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Special threading tools for performance in space

written by **Dr. Peter Schniering**

High end application small satellites in low earth orbits

Manufacturing threading tools for aerospace components represents a significant challenge for the machining industry. The focus is on crafting application-specific geometries and adhering to extremely tight tolerances when working with highly alloyed specialty steels.

Manufacturers of precision tools are accustomed to creating products capable of machining high-precision components. These components demand threads for motion and fastening that must meet extreme tolerances on the edge of technical feasibility. Fields like motorsports, turbine construction and medical technology continually introduce new materials, impose strict dimensional accuracy requirements and demand close to 100 % process reliability. But the demands for threading applications in aerospace far exceed those of terrestrial high-end industries.

Automated measuring system for the space taps from Zoller

The business in space: a high-growth market in transition

In recent years the market for space components, especially for satellites, has developed dynamically. While composite materials are being used increasingly, machining is also on the rise. In Europe the market for aerospace composites alone is expected to grow by an average of almost 10 % until 2028. Manufacturers of aerospace components are demanding ever more cost-efficient and faster production. Another important aspect is increasing miniaturization and the increased use of small satellites in low earth orbits. Modern small and lightweight satellites require high-performance connection and cabling systems that are technologically flexible and enable high data transmission rates. The market for space components is facing a phase of high growth due to technological innovations, the introduction of new materials and production techniques and the increasing demand for smaller satellites. Machining in general, and threading in particular, are highly demanding fields.

The journey into space: a challenge for threads

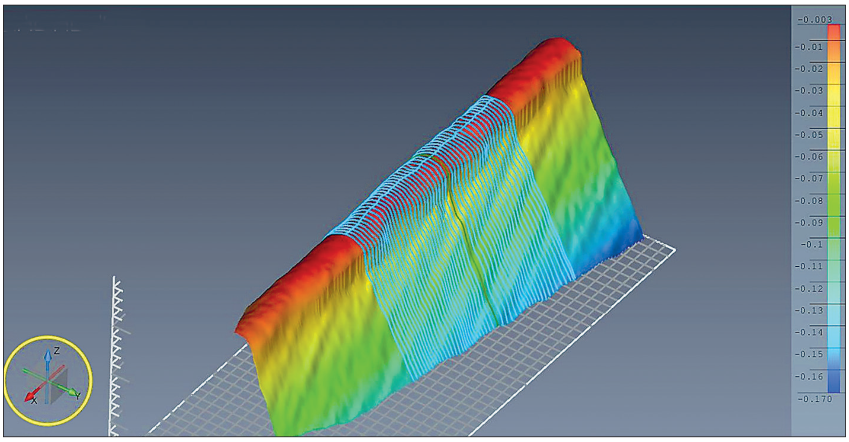
One major reason for these extreme demands is the operational environment. In orbit threads are positioned up to 36,000 km from earth, moving at speeds exceeding 11,000 km/h. No possibility for post-processing or maintenance exists; the threads must perform flawlessly to prevent system failures, such as the malfunction of an entire satellite.

To commission components in a geostationary orbit or a low-earth orbit (starting around 200 km altitude), they must first endure significant stress during transport via rocket, including intense vibrations and G-forces up to ten times earth's gravity. Designers and manufacturers must account for this during the entire planning process – representing a formidable challenge for the engineering teams at the customer and the tool producer.

Company information

Schumacher has been producing high-performance cutting tools for more than 100 years. The company's performance characteristics are – in addition to first-class product design – the provision of flexible services in the areas of customer-oriented research and development, warehouse management, logistics and after-sales support.

Schumacher is transforming from a traditional tool manufacturer to a service provider integrated into an international production and university network.



Measuring the cutting edge and the surface quality

Thermal and mechanical challenges in space

In addition to such mechanical stress, extreme thermal forces play a role. The near-perfect vacuum of space results in vast temperature fluctuations between the sunlit and shaded sides of a component. Sunlit surfaces can heat up to approximately 120 °C, while shaded areas cool to around -90 °C. Components exposed to such cycles, especially in geostationary orbits, must endure years or decades of thermal strain. Internal heat sources, such as electronics used for signal amplification, compound these issues. Active electronics create consistent heating and cooling cycles, adding further complexity.

