Research Status of Natural Gas Compressor Unit Failure

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Abstract

The compressor unit, as a key equipment in the natural gas production and transportation process, has made great contributions to the completion of natural gas production tasks for a long time. With the continuous expansion of quantity and scale, its technology selection, operation and fault management all show a series of characteristics. It is urgent to study practical and feasible compressor inspection and maintenance strategies. Taking the southwest oil and gas field branch as an example, this paper first introduces the overall working situation of the compressor unit from 1984 to 2017, and statistics on the operation failure of natural gas compressors, and then analyzes the development status of air compressors at home and abroad. Finally, a series of inspection and maintenance strategies are proposed for different compressor failure risks. This research work points out the problems existing in the current research work, and proposes the use of multiple strategies to achieve compressor fault prediction, fault alarm and fault elimination has certain guiding significance.

Keywords

Compressor unit, Natural gas, Inspection and maintenance strategy, Fault prediction.

1. Introduction

Natural gas compressors are widely used in the processing and transportation of natural gas and gas. Natural gas compressors are divided into two types, one is a centrifugal compressor; the other is a reciprocating compressor [1]. The working principle and performance of these two compressors are different. The centrifugal compressor mainly uses the high-speed rotation of the impeller to make the gas compress under the action of centrifugal force, while the working principle of the reciprocating compressor is through the compressor [2, 3]. The force of the connecting rod structure and the crank drives the movement of the piston, and the gas is compressed during the reciprocating motion of the piston. For a long period of time, the reliability of natural gas compressors is not commensurate with its importance. Especially critical is the gas valve, because its reliability or not has a great impact on the machine, for which the people have always attached great importance to the manufacture and research of the valve [4]. Another concern in piston compressors is the sliding seal. The sliding seal includes two aspects: one is the durability of the sealing element--the life; the other is the gas contamination problem caused by the oil-lubrication of the sealing element. For the former, it is devoted to the study of friction, wear and lubrication; in the latter, people have created many new types of compressors that are not polluted by oil. With the development and progress of the industry, people's requirements for compressor performance [5]. It is also getting higher and higher, and it is necessary to study the designers to constantly update the current technology and research the compressors that are suitable for the development of the contemporary society [6, 7]. Therefore, the research on this topic is very important and necessary. Because piston compressors have many disadvantages such as large wearing parts, large volume, high noise, large vibration, instability and danger. The first twin-screw air compressor developed by Sweden in 1936. Due to the relatively stable work, the small size of the machine, the high degree of automation of the Ingersoll Rand air compressor, the small amount of maintenance and small, the noise is also greatly reduced, and the vibration is also less than the basics, in 1986. Started to introduce China and was recognized by our customers [8].

2. Basic situation of the compressor unit

By the end of December 2017, the gas field developed and produced a total of 147 supercharged stations and 294 natural gas compressors [9]. In the annual natural gas production, the boosting contribution rate reached 33%, which is one of the main measures to ensure the development and production of gas fields. The branch compressor unit has a long service life, and now it has exceeded half of the total for more than 10 years. The equipment is generally old and over time, more and more units are running beyond the design life, and the faults and safety hazards entering the equipment loss period will increase significantly.

Table 1 Summary of the operating period of the compressor unit of the branch company (2017.12.31).

