



TOP QUESTIONS TO ASK ABOUT A CNC DENTAL MILLING MACHINE

Today there is a wide variety of CNC dental machining centers available to suite a variety of needs and choosing the right one for you can seem to be a daunting task. Knowing the construction characteristics of these machine tools and how they affect operation, reliability, quality of output and cost of ownership can aid greatly in making an educated decision when choosing the most effective one for a given application.

1. SPINDLE DRIVE

Generally, the spindle is considered the heart of the Dental Machining Center (DMC). The spindle holds the tool and performs the material-cutting operations. The spindle must have low, consistent runout, stiffness, rolling torque, low heat generation, and thermal stability.

Electric motors carry both continuous and short-term duty ratings. Machining forces, such as applying a cutting tool to a workpiece, put a load on the motor and the greater this cutting force, the more motor output is required to maintain RPM. As the motor output increases, so does the motor temperature, Machining processes have to be designed so required power/torque at a speed is less than the available power/torque. When the process exceeds the available power and torque, it overheats the motor -eventually burning it out. Yes burning it OUT! Obviously not a good thing as it results in a significant expense and loss of production.

Additionally, a spindle although rated for a power, rpm and torque specification may not operate at the maximum rating as the spindle driver/controller as set by the machine builder determines these important limits.

What is the MAXIMUM power rating of the spindle?

What is the MAXIMUM torque rating of the spindle?

What is the CONTINUOUS DUTY (S1) power rating of the spindle?

What is the CONTINUOUS DUTY (S1) torque rating of the spindle?

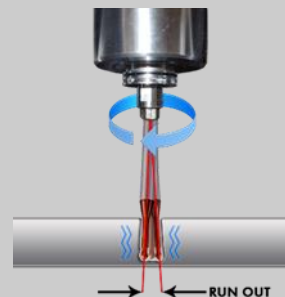
What is the spindle make and model number?

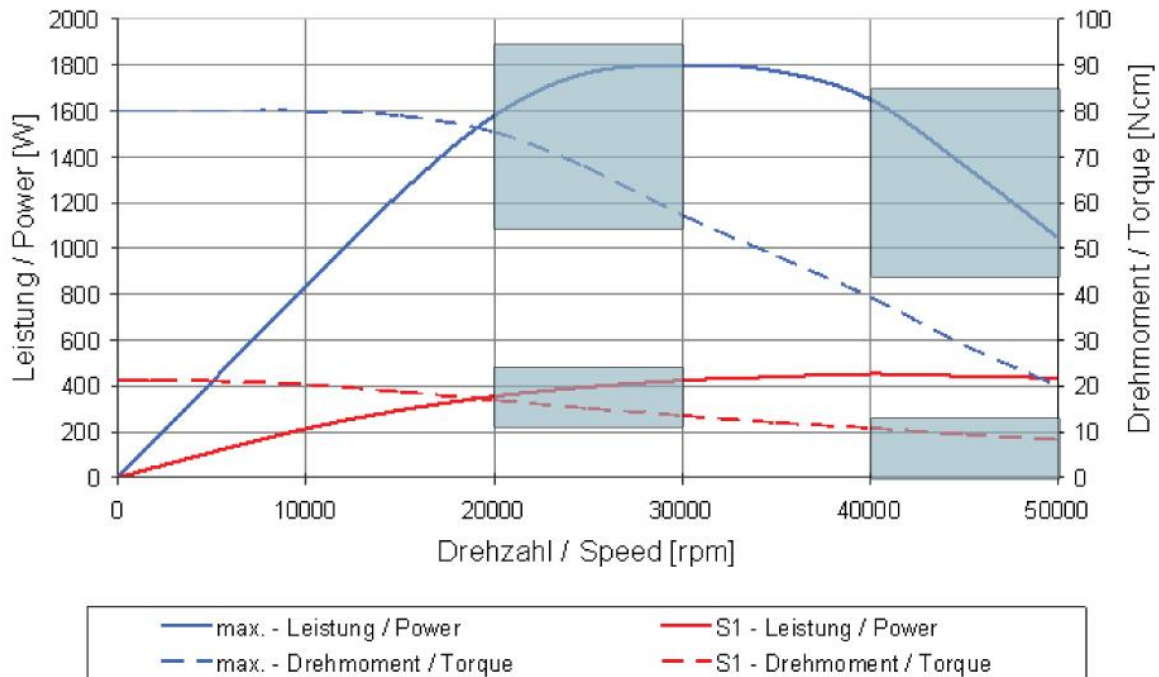
What are the operating parameters for torque and rpm as set for THIS machine?

