Collet Maintenance

Tool geometry, cutting material, and machine feeds and speeds are all important to the machine's performance. Basic tooling maintenance should be at the top of this list. Proper colleting and collet maintenance are essential, and directly affects the cut quality and longevity of the spindle. A clean collet, tool holder, router bit, and spindle taper allows for a firm grip of the tool, preventing tool runout. "Runout" occurs when the tool and spindle do not share the same center of rotation (they are not concentric). This runout puts enormous strain on the spindle bearings and can cause the spindle to fail prematurely. In addition, a tool that is not perfectly concentric will result in an uneven, wavy cut. It is recommended that the collet, tool holder, router bit, and spindle taper be cleaned each and every time you change a tool. When the machine is running, dust and debris collects in all crevices of the spindle, while resins can build up on the tooling. These resins will usually build up around the mouth of the collet. Because of this buildup, the tool may not be properly gripped, and a loss of concentricity ("runout") of the tool results. Proper cleaning and maintenance easily solves this problem.

Spindle Taper

Proper maintenance for optimal performance does not stop at the tool or the tooling accessories. Care should be taken to extend cleaning to the spindle as well. For instance, regular cleaning of the inside of the spindle taper should be part of your maintenance regimen. In addition, always leave a tool holder in the spindle, even when the machine is not in operation. This will greatly reduce the amount of dust and debris that can enter the spindle's interior, subsequently causing premature spindle failure.

Vacuum Hold-Down

The most common question asked when it comes to vacuum hold-down is how much vacuum does my application require? Vacuum systems should be evaluated based on the specific applications. The smaller the part or thinner the material to be held, the greater the volume of air flow required, thus increasing the size of the vacuum pump. Many people state that you can't have enough vacuum. This is somewhat a true statement. However, it can be a very costly fact. It is always easy to overbuy. Purchasing a single 40HP or 50HP pump can cost in excess of $25,000, and the purchase is only the initial cost. Depending on where your shop is located, the utility rates can vary considerably. Keep in mind that operating costs (utility) rarely go down, so these costs will increase year to year.

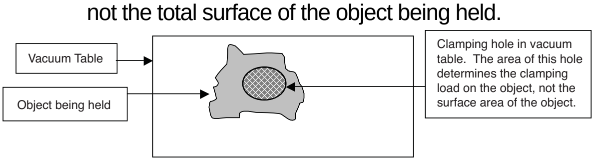
Purchasing a number of smaller pumps can help reduce the price of the pump as well as reduce the overhead to run these pumps. If you are processing sheets of materials that have large parts, then a single pump can be utilized. If the nest has numerous smaller parts, then it is best to run all the pumps for maximum air flow. There are other devices

which can be purchased to aid the vacuum hold-down system such as a spindle pressure foot, or roller hold-down. These devices push down on the material while being routed thus aiding the vacuum system.

Vacuum Table Basics

When selecting a vacuum table, the most important thing to remember is how a vacuum table works. The following six criteria should be carefully considered when determining whether your CNC application could benefit from using vacuum hold-down.

1) Atmospheric pressure is approximately 15 psi pounds/sq.in.). Each square inch of surface area has a load of approximately 15 pounds on it. (This pressure is more below sea level and less at the tops of mountains).
2) When we have a box that has no air in it; i.e., almost complete vacuum, the top and all other sides of the box are being loaded with 15 pounds of pressure on each square inch of surface. If the top of the box is 6”x6” then there is 6x6x15=540 pounds of load evenly distributed on the surface. The box will collapse or bend in if it is not strong enough.
3) A vacuum table; i.e., a box with holes in it, has the “holes” pulling down on the object above it with a pressure of 15 psi (assuming there is a complete vacuum). Note that the pressure on the object is based on the surface area of the hole in contact with the object being held, not the total surface of the object being held.



4) It is critical to realize that if the object is being machined; i.e., undergoing a side load, the actual force holding the object in place against the cutting force is now the friction between the object and the vacuum table. The magnitude of this relative friction force depends on the coefficient of friction between the object and the table, in addition to the actual vertical force on the object. Therefore, if the surface of the vacuum table is very slippery; e.g., Teflon coated, the object will tend to slip no matter how much downward force is being applied. If the surface of the table is nonslippery; e.g., it is rubber coated, then the object will tend to stay in place assuming there is enough downward force being applied. Note that for small pieces; e.g., small brass letters that have a surface area of less than .5 square in., it is unlikely that they can be held reliably with a vacuum table because the downward pressure on this object would only be about 7.5 pounds. It is important to remember both factors with respect to securing hold-down:
   a) contact surface area between the actual vacuum holes and the object.
   b) relative coefficient of friction between the object and the vacuum table surface.
5) Always consider the air permeability of the object being held down. The permeability is the amount of air that the object allows to pass through it. For example, a sponge is very permeable while a piece of aluminum is usually not. The permeability of the object determines whether a vacuum blower or a vacuum pump should be selected. A vacuum pump usually generates a very high vacuum; i.e., there is virtually no air in the vacuum chamber, but vacuum pumps tend not to draw or pull a great volume of air quickly. A vacuum blower tends to pull a great volume of air very quickly, but it does not necessarily create a very “complete” vacuum.
6) How big a vacuum pump or blower should I select? Consider the following questions when deciding:
   a) How large a part is being held down?
   b) How large is the vacuum table and its chambers?
   c) How much leakage will there be in the system?
   d) How permeable is the material?
   e) How quickly will the material be needed to clamp and unclamp?

