Minimizing motor vibration for hand-held dentistry tools

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Vibration is the enemy of a hand-held dentistry tool. To maximize the precision of a dental procedure, as well as optimize the comfort of the patient, the device must minimize any physical pulsation or resonance. The motor is the primary source of vibration, so careful attention must be paid to its design, including the ability to withstand the demanding environment of the autoclave, which is used for sterilization.

Milind Shinde, Design & Development Manager at Portescap, talks over the key motor design considerations.

Today, electrically powered hand-held tools are essential for a variety of procedures in modern dentistry, from crown and veneer preparation, through to operative dentistry. Compared to their pneumatically powered predecessors, electric hand-held dentistry tools achieve an improved outcome for the patient, where their constant torque and speed output enhance precision and reliability. These characteristics also improve comfort for the patient, while for the dental surgeon, they make electrical tools easier to use for longer periods of time.

Fundamental to an electrically powered hand-held dental tool is the motor that drives it. Miniature brushless DC (BLDC) motors are preferred thanks to the advantages in precision control they offer compared to traditional brush DC designs. Providing higher torque enables a more compact footprint, and a lower mass design, enhancing handling and operation for long durations by the dentist. Similarly, BLDC motors are more efficient, which is particularly important for cordless tools, as this enables a smaller, lighter battery pack.

The challenge of the autoclave

For long life and reduced maintenance, the brushless design also reduces mechanical wear. Even though the BLDC design aids durability, and a sealed casing withstands the liquids and debris inherent to a surgical procedure, the most significant challenge to motor health is typically found during the autoclave cycle. As the standard method of sterilization between dental procedures, autoclaving removes bacteria, viruses, and other pathogens, with the process exposing the instruments to high temperature and pressure steam. Typically, this involves a 20-minute cycle exposing the equipment to steam up to 135°C with pressure ranging from 0.5 bar vacuum to 2 bar.

While autoclaving can impact the electrical integrity of the BLDC motor if it's not sufficiently protected, repeated autoclaving can gradually lead to the degradation of motor component materials. This can result in unwanted movement, giving rise to vibration, as well as noise. Most significantly, increased vibration will impair control precision, reducing the quality of the dental procedure. As well as reducing comfort for the patient, increased vibration and noise will also heighten the physical and mental duress for the dentist, especially over repeated, long-term exposure.

Vibration controls

For these reasons, the latest BLDC motor designs for hand-held dental tools typically integrate a variety of measures to minimize inherent vibration, as well as protecting against vibration developing from repeated autoclave cycles. The most common design consideration relates to fine rotor balancing, not least because the rotor, if not properly balanced, is the component most likely to cause vibration. Most of the unbalanced mass typically stems from the magnet, and to address this, separate balancing rings can be added to the shaft. With incremental adjustment using advanced balancing machines, rotor imbalance can be virtually removed.

Another common source of vibration, exacerbated by autoclaving, is movement of the magnets. Magnets are usually affixed to the shaft using a gluing process, and for sufficient gluing strength, there must be a minimum clearance between the shaft and the magnet’s inner diameter. Autoclaving can affect the glue adhesion, potentially resulting in movement of the magnet. In this case, a slight positional change, leading to an offset location to the motor axis, can cause vibration. To mitigate this issue, motor designers can use a stepped shaft design to align and guide the magnet's inner diameter, providing a more uniform surface for glue distribution.

Degradation over time

Another component, the ball bearings, inherently possess radial play, which can significantly influence motor vibrations. This can be mitigated by applying specific preloading, which reduces radial free-play and brings added benefits such as noise reduction and increased longevity. While motor designers should incorporate methods to maintain preloading integrity post-autoclave cycles, they must pay close attention to lubrication.

Ball bearing grease often evaporates or loses its properties when exposed to the high temperatures and pressures of steam. When the grease diminishes, the bearings will experience heightened noise and friction, adversely affecting the smooth and quiet operation of dental hand tools. Designers must take special care in choosing the right lubrication, taking guidance from the manufacturer to ensure optimal performance during a targeted number of autoclave cycles.

Corrosion is another clear challenge of the autoclave process, and magnets can rust when exposed to steam due to their material composition. Rusting may cause small particles to chip off the magnet surface, and this degradation can cause rotor imbalance, which in turn increases vibrations. The choice of materials at the outset is an important consideration, and designers can also employ various types of plating or coating. Metallic sleeves can also be fitted to enclose the magnet and protect it from steam exposure.

As dental hand tools often require high speed motor operation, naturally generating increased vibration, damping components such as rubber O-rings, or washers to improve bearing support, are often utilized. Rubber-based materials are commonly used, yet under repeated autoclave procedures, they can deform and reduce damping effectiveness. As a result, synthetic materials like silicon and fluorocarbon rubbers are preferred for dental tool applications, maintaining their properties even when exposed to high steam temperatures and pressures.

Motor specification is vital

As the primary source of vibration, the motor's characteristics significantly impact the performance of a hand-held dental tool. This means that in motor specification, the careful evaluation of operational characteristics is fundamental to motor design and material selection. Environmental conditions will also play a key role, especially considering the use of the autoclave. As a result, a BLDC motor that can withstand the required number of cycles, yet remain vibration free, is imperative to a high-performance dental hand tool.