What is the spindle warranty and what is the average spindle life for your customers?

Can I obtain the specification/performance graph of the spindle rpm, torque, power performance curves?

What is the spindle run-out for this machine?





2. TOOLING

Tooling plays an important part in determining operational costs and final restoration quality. Small diameter shank sizes are not as strong, proprietary shank configurations limit selection and affect costs.

What shank diameter tools does the machine utilize?

Does the tool shank require special grinds or collars?

Are the tools proprietary or can off-the-shelf tools be used?

What tools are used in your templates and what are their types, costs and life-cycles?

3. CONSTRUCTION

The highest quality DMCs utilize castings because of their superior overall strength, vibration damping characteristics and low cost. Castings should have uniformly thick walls because variation in wall thickness can cause cooling and distortion problems. Thin sections can become brittle and cause distortion when under stress.

Some DMCs utilize weldments, which are usually made of steel. In small quantities, weldments cost less than castings and are stiffer and stronger when compared to castings of the same size and weight.



Aluminum frames, while offering strength and rigidity provide less vibration dampening than cast machine frames.

However, generally speaking, weldments are stiffer than castings and have less damping characteristics. So, they perform well at low speeds, but at high speeds weldments are more susceptible to vibration and chatter that can cause rough surface finishes, chipped margins and diminished cutting tool-life.

Newer materials that are lighter, such as composites, aluminum and titanium, are also used in machine tool construction. These materials can provide significant advantages in the newer higher performance machines. For example, reduced mass makes acceleration and deceleration easier. The use of composite type materials has increased because of high strength-and-stiffness to weight ratios as well as thermal stability.

Is there an actual machine frame?

What type of frame is used in the machine construction?

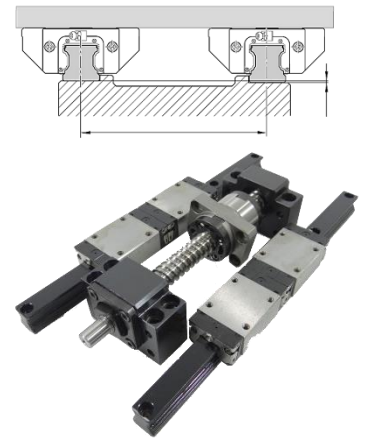
What is the weight of the machine?

****The weight of the machine (in large part determined by its frame) plays an important part in reducing vibration, the ultimate quality of the restoration and tool-life.***

4. WAY SYSTEM

The machine tool way system includes the load-bearing components that support the spindle and table, as well as guide their movement. Box ways and linear guides are the two primary types of way systems. Each system has its positive and negative characteristics. Unfortunately, one type of way system is not appropriate for all applications. So, when you're in the market for a machine tool, you must match the way system to your specific application.

The vast majority of high-quality DMC's utilize linear guides which provides fast positioning and smooth motion with light-weight dental materials- at a comparatively low price point when compared to box ways.



Dual linear guide system with ball screw



Rear view of the Versamill 4X-100 showing cast aluminum-alloy castings linear guide ways

Not all liner guide systems are created equal.

It is important that a DMC's guide system be of adequate size to support short-travel, friction-free positioning of the machine, fixture and part components being transported. In the case of axis drives, dual guides are mandatory. Further the system should use contained lubrication that does not require on-going application of lubricating grease that is subject to contamination do to exposure to the elements. Additionally, quality DMC's liner guide systems contain a pre-load block for greater consistency and increased accuracy.

What way system does the machine utilize?

If linear guides, single or dual system?
Are pre-loaded blocks utilized?

Are the tools proprietary or can off-the-shelf tools be used?

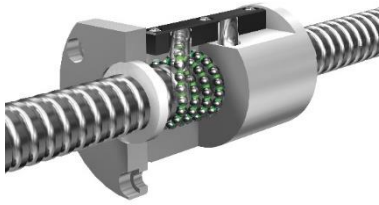
What tools are used in your templates and what are their types, costs and life-cycles?

