Risk Based Inspection on the equipment of low density polyethylene

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Abstract

In this paper, the basic principles of Risk Based Inspection (RBI) are introduced and RBI method is used to the high pressure polyethylene device of a petrochemical enterprise. The results show that about 8\% of the equipments and pressure pipelines undertake 90\% risk of high pressure polyethylene devices. High-risk equipments are found, and the foundations are provided for inspection strategy.

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Keywords: RBI; LDPE; Inspection strategy

1. Instruction

Risk Based Inspection (RBI) is a method which pursues the uniformity of security and economy. It has been widely used in the western countries since 1990s \cite{1}. RBI method has been started to use in Sinopec after the notice of National Quality Inspection Board since May 2006. By December 2008, the RBI method had been used in more than 25 subordinate enterprises in Sinopec. Nearly one hundred equipments, including all the devices of refining and main chemical devices of cracking ethylene, vinyl chloride, and styrene and so on, were evaluated by RBI \cite{2}. In this paper, high pressure polyethylene devices from a petrochemical enterprise are analyzed by RBI method. Next, the work flow of this equipment is showed. The raw material of high pressure polyethylene is ethylene which pressure and temperature are 3.2\textit{MPa} and 30\textdegree{}C respectively. The ethylene is pressurized by compressor to working pressure (about 300\textit{MPa}), and then, transferred into tubular reactor to polymerize under the action of organic peroxides. The materials from tubular reactor are transferred to the high-pressure separators to separate unreacted ethene from polymer. Then the separated high-pressure gas return to compressor entrance and the separated mixture enters into low-pressure separators to separate at the second time. At last, polymers are extruded and pelletized by extruder. This device was put into use in December 2001. It has been shutdown to service for several times. According to the plan of overhaul, next overhaul period is April 2013. Therefore, the static equipments and pipes inside high pressure polyethylene devices should be evaluated by RBI method in order to improve test efficiency and save resources.

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2. Risk assessment methods

2.1 Qualitative analysis

Qualitative analysis requires the input of descriptive information, which is based on the probability of failure and the consequences of failure. The result of risk analysis is often in the qualitative form, such as the probability of failure are divided into 1-5 levels, the consequences of failure are divided into A-E levels. When the risk is assessed, the abscissa is the level of the consequences and the ordinate is the level of the probability, as shown in figure 1. The results from risk analysis are put into risk matrix in order to determine the ultimate level of risk. In figure 1, the number of the box represents risk level and the depth of box color represents the risk level, and the higher level is darker. Because the significance of consequences is greater than that of probability, the shadows of figure 1 are unsymmetrical. Qualitative method is similar to quantitative analysis, but qualitative method just demands less details and less time than quantitative analysis. The result of qualitative method is not more accurate than quantitative analysis, but it provides foundation for the priority order of check program [3].

![Figure 1 the risk matrix of qualitative analysis](image)

The value of qualitative analysis lies in completing risk assessment in lacking specific quantitative data. The accuracy of the result depends on background knowledge and experience of analysts. Qualitative RBI method has three functions: ① The device is selected to determine the level of analysis and prove the benefit of the further analysis (such as quantitative RBI or other methods); ② The level of risk in the device is classified and located in some location of risk matrix; ③ The potential problem is identified in order to improve the inspection procedure. The possibility of the failure is ensured in the area, and then it is combined in risk matrix to classify the risk of the device.

2.2 Quantitative risk assessment

Quantitative method evaluates the degree of danger of system by the probability and the consequences of its accident. Fault tree analysis, event tree analysis method and so on are quantitative method. This kind of method has sufficient theoretical basis, and its results are correct and reliable. Quantitative method is widely used in the fields of aviation, aerospace and nuclear energy. However, this kind of method requires accurate and full data, can fully describe the uncertainty of system, and usually has to spend a lot of time and resources.

Quantitative risk analysis uses logical model to describe the combination of events that leads to serious accident, the process of the accident and the dangerous material in the propagation of the environment. Quantitative RBI program divides these consequences into four aspects: flammable or explosive events, toxic medium leaking, environmental risk and business interruption. Quantitative analysis and evaluation calculation for each equipment or pipe are done to high risk items after qualitative analysis and screening generally. It takes a long time for first calculation, but it doesn't need more experts. Quantitative risk analysis can provide the detailed effective inspection plan [4].

