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RIG-TEST EVALUATIONS OF OIL-FLOODED ROTARY AIR COMPRESSOR'S LUBRICANTS AND THEIR APPLICATION IN CHINA

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ABSTRACT

This paper introduces rig-test technique of lubricants used in oil-flooded rotary air compressors, which was developed by authors in past ten years. Evaluation experiences showed that rig-test evaluations are more reliable and applicable than physicochemical experiments for examining rotary compressor lubricant performances.

INTRODUCTION

Most of rotary compressors are oil-flooded. Major functions of lubricants in these compressors are lubricating, cooling, sealing and rust-resisting and so on. Investigations on rotary air compressors operating in industrial field showed that over half of all failures of oil-flooded rotary compressors are related to the performances of oils used in them.

Since 1990, rotary compressors have been fully developed in China. Their output in last year occupied over 40% of that of total displacement compressors. However, this proportion is only about 5% ten years ago.

Many large petrochemical companies in China have developed various kinds of rotary compressor lubricants in according to ISO/DP 521-3 to meet the needs of compressor's manufacturers and users in recent years. In all rotary compressor lubricant standards physicochemical characteristics are regarded to be the only criterion to indicate oil quality. A lot of the lubricant's applications proved that oil service performances are not all coincident with the results of physicochemical tests.

Furthermore, Kensuke suyiura[1] pointed out long ago in 1982 that the differences between the process of oxidation experiment in laboratory and that of oil oxidation in compressor operation. He suggested that it is essential to examine performances of rotary compressor lubricants with a typical rotary compressor. A. J. Mills[2] reviewed performance tests of rotary screw air compressor lubricants in Europe, and put forward a method to test coalescer blocking tendency of the oils. J. W. Miller[3] and C. Cohen[4] evaluated candidates of synthetic lubricants of rotary air compressors respectively with specially selected compressors. They showed the reliability of evaluations by comparison of results of rig-tests with those of physicochemical tests.

Up to now, standards of oil-flooded rotary compressor oils executed in different countries don't contain criteria about rig-testing evaluations. The possible reasons can be described as follow:

(a) Essentiality of rig-test to evaluate rotary compressor lubricants is not realized by all compressor manufacturers and users.

(b) A strict evaluation system about rig-tests has not been established.

STRUCTURE OF A TEST RIG AND ITS OPERATION PARAMETERS

Evaluation procedures of rig-tests of rotary compressor lubricants can be briefly described as follow: taking a typical and representative oil-flooded rotary compressor as the testing rig, taking an oil to be evaluated as the compressor lubricant, operating the compressor in strictly controlled working conditions and parameters for a specified period, examining if the oil can meet the demands of the compressor operation, examining if some related physicochemical characteristics of the oil after the specified period of operation exceed defined values, examining if abnormal wear and rust take place on some surfaces of the compressor parts.

It is a fundamental consideration that evaluation methods with rig-tests should be applicable to variety and different prescriptions of rotary compressor lubricants. Therefore, the model of the compressor used in rig-tests must be possessed of follow characteristics:

(a) It is extensively representative and typical.

(b)Rig-test cost is lower, installation and repair of the testing rigs are convenient.

(c) Operation conditions of testing rigs are widespread to be adapted for the evaluations of different kinds of oils.

(d) Compressors used as the testing rigs are of high quality and reliability.

Consequently, LG-3/0.7 compressors are suitable to act as the testing rigs of rotary compressor oils.

The major characteristics and original parameters of this type of screw compressors are:

Model: oil-flooded screw, air cooling and stage single

Discharge pressure: 0.7 MPa

Volumetric flow rate: 3 m^3/min

Motor power: 22 kW

Screw rotary speed: 2960 r/min

Discharge temperature: 75℃-95℃

In order to convert a compressor into a oil-testing rig, some structure of it must be modified and many operation parameters must be changed in accordance to the classifications of lubricants for air compressors[5]. Duty classifications of oil-flooded rotary air compressors are listed in Table 1. That is to say, qualified DAG and DAH oil products evaluated with this testing rig should not give rise to any compressor failure for reasons of oil performance and quality.

Most reports about oil service problems include one or more of following items:

(a) Oil deteriorates seriously, which is often indicated through darkening oil's color、 and increases in viscosity and total acid number (TAN) determined by periodical oil analysis.

(b) Lubricants in the oil/air separator produce much foam in compressor operation, which floods the separator core itself.