Is the system sealed or does it require lubrication? If yes at what intervals?

5. AXIS TRAVERSE

The method of traverse can be through rack-and-pinion, lead screw, ball screw or the least preferred, cable and pulley system. Quality DMC's utilize ball screws.

A ball screw is a mechanical linear actuator that translates rotational motion to linear motion with little friction. A threaded shaft provides a helical raceway for ball bearings which act as a precision screw. As well as being able to apply or withstand high thrust loads, they can do so with minimum internal friction.



They are made to close tolerances and are therefore suitable for use in situations in which high precision is necessary. The ball assembly acts as the nut while the threaded shaft is the screw. Low friction in ball screws yields high mechanical efficiency compared to alternatives. Lack of sliding friction between the nut and screw lends itself to extended lifespan of the screw assembly (especially in no-backlash systems), reducing downtime for maintenance and parts replacement, while also decreasing demand for lubrication.

One phenomena that occurs with any screw and nut base system is backlash. Backlash is any non-movement that occurs during axis reversals. The problem with backlash is that it can impose positioning error in a positioning system.

In cases where the amount of backlash is known and it is always known which side of the screw thread is contacting the nut thread, it is possible to simply subtract out the backlash where appropriate. This is the essence of software backlash compensation, which is offered by some of the computer software available to drive Computer Numerical Control (CNC) machines.

Most backlash reduction schemes employed by quality DMC's involve mechanical pre-loading of the nut for movement in both directions. In the examples above when the screw was actually driving the nut and carriage, the screw was driving the load of the carriage assembly. If it starts turning the other way it is unloaded until the backlash is taken up, at which point it begins driving the load of the carriage assembly the other way. Preloading, that is, imposing a load on both sides of the screw thread simultaneously even while it is not moving means there is never backlash that needs to be taken up

What axis travers method does the machine utilize?

Ballscrews are essential. What is the screw diameter and what method does the machine use to compensate for backlash (ball nut, software, etc.)?

Is the system sealed or does it require lubrication? If yes at what intervals?

6. MOTOR CONTROL SYSTEMS

CNC systems require motor drives to control both the position and the velocity of the machine axes. Each axis must be driven separately and follow the command signal generated by the CNC control. There are two ways to activate the servo drives: utilizing an open-loop system or a closed-loop system.

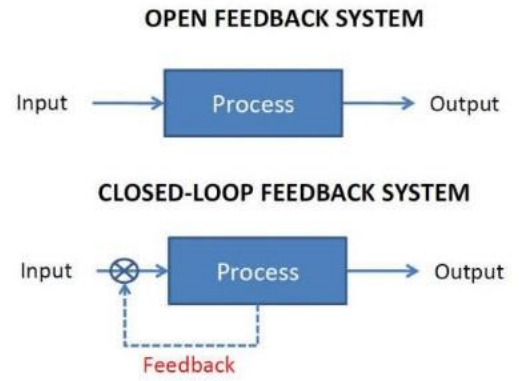
Open Loop: Programmed instructions are fed into the machine controller through an input device. These instructions are then converted to electrical pulses (signals) by the controller and sent to a servo amplifier to energize the servo motors. The cumulative number of electrical pulses determines the distance each servo drive will move, and the pulse frequency determines the velocity.

The primary drawback of the open-loop system is that there is no feedback system to check whether the program position and velocity has been achieved. If the system performance is affected by load, temperature, humidity, or lubrication then the actual output could deviate from the desired output.

Closed Loop: The closed-loop system has a feedback subsystem to monitor the actual output and correct any discrepancy from the programmed input. The feedback system could be either analog (resolvers) or digital (linear scales). The analog systems measure the variation of physical variables such as position and velocity in terms of voltage levels. Digital systems monitor output variations by means of electrical pulses.

Closed-loop systems are very powerful and accurate because they are capable of monitoring operating conditions through feedback subsystems and automatically compensating for any variations in real-time.

