FOR IMMEDIATE RELEASE

Contact:

Seco Tools AB
Björnbacksvägen 2
73782 Fagersta
Sweden

Bettina LIEBL
Phone: +49 211 2401-313
E-mail: bettina.liebl@secotools.com
www.secotools.com

Milling and drilling the tough materials

Fagersta, May 2013 – The goal of aircraft weight reduction is driving the current increased use of advanced exotic materials such as composites, titaniums and Inconels in the aerospace industry. While materials such as these are lighter, yet stronger than those typically used, they each present their own sets of challenges when it comes to machining, more specifically milling and drilling.

For milling and drilling operations, aerospace manufacturers often use solid carbide and/or solid high-speed-steel tools. During those machining operations, these manufacturers must achieve the highest levels of quality possible – often accomplished through carefully monitored and maintained process security. There are concerns about cost per part, but in most instances, producing perfect parts is a much higher priority, and increasing productivity tends to be secondary.

Aerospace manufacturers strive for process security and consistency through predictable performance of machines and tooling. In the case of tooling, these manufacturers must have milling cutters and drills that deliver practically the same exact amounts of tool life from one tool to the next. And even when they do know precisely how long a tool will last, aerospace manufactures often schedule machines to exchange tools well before they are completely worn.

Thanks to machine and cutting tool technologies, materials such as composites, titaniums and Inconels have advanced from a stage of being almost impossible to machine to a point today where aerospace manufacturers machine them with confidence and efficiency. One tooling technology that gives better process control and consistency is advanced specialised solid rotary mills and drills. These tools have been developed specifically for overcoming the machining challenges presented by these materials. Through the incorporation of various innovative coatings and geometries used in tandem with advanced machining techniques and strategies, these specialised tools will not only provide process security, but will also increase production speed and output.

Milling
Composites. The market for machining Carbon Fibre Reinforced Plastics (CFRP) materials is surging within the aerospace industry. However, the materials are difficult to machine because they are very abrasive and tough on milling tools. Plus, delamination – when individual carbon fibre plies separate – must be prevented from occurring while machining. These challenges can be overcome with hard, sharp solid-carbide milling cutters that employ special surface coatings.

Two types of coating processes commonly used are Physical Vapour Deposition (PVD) and Chemical
Vapour Deposition (CVD), along with an advanced cutting material Polycrystalline Diamond (PCD). PVD coatings involve a physical process and include aluminium nitride, chromium nitride and titanium nitride coatings with hardnesses of approximately 3,000 Vickers. The Diamond coatings that are imparted by the chemical process CVD are about three times harder, resulting in a Vickers rating of 10,000. PCD tools incorporate solid PCD-plates that are brazed to solid-carbide cutter shanks.

From a geometry standpoint, effective cutters for composites incorporate low helix angles to reduce axial forces on the laminate layers of the material to prevent delamination. Additionally, cutters with both a left and right helix are also effective geometries for composite materials. These types of cutters, often known as compression routers, direct and compress cutting forces toward the centres of workpiece thicknesses – in the case of side milling – to keep the laminate layers intact. Plus these types of cutter geometries make for much freer cutting of composites.

While compression cutters are a common approach, some cutting tool companies, such as Seco, have developed compression cutters with new different geometries, such as a double helix. Seco, for instance, developed two such double-helix routers. One is a multi-flute tool with smooth cutting edges. The other has fewer flutes, providing more chip clearance, and chip breakers on its cutting edges. The latter is more for roughing operations, while the former multi-flute option without chip breakers offers ideal performance for finishing operations.

As far as machining techniques are concerned, cutting parameters for composites are often dependent on the various materials themselves. Typical speeds for solid-carbide cutters for composites are about 150 m/min, and feed rates are around .07 mm. But it should be noted that within this group of materials, there are a variety of different types of binders used, each requiring their own speeds and feeds. The melting points of these binders are often what determine speeds and feeds when cutting composites. Also fibre content and fibre orientation have a significant influence on the machining process governing cutting speeds and feeds and the optimum tool path.

Titanium alloys. Within the aerospace industry, titanium alloys are often used in three basic application areas: aircraft structural parts, cold section components of jet engines and landing gear systems. One commonly used titanium is 5553, which is a near-beta alloy typically used for landing gear parts. TiAl6-4 is an alpha-beta alloy that is one of the most commonly used types of titanium particularly for structural parts.

The factors that make titanium alloys a challenge to machine and contribute to its low machinability rating are its thermal conductivity, high adhesion, and strain-hardening element. Titanium alloys have a low thermal conductivity, which means that during machining, the heat generated by the process transfers into the cutter instead of being carried away from the cutting zone within the chips.

Titanium’s high adhesion means that chips tend to stick to cutters, so very long chips are generated, as opposed to more favourable shorter easily extracted ones. The material’s strain hardening element that comes into play during machining causes a small thin layer of the material to harden from the effects of pressure generated during the machining process.