3. The application of RBI in the polyethylene device in high pressure

3.1 Qualitative analysis

Through the review of the stage process in the high pressure PE device, hazard and danger zones are identified. There are some risks: the leakage of high pressure equipment and pipe; the explosive decomposition of ethylene led by residual heat; the expansion of equipment led by the polymerization and decomposition of ethylene in pipes or compression equipments; the potential danger
of granular carbon black during decomposing ethylene; the explosion accidents caused by impurities of material and excessive catalyst; ethylene-air explosive mixture in equipment.

3.2 The quantitative analysis based on the RBI software

In high pressure polyethylene device, the total risk matrix of pressure vessels, pressure pipes and heat exchangers are respectively shown on figure 2, figure 3 and figure 4, the total risk distribution of pressure pipes and pressure vessels is shown on table 1. According to the results of analysis, the paper will divide risk degree into high level, middle level (middle-high and middle) and low level.

| Risk level   | High | Medium high | Medium | Low | Total |
|--------------|------|-------------|--------|-----|-------|
| Number of pressure vessel unit | 0    | 5           | 41     | 56  | 102   |

There are no high risk in pressure vessels and pipes of high pressure polyethylene device, the middle-high risk pressure vessels have five ones, heat exchangers have one and pipes have zero. The failure possibility of middle level pipes is higher, others have higher failure results. Table 1 show that there are five pressure vessels and a heat exchanger in the middle-high risk, their degree is five. Through the data detection and analysis, testing frequency and detection accuracy of these six devices needs to be strengthened because of its thinner thickness.
3.3 The review of the total risk analysis results.

Figure 5 shows that the less pressure vessel/pressure pipe undertakes the most risk. As to the high pressure polyethylene devices, 8% of the pressure vessels and pipes have 90% of risk in devices. It shows that 95% of risks can be controlled if these pressure vessels and pipes are taken seriously, so these optimize resources and reduce risk greatly. The distribution of high risk equipment is shown on table 2.

| Unique ID | Eop. ID         | Eop. Type | Eop. Name                | Risk(Safety Area)[m^2] | %   |
|-----------|-----------------|-----------|--------------------------|------------------------|-----|
| 1388      | WI-13017-3-1S1  | PIPE-4    | Pipe of waste initiator  | 1.84E+00               | 7.7%|
| 437       | HX-19305-2-1P1  | PIPE-2    | Pipe of ethane           | 1.57 E+00              | 6.6%|
| 452       | OM-12061-2-3P1  | PIPE-2    | Pipe of regulator        | 1.25 E+00              | 5.2%|
| 573       | E-1102/1-ts     | EXCHANGER-75 | Cooling pipe of single stage compression | 1.23 E+00  | 5.2%|
| 580       | E-1102/2        | EXCHANGER-75 | Cooling pipe of single stage compression | 1.16 E+00  | 4.9%|
| 454       | WO-15513-2-1P1-1T | PIPE-2 | Pipe of waste oil        | 1.10 E+00              | 4.6%|
| 458       | WO-15511-2-1P1  | PIPE-2    | Pipe of waste oil        | 9.78E-01               | 4.1%|
| 450       | HX-19307-2-1P1  | PIPE-2    | Pipe of ethane           | 9.73 E-01              | 4.1%|
| 453       | OM-12001-2-3P1-1 | PIPE-2 | Pipe of regulator        | 8.05 E-01              | 3.4%|
| 441       | HX-19309-2-1P1-1 | PIPE-2 | Pipe of ethane           | 7.99 E-01              | 3.4%|

4. Conclusions

Though analyzing RBI risk assessment technology applied in the high pressure polyethylene device of a petrochemical enterprise, the following conclusions are obtained:

(1) Approximately 8% of the pressure vessels and pipes have 90% of risk in the high pressure polyethylene devices.

(2) Due to the large number pressure pipes, the accumulation of the risk is higher, and the average risk of the pressure vessel is also higher.

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