Journal of the Korean Vacuum Science & Technology; JKVST
Vol.6, No.4, 2002, pp.158 ~ 161

Introduction of the Oil-Free Scroll Vacuum Pump

Shuji Haga†

Vacuum Pump Dep., Anest Iwata Corporation

1. Introduction

The scroll, which is one of many positive displacement and kinetic mechanisms, is currently utilized for refrigerant compressors in air conditioners, air compressors, and vacuum pumps because of its features and advantages. The scroll has been the focus of research and development in order to improve performance and seek new applications. Although the principal of scroll technology developed a long time ago, it had not been utilized until recently. This was due to a highly precise machining processes and technological advances. Nowadays, such difficulties have been resolved by improved machining centers, so many products with unique scroll mechanisms have been introduced. Anest Iwata was the first to develop and supply oil-free scroll compressors and air-cooled oil-free scroll vacuum pumps to the market. An improved type of scroll vacuum pump is introduced herein.

2. Scroll Compression Mechanism and Features

Scroll fluid machines have at least two scrolls processed in an involute curve on a wall while one scroll is oppositely processed at 180-degrees. One of the scrolls is in a fixed state, which is called Fixed Scroll (FS), and the other orbits to the center of FS, which is called Orbiting Scroll (OS). The OS orbits around the designated circle, rotation being prevented. The wall of OS has a narrow clearance to that of FS, and the clearance (Radial Clearance: RC) has been kept during the orbiting. The two scroll walls form a crescent compression space(pocket).

Figure 1 indicates the position of OS at every 90-degree rotation. The intake gas from the inlet, which is located at the end of the outer scroll, is gradually compressed to the center while moving the OS. Finally, the compressed gas is exhausted from the outlet port. Although the compression ratio is around 3 to 4 times atmospheric pressure in air compressors, the inlet pressure is below 1 Pa and outlet pressure is atmosphere (100 K Pa) in vacuum pumps, which means the compression ratio is much larger than that of air compressors. That is why designers for the scroll vacuum pumps should take note of the different factors that affect displacement performance concerning the scroll compressors. The

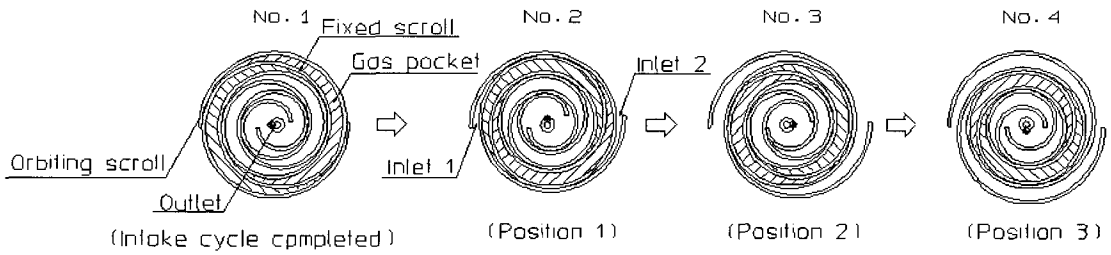


Fig. 1.

† E-mail : sayou@woovac.com

functions of intaking and exhausting can be executed at the same time during one orbiting rotation due to multiple crescent pockets, which is created from rotating one scroll 180 degree in relation to the other, gradually getting smaller. In addition, several medium pressurized pockets are formed between inlet pocket and outlet pocket.

These features result in minimal torque fluctuation and negligible leakage because the pressure difference between adjacent pockets is smaller than that of other compression mechanisms, such as piston pumps and rotary pumps. The small leakage results in high efficiency. The movement of OS is an orbiting motion rather than rotation. In general, OS operates within a 4 to 6 mm radiuses. That is, the FS friction is extremely small while pumping is smooth and torque fluctuation is minimal because every point of OS moves with many small diameters. As a result, both vibration and noise level are very small. Generally speaking, a large number of involute spiral scrolls means smooth compression. However, it is limited from 3.5 to 4.5 involute spiral scrolls because creating many involute spiral scrolls is dependent on the performance of machining accuracy.

