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A SUBSTITUTE OF ROOTS BLOWER —
MONOTOOTH ROTARY COMPRESSOR

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ABSTRACT

Having built-in compression process, monotooth rotary compressor can reach larger discharge pressure with higher efficiency and lower discharge temperature when compared with Roots blower. So it is a good alternative for Roots blower used in various fields. In order to put this kind of compressor into market as soon as possible, theoretical and experimental study of the monotooth rotary compressor is carried out in this paper.

INTRODUCTION

Roots blower is a kind of gas processing machine whose main advantages are high reliability compared with reciprocating machine in terms of running life and maintenance, and with turbo-blower in terms of adaptability under variation in condition (pressure and delivery volume etc.) as well as simple manufacturing and low cost. Its performance, however, is poor compared with the other machines. For instance, under higher discharge pressure its efficiency is extremely low and its delivery volume can decrease a lot.

The reason for those is no built-in compression in Roots blower. That means no pressure boost occurs in cylinder, and gas pressure in the working cell increases to discharge pressure immediately as the working cell is connected with discharge port.

The compression process of Roots blower is isovolumetric (1-2 in Fig. 1) and it is no built-in compression. If we manage to make a machine with built-in compression, its compression process will be adiabatic (1-3 in Fig. 1). The energy saving for the machine with built-in compression at one rotation
compared with Roots blower can be shown as the area 1-2-3-1 in Fig. 1. The higher the pressure ratio is, the more the energy saving is. One hopes to find a substitute of Roots blower in higher pressure ratio application for better performance.

The authors have developed a new type of blower/compressor—monotooth rotary blower/compressor which can create built-in compression in cylinder, therefore has improved performance in higher pressure ratio condition. It is an ideal substitute for Roots blower. The authors have done the following work for the monotooth rotary machine: profile study, machine design, performance simulation, prototype building and performance testing.

PRINCIPLE AND PROFILE

The monotooth rotary compressor consists of two rotors rotating at clockwise and counterclockwise respectively whose timing is ensured by a pair of timing gears. The configuration of the machine is similar to Roots blower, while its suction port is radially located in the cylinder and discharge port at the end covers.

The working process of the monotooth rotary compressor is shown in Fig. 2.

a) The cell is isolated from suction port and the compression will begin at the next moment. The cell volume decreases and the gas pressure increases with the further rotation of rotors until the cell has got in connection with discharge port;
b) Discharging when the cell is joining discharge port;
c) the discharging process terminates when the cell sweeps over the discharge port and is isolated from the port;
d) The next cell is formed and connected with suction port, the suction process begins. The suction continues as the cell volume increases and is kept to open to suction port;
e) The cell volume reaches the maximum and the suction continues;
f) The suction ends at the moment when the cell is separated from the
suction port, and the process goes back to a) for next cycle.

We can see the following features of monotooth rotary compressor:
1) One cycle (suction, compression, discharge) for each cell is completed in two rotations, while two cells are working in these two revolutions, so there is always one discharge process in a revolution;
2) Suction process occurs at the most part of a rotation, which brings on sufficient inlet and less pulsation;
3) Built-in compression in the compressor causes benefit of energy saving, especially for higher discharge pressure service;
4) The monotooth rotary compressor, because of having no such wearable parts as valves, piston rings and rod packing, has longer service time than reciprocating machines. Its two-dimension profile is easy manufacturing compared with three-dimension profile of screw compressor.

The profile for each rotor can be the same or differ, but the profile should ensure perfect mesh of the pair of rotors, easy manufacturing for rotors, and suction port and discharge port as large as possible for less resistance.

A typical rotor profile is shown in Fig. 3. It consists of lines, circular arcs and straight lines:
AB—Straight line tangent to circular arc with \( r_1 \);
BC—Circular arc;
CD—Circular arc with cylinder radius \( R \);
DE—Generative line by tooth tip D;
EF—Circular arc with root radius \( r \);
FG—Circular arc;
GH—Generative line meshing with AB;
HA—Circular arc with radius \( r_r \).

THE PROTOTYPE

The authors have designed a prototype with the following specifications:
Suction pressure: 0.1 MPa
Suction temperature: 20°C
Discharge pressure: 0.2 MPa
Delivery volume: 10 m³/min
Rotation speed: 2950 rpm
Shaft power: 22 KW
Working substance: Air

The main dimensions of the prototype are listed in Table 1.

<table>
<thead>
<tr>
<th>Items</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor axis space</td>
<td>160</td>
</tr>
<tr>
<td>Tip radius</td>
<td>105</td>
</tr>
<tr>
<td>Root radius</td>
<td>55</td>
</tr>
<tr>
<td>Rotor effective length</td>
<td>190</td>
</tr>
<tr>
<td>Meshing clearance</td>
<td>0.16~0.20</td>
</tr>
<tr>
<td>Tooth tip clearance</td>
<td>0.08~0.14</td>
</tr>
<tr>
<td>Rotor fixed end clearance</td>
<td>0.10~0.14</td>
</tr>
<tr>
<td>Rotor free end clearance</td>
<td>0.14~0.20</td>
</tr>
</tbody>
</table>

The suction port should be designed in accordance with that the cell volume reaches the maximum when it is separated from the suction port so that the compression will begin at the next moment. The shape of suction port in cylinder body is of rectangle and gradually becomes circular towards the joint flange.

The design of discharge port is extremely important to the built-in compression in the cell. The port should be designed in accordance with that the built-in pressure in the cell is equal to discharge pressure when the cell just arrives at the margin of discharge port.

To reduce rotor’s vibration to minimum extent it is necessary to keep the potor’s static and dynamic balance by drilling holes parallel to rotor axis in the opposite direction of rotor’s centroid to compensate the unbalanced centrifugal
forces. A dynamic balance testing machine is used for further balance calibration after all the rotor parts are assembled.

**PERFORMANCE ANALYSES**

An ordinary compressor performance testing system is used for testing the performance of the prototype. A controllable silicon speed-variable electrical motor is adapted for the compressor driver, and the rotation speed and torque are measured by a torque-speed transducer mounted between motor and compressor. The delivery volume of compressor is measured by a standard orifice device.

Fig. 4 and Fig. 5 show the performance comparison of monotooth rotary machine (curve 1) and Roots blower (Curve 2) through test. It can be seen from the testing results:

1) The monotooth rotary machine has higher volumetric efficiency than Roots blower, and the difference between them increases with higher discharge pressure;

2) The performance of monotooth rotary machine is poorer than Roots blower under lower discharge pressure and becomes better after a certain higher discharge pressure. So the monotooth rotary machine shows its advantage in higher pressure ratio application;

3) The discharge temperature of monotooth rotary machine at $p_d = 0.2$ MPa, $n=2980$ rpm is only $120^\circ$C which is much lower than that of Roots blower ($180^\circ$C) at the same condition;

4) The monotooth rotary machine has poor performance at lower rotation speed since the leakage becomes severe.

**CONCLUSIONS**

The monotooth rotary machine shows better performance than Roots blower at higher discharge pressure. It is an ideal substitute of Roots blower when reaching pressure ratio $p_d/p_s>2$. It can also be reformed as oil-free or oil-flooding compressor.
REFERENCES


Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Volumetric Efficiency (%)

Specific Power (KW·min/m³)

Discharge Pressure (MPa)

Discharge Pressure (MPa)