While titanium can be machined with general-purpose solid-carbide cutters made for various materials, those cutters designed specifically for the machinability characteristics of titanium will nearly always provide superior results. These special cutters provide extremely high levels of performance, but they can be less versatile when it comes to the number of different materials to which they apply.

For example, Seco has a high-speed steel (HSS) cutter in its programme designed for both titanium and Stainless steels. Cutters that are part of the Jabro® HPM (high performance machining) Series are specifically designed for certain material designations like titanium. These cutters incorporate special geometries and design qualities that have been optimised for titanium.

The geometries and design qualities include high helix angles between 40 and 50 degrees; internal through coolant channels to keep chips from sticking to the cutter flutes and to quickly evacuate chips as well as cool the cutting zone; uneven tooth pitches for reducing vibrations during high depths-of-cut; and a combination of carbide with aluminium chromium nitride coating. No titanium nitride is used, this prevents a chemical reaction between the cutter and material.

There are certain factors that dictate when to use a solid-carbide tool or an HSS tool, and the main factor is cutter diameter. Solid-carbide tools should be used when applications require smaller diameter
cutters and when workpiece geometries are extremely complex, or if taking heavy depths of cut \((a_p)\) is the goal.

HSS cutters are recommended for less-complex workpieces in high-volume applications and when both large widths of cut \((a_e)\) and heavy \(a_p\) are the goal. The tools should also be considered when older conventional machine tools with high torque and high horsepower are being used.

**Inconel.** As is typically the case in aerospace manufacturing, Inconel parts tend to be very expensive, not only in the cost of the material itself, but also in the investment of time put into producing them before they even get to the machining stage. Huge losses result when parts are scrapped after hours or even days worth of machining have already been put into them.

There are certain similarities between Inconel and titanium. But in terms of machinability, Inconels (nickel-based superalloys) are the most difficult materials to machine. They have very low thermal conductivity and very high levels of strain hardening – higher even than those of titanium. Inconel also has high adhesion, so cutting speeds can rarely exceed 25 or 30 m/min when applied in a conventional machining method.

Cutter geometries for machining Inconel differ greatly from those used for titanium. Inconel geometries are angular relieved with very steep angles. Such geometry reduces contact between the cutter and material as much as possible. This is critical because Inconel is flexible and has a high memory, meaning it will "give" somewhat when subjected to the forces of a cutting tool. So the longer the contact time between the cutter relief and material, the higher the abrasive wear on the tool and the shorter its working life. To further reduce the friction between cutter and Inconel, Seco incorporates a coating of aluminium titanium nitride that is polished to an extremely smooth and fine surface finish.

**Four machining strategies for titanium and Inconel**

There are basically four machining techniques, or strategies, for titanium and Inconel. The first is conventional machining, which involves a balance between \(a_e\) and \(a_p\) of 1x1. This means that machining is done at full cutter width \((1*D_c)\) and at a certain depth of cut up to 1 times cutter diameter and running at average feed rates.

The second strategy is high performance machining (HPM), which involves cutters specifically designed for titanium and Inconel, such as Seco’s HPM line of cutters. These cutters are run at large \(a_p\) (up to 1.5\(*D_c\)) and at full \(a_e\). Large volumes of metal are removed in a short amount of time for increased productivity.

The third strategy is high-feed machining (HFM) that uses very small axial \(a_p\) and full \(a_e\); so width of cut is 1 \(*D_c\). The specific geometries of cutters used for this strategy direct cutting forces into the machine tool spindle, so this strategy is especially useful in unstable machining conditions due to large tool overhangs and complex applications like pockets with depths of 5 \(*D_c\) and more.

The fourth machining strategy is high-speed machining (HSM) that uses fairly low \(a_e\) radial depths of cut and very large \(a_p\) depths of cut. Because the radial depth of cut is relatively low, there is a small arc of contact that helps reduce heat in cutting zones due to smaller contact time and thus allows for higher cutting speeds to compensate and gain productivity.

Both machine tool and cutting tool advancements have made these strategies possible. For instance, Seco’s HPM cutter geometries have special features, such as uneven tooth pitches and curved helix angles, providing necessary stability for high-performance machining strategies. In the case of high-feed and high-speed machining, those strategies tend to be more dependent on machine tool capabilities as well as cutter geometries.

For the most part, machines and cutting tools work in unison to meet the specific material machining demands of aerospace manufacturers. Both the right machine tools and the right cutters are needed. This is especially true for high-feed and high speed machining, which requires not only a machine tool with a high feed rate capability, but also CNC controls that can handle the larger programs and NC files associated with high-feed and high speed milling operations.

**Drilling**

**Composites.** For aerospace applications, drilled holes in composites must be perfectly clean and
without ragged or frayed fibres that can interfere with and compromise subsequent assembly operations.