3. Leakage Mechanism in Scroll (Performance affected)

The scroll mechanism, which consists of two scroll walls, has two leakage points. One leakage comes from a very narrow clearance in the radial direction between FS and OS. This RC is made of two circles of quite similar curvature, which results in high performance of sealing and volumetric efficiency. Professor Sawada at Akita University has theoretically conducted research on this kind of leakage mechanism. For designers of scroll vacuum pumps, how narrow a clearance they can create is an important factor. In order to maintain the narrow clearance in every running condition, they have also researched the way of economizing highly precise processes and cooling with minimal difference in thermal expansion rates between FS and OS. In general, the RS is around 10 to 50 microns. If the RC is too narrow, too much pressurization occurs when the pumps start to intake gases. Therefore, it should be of appropriate clearance. This design control is very important, especially for compressors. Many vacuum pump designers also elaborate on how they can deal with too much pressurization at atmospheric pressure.

The other leakage, called axial clearance (AC) comes from between the end of the scroll wall and the bottom of the other scroll. If the sealing of AC leakage is insufficient, compression efficiency is deteriorated because compressed gases leak to an adjacent pocket. Since the leaked gases should be compressed again, the power must be increased. The most effective way to prevent AC leakage is to use a seal, such as Tip Seal, in the groove processed at the end of the scroll wall. AC leakage is prevented while the Tip Seal keeps contact with the bottom of the other scroll. Generally speaking, the Tip Seal is made from high performance anti-wear and lubricating material, such as Teflon, which is mainly composed of fluorine. Every manufacturer elaborates on various ideas concerning the usage of Tip Seal.

4. Anest Iwata Oil-Free Scroll Vacuum Pump

(1) Structure of Single Wrap Scroll (General Scroll)

Figure 2 While the involute curve can be processed from the center of the scroll, which can obtain the highest compression ratio in the case of a single wrap scroll, this structure should be cantilever. The cantilever structure means that two balance weights are necessary to maintain the centrifugal force generated by OS movement. Especially when length L drawn in Fig. 2 is long and a shaft rotates at a high speed, an upsetting moment generates. Since the moment causes shaft deflection, the single wrap structure is not dynamically stable.

(2) Structure of Double Wrap Scroll (Crank Shaft at the Center of Scroll): Figure 3

A double wrap scroll structure is such that the OS is processed in an involute curve on both sides and a

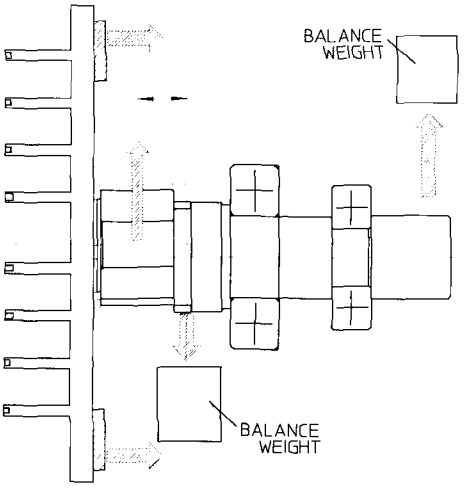


Fig. 2.

shaft passes through the center of OS. Because of this, OS can be supported on both sides while balance weights can be set at the same length from the center. This means that the double wrap scroll can ignore shaft deflection, resulting in a dynamically and statically stable structure. On the other hand, the compression ratio is deteriorated because the involute curve can not be processed at the center of scrolls. In order to overcome this disadvantage, designers come up with ideas of a starting angle and ending angle of the involute curve. One example of their thoughts is the shape of exhaust port on the scroll and inlet port.

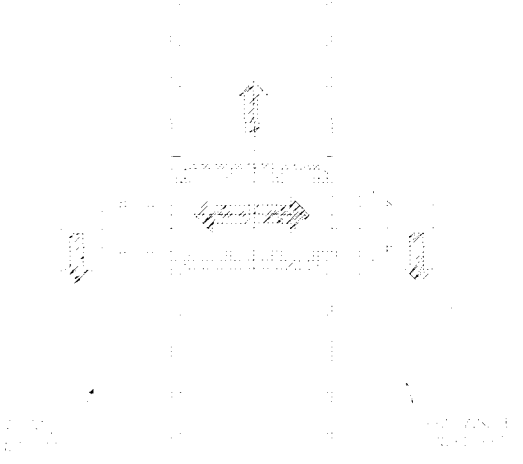


Fig. 3.