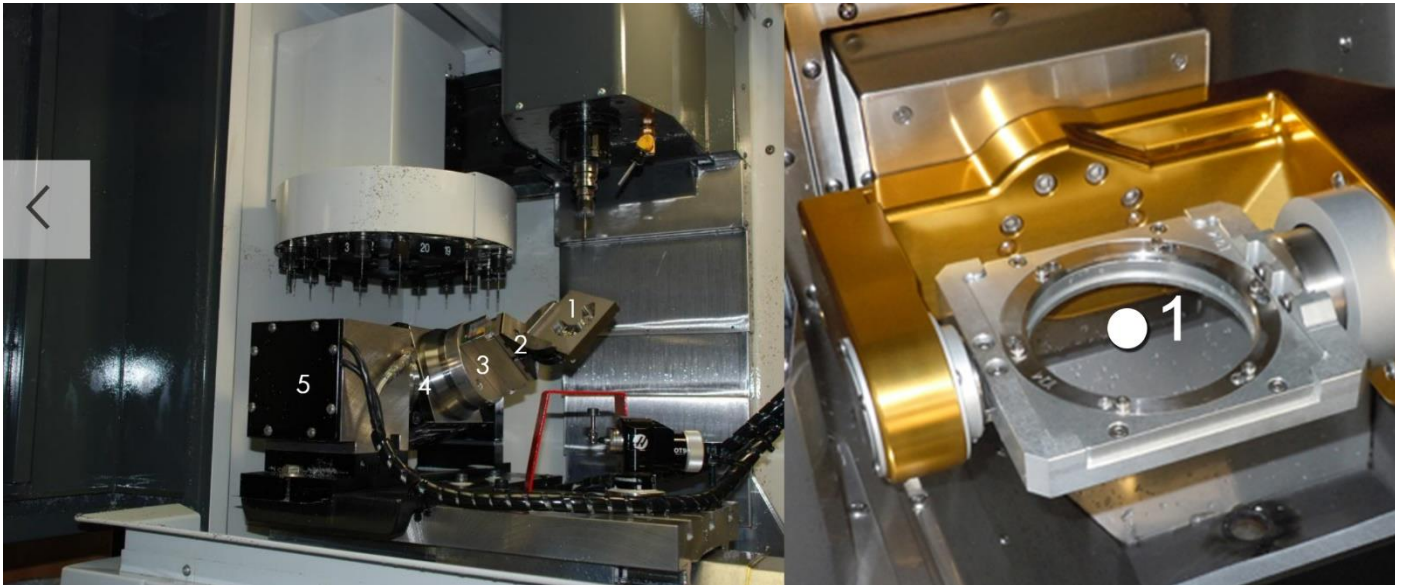
Most modern closed-loop CNC systems are able to provide very close resolution of 0.0001 of an inch. Closed-loop systems require more control devices and circuitry in order for them to implement both position and velocity control. This makes them more complex and more expensive than the open-loop system.



What type of motors does the machine utilize - servo or stepper? Is it an open-loop or closed-loop system?

What are the machine specifications for: accuracy, repeatability and drive resolution?

7. ROTARY AXIS



Compare the superior zero stack tolerance configuration on the right with aligned rotational centers with the highly inaccurate fixturing on the left with off-center masses of significant weight and extensive stacking. All of which results in poor performance, inaccuracies, repeatability problems, wear and maintenance.

When dealing with 5-axis machining, it is important that we remember there are actually two separate rotary axes - that are essentially stacked upon one another - and given the fact that each individual axis is

allowed some positional tolerance, this can also affect overall accuracy of the workpiece, and must be considered.

It is important to note that these tolerance specifications are measured from the center of rotation for a particular axis. This means that the farther away from the point of rotation, the more measurable an angular mis-position will be magnified – and, therefore, the less accurate the positioning of a particular feature on a part might be. Keeping the fixture height as short as possible, therefore keeping the part as close to the point of rotation as possible, can make a huge difference in the overall success of a setup

Simultaneous vs 3+2 5-axis Control

In simultaneous 5-axis machining, the machine tool's three linear axes (X, Y and Z) and two rotational axes (A and B) all engage at the same time to perform complex contour surface machining. There are many advantages of full 5-axis machining, all of which significantly impact productivity and profitability.

With 3 + 2 machining the machine executes a 3-axis milling program with the cutting tool locked in a tilted position using its two rotational axes. The process, also known as 5-axis positional machining, relies on the fourth and fifth axes to orient the cutting tool in a fixed position rather than manipulate it continuously during the machining process.

Is the machine (and supporting templates) configured for simultaneous 5-axis motion or merely 3+2 machining applications?