Table 1 Duty classifications of oil-flooded rotary air compressor

Duty	Symbol		Operation conditions
Normal	DAG	Intermittent operation or continuous operation	Maximum air/oil temperature at discharge flange of air end, any stage <100℃
Severe	DAH	Intermittent operation or continuous operation	Maximum air/oil temperature at discharge flange of air end , any stage ≥100℃

(c) Sludge deposits emerge in various parts of compressors.

(d) Oil strainer plugging.

(e) Bearing failure and screw rotors scuffing as oil deterioration.

The tendency of oils to lead to failures in compressor operation often can not be effectively reflected through physicochemical index measured. However they can be precisely predicted through rig-test evaluations.

Discharge temperature is a most decisive factor affecting oil deterioration in all operation parameters of an oil-flooded rotary compressor. If the discharge temperature of the compressor in the rig-test was taken as that of compressors in common applications, it would spend over hundreds of hours to test final service life of an oil because of too slow oxidation process, and it, of course, can not be accepted. An accelerated rig-test schedule was conducted by raising the discharge temperature of test-rig by authors. According to the statement of reference[1], an assumption was made that there is a reduction of one-half of the oil life for every 10℃ increment above 82℃ serving temperature. An expected multiplying factors of seven or eight was used to predict the life expectancy for a lubricant under normal operating conditions (about 82℃ discharge temperature).

However, excessively high discharge temperature (specially over 130℃) will make some additives in oils lose effectiveness. The results tested under this temperature can not characterize actual performances in industrial services. It seems more reasonable to control the oil/air discharge temperature for rig-tests of DAG oils in the range of 114-116℃, and for DAH oils in the range of 119-121℃.

Because oil/air separator cores in the rigs made of artificial fiber often are damageable as undergoing high temperature of over 110℃, authors reequipt the oil/air cycle system of the testing compressor as shown in Fig 1. Detail rig-test parameters are listed as in table 2.

Table 2 Rig-test condition for DAG and DAH oils

parameter	DAG	DAH
Rotary speed r/min	2940	
Suction temperature ℃	30-40	
Oil/air discharge temperature	115±1	120±1
Oil temperature after cooler ℃	90-94	100-104
Discharge pressure MPa	0.68-0.74	0.76-0.80

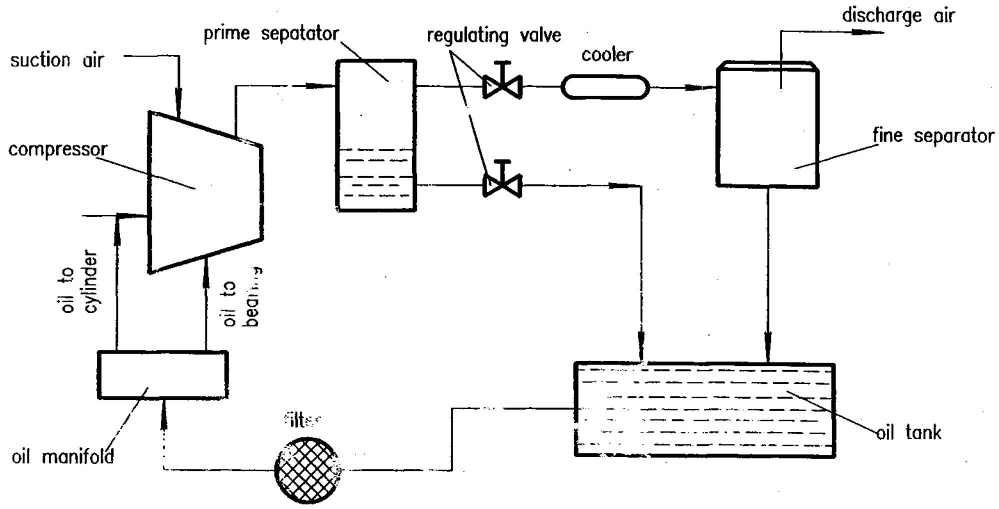

Figure.1 Reequipt oil/air cycle system of the rig–test compress

CRITERIA OF ROTARY COMPRESSOR OIL EVALUATIONS IN RIG TESTS

(a) **Evaluation of foaming resistance** The foam height in oil-scale window of oil tank should not exceed 10mm in accelerated rig-tests.

(b) **Performance evaluation of coalescer blocking tendency** Pressure differential in front and behind of oil/air separator increases no more than by 0.02MPa after 450 hour's accelerated operation for testing DAG oils, and after 600 hour's for testing DAH oils.

(c) **Evaluation of serving life** TAN (total acid number) and viscosity of tested oils increase no more than by 0.4 mgKOH/g and 10% respectively after 450 hour's operation for DAG oils and after 600 hour's operation for DAH oils.

