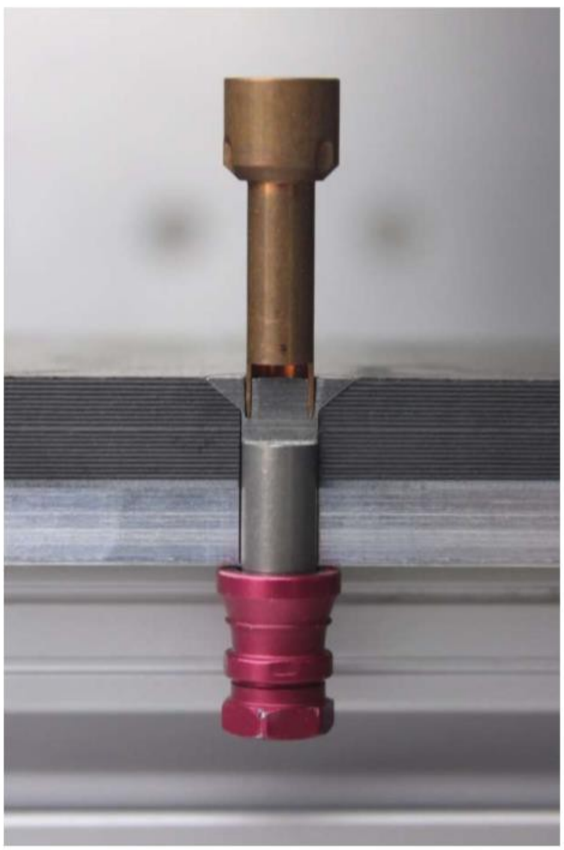
Perfect Point

E-drill Design Features to Prevent EDM Damage to Aerostructures



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Perfect Point Engineering White Paper

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Background

Perfect Point has developed the E-drill - a revolutionary fastener removal process that utilizes Electrical Discharge Machining (EDM) to precisely cut through the head or collar of a fastener allowing for fast and easy removal. Progressive design iterations of the E-drill have improved the quality of the fastener removal process by reducing the probability of damage by providing tools and guides for higher precision location on the fastener.

Traditional methods for removing fasteners are time consuming, strenuous, require years of experience, often causes airframe damage, and always produces FOD. Using the E-drill for fastener removal reduces process time by 20X, reduces damage occurrence rates, and simplifies the removal process, all while producing minimal FOD and substantially reducing both material and labor costs. Perfect Point's E-drill provides a clean, safe, repeatable EDM process. The purpose of this document is to discuss the design features of the E-drill which prevent damage to the airframe by focusing the EDM process internal to the fastener.

The Perfect Point E-drill has many features and accessories that focus on damage mitigation and process efficiency. There are four key features that prevent the E-drill from damaging airframe structures. Perfect Point has developed a system whereby the EDM cut is designed to be contained internal to the fastener shank, precisely controlled to a specific depth, located accurately over the fastener, and cooled by a stream of high-pressure/high-flow coolant. These features have substantially improved the E-drill fastener removal process making it consistent, reliable, and repeatable.

EDM creates a high-power DC circuit between the electrode and the fastener resulting in a spark erosion event which removes a specific amount of material internal to the fastener.
The E-drill is an EDM process that is precisely controlled to cut and measure the cut depth more than a 1,000/second to mitigate the risk of damage to an airframe or engine's substructure.
The process is consistent, precise, repeatable, and reliable.

In the event the E-drill is misused or misaligned, the material surrounding the fastener can be exposed to the effects of the EDM process. The damaged work piece must then be repaired in accordance with an engineering disposition. Perfect Point has performed exhaustive studies on the effects of EDM Damage to parent materials. Please see Perfect Point's: E-drill Damage Rectification Process Validation technical paper for details.

Preventing the Heat Affected Zone (HAZ) in Surrounding Structure

EDM is a plasma event designed to cut metal, but because the E-drill cuts, measures, and cuts again in an iterative process while flushing and vacuuming with water, the heat from the EDM process does not migrate outside the fastener to the surrounding structure. EDM creates a layer of crystallized material known as Recast, localized directly adjacent to the work-area, and a layer of annealed material known as the Heat Affected Zone (HAZ), that propagates out past the Recast Layer. The different layers of altered material are created by the high-temperature of EDM, but in the case of the E-drill, this altered material is localized **internally to the fastener** being removed and then discarded.

The E-drill process is designed to account for the effects of EDM. When properly used, the heating event is localized to the fastener and does not affect the surrounding material. E-drill limits the duration of the sparking event to **630 μs** and actively flushes the working area with a closed-loop cooling system, which removes molten material as quickly as it is produced. This prevents the heat from propagating outward from the fastener, and the area surrounding the fastener remains within a few degrees of ambient temperature.

