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DEVELOPMENT OF A NEW GENERATION OF SLIDING VANE COMPRESSOR

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ABSTRACT

A new type of oil-flooded sliding vane air compressor and its purifying system are introduced in this paper. The efficiency of the compressor is higher than conventional one because of reduction of gas leakage and mechanical friction losses by means of special design. The capacity control and air purifying system also have their own features. The test performance of a prototype compressor is also provided in this paper.

INTRODUCTION

The mechanical efficiency of conventioal sliding vane compressor is lower, the abrasion of vanes and cylinder is severer since direct contact friction of vane tip with cylinder wall. And some rotary compressors, in general speaking, have disadvantage such as lower volumetric efficiency because of higher leakage caused by existence of clearances between moving and static parts. A new configuration of compressor has been developed. The measures are applications of non-contact load-relief devices between vane tips and cylinder, and end plates with ring-shape sealing and radial sealing. The mechanical efficiency, volumetric efficiency, abrasion and service life of parts for the new type of compressor are much better than conventional one.

Moreover The compressor unit adopts continuous capacity control system to overcome disadvantage of two step capacity control (zero or full load) system.

SPECIFICATION OF THE COMPRESSOR UNIT

Compressor

Type	Two stages, oil-flooded
Medium	Air
Suction pressure	Atmosphere
Suction temperature	$\leq 40℃$
Discharge pressure	1.0 MPa
Discharge temperature	$\leq 120℃$
Delivery volume	$6m^3/min$

Purifying System

Drying method	refrigerating
Operating pressure	≤ 1.0 MPa
Inlet temperature	$\leq 40℃$
Dryness (atmosphere dew point)	$-26℃$
Receiver volume	$2\times 1.5m^3$

COMPRESSOR DESIGN

Optimization for the Compressor

The following compressor parameters are optimized by a computer program: number of vanes, radius and length of cylinder, eccentric between rotor and cylinder, vane thickness etc.. The compressor is designed into two stages in consideration of relieving stress of the parts, reducing leakage and designing discharge port under higher discharge pressure. The pressure ratio for each stage is approximatively equal. Allowing a bit of under-compression, the discharge ports are designed to be slightly larger in order to reduce gas resistance losses through the ports

Load-relief Ddevice

A special device for reducing friction and sealing gas is developed to improve the faults of higher friction and leakage of conventional sliding vane compressor which cause lower mechanical and volumetric efficiency and severe abrasion of the parts. The load-relief device(as shown in Fig.1) which consists of an inter-ring, an outer-ring and rolling parts is set in each side of the cylinder. The axial length of the device depends on contact stress of vane tip, while its radial dimension depends on its axial length and diameter, shape, row

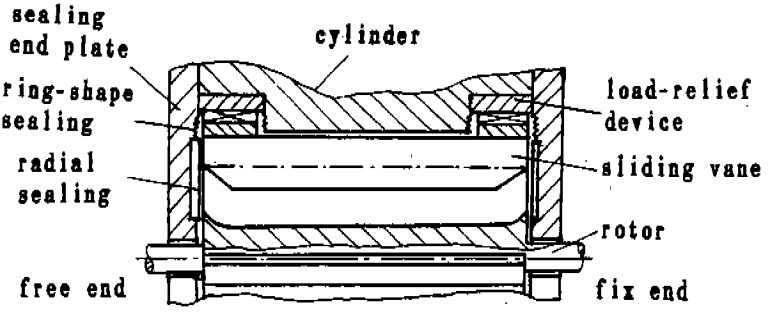

Fig. 1 Load-relief and Sealing Divice

number of rolling parts. When the compressor is running, sliding out of rotor grooves by centrifugal forces, the vanes contact inter-rings of load-relief device rotated by friction forces of vane tips. So the vane tips have no contact with cylinder wall and mechanical friction and abrasion between vanes and cylinder can be avoided. The relative motion between vanes and inter-rings with vanes is smaller, which results in lower mechanical friction loss and abrasion. In other words, the compressor will have higher mechanaical efficency and longer service life than conventional sliding vane compressor.

The compressor has three rotating parts: rotor, vanes and inter-ring of load-relief device. They have to keep certain clearances from static parts. Gas leakage through the clearances should not be very great. The compressor adopts end plates with ring-shape sealing and radial sealing to resist gas leakage from higher pressure region through those clearances, which results in higher volumetric efficiency and excellent performance —— the delivery volume has almost no decline with increase of discharge pressure.

Material of Vanes and Sealing End Plates

The relative motion between vane and inter-ring of load-relief device depends on friction coefficient and specific force between them. The greater the specific force (caused by higher vane mass and tip speed) and fricition coefficient are, the smaller the relative motion between them is (lower mechanical friction loss and abrasion) . It is theoretically beneficial to adopt the vanes with high density,

speed and friction coefficient. However, it is not such a simple question in fact. Higher contact stress of vanes and inter-rings caused by high material density and tip speed should be prevented, or the abrasion of vanes and inter-rings will be severe because of over-stress. High density or tip speed, on the other hand, causes great deformation of the vanes, and results in no function of load-relief because the middle part of vane has contacted with cylinder wall.

It is suggested that aluminum alloy is suitable for vane material when tip speed u=8~20 m/s, and the thickness of vane has to be reduced 50~70% if iron or steel is used for vane material. Moreover, the vane material should be selected carefully to prevent damage in case of contact of end plates with the other moving parts.

