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Y. Kang

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THE TEMPERATURE MEASUREMENT FOR ROTARY COMPRESSOR
WITH OIL INJECTION

Kang Yong

Division of Air Conditioning, Department of Textile
Engineering, North-west Institute of Textile Science
and Technology, Xi'an, CHINA

ABSTRACT

The discharge temperature of rotary compressors with oil injection is generally measured by a thermometer directly put in the discharge pipe. Oil and gas are mixed and have different temperatures, so that the measurement is not exact. In this paper, a measuring method placing a centrifugal sheath for separating oil from gas, is put forward, in which the discharge temperature can be more exactly measured. The method is convenient in use and has a simple structure and a good stability through experiments. In order to analyse the error of the measurement, a inequality is built according to the two phase flow theory, then count out the one-side-maximum error.

SYMBOLS

t_G	gas temperature
d	diameter of centrifugal separating sheath hole
Z	pipe length
Q	quantity of heat transfer
C_{Pg}	isobaric specific heat of gas
W_G	mass flow of gas
L_o	volume flow of oil
τ	time
F	area
δ_{oo}	one-side-maximum-relative error
δ_{oa}	one-side-maximum-absolute error
δ_o	relative error

δ_a absolute error
t measuring temperature
 Δt temperature difference between oil and gas

INTRODUCTION

Depending on the experiment of mixed flow in a pipe with oil and air, having different temperatures, it has been found that the air temperature of measurement can appear as different values by putting a bare thermometer and a shelter thermometer into the pipe, so that the research, the discharge temperature is generally measured by a bare thermometer directly put in the discharge pipe in rotary compressors with oil injection, is necessary.

It is known that temperature measurement method can be classified into two kinds, one is contact measurement and another is non-contact measurement. The non-contact measurement is generally used in optics and requires transparent pipe and a more complex instrument. It is not easy in experiment and the running of compressors. This paper researches the contact measurement because it is convenience in use and does not require transparent pipe and a more complex instrument.

EXPERIMENTS AND ANALYSES OF THE MEASURING METHOD

If the contact measuring method is used in the mixed flow of oil and gas, two questions must be resolved; one is to separate oil from gas in the measuring spots and another is faster in the separating course. To completely separate oil from gas the separating time must be delay, more heat transfers between oil and gas to make the measuring temperature incorrect. But to separate fast the separating effect must be not good, the two questions are contradicting each other. Through experiments and analyses a new method is found and achieves a certain effect. This method can show consideration for the two aspects. The installation is shown in Fig.1. The separating principle concerning the centrifugal sheath is, three small holes on the sheath are located opposite to the direction of the mixed airflow in the pipe. The mixed airflow comes into the holes, then comes out from the underneath of the sheath because of the difference of pressure and gravity. The small holes are opened along the tangent of inner diameter of the sheath so that centrifugal force takes place to make the oil drops of the mixed airflow run into the inner wall of the sheath because of greater density of oil. Great viscosity of the oil can avoid oil drops breaking away from the wall, then the oil flows down along the inner wall. The gas coming into the sheath revolves down around the measuring

spot, it can guarantee to measure more exactly gas temperature. Through experiments in a smoke wind tunnel the revolving motion of gas in the transparent imitative sheath, same size, can be shown. This proves that the centrifugal circumstance can take place to separate oil from gas and measure the temperature.

The ratio of oil to gas in volume is generally 1:100 in the initial working volume in the rotary compressor with oil injection but the ratio in exhaust outlet is most, according to [3] the ratio can be counted out about 1:9. In order to examine the measuring method, an experiment rig of injecting oil into the airflow pipe, the diameter is 68 mm and the length is 4.2M, was built. Oil injected into the pipe by the centrifugal spray heads adopts No.30 turbine oil and gas adopts air given by a compressor. The experiment scope is;

$W_g = 7.2868 - 12.1234 \text{ Kg/min}$, $Lo = 15.6773 - 21.7578 \text{ L/min}$. In the experiment pipe the volume ratio of gas to oil is 1:8.9-9.1 and the pressure is 2.8713-3.7328 kg/cm .