All forms of EDM require a dielectric fluid to sustain the electrical circuit between the cutting electrode and the work piece. E-drill uses a pulse-cutting technique that measures, cuts, re-measures and then cuts again, and this repeating process occurs at a rate of **>1000 Hz,** while flushing the cut area and cooling the part. Located central to the axis of a fastener shank, this process does not allow the Recast or HAZ layers to escape from the fastener shank. The fastener is structurally weakened by the cutting process. A light punching force removes the fastener by severing the head from the shank.

During the cutting process there is a slight increase in overall temperature in the material immediately surrounding the fastener. This increase in temperature has been observed and measured by many users of E-drill and is confirmed by internal testing of the product. The overall temperature rise depends on the material of the structure as well as the metallurgy of the fastener. In all cases, the temperature rise in the surrounding structure is only a few degrees above the ambient temperature and well below any structural temperature measured when using mechanical drilling or grinding techniques. Therefore, it can be stated that there is no risk of thermal damage to airframe structure when the E-drill is properly used.

Preventing EDM Damage to Surrounding Structure

To prevent EDM Damage to the surrounding material, the E-drill system is designed to use specialized electrode cutters, which constrain the process to stay internal to the fastener shank. The electrodes produced by Perfect Point are typically in a tubular configuration and follow typical sizes for most fasteners. For special applications, any electrode size can be customized to meet an individual requirement. All Perfect Point Electrodes are intentionally designed and manufactured with an undersized margin dependent on the specific shank diameter. Typically, the electrodes are designed with a diameter 0.030" less than the fastener shank to provide adequate safety margin and acceptable punch out forces.

NOM. FASTENER SHANK SIZE			ELECTRODE DIA.	MARGIN
FRACTIONAL	DECIMAL	COMMON	DECIMAL	DECIMAL
3/32ND"	0.094"	-3	.078"	0.016"
1/8TH"	0.125"	-4	.105"	0.020"
5/32ND"	0.156"	-5	.135"	0.021"
3/16TH"	0.188"	-6	.159"	0.029"
1/4TH"	0.250"	-8	.220"	0.030"
5/16TH"	0.312"	-10	.282"	0.030"
3/8TH"	0.375"	-12	.345"	0.030"
7/16TH"	0.438"	-14	.406"	0.032"

(Table 1- *Nominal Fastener Diameters Compared to Nominally Sized Electrode Outer Diameter*)

The electrode mounts onto a conducting tube of the E-drill hand-tool which provides an intimate electrical connection between the electrode and the E-drill mechanism. Axial run out is designed to be minimal and, to ensure there is no axial misalignment on the cutting end of the electrode, a small guiding fixture is installed on the adapter tool.

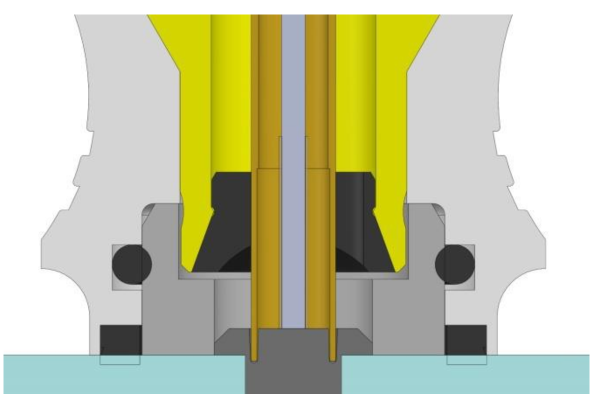

Figure 1- *(Electrode to Electrode Guide Interface Central to a Fastener)*

The guiding fixture, the electrode's undersize margin, and a taper at the end of the electrode, are design features to ensure that a co-axial cut is produced in the fastener head common-to its shank.

The E-drill system touch screen display provides further safety protection by visually displaying the correct electrode for the fastener selected on the display screen. When a user programs the E-drill for a specific fastener, a prompt is displayed on the visual display indicating exactly what electrode is required for the specified command. E-drill has also produced a mechanism internal to the hand-tool that detects the wear-rate of the cutting electrode. It also prompts the user to change the electrode at the end of its useful life. This prevents unintended damage to the mechanism and to the structure along with removing the human element from determining when a cutter is spent.

Preventing EDM Damage to Sub-Structure

The E-drill process relies on an electrode cutting a tubular groove into a fastener to a specific depth. The cut is produced by the electrode spark-eroding the fastener material and travelling to a predetermined depth. The E-drill controls the exact depth of the groove preventing damage to the substructure and reduces the overall risk of EDM damage. E-drill controls the depth of the electrode cutter with the use of a hyper-precision control code and a high-resolution step-actuator.

The fastener specifications are programmed into the E-drill system as determined by the fastener manufacturer's engineering drawings.

