During my visits with manufacturers who work with nested based CNC machines I am often confronted with questions regarding hold-down vacuum performance. Surprisingly, there is very little information available to these manufacturers apart from the specs of the vacuum pumps.

Manufacturers have told me when they have problems holding down parts to their table they often refer to the machine distributor who sold them the system. On occasion, they are told that the pump is not strong enough and that they must purchase a bigger pump. In some cases, after purchasing a bigger pump, the problem persists and they are told that the vacuum is not the problem, they must be doing something wrong.

In order to hold down a piece of wood to a table using vacuum, more than just the performance of the vacuum pump has to be taken into consideration. The air that will be drawn by the pump must first travel through a spoilboard; then through a plenum in the table; then through different valves and plumbing fittings and finally through a pipe or tube to the pump itself. Let’s take a look at each of these elements separately.

The spoilboard is usually made of MDF. MDF is permeable and as such it lets air pass through its entire surface. However, different brands of MDF, and even different batches of the same brand, will let air pass through differently. Since MDF is made of sawdust and resin, using different proportions or using sawdust from different wood species will affect the permeability of the material.
When choosing your spoilboard material it is important to look for a type that has been tried and tested by other manufacturers or to experiment with different suppliers. In the process of making MDF, the top and bottom layers are polished by the press' hotplate and are more dense than the middle layer. It is important to fly cut both these surfaces down at least 50 thousandths of an inch to get to a more permeable layer.

A proper spoilboard will allow a great quantity of air through with little pressure loss. However, good air flow will not necessarily translate into good hold-down power. In fact, you are looking for a balance between air flow and pressure in order to give the best hold-down force. This can be achieved by using a second sheet of MDF on top of the first one, which we will call the sacrificial sheet. This panel can be machined from a $\frac{3}{8}$" or $\frac{1}{2}$" sheet and will bear the brunt of the cutting. The sacrificial sheet will serve two purposes, the first being to restrict the airflow just enough to concentrate the vacuum onto the pieces of wood to be held down and the second to make it less expensive to change after multiple cuttings.

Another very important aspect to consider is that the spoilboard come into contact with the table plenum without incurring leakage along the edges. The table usually has a gasket along the edge where the spoilboard will lay but it is often very useful to add to this gasket by taping the edges of the MDF directly to the table base. This can serve another very useful purpose – to seal the edges of the spoilboard. Air will pass through the path of least resistance and if the whole surface of the table is covered by the material we want to cut, then air will try to leak through the edge of the spoilboard or through any route it can find. This is why I also recommend sealing the edges of the spoilboard with a good lacquer sealer or edgeband tape (shellac works very well also).

The plenum of the table serves a very important purpose – to distribute the air evenly from the plumbing to the surface of the table. Some CNC machines come with a plenum machined out of a sheet of plastic or aluminum. If you measure the diameter of the intake pipe at the vacuum pump and determine its surface, it is very important to understand that this surface cannot be smaller anywhere down the line as a narrower diameter will restrict the air passage. Quite often the plenum is not deep enough; the circumference of the inlet times the depth of the plenum is smaller than the surface of the pipe. In this case, purchasing a bigger pump will do very little to solve hold-down problems since no more air can pass through than that which already does.

Another source of air restriction happens in the plumbing under the table. Sometimes valves are smaller than the pipes they serve and occasionally sharp-angled fittings will offer resistance to the air. Another source of resistance in the plumbing is the length of the pipes; the longer a pipe is and the more turns it makes, the more resistance it offers to the air. I often find that the vacuum pump has been installed not too far away from the CNC table but they are joined by a coil of flexible piping. It is recommended to keep the piping length as short and as straight as possible. This will give the best performance.

After studying a number of vacuum systems on nested CNC routers, FPInnovations developed a series of tests that measure the performance of a vacuum system at the table, where it counts. By doing a vacuum audit on your nested CNC machine, FPInnovations can guide you in improving the vacuum performance of your nested router.
The Vacuum Audit

The cost of vacuum operation

- This part of the audit is derived from three separate figures: the cost of electricity, the cost of spare parts and consumables and the cost of maintenance of the vacuum system
- Electrical = (Cost per kWh) x (0.746) x (HP) x (annual hours of operation)
- Consumables = Cost of parts per year
- Maintenance = (Estimated cost per hour of maintenance) x (hours per year of maintenance)
- The cost per kWh used is the local rate for commercial and small industrial

Vacuum distribution efficiency

- The vacuum distribution efficiency is measured in pressure loss in the distribution network
- The goal is to reduce the pressure loss which will reduce the required vacuum output required.
- Delta P = (pressure at the pump) - (pressure at the table)
- The vacuum distribution efficiency is measured in two situations; when the table is open and free from parts and also when the table is loaded with the equivalent of a full 4’x8’ sheet of melamine

Air flow and pressure

- This part of the audit is designed to measure the quantity of air that flows through the surface of the table as well as the force of vacuum present on the surface
- Five measurements are taken for air flow and five for pressure at the four corners of the table and at the center
- A large difference in airflow or pressure between these five points indicates an inconsistency in the porosity of the spoilboard material or a design flaw in the distribution of the air through the plenum
- The best performance is achieved when a balance of both air flow and vacuum pressure is reached

Hold-down force

- The hold-down force is measured by the amount of force required to detach a 1 square foot sample of melamine from the surface of the table
- The hold-down force is measured both in a vertical and in a horizontal plane
- The higher the force measured, the better the suction performance of the vacuum system

Leak detection

- An ultrasonic leak detection device is used to determine if there are any leaks in the vacuum plumbing. This device can detect microscopic leaks that would be difficult to find otherwise

Stack mounted rotary claw vacuum pump from Busch.
After conducting these tests, recommendations can be made to improve the performance of the vacuum system. The audit also allows comparison of results to the industry average.

For more information on improving your vacuum hold-down performance, please contact:

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FPInnovations has a network of Industry Advisors available across Canada that can help to implement this information in your business. For more information on this topic, and how the results can be applied in your business, contact your nearest FPInnovations Industry Advisor:

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