Years	Chuanzhong	Chongqing	Weinan	Northwest Sichuan	Northeast Sichuan	Gas Storage	Chenghua General Factory	Total	Percentage
1984	\	\	1	\	\	\	\	1	0.32%
1986	\	\	5	\	\	\	\	5	1.6%
1987	\	5	1	\	\	\	\	6	1.92%
1988	\	\	3	\	\	\	\	3	0.96%
1992	\	\	6	\	\	\	\	6	1.92%
1993	\	5	1	\	\	\	\	6	1.92%
1994	\	\	2	\	\	\	\	2	0.64%
1995	\	1	6	\	\	\	\	7	2.24%
1996	\	8	6	\	\	\	\	14	4.47%
1997	\	2	10	\	\	\	\	12	3.83%
1998	\	\	9	\	\	\	\	9	2.88%
1999	\	\	5	\	\	\	\	5	1.6%
2000	\	7	3	\	\	\	\	10	3.19%
2001	\	1	3	\	\	\	\	4	1.28%
2002	3	1	\	2	\	\	\	6	1.92%
2003	\	2	\	2	\	\	\	4	1.28%
2004	2	11	3	1	\	\	\	17	5.43%
2005	5	7	5	\	1	\	\	18	5.75%
2006	\	1	3	1	\	\	\	5	1.6%
2007	5	7	7	2	5	\	\	26	8.31%
2008	2	13	16	6	\	\	1	38	12.14%
2009	5	12	4	2	5	\	\	28	8.95%
2010	3	13	2	1	4	\	\	23	7.35%
2011	2	3	5	\	3	\	1	14	4.47%
2012	\	2	5	1	2	\	\	10	3.19%
2013	4	4	\	\	1	8	\	17	5.43%
2014	2	\	3	1	\	\	\	6	1.92%
2015	\	1	4	1	\	\	\	6	1.92%
2016	\	3	\	\	1	\	\	4	1.28%
Under Construction	1	\	\	\	\	\	\	1	0.32%
Total	34	109	118	20	22	8	2	313	100%
Percentage	10.86%	34.82%	37.7%	6.39%	7.03%	2.56%	0.64%	100.00%	

3. Overview of the operation of the compressor unit in recent years

According to the statistics of natural gas compressor operation failures of the branch in the past years, a total of 4023 faults occurred in 2008-2016, with an average of 447 times per year, including classification according to fault failure types, mainly due to fracture, wear, jam, aging, etc. The parts with higher failure frequency are instrument control system, intake and exhaust valve, mixing valve, pipeline, water pump, ignition system, oiler, air cooler, governor, injection valve, spark plug, and other parts are relatively scattered. The impact of downtime on the total output increased, and the impact of single failure on production increased further, from 0.69 million square meters in 2009 to the current 68,300 square meters/time. In recent years, the impact gas volume has exceeded 10 million square meters [10,11]. It has been on the rise for 8 consecutive years.

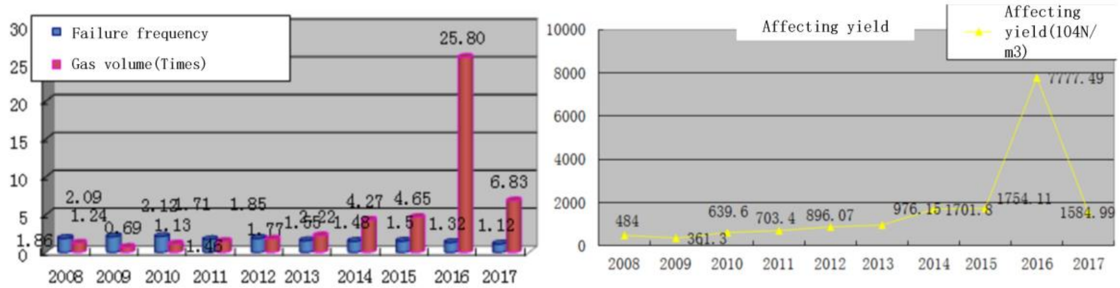

Fig. 1 Trends of compressor unit failure and production impact over the years

In terms of maintenance costs: According to the maintenance cost statistics for 2015-2017, the annual maintenance cost is about 60 million yuan. Among them, 34 units were overhauled in 2017, costing 278.552 million yuan, with an average of 819, 300 yuan/set; daily maintenance cost was 19,026,400 yuan, with an average of 91,900 yuan/set. The 172 units (excluding the Wei nan gas mine) involved in the foreign party's insurance transportation cost 15.644 million yuan, and the single-machine insurance cost is 91,000 yuan/set.