What are the PRACTICAL rotational limits (that which take fixturing/tooling into consideration to avoid collisions) of each rotary axis?

What is the speed of the rotational axis? This speed is then determining factor is establishing then maximum overall machining rates.)

What tools are used in your templates and what are their types, costs and life-cycles?

8. FIXTURING

The quality and the performance of the mass production cycle is influenced by jigs and fixtures as they responsible for the placing and holding of a component.

Good jigs and fixtures provide dental manufacturing professionals the following:

- A higher degree of positioning precision and the repeatability thereof.
- A greater accuracy for the positioning of precise hole centers.
- Tighter tolerances at micron levels with higher-quality surface finishes.
- A faster time frame to achieve these tolerances.
- Increased cutting tool life.



Versamill 5X-200 Universal Fixture offering complete stability and versatility. Notice fully-supported fixture held on both ends with precision cartridge inserts to enable quick change-over to different rough stock forms

Is the machining fixture fully supported on both ends? What is the process to change fixtures?

What is the repeatability of the machining fixture? From what material is the fixture made?

What is the life expectancy of the fixture and associated replacement cost?

9. MARGIN REINFORCEMENT

The margin is the area most prone to damage during the milling process. To preserve the integrity of the margin, additional thickness is added to the margin in software to strengthen it during milling and provide additional stock in anticipation of violation during the milling process.

While the margin reinforcement feature (which can be as much as 200 μ m in inferior systems) is helpful during milling, it must be manually removed afterward as part of the margin-finishing process. The primary reasons for these violations and requirement for margin reinforcement include:

- Machine rigidity.
- Machine spindle performance including; internal structural quality, excessive cutting tool run-out, tool deformation etc.)
- Fixture rigidity including lack of quality machine rotary axis gear reducers.
- Lack of available robust machine strategies or poor output generated from within the CAM software.
- Improper toolpath "processing" from within automated CAM software templates.
- Combination of all the above.



Excess margin reinforcement show in the pink highlighted area.

How much margin reinforcement is built into your machining templates for the materials & indications supported by your solution?

10. OTHER CONSIDERATIONS

Aside from the CAM software utilized and the vendor you choose to purchase a DMC from (both of which play a more than a significant role in supporting you in operating and maintaining your investment in digital dental technology) some other considerations include:

Open Source: Your choice of a DMC should always be an Open Source machine. It should be supported by a wide variety of CAM software including that which is currently utilized or likely to be utilized in the future. Additionally, a discussion over post-processor availability and or development assistance in creating a post-processor for a given DMC/CAM software should take place immediately upon investigating the effectiveness of any given DMC.

Machine Control: The machine control is of utmost importance. It is the Operating System or the brain of the machine and its performance is critical. A control with maximum block processing rate will ensure that the received data will be handled quickly and efficiently. This data should reside on a hard-drive located on the control. Incorporating numerical algorithm to calculate the velocity profile in the control will assist in smoothing machine motion.

In today's high-speed, high-efficiency machining environment it must meet many requirements, including:

- Open Systems Architecture
- Open to integration/automation at the user level
- Have extremely fast block execution times
- Look ahead feedrate control over more than 100 blocks
- Transformations, e.g. for clamping corrections or 5-axis transformation
- Elimination of contour error in the axes to provide greater path accuracy
- Torque damping along the feed path and in an axial direction to reduce machine wear
- Tool correction (length, radius, various types of cutter)
- Compensation for mechanically induced errors

KNOWLEDGE IS POWER

The cost of owning a Dental Machining Center is not determined by its initial selling price alone. A high quality DMC will save its owner far more money during its useful life in the reduction of; tooling costs, re-worked restorations, hand work, parts replacement and down-time than any up-front cost savings at time of purchase. Selecting the right DMC is not as difficult as you may think...you just need to know what to look for.

Following the guidelines presented here will help you make more informed decisions about which machine best fits your needs and the value one machine may have over another.

You will soon realize why there is a significant difference in price between various DMC's under consideration. Much of the criteria here is not published on manufacturer's website, their promotional material or product brochures. It is up to the consumer to ask the pertinent questions for which a vendor may not know the answer to, does not want to necessarily share the answer or knows how their machine compares in the critical areas presented here; but don't be afraid to ask.

Versamill 5X-200

Open Source, Quality Construction, High Reliability