Two common challenges of drilling composites are delamination and uncut fibres, especially on the backside or drill exit side of workpieces. When drilling, tool forces push down on the material and, as the drill nears the exit side, excessive force can cause the drill to push through, as opposed to cut through, the last portion of the hole. The result is composite fibres that are ripped and ragged instead of cleanly cut, causing material delamination.

To overcome these challenges, tooling companies strive to decrease drill feed forces against the material through the use of different point angles and helix angles on drills. It should be noted that some drill geometries generate lower feed forces and perform better than others.

For example, a 140-degree point angle – the most common for solid carbide drills – will work quite well for several holes when drilling composites. Unfortunately, as soon as the tool dulls at all, it loses its effectiveness. With C1 diamond coated solid carbide drill for composites, Seco imparts a geometry with two point angles – a 130-degree angle in the centre and 60-degree angle on the chamfer of the drill. In operation, the drill’s centre point exits the end of the hole first, cutting away some of the hole’s material. So when the 60-degree portion exits, the feed forces of the drill through the material are drastically reduced. Thus, there is less delamination and fewer, if any, uncut fibres.

In addition to two fluted, diamond coated drills, Seco has developed a unique 3-fluted PCD-tipped drill geometry for composites. Applied with the same cutting conditions as standard composite drills, this new PCD drill geometry provides much better results because three edges are cutting as opposed to only two. The drills have sharper cutting edges and generate less feed force per revolution, especially when exiting a hole. Additionally, with a full PCD tip, as opposed to diamond coated, the drill can provide up to four times more tool life in many instances.

**Titanium.** In the aerospace sector, most hole diameters are small. For diameters less than 1 mm and up to 20 mm, solid carbide drills are used quite extensively in drilling titanium as well as Inconel.

As occurs when milling titanium, heat from the drilling process also tends to go into the tool instead of being carried away within the chips. To combat this, drill geometries typically involve very sharp cutting edges. Normally, drills for titanium are uncoated because of this requirement of extremely sharp cutting edges. Also, coatings can increase friction somewhat, adding to heat generation. One more important part is the shrinkage of material after machining. Due to that a bigger back taper is needed on the drill body.

**Inconel.** Because Inconel is very abrasive and work hardens, effective drill geometries for the material are basically the same as those for titanium. However, coatings are added for increased wear resistance and to reduce friction. Seco, for instance, uses titanium aluminium nitride coatings to protect its Inconel drills and extend their working lives.

When drilling Inconel, lower speeds and feeds are used, mainly because the material is harder and more difficult to cut. The machinability of the material comes into play when drilling, much as it does when milling Inconel. In aerospace applications, hole depths in Inconel components are typically only 3 x D.

Coatings have played a key role in boosting aerospace drilling process security and productivity, and tooling companies such as Seco continue to gain better control and master drill cutting edge treatments. Through effective variations of coatings, such as titanium aluminium nitride, and control of cutting edges, Seco has been able to develop drills that can essentially allow for doubling drilling speeds and feeds.

In the future, there will be more changes made to existing geometries to further improve drill performance. Many of these minor changes will only be realised or possible with today’s advanced machine tool technology. Those aerospace manufacturers that are drilling millions of holes have already set their sights on such specialised drills.
Conclusion
To effectively machine today’s challenging aerospace materials, the key is to obtain a complete machining solution, not just a product. A complete cutting tool solution includes not only the necessary geometry and design, but application engineering support as well. The knowledge and experience of the human resource combined with the advanced product to form a complete solution and achieve ideal results.

Part quality and process security require the best possible tool designed for the particular application at hand, whether it be composites, titanium or Inconel. But that tooling must be acquired from a supplier able and willing to provide guidance as to the proper way to run it for optimum performance. Education and training is key to getting the most benefit out of today’s advanced tooling designed for tough aerospace materials.

By:
Teun Van Asten, Engineer Marketing Services, Seco Tools
Wilco van den Boogaard, Application Engineer Solid Milling, Seco Tools
Pär Nordberg, R&D and Project Engineer, Seco Tools

PCD drills, 3-fluted CX1 for use in CFRP.

PCD_drills.jpg

JC845 new double helix rougher with chipbreakers.

JC845_Application.jpg
JC840 in action.
JC840_Application_I.jpg

JC840, double helix finisher dura coated.
JC840_Application_II.jpg

JC840, double helix finisher dura coated.
JC880_Application.jpg
About Seco Tools:
Seco Tools is a leading manufacturer of high performance metal cutting tools. Seco’s product range includes a complete programme of tools and inserts for turning, milling, drilling, reaming and boring as well as complementary tool holding systems. With more than 25,000 standard products, Seco is a complete solutions provider for the metal cutting industry and equips machine tools from the spindle down to the cutting edge.

The company is headquartered in Fagersta, Sweden and represented in more than 50 countries worldwide with 40 subsidiaries, distributors and channel partners.

More information can be found at: www.secotools.com

###