Table 2 Statistics of unit failures of branch companies in 2015-2017

Project	2015 Total	2016 Total	2017 Total
Total number of units	328	311	294
Number of uses	251	211	207
Annual cumulative running time (h)	1104224.5	882151.6	747269.22
Number of failures	377	281	232
Downtime (h)	5611.16	4065.4	3002.43
Failure affects production	1754.11	7777.49	1584.9885
Maintenance costs (ten thousand yuan)	6111.71	5731.71	6252.5727
Number of failures / thousand hours	0.341	0.341	0.31
Mtbf	2929	2931	3220.988
Average utilization	51.2%	45.0%	41.8%
Average downtime rate	0.51%	0.55%	0.40%
Average newness coefficient	0.49	0.40	0.34

4. Status of compressor inspection and maintenance

4.1 Development of compressor maintenance technology

After several decades of development, the types and methods of equipment maintenance have gone through three stages:

Passive maintenance is repaired after equipment failure, and equipment management adopts passive maintenance. This method will lead to unplanned shutdown of the equipment. The consequences will not only cause loss of production, but also may affect safety and the environment. The cost of maintenance is greatly increased, and there is great uncertainty in the failure of equipment.

Regular maintenance of scheduled maintenance based on time intervals, including regular repairs and periodic replacements. Preventive maintenance methods can reduce unplanned downtime, reduce repair time, and improve repair quality. However, some equipment failures have nothing to do with the equipment usage time. Therefore, preventive maintenance only considers the time interval, there is blindness, and it is easy to produce insufficient maintenance and over-maintenance.

State maintenance, condition-based maintenance This maintenance method is based on the pf interval of equipment failure, and then with the monitoring and diagnosis technology of the equipment (such as oil-water analysis, thermal imaging analysis, vibration analysis, motor current analysis, etc.), by measuring the state of the equipment, Identifying upcoming problems and anticipating the timing of repairs to reduce equipment failures. Predictive maintenance has the advantage of knowing the current state of the equipment in advance and performing targeted repairs on possible faults, thus avoiding over-maintenance or under-maintenance. Phenomenon, enhance the availability and reliability of the device.

Table 3 Comparison of maintenance methods

Maintenance method	Features
After-the-fact repair	Unplanned downtimes, production, maintenance costs, safety, environmental impact, and uncontrollable equipment management
Regular maintenance	Reduce unplanned downtime, prone to over-maintenance or under-maintenance
State maintenance	Monitoring equipment and predictive status can avoid over-maintenance and avoid inadequate maintenance, but fail to eradicate the fault

4.2 Status of domestic compressor inspection and maintenance technology

4.2.1 Maintenance guidelines

At present, domestic petrochemical enterprises still regard after-the-fact maintenance and regular maintenance as the maintenance guidelines of enterprises. Regular maintenance is based on historical experience and equipment failure records, to determine the approximate time interval of equipment failure, and to arrange maintenance methods during this period. This type of maintenance is quoted from the former Soviet Union and has uniform standards for the maintenance cycle and maintenance content of the equipment. Before the equipment reaches the overhaul period, there are usually several failures that cause the system to be temporarily shut down. This is an unplanned maintenance, that is, after-the-fact maintenance. With the development of technology, this maintenance mode cannot adapt to high automation equipment, often has the following drawbacks: 1) the maintenance cycle is unreasonable; 2) the maintenance project is not targeted; 3) the maintenance task is not scientific, See Table 4 for a comparison of the three maintenance methods.

Table 4 Features of maintenance methods

Maintenance method	After-the-fact maintenance	Regular maintenance method	State maintenance method
Can it be prevented?	No	Can	Can
Maintenance project	One or more	One	One
Inspection method	Disassembly	Disassembly	Not disassembled

Basic basis	System failure statistics or maintenance experience	Wear and failure rules or maintenance experience of system components	System state detection technology and evaluation criteria for detected state parameters
Maintenance criteria	According to the fault statistics, take the corresponding maintenance method	Completely disassemble, overhaul and replace with the wear and tear of equipment	Detecting the status parameters that should be detected before the system failure occurs, and based on it, decide whether to replace and repair
Scope of use	Random faults that are not directly affected by safety, and faults that are less than the preventive maintenance costs	A lossy failure with safety and environmental consequences and rapid development without detectable or state parameters	The fault develops slowly, and it can determine the time required for the fault to develop; it has a direct hazard to safety, and there is a hidden function that can be detected by the working state parameter and can be detected in situ.
Advantage	Reduced the cost of equipment repair and inspection	Reduced downtime	Increased equipment availability time and reduced downtime
Disadvantage	Lack of flexibility; there is equipment downtime loss	Need to prepare enough spare parts, there is mechanical equipment downtime loss	Need high investment and daily inspection costs, but no mechanical equipment downtime loss