The inner diameter of sheath is determined by the temperature sensor head. In these experiments mercury thermometer, diameter 6mm, are used so that the inner diameter of the sheath is 14mm, enough to guarantee airflow revolution around the thermometer head. The mixed flow situation in the sheath relates the size of the small tangent holes. If the holes are too large, the airflow speed is high and oil membrane on the inner wall is thick in the sheath and that make the oil break away from the inner wall to the thermometer, so that the separating condition becomes ineffect. If the holes are too small the airflow speed in the sheath is low, more heat transfers, it makes a delay in the measuring temperature. To a flow model, a good diameter must exist. If a curve of the measuring temperatures is made with difference diameters of the holes, then a best diameter can be found. In Fig.2. Through experiments the scope of the diameters, 0.8-1.2mm, is better, therefore the diameter, 1.5mm, is adopted in our experiments and the measuring spot is centered in the experiment pipe.

Several measuring methods are compared with each other in the experiments, the measuring results and patterns are shown in Fig. 3-6 and the third curve is measured by putting the bare thermometer directly into the pipe. At the beginning, the oil temperature is 60°C and the gas temperature is 110°C. The method of the centrifugal separating sheath is evidently more satisfactory from the Fig.3 and the methods 1-3 is ineffect because they can not show the change tendency of gas temperatures from high to low. The fourth given out in [1] does not have a

good effect although trying several different ways.

Comparing the directly putting method with the centrifugal separating method, the measuring temperature difference is 13°C at $Z=0.2\text{M}$. This is the result of the oil effect. If the measuring spot is changed 15mm from up to down between the cross section of the experiment pipe at $Z=0.2\text{M}$ the measuring temperature, measured by a bare thermometer, can change 20°C because the oil is unequally distributed in pipe, so that the directly putting method is unstable for measuring the discharge temperature. On the contrary, the centrifugal separating method is very stable for measuring gas temperature in this proportion of oil to gas. In experiments the measuring spot is changed 10mm at same conditions, using the centrifugal separating method, but the measuring temperature change did not reach 1.5°C and more than hundred groups of experiments show it firmly, using regression analysis the obtain equation is highly marked.

THE ERROR ANALYSIS

All of the thermometer used in the experiments were demarcated but what is the difference between the measuring temperature and the actual gas temperature. Because the actual gas temperatures are difficult to be determined, this paper tries to find a maximum error by analyses of the expending error. First, a inequality is built according to the two phase flow model, then count out the one-side-maximum error.

It is known that the closer to the beginning the experimental pipe, the larger the disorderly degree of the turbulent flow in the pipe and the more difference the temperature between oil and gas. Therefore, the larger the heat flow indensity, d^2Q/dz^2 , the closer to the beginning the pipe. Then there is a relationship at $Z=0-0.2\text{M}$ because the airflow speed in the pipe changes a little

$$\left| \frac{d^2Q}{dz^2} \right| \Big|_Z > \left| \frac{d^2Q}{dz^2} \right| \Big|_{Z+\Delta Z} \quad \Delta Z > 0$$

where $Q = C_p G W_G (t_{G0} - t_G)$

then becomes

$$\left| \frac{d^2t}{dz^2} \right| \Big|_Z > \left| \frac{d^2t}{dz^2} \right| \Big|_{Z+\Delta Z}$$

Through testing the temperature measured in the experiments with inequality, the supposition above is correct.

Using measurement temperature, a curve is built and Z_0 expresses the nearest measuring spot, shown in Fig.7. Another curve can be supposed between P_0 and P , and satisfies the inequality. Therefore, the difference between the temperature of the supposing curve at $Z=0$ and the initial gas temperature, which can be exactly measured, is the maximum measuring error about the centrifugal separating sheath method. In this paper, the second derivative on the supposing curve is a constant value which is the same as the value of experimental curve at $Z=Z_0$. In other words, because the absolute values of the derivative and the second derivative are smaller than the actual absolute values in all of the curve, so that the closer to the beginning the experimental pipe, the more the difference between the actual temperature and the temperature of the supposing curve, then reach maximum at $Z=0$.