RELIABILITY ANALYSIS OF RIG-TEST RESULTS

In recent years authors have performed rig-tests of tens of rotary compressor lubricant candidates, which were developed by many Chinese petrochemical companies.

Meanwhile, industrial examinations for some of those oil candidates were carried out with some oil-flooded screw compressors which were operating in several factories. In both of rig-tests and of industrial examinations, three of those candidates foamed over the oil tank, and foam overflowing in the oil/air separators. However, the foaming resistance of those oils tested through physicochemical analysis were all up to the standard ISO/DP6521-3-81. Some tested results about increases of viscosity and TAN of 9 oil candidates are listed in Table 3. Though increments of both viscosity and TAN often characterize the aging degree of oils, they do not

Table 3 Rig-test results for nine DAG oils

		32-1	32-2	46-1	68-1	32-3	46-2	32-4	46-3	46-4
Rig test	Viscosity Increment (%)	10	13	0.2	3.8	9.8	4.5	5	18* / 360*h*	5
	TAN increment (mgKOH/g)	0.05	0.08	0.12	0.25	0.34	0.12	0.1	0.46 / 360*h*	0.19
Industrial application	Viscosity Increment (%)	7 / 2500*h*	11 / 2500*h*	0.8 / 2800*h*					separator failure / 2000h	
	TAN increment (mgKOH/g)	0.07 / 2500*h*	0.1 / 2500*h*	0.11 / 2500*h*						

*Period of rig-test is 450h except some marked

coincide with each other for different lubricants. The conditions of qualifying an oil candidate are:

Viscosity increment ≤ 10%

TAN increment ≤ 0.4 mgKOH/g

Fig 2 shows changes of viscosity and TAN of two DAG 46 oils in repeated rig-tests. It is obvious that the repeatability of two tested results is very well for each kind of oil.

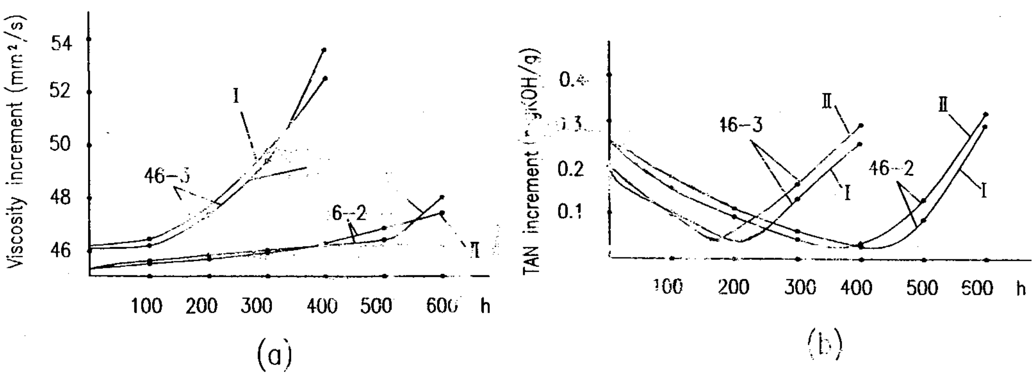

Figure.2 Changes of viscosity and TAN of two No46 oils in repeated rig tests

Deteriorated oils often produce carbon deposits and gummy substance. These materials accumulate inside of fiber organization of oil/air separator cores, and give rise to large resistance for flowing compressed air. Therefore, coalescer blocking tendency of rotary compressor lubricants is related to oil's deterioration and oxidation to a large extent. The increment of 0.02MPa for the pressure differential in front and behind of the separators is generally a critical value after above defined period of rig-test operation.

APPLICATION OF RIG-TEST TECHNIQUE OF ROTARY COMPRESSOR OILS

As having a function that cannot be replaced by physicochemical experiments, the rig-test technique has been widely applied in China. Almost all of new developed rotary compressor lubricants in China have been evaluated with this rig-test technique in oil candidate selections. From this, major applied performances of oils can be determined, which include oil's deterioration, service life, foaming resistance、coalescer blocking tendency、wear resistance and corrosion resistance etc.

CONCLUSIONS

(a) In order to evaluate and control quality of oils used in oil-flooded rotary compressors, rig-tests are necessary besides physicochemical experiments

(b) Reasonable selections of rig-test compressors, rig-test conditions and parameters are basis of accurate performance evaluation of rotary compressor lubricants. Major critical characteristics to qualify an oil contain service life、foaming property, coalescer blocking tendency、wear and rust resistance etc in evaluations of oils with rig-test.

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