UNITED STATES CUTTING TOOL INSTITUTE
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HOW TO TROUBLESHOOT HOLEMAKING IN STAINLESS STEEL

Unlike machining other materials, machining stainless steel requires review of a myriad of aspects prior to beginning work in the machine shop. Not only should cutting tool specialists and coolant specialists be consulted, but machine capabilities should be addressed as well. Furthermore, one must verify that the correct tooling components are being used: cutting tool geometries, substrates, and coatings, type of coolant and coolant pressure among others. Still though, machining stainless comes with many unique challenges because of its low machinability—a machinability rating that needs to be overcome to utilize the many benefits of stainless steel.

Stainless steel is offered in varying grades based on specific properties. These grades are also split into groupings based upon metallurgical qualities. Outlined below are the different families of stainless steel.

- **Austenitic** – A rather common material, austenitic steel is identified as the Type 300 series; grades 304 and 316 are the most accessible. While austenitic stainless steel cannot be effectively heat treated, it can be hardened through cold working—the process of changing the shape without the use of heat. Corrosion resistance, low magnetism and good formability are also characteristics associated with this family of stainless.

- **Ferritic** – As part of the Type 400 series, ferritic stainless steels are characterized by their corrosion resistance, strong ductility and magnetism and are typically iron-chromium alloys. This family can be altered through cold working rather than thermal hardening methods.

- **Martensitic** – Similar to ferritic stainless, martensitic are also iron-chromium alloys within the Type 400 series; however, this grade is able to be hardened by heat treatment unlike the ferritic grade. Other characteristics include magnetism, good ductility and corrosion resistance.

- **Precipitation-hardened (PH)** – Through the precipitation hardening process, precipitation-hardened stainless steel attains more strength in addition to greater corrosion resistance. Additionally, it is similar to martensitic stainless in terms of chemical makeup.

- **Duplex** – With a composition made up of nickel, molybdenum and higher chromium levels, duplex stainless steels combine features of ferritic and austenitic stainless, yet this family demonstrates greater strength and high localized corrosion resistance.

Whether machining valve choke bodies for the offshore oil industry (410 stainless), pump covers for the food processing industry (316 stainless steel), bushings for the aerospace industry (17-4 stainless steel) or pumps for the water and wastewater industry (304 stainless steel), knowing and understanding the varying grades and properties of stainless steel will enable machinists to effectively utilize stainless steel and overcome its challenges when they arise.

One of the greatest challenges of machining stainless steel is chip control. Alloying elements such as nickel cause stainless steel to be partially heat resistant, which results in difficulty forming a chip and, thus, poor chip evacuation. In typical steel cutting applications, heat transfers into the formed metal chip. When machining stainless, the heat resistant nickel alloys prevent this heat transfer. This leads to higher cutting temperatures and increased rates of tool deterioration when compared to common steel machining. Simply stated, the nature of the material and its high amount of elasticity make it difficult to achieve chip formation and induce quite a bit of wear on the cutting tool.

Combatting these challenges can be done a few ways—one of those being understanding machine conditions. While machine type does play a small factor, machine condition is more detrimental. Machinists must ask themselves, is the spindle rigid? Is the alignment reasonable or near zero runout on a lathe? Knowing these factors can greatly benefit or cause significant issues when trying to machine stainless steel. Additionally, running through the tool coolant provides significant tool life advantages over flood coolant. Ultimately, due to its alloying elements, more torque and horsepower are required to drill stainless than typical steel or aluminum materials.

These challenges in stainless applications can also be resolved by working with a more aggressive geometry to attempt to get the chip to form. In austenitic stainless like 316, it is best to use a geometry with a higher rake angle to produce a more manageable chip; however, when working with a harder material such as PH stainless, this method is not effective. In this instance, increasing the rake angle causes the cutting edge to weaken—in turn reducing tool life. With harder materials, this makes the negatives often outweigh the positives.

Nevertheless, the benefits of stainless are so numerous that it is beneficial to overcome these challenges when possible. Corrosion resistance is one of the key benefits of stainless steel. Because a number of grades of stainless are highly corrosion resistant, it is the material of choice in applications where weather or corrosive materials will be in direct contact. For example in the energy industry, electrical wiring that is run through the ocean for offshore wind farms is made out of stainless steel or a high temp alloy material because of its corrosion resistance, which does not allow salt water to negatively impact it as it does other materials. Similarly, offshore drilling utilizes stainless steel because of the corrosive and abrasive materials that are being pumped through these lines.

The food industry is another industry where stainless steel is often used. Stainless steel's chromium composition, which must be a minimum of 10%, is highly reactive to oxygen environments. This forms a strong, unreactive barrier on the surface of stainless steel, making it the material of choice for the food industry. Finally, the naturally high strength of stainless steel as well as its resistance to corrosion and weather make it a vital material for the aerospace industry in terms of precision parts, fittings, and other components.

All in all, stainless steel is not a material that can be brought into a machine shop to machine straightaway; every aspect must be reviewed prior to machining stainless steel. Not only do machinists need to firmly understand the different grades of stainless and their properties, but they also need to examine machine capabilities. Yes, tool wear and excellent chip formation are challenges that one will face when drilling stainless. Fortunately, these can be managed through proper coolant usage and correct choice of insert geometries, coatings and substrates—because one cannot get away with just anything when machining stainless steel.

Information provided by Allied Machine & Engineering Corporation