By comparing the better imitate curve of the experimental temperature can express

$$t_g = a + \frac{b}{Z + c}$$

the second derivative of the supposing curve is constant as same as the imitate curve's at $Z=Z_0$.

$$\frac{d^2 t_g}{d Z^2} = \frac{2b}{(Z_0 + c)^3}$$

Using boundary condition, the formula becomes

$$t_g = \frac{bZ}{(Z_0 + c)^3} - bZ \left[\frac{Z_0}{(Z_0 + c)^3} + \frac{2}{(Z_0 + c)^2} \right] + a + \frac{b}{Z_0 + c} + Z_0 b \left[\frac{Z_0}{(Z_0 + c)^3} + \frac{1}{(Z_0 + c)^2} \right]$$

Take a example using the curve in Fig.1

$$a = 74.219 ; \quad b = 3.608 ;$$

$$c = 0.07086 ; \quad Z_0 = 0.2$$

then, count out

$$t_g = 104.64^{\circ} \text{c}$$

Both the initial temperatures of oil and gas are 60°c and 110°c , so that

$$\delta_{oo} = 10.7 \% ; \quad \delta_{oa} = 4.9 \%$$

But the values are one-side-maximum errors. Half of the one- side-maximum error can be added to the measuring temperature, therefore the real error about the revisal temperature is

$$\delta_o = 5.4 \% ; \quad \delta_a = 2.5 \%$$

The revisal temperature can be used as the result of the real gas temperature which can be counted out

$$t_g = t_m + 0.5 \cdot t_m \cdot \delta_{oa}$$

or

$$t_g = t_m + 0.5 \cdot \Delta t \cdot \delta_{oo}$$

CONCLUSION

In the mixed flow of gas with oil, more exact measuring of gas temperature depends on two conditions; one, completely separate oil from gas and the other is to separate quickly. The method, of directly putting a thermometer into the discharge pipe to measure gas temperature, can not measure the discharge temperature better because of the oil effect.

A new measuring method, placing a centrifugal sheath for separating oil from gas, is found, in which the discharge temperature can be more exactly measured. The method is convenient to use and has a simple structure. Through more than one hundred experiments, the measuring values of gas temperature are stable. By means of theoretical analyses the relative error of this method is satisfactory, $\delta_o = 5.4 \%$.

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- [2] B.Butterworth, et al, "Two Phase Flow and Heat Transfer" Oxford University Press, 1978
- [3] R.W.Lockhart, et al, 'Proposed Correlation of Data For Isothermal Two Phase, Two Component Flow in Pipe' Chen Engng Prog, Vol. 45, 1949