4.2.2 Maintenance Management System

In terms of management, through comparison with major oil fields, the current compressor management of the branch is between Tuha Oilfield and Tarim Oilfield. The Tuha Oilfield will manage the compressor unit as a type of equipment, and the second unit will have full-time positions. The grassroots level also has full-time or part-time technical personnel responsible for the daily operation and management of compressors. The management of Tarim Oilfield and Changqing Oilfield is similar, mainly integrated management, and is positioned as "industry management guidance service". Each oilfield has successively formulated relevant management systems, but the management interface and content involved are quite different, and all of them pay attention to the operation, maintenance and repair of the compressor unit. See the table below for details. The branch has a big gap in condition monitoring and fault diagnosis; the daily maintenance and maintenance of the machine is usually based on the principle of fixed operation and maintenance. It adopts the "three-level maintenance" strategy and is divided into monthly insurance, semi-annual insurance and annual insurance. The lack of applicability of such maintenance and repair strategies often results in waste of resources. Will affect the service life of the equipment. At the same time, it is also researching and promoting new technologies for condition monitoring and fault diagnosis of compressor units, and promoting the compressor units of key stations. Repair shift to predictive maintenance. Because now in the research phase of the technology, fault diagnosis and lack of experience related to the basis on natural gas compressor condition monitoring relevant normative standards also not been established.

Table 5 Relevant management systems for compressor units of major oil and gas fields

company name	Equipment management system	Compressor management system	technical standard

Tuha Oilfield	Equipment Management Measures Equipment Lubrication Management Measures	"Compressor Maintenance Management Measures", "Status Monitoring and Fault Diagnosis Technical Regulations", "Operation and Maintenance Procedures" and various operation cards	More than 70 compressor technical standards
Tarim Oilfield	Equipment Management Regulations "Implementation Rules for Equipment Repair" "Implementation Rules for Localization of Imported Equipment Parts"	Implementation Rules for Operational Maintenance Procedures, Implementation Rules for Oil and Water Management, Regulations for Condition Monitoring and Fault Diagnosis, and Guidelines for Winter Use of Two-Stroke Compressors	Technical Specifications for Reciprocating Compressor Repair
Southwest oil and gas field	Equipment Management Measures	"China Petroleum Southwest Oil and Gas Field Branch Company Natural Gas Compressor Group Management Measures", "Supercharged Production Management Regulations", "Reciprocating Compressor Medium Replacement and No-load Operation Regulations", "Integrated and Split Unit Operation and Maintenance Procedures", Natural Gas Compressor Group Operating Parameter Control Technical Regulations and various operation cards	"Technical Conditions for Overhaul of Reciprocating Compressor Units", "Technical Specifications for Reciprocating Compressor Lubrication and Cooling", "Integrated Energy Saving Monitoring Methods for Integrated Compressors", "Economic Operation Specifications for Natural Gas Compressor Units", "Technical Specifications for Installation of Reciprocating Natural Gas Compressor Units"

5. Conclusion

By collecting the basic situation of the equipment, rcm analysis of the equipment to determine the risk level of the equipment, and determining the maintenance mode of the equipment according to the logic decision tree, calculating the period of the state monitoring combined with the fault data, completing the formulation of the maintenance strategy. The main route is shown in Figure 4.1.

