VSD Screw Blowers:
Can You Save Energy and Increase Reliability?

Modern variable speed drives (VSD) have been used with positive displacement equipment for well over 20 years. VSD technology originated around the 1960s, first for small DC motors and evolving over time to be used on large induction motors. The implementation of pulse width modulation (PWM) technology using IGBT's led to smaller, more economical options and wider use. Inverter duty (VSD duty) motor designs soon followed to allow for the widespread use of VSD technology for variable load applications. Positive displacement (PD) blowers are often used in these variable load applications, and VSD technology can provide more energy savings over alternative options.

PD lobe blowers have been used since their invention in 1856 by the Roots brothers. Like any positive displacement machine, the delivered volume flow is roughly proportional to the blower's operating speed. A large majority of rotary lobe blowers are belt drive, and the blower's operating speed is set by the size ratio between the motor pulley and the blower element pulley. Operating pressure slightly varies the flow output of lobe blowers as higher discharge pressures increase the internal leakage within the blower. In result, blowers were sized as closely to the application needs, with the correct pulley ratios in belt driven units, for many decades. The only way to adjust the output flow or an operating machine was through the use of a relief valve to blow off some of the discharge air flow to the atmosphere or start/stop machines on the same header pipe. These methods were used to supply a variable flow output for applications that required it, including wastewater treatment aeration, aerobic fermentation, cooling and combustion air, and more.

VSD Efficiency

Beginning in the 1990s, the introduction of new VSD technology and inverter duty designs for 3-phase induction motors made it easy and economical to begin providing variable speed packages. Instead of using a blow off valve or starting/stopping, the VSD was used to vary the output frequency of the blower directly. Varying the blower operating speed adjusts the pressure vs. flow curve of the blower, with lower operating speeds displacing less volume flow.

Why is this significant? Slowing down the blower can be significantly more efficient than blowing off air.

A blower running at its nominal speed on a VSD compared to a fixed speed will have the same flow output and require a slightly higher amount of power input due to VSD electrical losses. With modern VSD equipment, this loss is typically less than 3 percent. However, with more flow reduction, more energy can be saved using a VSD. A lobe blower operating with VSD has a turndown of 60-70 percent, meaning that the minimum flow is 60-70 percent lower than the maximum flow. For a blower operating with a blow-off valve, it still produces the same amount of flow in the blower, and the only energy savings is potentially a

Delivered Flow m3/hr	Operating Pressure mbar (g)	Blow Off Power (kW)	VSD Power (kW)	Operating Time (%)	Yearly Energy Savings (₹)*
1700	551	36	37	10	-
1360	537	36	29	40	₹ 168,000
1020	524	35	22	30	₹ 234,000
680	510	34	15	20	₹ 228,000
*Total Savings , considering 8000 operating hours per year and unit power cost @ Rs 7.5					**₹ 630,000**

slight decrease in the system pressure. Therefore, a VSD can offer almost 60-70 percent in energy savings in a process requiring 60-70 percent less flow than the blower's nominal output. For any application with a large, variable flow demand, these savings easily pay for the extra investment cost of the VSD. A quick example of these savings can be seen in the table above.

An additional performance benefit of VSD is the ability to increase the operating speed beyond the base frequency (50 Hz in the India). Older pieces ofequipment can be retrofitted with VSD and a larger motor, if necessary, to increase the performance output of the equipment. The investment costs for this retrofit are considerably lower than purchasing new equipment to get a slightly higher flow output.

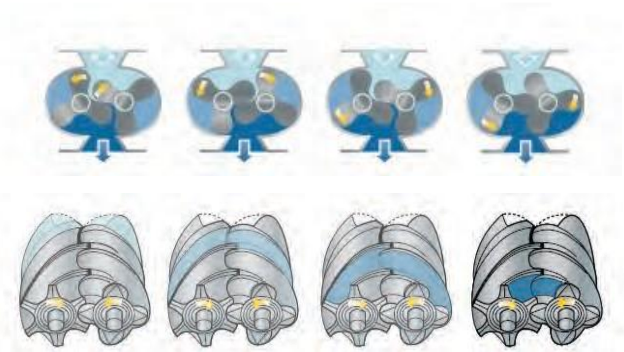
VSD Reliability

In addition to the energy savings offered from VSD driven blowers, their use also improves the equipment reliability in a few ways - reduced starting torque, lower bearing loads, and tighter flow control. Without the use of a VSD, the motor is started using either a direct-on-line (DOL) starter, star-delta starter or soft starter. The DOL starter has significantly higher torque than the blower's required load torque. The star-delta starters reduce this starting torque, and soft starters provide even smoother starting. However, a VSD can be thought of as the "ultimate" soft start. A VSD can directly vary the voltage and current required during motor startup to precisely match the required torque. This feature reduces loads on the motor as well as the drive system between the motor and blower, helping to increase their lifetime.