CAPACITY CONTROL SYSTEM

The suction control valve consists of start-inlet valve, set-up valve, pressure control valve and relief-nonreturn valve. The start-inlet valve allows a bit of air to enter compressor through a 5 mm hole when compressor is set up, and switches off when compressor is put into normal operation. The auto-switch of compressor from zero load to normal operation is controlled by a set-up valve. The pressure control valve used for adjusting discharge pressure of compressor. The relief-nonreturn valve has the function for auto-control of compressor capacity and can switch off in time to prevent return flow of compressed air. Co-actions among suction control valve, minimal pressure valve and auto-relief valve allow compressed air in compressor to be fully released out when compressor is stopped to ensure no load in next set-up. The suction control valve is an advanced continuous step auto-capacity-control valve in which 0 ~ 100 % range capacity can be automatically adjusted when consumption of compressed air is fluctuating. Fig. 2 shows the overall system of the compressor and its accessories.

PURIFYING SYSTEM

An absorbing process or refrigerating process can be used as purification for compressed air. Comparing with each other, the capital cost of hot air re-generation absorbing dryer is higher than refrigerating dryer and the operating cost of the former is 4 times of the later. The refrigerating dryer has no

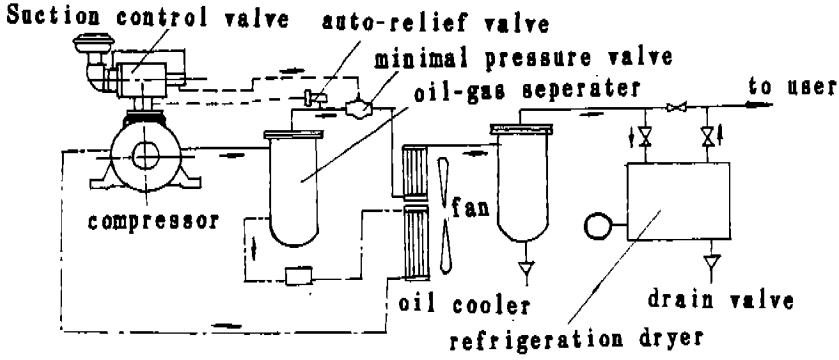

Fig. 2 Purifying and Operating System

on-off-switch, it is therefore reliable for operation and easy for maintenance. An advanced refrigerating dryer is used in this unit. Besides inlet air filter, it is important to combine water-gas seperater, oil-gas seperater, after-cooler and refrigerating dryer for seperation of dust, oil, water in compressed air to ensure air quality (making dust, oil, water and impurity in compressed air to minimum). The mixture of oil and air after discharge port in this oil-flooded machine must be effectively seperated. The core of oil seperater is made of super-fine glass fiber. Its resistance is 0. 01 bar and the particles with diameter $<5um$ can only be passed through. After oil seperater there is an excellent plate after-cooler by means of wich the temperature of compressed air drops down to bellow 40℃, most of water vapor in saturated compressed air is condensed into water then drained off through an auto-drain valve at the bottom of water-gas seperater. The compressed air having very low humidity then enters refrigerating dryer in which its temperature further drops down to 0℃, the vapor in it is further condensed. The dryness of compressed air can reach to atmosphere dew point -26℃. The oil vapor in it is simutaneously condensed when water vapor is condensed in after-cooler and refrigerating dryer, then drained off through water drain valve. The quality of compressed air could be very high:

air —— atmosphere dew point -26℃;
oil —— 3. 5～5mg/m³;
dust —— 5mg/m³.

PERFORMANCE OF PROTOTYPE COMPRESSOR UNIT

Compressor

Suction condition:

P_o=733mmHg=0.0977MPa

t_o=16℃

ψs=81% (relative humidity)

Tab.1 Compressor Performance

Discharge pressure, MPa(g)	0.410	0.505	0.61	0.7	0.8	0.9	1.0
Delivery volume, m^3/min	7.020	7.018	6.980	6.970	6.952	6.936	6.924
Shaft power, kw	40.44	43.31	45.69	48.54	51.83	55.56	58.31
Volumetric efficiency, %	89.1	89.1	88.7	88.5	88.4	88.2	88.1
Specific power, kw/m^3 · min-1	5.76	6.17	6.54	6.96	7.46	8.01	8.42
Rotation Speed, rpm	1482						

Purifying System

The measurement for the system is under the condition: presure of compressed air out of refrigerating dryer —— 1.0 MPa.

Tab.2 Performance of purifying system

Items	unit	Specification	Measurement
Atmospheric pressure	mmHg	——	733
Atmospheric temperature	K	——	285
Atmospheric relative humidity	%	——	81
Discharge temperature of compressor	℃	< 120	96
Air temperature after cooler	℃	< 40	31
Outlet pressure of dryer	MPa	1.0	1.0
Dryness (atmosphere dew point)	℃	-26	-26
Oil in compressed air	mg/m^3	< 15	8
Dust in compressed air	mg/m^3	< 5	——
Dust diameter	mg/m^3	< 10	5

CONCLUSIONS

1. Special Load-relief devices of vane tip and cylinders well as sealing end plates are applied to this new generation of sliding vane compressor. Its performance (efficiency, capacity, etc.) is better than conventional sliding vane compressor.

2. Simple configuration, small dimension, light weight, stable operation, high discharge pressure, high capacity as well as capacity auto-control of range 0～100% of this new type of compressor are advantages comparing with reciprocating compressors.

3. Load-relief device also has long service life and high reliability.

4. Purifying system in this unit brings high quality of compressed air as well as lower running cost.

In a word, this new generation of sliding vane compressor has high performance and reliability, also simple to manufacture, easy to maintain as well.