Vacuum Pumps

Vacuum hold-down and which pump to choose can be very complex subjects. There are several different pumps available for use with a CNC machine and all have varying specifications and price ranges. The proper selection of a vacuum pump is imperative for optimal machine performance. To avoid paying too much or not enough, vacuum systems need to be evaluated based on the customer's specific applications rather than cost alone.

There are two main items of concern when looking at the specifications of a pump: vacuum level and flow. Vacuum level is typically measured in terms of inches of mercury (i.e. "Hg). This is the same term used when reading a barometer. So, it's no surprise that the vacuum utilized in CNC vacuum hold-down works by atmospheric pressure applying 15 lbs/sq.in. (psi at sea level) in all directions. During a CNC routing operation, when you use vacuum to remove air from one side of the material being cut (the underside), then the atmospheric pressure on the other side (topside) increases, in effect, pushing on the material. How much hold-down force is applied to the material can be calculated by reading the vacuum level gauge, multiplying that numeral by surface area of the material (sq.in.) and multiplying that by 0.5. For example, let's look at a gauge that reads 22"Hg for a material workpiece that is 24" square (576 sq.in.).

Clamping Force =
Gauge Reading ("Hg) x Material Surface Size (sq.in.) x .5
22 x 576 x .5 = 6336 lbs

Vacuum flow is the other important specification to consider when opting for CNC vacuum hold-down. Flow measures the volume of air pulled in by the pump. Measured in cubic feet per minute, vacuum flow is referred to as either *open flow* (CFM) or *specific flow* (SCFM). Open flow is the maximum flow without any restriction on the air being drawn by the pump. Whereas, specific flow refers to the level of air being drawn by the pump at a specific level of vacuum, usually the optimum level in relation to "Hg. Since SCFM is directly related to the vacuum's level of maximum clamping force (via the "Hg gauge reading), SCFM or specific flow is the more relevant measure of vacuum flow.

All pump manufacturers have performance curves that show the specific vacuum level vs. flow rate. Take for example, a 10HP pump that is rated for 11"Hg @ 105 cfm and has an open flow rating of 280 cfm. When the open flow reaches 280 cfm, the vacuum level is at 0"Hg, which using the clamping force equation above translates into zero hold-down. But, at 105 cfm the pump will not drop below 11"Hg until it exceeds that flow rate. At 106 cfm and above, the vacuum level will drop, effectively decreasing your vacuum hold-down. Diagram 1 illustrates the loss of vacuum as the flow increases.