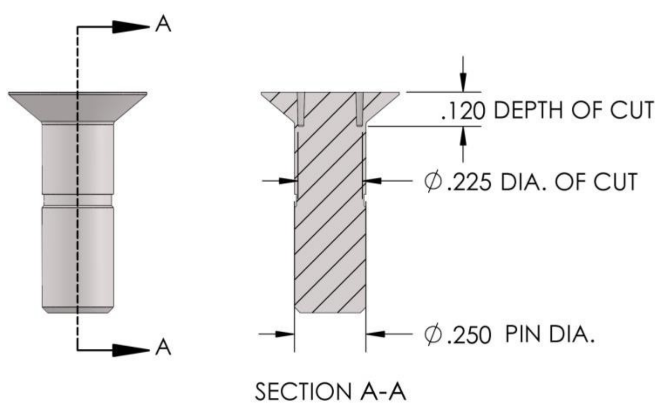

Figure 2- *(Cut Parameters Based on Fastener MFG Drawing)*

Perfect Point has developed a unique code that compensates for the fastener head geometry, chamfer radius, and overall true diameter of the shank. This information is reduced into a single line of code pre-programmed into the system and is displayed on the terminal controller of the tool. The analysis of the head geometry and chamfered radius determines the overall depth of cut, and the true diameter of the fastener determines the electrode callout on the display controller. The program code is then used to control the step-actuator in the hand-tool that advances the electrode to the pre-determined depth of cut.

The step-actuator is held to an advancement precision of 0.001” (±0.0003”) and provides real-time feedback of the cut progression to the controlling computer. When the electrode first contacts the fastener, a feedback signal is sent to the controller stating the electrode is at a neutral-plane, and the controller baselines this information as the height of where the cut is to begin. As the electrode removes material, it measures its progression against this original measurement, while compensating for sacrificial wear of the electrode itself. The feedback and measurement process occur at a rate of 1,000Hz, making the controlling resolution of the EDM cut extremely accurate.

When the electrode has cut to the predetermined depth, the controlling mechanism terminates the cut process, sends a command to retract the electrode, illuminates a display light on the tool, and displays a cut status report on the controlling terminal. This informs the user that the process is complete, and the fastener may now be removed. If there was an anomaly in the cutting performance, the tool prompts the technician to confirm the cut parameters.

Preventing Misalignment of the E-drill Tool

The most important parameter of the E-drill process is the centering on the fastener. The design features listed above, can all be defeated if the tool is mis-located over the center of the fastener, which makes the locator tools a key component of the E-drill fastener removal process. The methodology of the locating tools has been improved by incorporating field testing, customer feedback and internal research. Early generations of the E-drill locator tools were mostly non-aided visual alignment tools using different plastic fixtures, each requiring the user to hold the fixture stationary during the cut process. These early-design locator tools were a source of misalignment of the E-drill tool, as users either did not locate correctly over the axial plane of the fastener or did not hold the fixture stationary during the cut.

Perfect Point has developed a series of mechanical and visual locating devices each designed to take as much human interaction out of the process as possible. Locating methodology depends on the configuration of the fastener (i.e. countersunk, protruding, collar, etc.). Perfect Point has developed precision locator solutions for most typical applications of fastener installations, and continues to develop solutions, guided by Customer input and field experience.

In applications where the cutting surface has pronounced features (protruding head or collar), Perfect Point has developed locator tools using a mechanical lock to ensure the E-drill is aligned both concentric and coaxial to the fastener. Typically, a workpiece with a protruding feature is located by utilizing a metallic bushing machined to the same outer diameter as the workpiece. This ensures the tool's location is central to the axis of the fastener and when used correctly completely prevents misalignment of the E-drill. In trial studies, this device has yielded an overall repeated accuracy of 0.0015" of eccentricity which is significantly within the tolerance to prevent damage.

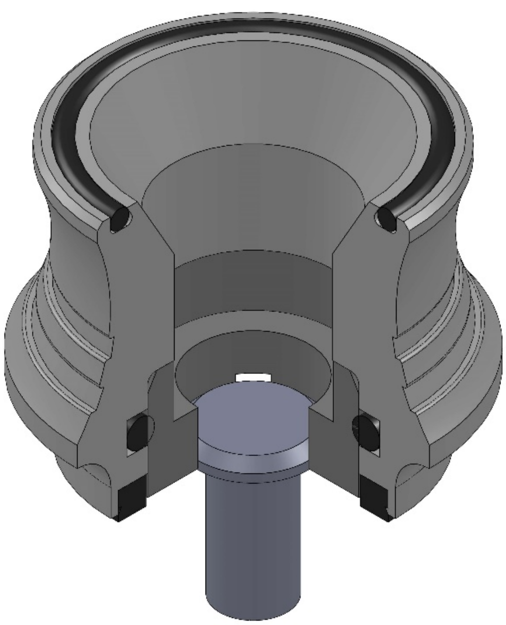

Figure 3- *(Button Head Locator Properly Aligned to Protruding Head Fastener)*

In applications where a fastener is flush and has mechanical features, Perfect Point has created a series of locating devices that engage into the feature. Applications such as Jo-Bolts or Composi-Lok's that have a cruciform feature and a centralized pin an alignment tool is used that matches the geometry of that feature. The device is used in conjunction with a vacuum assisted locating jig that locks onto the workpiece once alignment is complete. Trial studies of this device style have yielded accuracy similar-to that of the protruding head bushing.