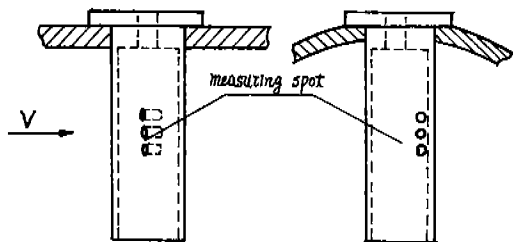


Fig. 1 The centrifugal separating sheath for measuring gas temperature

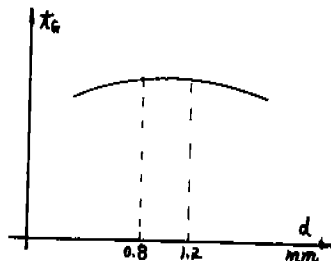


Fig. 2 Relationship between measuring temperature & small holes of the sheath

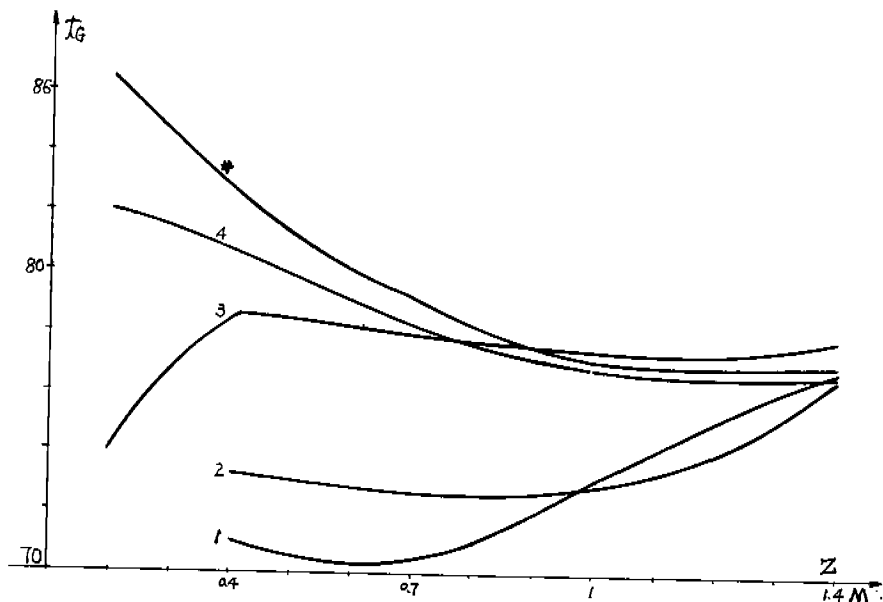


Fig. 3 Comparison of several measuring methods for gas temperature

* - gas temperature curve measured by the centrifugal method

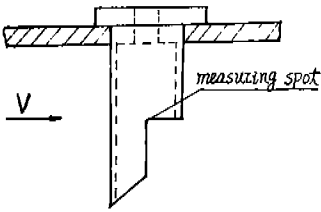


Fig. 4 The measuring method for curve 1

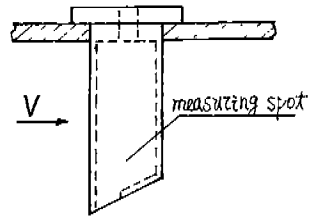


Fig. 5 The measuring method for curve 2

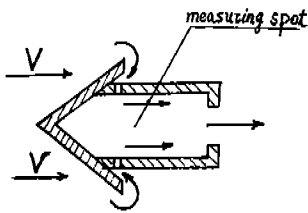


Fig. 6 The measuring method for curve 4

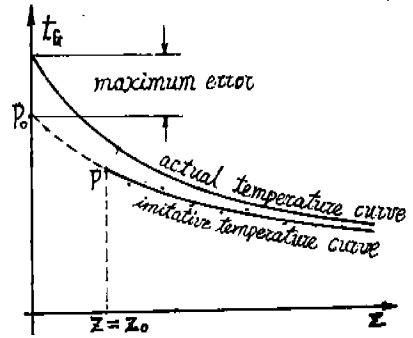


Fig. 7 Sketch map for analysing the maximum error

RATING TECHNIQUE FOR RECIPROCATING REFRIGERATION COMPRESSORS

Mr. Stuart Lawson,

Prestcold Limited, Station Road,
Theale, Reading RG7 4AF,
England.

Mr. Hank Millett

Copeland Corporation,
Sidney, Ohio
U.S.A.

ABSTRACT

As refrigeration compressor manufacturers introduce machines with improved efficiencies there is a need for updating performance data.

The compressor performance data which is published should be a true representation of the actual compressor performance, historically this has resulted in lengthy test programmes for the compressor manufacturer. A system is required which can accurately produce performance data from a manageable number of tests.

As a result of analysing the behaviour of reciprocating refrigeration compressors, relationships become apparent which could reasonably be expected to form the basis of a technique which will economically generate accurate performance data over the full matrix of operating conditions.

The basis of possible techniques will be described and justified by reference to the principles of operation of reciprocating compressors.

INTRODUCTION

Specifiers of refrigeration equipment are continually required to select compressors which best match the needs of a specific system. When considering packaged equipment, the incorrect selection of a compressor will result in additional development time and expense.

The existing techniques for providing performance data vary from one compressor manufacturer to another. Although tests may be carried out to the same procedure on the same machine by two test houses it is highly likely that the data sets generated will have