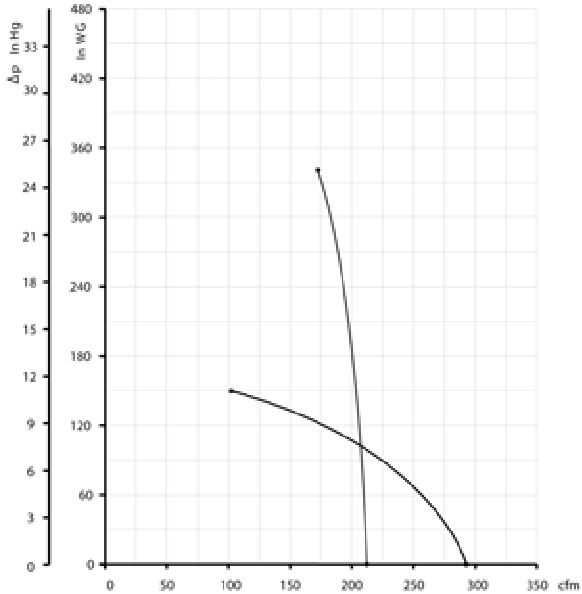


Diagram No. 1

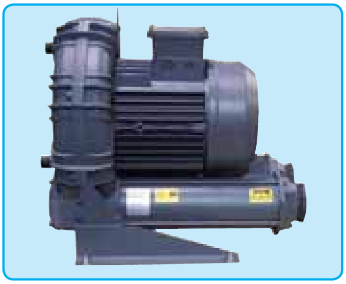
Once the vacuum begins to decrease, the part or parts you are machining can shift and move due to the loss of clamping force. This is primarily a concern in nested-based manufacturing where flow-through methods are used. Flow- through is the method of using an mdf scavenger board or sacrificial board to protect the CNC machine's surface. A sacrificial board is made out of porous material so that air can be vacuumed through the board, helping secure the workpiece to the table. A sacrificial board (i.e. a sheet of MDF) is put between the CNC machine's table surface and underneath the material being routed. The scavenger board allows the CNC Router tool bit to penetrate the workpiece while the board protects the surface and the vacuum table's grid structure.

The pump previously mentioned was used to illustrate the value of specific flow rate based on the usage of a 10HP regenerative vacuum blower. This example was the easiest method in which to illustrate how vacuum pumps and specific flow rates operate in the real world. There are many other pumps to choose from such as rotary vanes, positive displacement blowers, and rotary screw pumps. Prices from one system to another can fluctuate a great deal, but these few are the most commonly used units in the CNC Router industry. The differences in a cost-to-performance ratio from one system to another are best described by comparing the pros and cons of each system. For each system, a 10HP example will be used in relation to “Hg at scfm, decibel levels, approximate cost, typical applications and maintenance requirements.

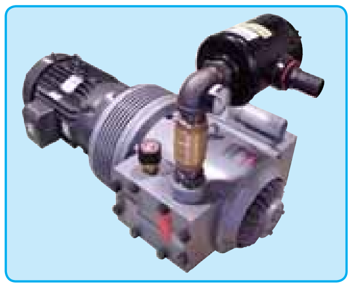
In comparison to the other vacuum systems, a 10HP regenerative blower is the lowest in cost, generally retailing for around $5,000. Regenerative vacuum blowers, consist of an electric motor coupled via belt or direct drive to the vacuum pump impeller. The motor rotates the impeller, drawing air in the inlet and discharging the air through the exhaust, creating vacuum. Because the inexact dimensional tolerances from the impeller to the housing, air is allowed to escape, resulting in lower vacuum pressure. This is known as slippage. Regenerative vacuum blowers typically generate low vacuum pressure, but generate greater volume of air as described in the earlier example of 11”Hg at 105 scfm. The noise consideration is a very real concern for these products. A regenerative vacuum blower runs in a decibel range of 85 to 95. This type of vacuum is ideal for holding less dense materials such as foam and other porous materials. The required maintenance is minimal with regenerative blowers, usually limited to replacing air filters.


Grid pattern offers maximum flexibility and provides easy customization of table surface.

Rotary vane vacuum pumps also consist of an electric motor coupled via belt or direct drive to the vacuum pump impeller made up of self-lubricating carbon vanes. The vanes rotate in the pump housing drawing air in the inlet and discharging the air through the exhaust, creating vacuum. Because of the close tolerances generated by the carbon vanes, greater vacuum pressure results. Up to 25”Hg at 173 scfm can be achieved for an $8,300 10HP unit. The increased vacuum results in superior hold-down capability, and is ideal for wood, plastic, and other nonporous sheet-like materials. In addition, these shop friendly pumps run quieter with a decibel range of 80 to 85. The downside to using these pumps is that the carbon vanes need to be replaced after 6000 to 8000 hours depending on conditions. Increased heat in the pump reduces vane life; dirty and/or blocked air filters and relief valves will cause the vacuum pump to heat and decrease vane life.


Regenerative Vacuum Blower

The electric motor for a positive displacement rotary blower is also coupled via belt or direct drive, but instead of carbon vanes it connects to two rotors that rotate in the opposite direction. When the rotors pass the blower inlet, it traps a quantity of air through the blower housing and discharges this compressed air out the exhaust. Because the pump compresses the air, when it is exhausted it is very loud due to the release of this pressure. Typical decibel ranges for a $8,500 10 HP unit run from 95 to 100. Positive displacement rotary blowers should be enclosed providing some sound protection. A max vacuum of 15”Hg @ 250 scfm makes these units ideal for wood, plastic, and other nonporous sheet-like materials. Regular maintenance such as oil changes are required between 5000-6000 hours of operation. Proper disposal of these oils are required.


Rotary Vane Vacuum Pump

Lastly, rotary screw vacuum pumps, which are the most costly pump at about $15,000 for a 10 HP unit, are ideal for wood, plastic, and other nonporous sheet-like materials. They have their electric motor coupled via belt or direct drive to counter-rotating twin screws. These pumps are the most complex of all, but also yield the greatest vacuum at 29”Hg at 150 scfm. They require cooling systems with complex electrical system controls to operate the unit.