The most reliable path to specifying the right BLDC motor design for the dental tool’s requirements is to partner with an experienced motor engineering team. Not only will this approach enhance performance long term, for patients and tool users alike, but it can also achieve a faster, easier development process, reducing the timescale for design and testing.

Image captions:

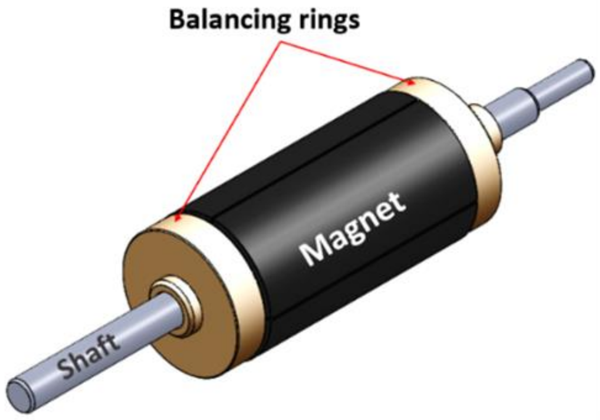

Image 1: Balancing rings can be added to the shaft to stabilise the motor.

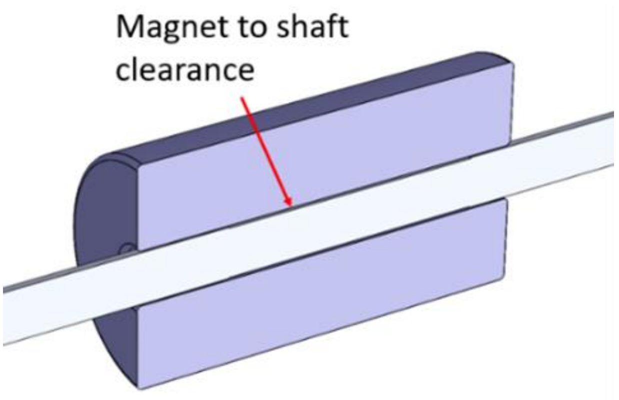

Image 2: For sufficient gluing strength, a minimum clearance between the shaft and the magnet's is required.

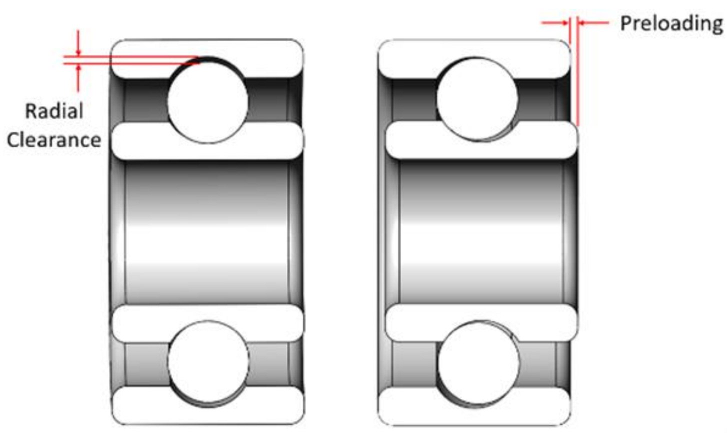

Image 3: Bearing vibration can be mitigated by applying specific preloading.

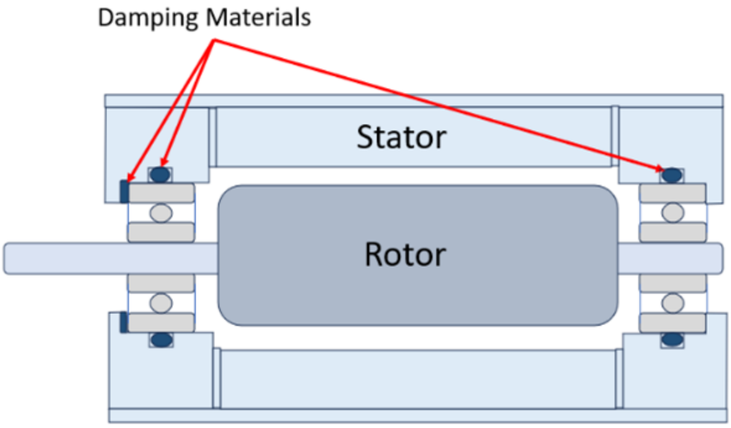

Image 4: Dampers to improve bearing support are often utilized to minimise vibration.

Image 5: Premium quality dental hand tools are driven by low vibration motors.

About Portescap

Portescap offers the broadest miniature and specialty motor products in the industry, encompassing coreless brush DC, brushless DC, stepper can stack, gearheads, digital linear actuators, and disc magnet technologies. Portescap products have been serving diverse motion control needs in wide spectrum of medical and industrial applications, lifescience, instrumentation, automation, aerospace and commercial applications, for more than 70 years.

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