Reducing blower speed instead of using a blow-off valve also means that the bearing loads are reduced. A bearing's expected lifetime is a function of these loads and the operating speed, allowing the bearings to last much longer using speed variation. Finally, a VSD can be controlled much more finely than a blow-off valve. This does not have a direct effect on machine reliability except in one area - reducing the number of stops and starts in certain cases. This is obviously true in comparison to blowers only operating with on/off functions, but still true compared to blow-off control. The VSD offers wider operating range, leading to tighter process control and fewer requirements for starting or stopping multiple pieces of equipment.

Rotary Screw Blowers

As discussed, VSD use with traditional positive displacement blowers such as rotary lobe machines can show significant benefits. Combining VSDs with newer positive displacement technology takes efficiency and reliability to the ultimate level. Rotary screw blowers are an improvement in PD technology that uses internal compression within the blower element to increase energy efficiency. For a detailed look at this difference, see the diagram below:



The lobe blower simply moves air from the blower inlet to the outlet along its casing walls. It is trapped at the outlet and therefore forced into the discharge pipe – which means all the developed pressure is created in the system piping. This principle works but is inefficient. In the screw blower design, there is an uneven number of lobes and flutes (4 and 6 in the diagram above) that reduce in clearance volume from the inlet to the outlet. This internal compression is more efficient than the lobe principle. On average, the screw blower is 30 percent more efficient than a lobe blower of the same flow, with higher improvements at higher pressures. This increased efficiency has an additional benefit as well – the screw blower can turn down even further (80-85 percent) on VSD operation because the required motor torque is lower at these lower flows.

One final feature worth discussing is the implementation of gear drives on rotary screw blowers vs. the traditional belt drive on lobe blowers. Gear drive screws gain some efficiency over belt drive options as the gear losses of high-precision helical gears are in the range of 2 percent. Mechanical losses from a belt drive are initially 3-5 percent and approach 10 percent as the belts wear over time. These savings will not be seen on project evaluations normally, but will be present in real world operating conditions. Gearbox drives are also designed to be more sturdy, reliable drive systems requiring no overhauls over the life of the blower equipment – assuming the oil is changed at regular intervals. This is a more advanced option that can have higher capital costs, but it avoids the regular breakdown and maintenance costs associated with belt drives.

Case Study

Here's a real customer story that demonstrates the potential energy savings. A 18.18 MLD wastewater plant in northern Kentucky purchased three 100 HP high-speed turbo blowers in 2010 as part of a plant expansion to improve the plant's energy efficiency and potential future expansion. The expectation was for steady growth in local industry that would increase the plant's demand over time. The high-speed turbo blowers were also supposed to offer significant energy savings as this technology is the most efficient option for a given blower size. However, over a few years, the local industry growth did not occur and a large industrial manufacturer moved out of the region. This caused the plant's average demand to be well below projections and well below the operating range of the purchased turbo blowers. The turbo blowers have a turndown of 50-60 percent, and the plant was forced to blow-off the excess air for the blowers into an unused basin, wasting this energy. The operating budget of the plant had relied on lower energy costs, but due to the wasted energy from having blowers that were too large and could not be turned down, the plant could not cover its costs.

In 2015, a rotary screw blower with gearbox drive was installed to combat this situation. High speed blowers are typically 10-15 percent more efficient than rotary screw blowers over the turbo blower's operating range. However, because of the very high turndown of over

80 percent for the screw blower, the plant could meet their permit and save the ~20 percent of energy from producing lower flows. The savings were immediately significant and the plant could achieve the originally projected energy savings expected from the turbo blowers. This example demonstrates that for some processes requiring highly variable flow, or when a flow demand is reduced due to unforeseen reasons, rotary screw blowers can be the most efficient option.

Permanent Magnet Motors

A new feature in rotary screw blowers and compressors is the implementation of permanent magnet (PM) motors. This technology is already found in high-speed turbo blowers and other rotating equipment, and the implementation on rotary screw blowers with VSD drives continues to push the efficiency and reliability of this product further. Permanent magnet motors are more efficient than induction motors because there is no extra electrical energy required to induce a magnetic field in the rotor, it is created with magnets fixed to the rotor shaft. This eliminates "secondary copper losses" to improve the efficiency at full load by 2-3 percent.

PM motors also have a near constant power factor at partial load, so the efficiency gains vs. induction motors are even higher at lower loads. Finally, permanent magnet motors are more compact and often cooled with water or oil. This means PM motors can carry an IP66 rating, making them suitable for the most extreme environments and have maximum reliability.

Conclusion

VSD technology has truly provided enormous improvements in energy efficiency for traditional positive displacement blowers used in variable load applications, as well as a considerable increase in robustness. The advancement of PD technology with the introduction of screw blowers utilizing internal compression has also greatly reduced the power consumption in these products. The incredible turndown of these units allows flexibility in processes requiring a wide flow range to potentially maximize the realized energy savings. Additional features such as new motor designs and drive systems will continue to offer a path to more efficient and reliable equipment in the future.

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