in Table 7 was obtained.

The result of Table 7 show that alternative number 7, Sparger failure of filters was at the highest rank of risk, located at the semi critical level. This failure with number 70.5 of risk is the first priority for an action plan in Fajr Petrochemical Company according to risk-based maintenance. The latest priority is humidity ingress into internal parts of the medium and low air (MAC and LAC) compressors with the lowest rank of risk (6), located at non critical levels. The highest consequence failures are related to sparger failure of filters with 23.5 level of consequence. The blow-down pump performance problems are at the highest level of frequency failures. The criticalitiy assets were located within the criticality matrix as presented in

Table 2. OI classification and scale.

Operational impact factor (OI)	Consequence	Model scale
Extremely high	Immediate plant shut down	10
Very high	Partial plant shut down	6
High	Impact production levels or quality	4
Average	Operational cost associated with unavailability	2

Table 3. OF classification and scale.

Operational flexibility (OF)	Consequence	Model scale
High	No spare nor alternative operation	4
Average	Spare function shared	2
Low	Spare function available	1

Table 4. MC classification and scale.

Maintenance cost (MC)	Consequence	Model scale
High	C ≥ 5,000 U.S. $	2
Medium	2000 US $ < C < 5000 U.S. $	1.5
Low	C ≤ 2000 U.S. $	1

Table 5. ISE classification and scale.

(ISE)	Consequence	Scale
Extremely high	Impact on internal and external human safety requiring notification of public institutions	8
Very high	Irreversible environmental impacts	6
High	Impact on operations facilities causing severe damage	4
Average	Minor accidents and incidents	2
Low	Environmental effects without violation of law	1
Very low	No impact(s) on human, environmental, or operational facilities	0

Table 6. Levels of asset criticality.

Asset criticality level	risk value
Critical	R >100
Semi-critical	40 < R < 100
Non-critical	R < 40

Source: [8].

Table 7. Asset (subsystems) priorities according to their risk assessments.

Alt	Asset	F	OI	OF	MC	ISC	C	R	Priority
7	Sparger failure of filters	3	10	2	1.5	2	23.5	70.5	SC
16	Bearing failure of pump electric motors in air compression units	2	10	2	1.5	0	21.5	64.5	SC
20	Repair of all aerators in wastewater treatment	2	10	2	1.5	4	25.5	51	SC
21	Digester repair of Evapo transpiration (ET) plant	2	10	2	1.5	4	25.5	51	SC
5	Blow-down pump performance problem	4	10	1	2	0	12	48	SC
8	Reverse osmosis (RO) pump maintenance problem	2	10	2	1	2	23	46	SC
9	Screw pumps maintenance problem of water treatment units	2	10	2	1	2	23	46	SC
6	Instrument calibration problem of gas turbine damper diverter	2	10	2	2	0	22	44	SC
12	Belt press pump maintenance of water treatment units	2	10	2	1.5	0	21.5	43	SC
11	Diaphragm pump maintenance of water treatment units	2	10	2	1	0	21	42	SC
14	Pitting of sodium hypochlorite storage tanks in water treatment units	2	10	2	1	0	21	42	SC
18	Bar screen corrosion and breakage of temperature swing adsorption (TSA) vessels in the air compression units	2	10	1	1	0	11	22	NC

C – critical, NC – non critical, SC – semi critical

Fig. 2. From this matrix and analysis the preventive maintenance actions were prioritized according to the resulting ranking. Also, the resource alloction for sudden corrective actions was prioritized by using a matrix. From the critically matrix the consequence of 10 assets out of 22 were between 20 to 30 score. The 11 assets out of total were located in semicriticality of risk allocation. Sparger failure of filters and Bearing failure of pump electric motors in the air compression units were in the semicritical level with 70.5 and 64.5 of highest risk rank.

When comparing a literature review from the Delphi group method and discussion with experts from five petrochemical industries in Petzone to validate the scales and factors categorization, the expert group argued for the scales unless for cost maintenance scale and categorization, they proposed categorizing the cost in three levels with different costs from the Marquez scales [8].

As stated in the introduction, compressors, pumps, and piping saw the most failures in the petrochemical companies [3]. This study argues to these failures but in prioritizing the failures based on risk failures, the filters and pumps were at most risk compared to other asset failures.

Conclusion

A total of 22 failures were identified and assessed based on maintenance management framework. The Sparger failure of filters and Bearing failure of pump electric motors were 2 failures with the highest levels of risk by 70.5 and 64.5 numbers of risk at the semicritical level. In this study, risk assessment was carried out for prioritizing the assets and aligning maintenance actions. By doing so we ensure that maintenance actions are effective, that we reduce indirect maintenance costs and the most important maintenance costs, namely those associated with safety and environmental risk, production losses, and customer dissatisfaction.

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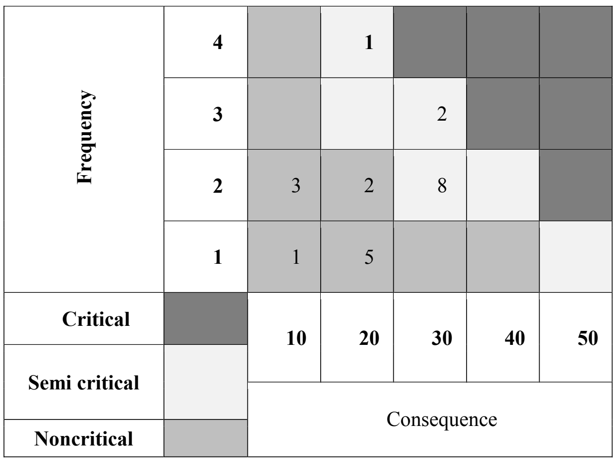

Fig. 2. Ciriticality matrix and assets matrix.

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