MEDICAL
DESIGN BRIEFS

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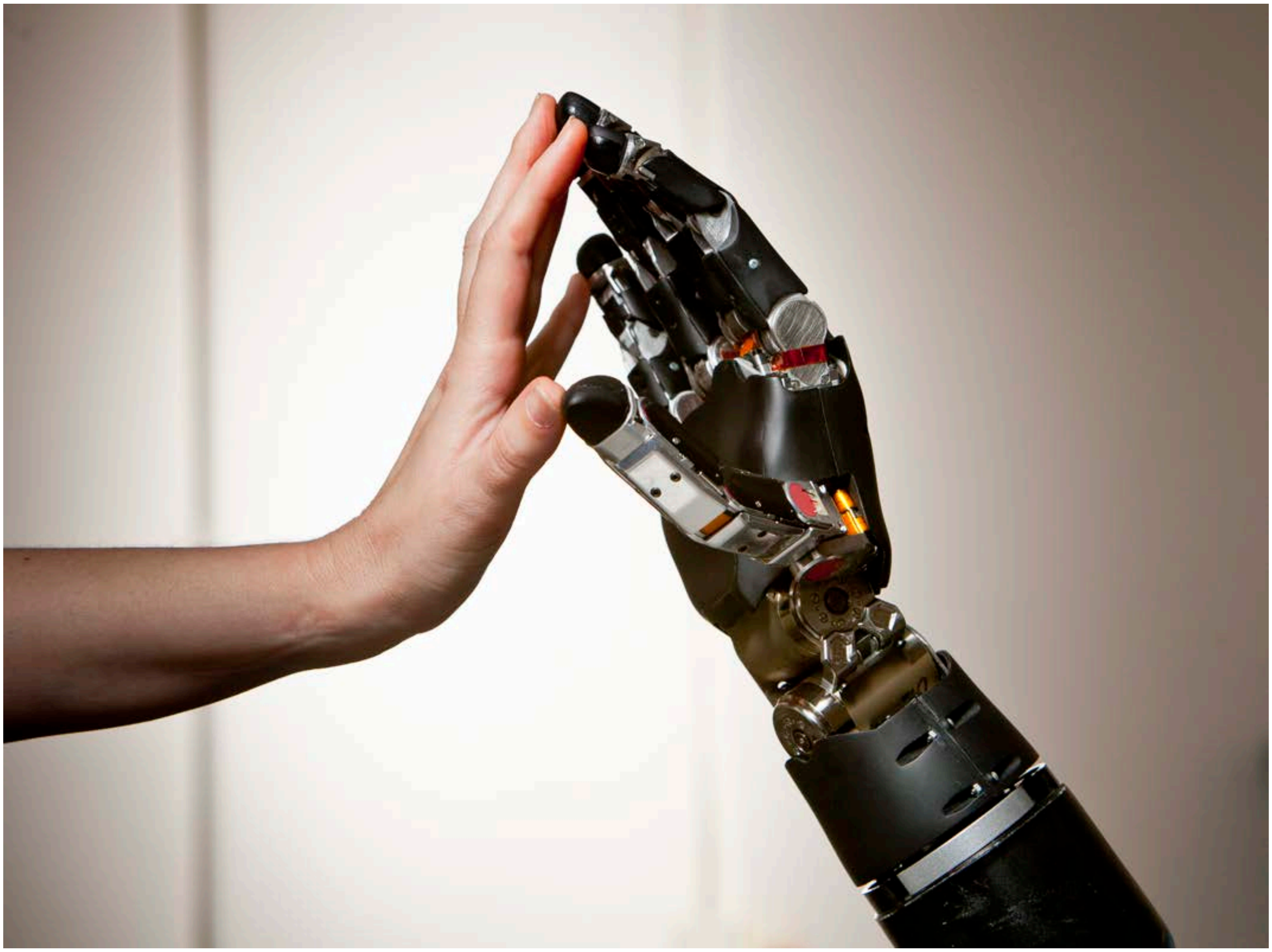

Functional prosthetic arm (courtesy of the John Hopkins University Applied Physics Laboratory)

Fig. 1 – Cranial mesh plate.

Accelerating Abrasives with the Greatest Precision to Produce Intricate Medical Components

The latest medical developments typically involve smaller, more precise structures. These can be implants, assemblies, or components and motors in robotic equipment. With the demand for smaller parts, the requirements for producing these parts have become more challenging.

We often think of medical components as implantable structures such as bone supports, or cranial and ocular mesh plates (see Figures 1 and 2). Feature tolerance and location are both important to the proper function of these structures.

The prosthetic limb of the future is one that can be controlled by the patient's nervous system. These limbs are functionally proper, and replicate the movements and capabilities of the limbs that they are replacing (see Figure 3). From the shoulder mechanism to the knuckle on each finger, these manipulating assemblies are designed to operate so that the slightest movement or amount of pressure desired is properly applied to the device.