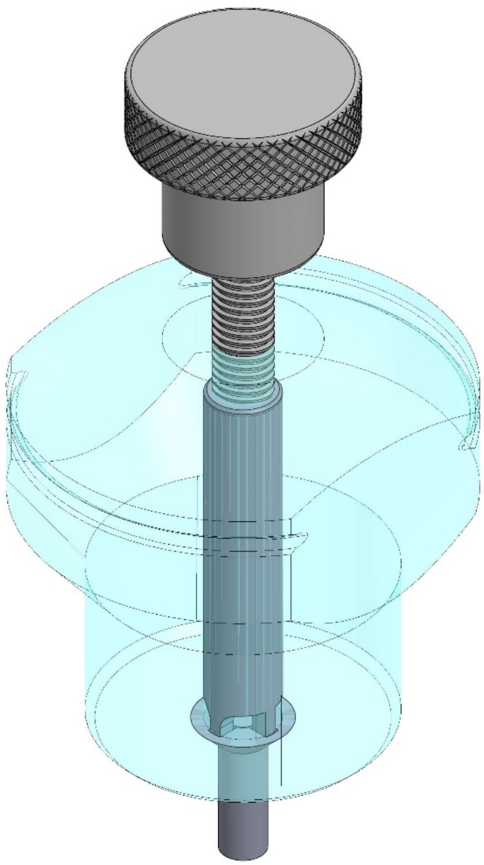

Figure 3- *(Button Head Locator Properly Aligned to Protruding Head Fastener)*

In applications where a fastener is flush and has no mechanical features for alignment, Perfect Point has created a series of vacuum assisted fixtures that utilize an optical aligning tool. The “bombsite” illuminates and magnifies the fastener head and has visual indicator rings that precisely align with most common configurations of flush fastener heads. New iterations of this device have increased magnification and the ability to filter the aperture to the exact size of the fastener.

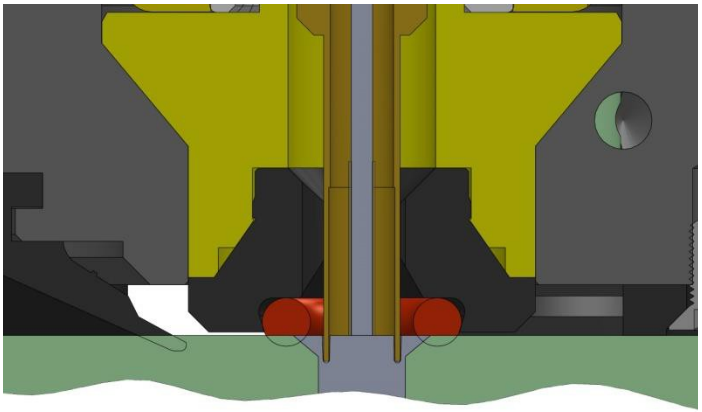

Figure 5- *(Vacuum Aligning Fixture Located Correctly on a Countersunk Fastener)*

These locator tools align the E-drill over the center of the fastener and the tool remains completely stationary during the cut due to the vacuum assist features. While there is no safeguard against misaligning this tool, when compared to non-aided mechanical removal methods, the accuracy is unparalleled. The user simply places the locator tool over the fastener head and aligns the final position using the optical alignment tool. Once optical alignment is complete, the user removes the optical aid and inserts the E-drill tool and removes the fastener.

Closing Remarks

While no process can completely mitigate the risk of intentional or unintentional misuse, the E-drill fastener removal system has designed in multiple layers of protection against misalignment or misuse and is better than other comparable processes. Perfect Point understands that there are reasonable concerns regarding its specific use of EDM for fastener removal, however, over the last 8 years, it has focused its R&D budget on perfecting its process. The current generation of the E-drill product line has advanced the technology to meet the standards of aerospace maintenance. E-drill is a first-of-kind solution to one of the simplest requirements of aerospace maintenance, fastener removal. When compared to other fastener removal processes, the E-drill produces exceptional accuracy with an exponential decrease in process time, damage rate, material costs, and injuries.