(3) Features of Double Wrap Scroll

Although a scroll mechanism cannot obtain much displacement space due to its limited diameter, the double wrap scroll can displace twice as much as a single wrap can. This is shown in Fig. 4. The OS is not fixed to the crankshaft and two FS's in the direction of thrust. The force to OS is cancelled because compression ratios on both sides of OS are exactly the same. Therefore, electric power can be minimized.

In the case of the single wrap scroll, leakage occurs in the outer scroll, which dynamically seals between atmospheric pressure and ultimate pressure in a vacuum. On the other hand, leakage of the double wrap scroll occurs around the crankshaft at the center. The pressure at the center of this structure is around atmospheric pressure, so this small difference in pressure results in small leakage.

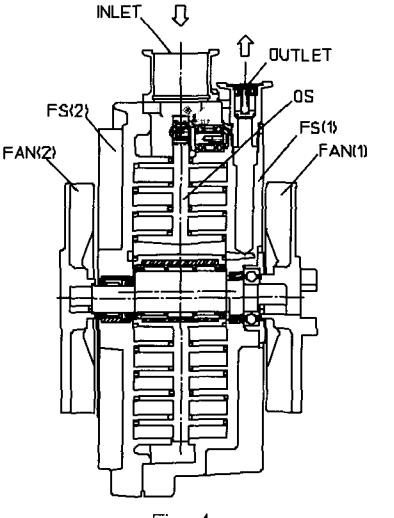


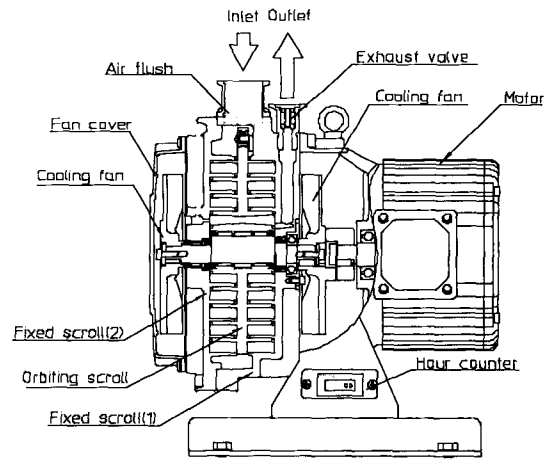
Fig. 4.

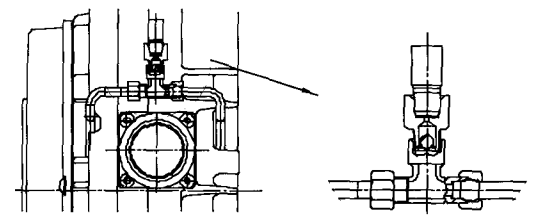
(4) Improved Anest Iwata Scroll Vacuum Pump

The weak point of the double wrap scroll is the accumulation of intake gases, particles, and dust which wear Tip Seals around the crankshaft at the center. This

accumulation harms bearings around the shaft. This has a bad influence on pump reliability, and occurs especially when the scroll pump is used as a rough pump for a turbo molecular pump and when the scroll pump runs at ultimate pressure for extended periods, which means no flow inside the scroll pump. The modified Anest Iwata Scroll Vacuum Pump has been improved to overcome this weak point.

Although old versions of the scroll pump have a single-lip seal, the improved pump has a double-lip seal with a spring attached to all seals in order to prevent the outflow of grease in bearings and the invasion of particles and condensed vapor. In addition, the improved pump employs the Air Flush, which is a device to blow out accumulated particles and condensed vapor while pump is operating with vacuum. When the Air Flush device is on, the accumulated particles and vapor are automatically excluded from the pump to the outside without any influence on ultimate pressure. Due to these improvements, the reliability of Anest Iwata Scroll Vacuum Pumps has been dramatically improved, and the maintenance cycle expanded from every 6,000 hours to every 8,000 hours. As a result, total durability of the scroll pump has also been expanded by 12,000 hours.





Air Flush

(Material is provided by Woosung Vacuum Co. LTD.)