There are also R&D and laboratory devices and components, such as the assay array shown in Figure 4 cut from Hiperco-50 used in optical microscopes. The critical geometry and spacing from anode to cathode in the array must be accurate and consistent.

One of the most recent surgical developments is the introduction of robot-assisted surgery. These human-to-computer-controlled machines are capable of performing procedures with much more precision and less trauma than previous open surgery techniques. It is essential that these robots are designed and built to extremely high tolerance specifications, from the drive motors and measuring system, to the mechanical gearing and manipulators that come in contact with the patient.

In addition to the increased demand for high-tolerance specifications and reduction in component size, new materials are being developed. Therefore, a method of manufacturing for new materials must also be developed. New superalloys, as well as metals and elastomers with memory and shape-changing characteristics, are becoming more common as developments advance in biocompatible materials. Many of these materials are heat-sensitive; they are "programmed" at a specific temperature to function properly. Inducing heat by means of thermal material removal, such as wire electrical discharge machining (EDM) or laser cutting, will negatively impact such materials, and in some cases, these manufacturing processes are not even a compatible option.

Some characteristics related to thermal cutting can include both a recast layer and an annealed layer below the recast surface. These characteristics often have to be eliminated by post-processing such as heat treating.

For thin films and foils, the parts often curl up during the thermal cutting process, resulting in deformed parts that are deemed unacceptable. Very often, thin materials are machined by means of photochemical etching. Multiple features are created simultaneously, and accuracy is sufficient for many applications. However, accumulative tolerance can be an issue if part-to-part consistency is critical. In addition, thicker materials may need to sacrifice dimensional tolerance because this process relies on a time-based chemical reaction.

High-precision small components and implants have traditionally been cut using wire EDM; however, there are undesirable characteristics due to the thermal process of EDM cutting. For materials that are nonconductive, wire EDM cutting is incompatible.

Abrasive Waterjet Micromachining

Advances in abrasive waterjet micromachining have been developed and continue to be developed in order to refine the process of machining by means of abrasive particle acceleration through a high-velocity water stream. Today, cut features as narrow as 200 µm to an accuracy of 10 µm are being

Fig. 2 – Ocular mesh plate.

Fig. 3 – Functional prosthetic arm. (Courtesy of the Johns Hopkins University Applied Physics Laboratory)

achieved globally with the use of micromanufacturing with abrasive waterjet technology.

Aside from abrasive waterjet micromachining being designated as a "cold" machining process, there is a significant processing speed difference when compared with wire EDM machining. Because wire EDM cutting has an advantage where thicker material is concerned, there is an opportunity to stack thinner materials in a fixture in order to process multiple layers of material in a single cut. In some cases, this serves as a speed advantage over abrasive waterjet micromachining. For example, if cutting a single part by wire EDM takes five hours, the same material can be stacked 50 layers thick, reducing the per-piece time to six minutes per part. This only serves as an advantage if the heat-affected zones referred to earlier are not vital to the part being produced. Additionally, thin foils can be problematic for wire EDM cutting in a stacked configuration due to the potential of the thermal process essentially welding the layers of thin foil together along the cut edge.

With any manufacturing process, there will be limitations. For abrasive waterjet micromachining, material thickness is the primary concern when striving to achieve precision results. For most materials, a substrate thickness greater than 1.5 mm will result in draft angles that will likely exceed 10 µm. In addition, the process of waterjet micromachining is currently two-axis, and is only conducive to cutting parts from flat material, or material that can be constrained in flat form.

Pure waterjet cutting is sometimes an option with softer materials, such as silicone and soft durometer elastomers. Pure water cutting typically slices material as a blade would, without actually realizing a kerf line. Pure water cutting is often used when the material being machined has an open cell configuration, and is susceptible to holding unwanted particles such as abrasive media. The water stream diameter for pure water cutting can be as small as 80 µm.

However, materials such as silicone rubber react to pure water cutting much like they would react to blade cutting. The material, depending on thickness and durometer, may displace while cutting, affecting the geometric profile of the device or part being created. In addition, pure water cutting may realize characteristics in the material such as striations and/or draft angle. The solution to these challenges is, when applicable, to use a small abrasive waterjet cutting system and closely regulate and monitor the amount of abrasive being accelerated through the material. This allows the abrasive to perform the majority of the cutting action without displacing material, thus removing material at the kerf and creating a much finer cut edge surface.

Fig. 4 – Free-floating magnetic probes.

Considering the various advantages that abrasive waterjet micromachining has over traditional manufacturing methods, this process is not a solution for all cases. Due to the ease of programming and setup, it is ideal for developmental and short-run production applications. When it comes to high-volume part manufacturing — usually in the thousands of pieces per delivery — this process is not necessarily going to be the fastest or most effective, unless the material is so unique that it cannot be punched or stamped.

This article was written by Steve Parette, Managing Director at Micro Waterjet LLC, Huntersville, NC. For more information, visit ***http://info.hotims.com/61066-201***.