Swiss Machining: The Gold Standard Advances

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Lean and Green Machining

Strong Backbone Meets Success
Using Green Technology to Machine Materials

Generating a feature in standard alloys can be challenging. Design criteria mandate smaller products, more-defined features, and thinner material sections. In some cases, feature size is smaller than the residual burrs created when attempting to complete them using most conventional manufacturing methods. Add to the equation a demand for a fine feature required in a superalloy or memory material, and the challenges grow exponentially.

Properties such as improved strength-to-weight ratios enable materials to have increased wear resistance but remain light for biomedical implantation. However, such alloys are difficult to conventionally machine or grind. Through friction, the manufacturing process produces unacceptable heat or mechanical stress. Exotic shape-memory alloys hold much promise for a growing number of medical applications but also present significant manufacturing challenges for many of the same reasons.

Molecular Decomposition Process

The molecular decomposition process (MDP) negates these obstacles and enables the production of relatively simple geometric configurations for both medical implants and instruments. More importantly, MDP produces no thermals or mechanical stresses to the material being manufactured. The results are superior surface finishes and repeatable dimensional results that yield a burr-free component without influencing the elemental profile of the materials. The benefits of MDP enable a manufacturer to make a product with fewer steps.

Research and development to applied MDP projects has been proven to eliminate the need for a secondary deburring or polishing operation. This preserves the integrity of the feature by not violating the specified geometry. For material removal with the applied MDP technology, finer grit sizes for the abrasive can be used to roughen and finish a product. A finer grit enables crisp geometry as related to the abrasive size of a proprietary formulated grinding wheel.

MDP was developed for removing or cutting material using an electrochemical action with an abrasive assist. The process uses an abrasive wheel combined with a steady supply of electrolyte solution and electric current. As current flows through the electrolyte between the positively charged workpiece and the negatively charged abrasive wheel, the material oxidizes at the point.
of contact, causing a decomposing action known as anodic dissolution. As the process repeats, the oxidized surface is then wiped away by the grinding wheel.

Throughout its history, anodic dissolution machining has been used extensively to machine electrically conductive materials such as titanium, stainless steel, and other high-performance alloys, but repeatability was heavily dependent on operator expertise. Typically, the operator set all key parameters, including electrical current and feed rate, adjusting them as the cut progressed. Adjustments were usually based on visual inspection of the interface area, because the color and amount of sparking would indicate the reaction of the material to the removal rate and depth of cut.

MDP adds new levels of control that allow for greater dimensional accuracy, surface finish, and repeatability. Stringent sphericity and surface finish specifications with tolerances in the submicron level have been consistently achieved. The power supply is closely controlled with proprietary algorithms that maintain consistent power to the system, eliminating power spikes or brownouts. The lower levels of power required to operate the system make it more energy efficient. New developments in electrolytic solution further optimize current flow. Research in grinding wheel composition has helped to develop formulations that maximize conductivity for the material being shaped. Such formulations enable the removal of stock with only 10% of the abrasiveness created in conventional grinding, resulting in extended wheel life. Because the process produces no thermals, mechanical stresses, or burrs, MDP increases material choices for medical product designers while satisfying demands for precision and efficiency.

**Medical Applications**

MDP is an appropriate method for making profiles as sharp as possible without burrs. Traditionally, ability and kink resistance and these distinctive characteristics make nitinol an appropriate choice for medical guidewires.

Other examples of superelastic devices include vascular, esophageal, and biliary stents; medical guide pins; surgical localization hooks; flexible, steerable, and hingeless laparoscopic surgical instruments; remote suturing and stapling devices; and bone suture anchors.

Because heat is a factor in causing the alloy to exhibit its memory characteristics and return to its original shape, conventional friction-based manufacturing processes such as milling, turning, grinding, and honing can cause adverse effects, effectively giving nitinol amnesia. Fine feature generation into an alloy that has extraordinary flexibility and torque ability would be equally difficult since the material would deflect (plastic deformation) during the attempted cutting or grinding process. Plastic deformation of memory alloys during conventional machining
can assist in breaking tool inserts or causing work material to bulge at the deformed zone. These negative effects are a direct result of the desirable characteristics of shape-memory alloys such as nitinol. Should the material yield to being cut or ground, burr removal from these operations becomes a larger task than generating the required features.

MDP is suitable for grinding memory alloys because the process introduces no heat or mechanical stress to the work piece. One patent-pending process has yielded threaded nitinol wire (0.04 in. diam.) with a thread pitch of 101 threads per inch. MDP enables the threads to be produced in a single cut at full depth, producing outcomes, separate lab experiments are fully recorded in which process parameters are developed inclusive of the necessary perishables required for the production of such fine details.