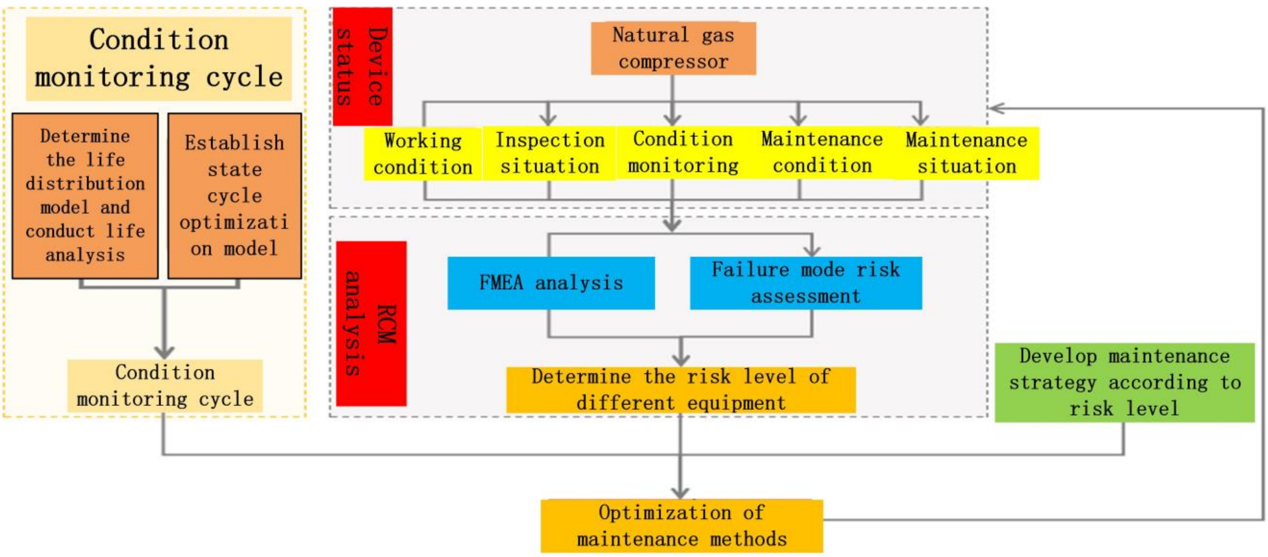

Figure. 2 Technical route

During the development of the entire maintenance history, the most common use of the actual maintenance activities are the following three methods: after-sales maintenance, regular maintenance, and status maintenance. To further deepen the understanding of maintenance and to clarify specific maintenance tasks, a list of optional maintenance methods for compressors is now available, as shown in Table 4.1.

Table 6 Detailed description of the maintenance method

Maintenance method	Specific classification	Specific work	Characteristics
Regular maintenance	Regular maintenance	Daily maintenance work, including wiping, lubrication, cleaning, fastening, etc., can ensure the normal performance of the components.	Simple technical requirements and low resource consumption.
	Regular replacement	Regular disassembly is smoother to ensure the normal performance of the components.	There are certain technical requirements, and sufficient maintenance spare parts and maintenance tools are required.
	Periodic inspection	Check regularly to determine if a fault has occurred. The timing of preventing the fault is actually after a malfunction.	Primarily for concealed functions, the intention is to avoid multiple failures that result.
State maintenance		Monitor device status in real time and take the necessary precautions for system components that may be malfunctioning.	Appropriate monitoring methods must be adopted to compare the monitored conditions with normal conditions and then determine whether to take measures.
After-the-fact repair		Allow this type of fault to occur and take action after it occurs.	For some minor, failure modes with no serious consequences.

The current rcm maintenance strategy selection gives a maintenance decision model based on logic analysis. This paper also proposes a logic analysis decision model based on the rcm criterion. The model fully combines the failure mode and the impact analysis results.

The maintenance strategy of the equipment mainly refers to the maintenance of the equipment at what time. This chapter first uses the maintenance decision tree model to determine the maintenance mode of the equipment. The decision tree model is a predictive model that reflects the mapping between the properties of an object and the value of an object. Each node of the tree represents an object, each branch path represents a possible attribute value of the object, and each leaf node represents the value of the object represented by the path between the root node and the leaf node. This paper will use the decision tree to analyze the risk level of the equipment to determine the maintenance method of the equipment. Decisions on equipment repair can be made using the following decision tree model. Low-risk equipment means that the failure of the whole system is less affected and the cost of the parts is lower. If the method of reducing the frequency of failure is not received, good results will not be obtained. In this regard, we have chosen to carry out after-sales maintenance in the case that the preventive cost is greater than the after-sales maintenance cost. For equipment with preventive costs less than the after-sales maintenance cost, we choose the method of regular maintenance to determine the maintenance decision tree of the maintenance method. The figure shows:

The failure of medium and high-risk equipment may endanger the safety of the operator or cause serious economic consequences. By reducing the frequency of failure or adjusting the maintenance mode of the equipment, the reliability of operation can be greatly improved. In this regard, we have chosen to perform state maintenance in the case where we can monitor the status of the equipment. For equipment that cannot be monitored, we choose the method of regular maintenance. Its maintenance decision tree is shown in the figure:

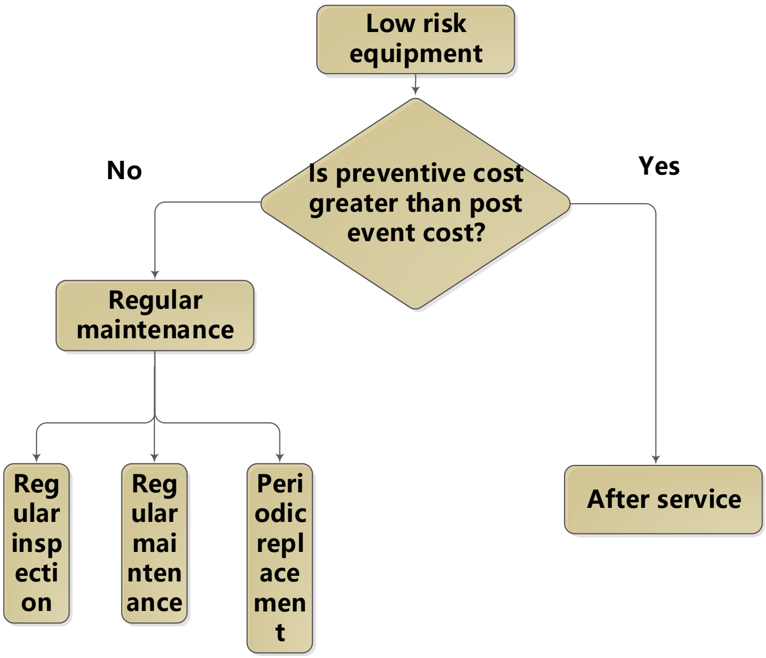

Figure. 3 Low Risk Maintenance Decision Tree

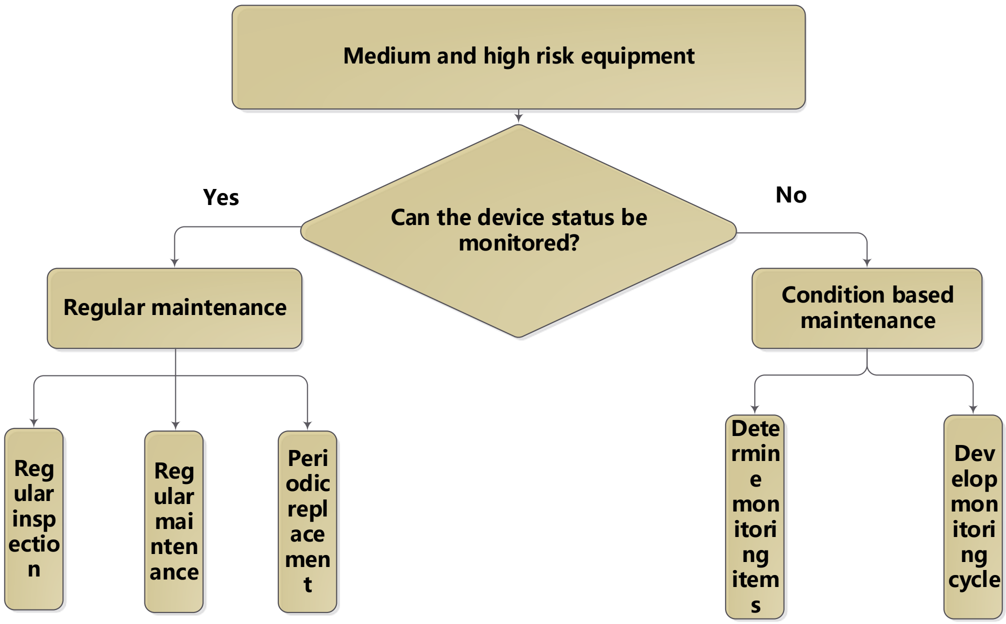

Figure. 4 High Risk Maintenance Decision Tree

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