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Burr-free threads without any rearing or smearing of the nitinol material. The gentle process allows for the production of these fine features measuring 0.0035 x 0.003 in. deep. Examining the elemental profile of the material surface illustrated no changes to the chemistry of the product.

Titanium Carbide. Titanium carbide is another specially formulated alloy that presents unique manufacturing challenges. Titanium is light, strong, and easily machined, making it ideal for the medical industry. Carbide, introduced to extend implant life, requires grinding methods to control size and surface finish.

Conventional grinding, however, can introduce a smearing action at the work surface. This not only makes achieving the best possible surface finish difficult, but it also transfers titanium particulate to the diamond wheel face.

In conventional grinding tests on a titanium carbide component using a 600-grit diamond wheel, grooving and smearing of material occurred at the work surface due to the abrasives within the conventional grinding wheel. In comparison, MDP produced a uniform surface with a similar 600-grit wheel due to the MDP depleting and wiping process without any material deformation.

The ease of equipment operation, tied to the mathematical algorithms, adds to the repeatability and dependability of MDP technology. From the early stages of development to current details regarding inputs and outputs, separate lab experiments are fully recorded in which process parameters are developed inclusive of the necessary perishables required for the production of such fine details.

Keeping It Green
A major contributor to the stability of the entire closed-loop system is the electrolyte management system. It keeps the electrolyte consistent during production for months at a time. Readily available systems typically do not provide the benefits of months after production. In fact, the industry standard for electrolyte management enables a 40-hour production level and yields undesirable by-products such as heavy metals (hexavalent chrome). This drawback was a driving factor for the design review and collaborative efforts to generate a unique system that, unlike others in the marketplace, does not have heavy metals as a by-product. Through the design and implementation of this system, some of the main focal points included protecting the operator and environment by managing waste in an easily controlled system where the resultant waste material, produced during the stock removal process, could easily be removed and recycled.

Additional focus includes the control of conductivity within the electrolyte, fluid levels, and delivery to the interface area of product and equipment. The electrolyte formulations that are used mainly consist of simple salts and deionized water. A complete MDP system uses this...
electrolyte management system interfaced with the system controller to maintain electrolyte levels, conductivity, and cleanliness. The design allows for ease of operation, as well as extended electrolyte life to six months of manufacturing (compared with the industry standard of 40 hours) without the generation of heavy metals. These advances make the process safer for the environment while enabling small, very accurate feature production during the anodic dissolution process.

**Achieving Finer Features**
Generating and maintaining fine features during stock removal is a common challenge for manufacturers in general. Unique formulations are required to enable the material to be removed while attempting to gain as much tool life as possible. These problems grow exponentially when applied to shape-memory alloys. The advantages that these alloys present become the negatives in material removal, especially in the areas of fine features, as illustrated in the thread grinding of nitinol. Applying MDP technology to this part production enables the product to be manufactured with many benefits associated to the mechanical and elemental conditions of the subjected material (in this case nitinol). Extending or maintaining fine features during stock removal is still a focus point, because as with any manufacturing system, the longer the tool life, the more products are produced with less review of the system in general. This extends capability by requiring fewer tool changes, or dresses of the tool, during the required production.

The ability to address tooling life by an applied system such as MDP has yielded some exciting results. For example, to be able to remove 0.005 in. of stock from full hard stainless steel in a single pass, with a 600-grit grinding wheel, is something that would never be considered due to the increased thermals and slow cutting rates to the applied workpiece. However, with the ability to choose abrasive types and formulate a wheel to work in tandem with the MDP technology, manufacturers are able achieve this type of unheard of capability, while maintaining size, surface finish, and burr condition.

To achieve these benefits, a company can employ direct interaction to best define customer needs and, using their exclusive, proprietary formulations and manufacturing process, develop the necessary perishables. This interaction is a vital element to using MDP technology to its greatest capacity. Being able to refine the perishables according to a customer's exact requirements adds a new level of specificity and precision to manufacturing.

The custom wheel formulations generated by grinding wheels assist in the production of fine features and are the last ingredient to ensure the applied MDP process yields a consistent product. In addition, the detail of crisp geometry and burr-free condition, as produced by MDP technology with a new technology abrasive formulation, adds to the consistency of being able to produce a product without thermal or mechanical stresses while maintaining geometry and size.

**Conclusion**
New technologies such as MDP can help medical device manufacturers machine materials more efficiently. They eliminate the impediments of many promising new alloys for medical applications, both in implants and instruments. As a result, the future of promising new alloys achieving new standards of strength and endurance is very possible because of the innovative manufacturing techniques that shape and form them into products that improve the quality of life.

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