Such high thermal and mechanical demands place unique requirements on materials. High-performance aluminum and iron-nickel alloys with low thermal expansion coefficients are often employed. Two examples serve to highlight the implications for customized threading tools:

Advanced materials for space applications: #1 – aluminum

Threads in high-performance aluminum alloys must be burr-free and particularly smooth for aerospace applications. The use of high-alloyed aluminum components is characterized by three aggravating factors:

1. increased wear: the high silicon content leads to an abrasive effect on cutting tools, as silicon is very hard. In addition to rapid wear, this can cause damage to the tools' cutting edges, which represents a risk factor in view of the need to avoid burrs.
2. brittleness: AlSi alloys with a high silicon content are often more brittle, which increases the risk of material chipping or cracking during thread production, which in turn poses a risk to the flawless process in the component.
3. chip formation: due to the abrasive nature and high hardness of the material, chips tend to break irregularly, further complicating process control. In addition to burrs very short chips are also a challenge for aerospace components should they remain in the workpiece unnoticed.

For aluminum with such high silicon content (more than 35 %), conventional thread tool geometries are modified prior to production. Collaborations with research institutions, such as *Research Institute Forschungsgemeinschaft Werkzeuge und Werkstoffe* (FGW) in Germany, have resulted in geometry changes, like optimized cutting angles and modified relief angles in combination with a customized surface treatment. Combined, these measures ensure burr-free chip formation and smooth thread flanks.

#2 – tailored solutions for special nickel alloys

For iron-nickel alloys with high nickel content, threading tools face unique challenges due to the material's particular abrasiveness. Cutting angles are adjusted, and cutting edges are coated with multi-layer friction-resistant materials to maintain the required thread flank quality.

In both cases, achieving process reliability involves modifying tool geometry and using coatings tailored to the application. This ensures threads meet the extreme demands of aerospace systems.

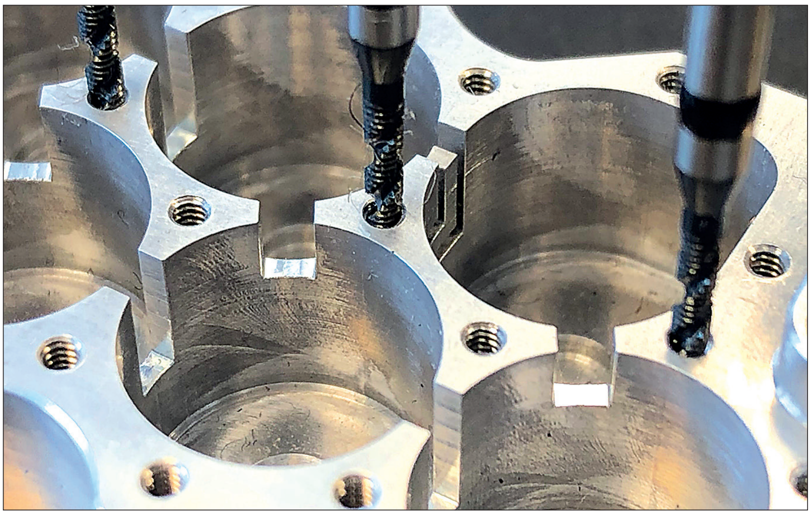
Special tap lines for aerospace applications

Testing new materials for space components

Consistent support along the value chain is key

From initial design to final production close collaboration between tool manufacturers and aerospace manufacturers is essential. This includes optimizing peripheral systems, such as clamping technologies, coolant-lubricant systems and pre-drilling tools. Adjusting cutting parameters and defining tool lifespan are critical to meeting the demands of burr-free results and process safety.

Process monitoring and measurement technology play a particularly important role in the production of flawless threads for aerospace components. In a process lasting two decades we have succeeded in guaranteeing redundancy-free data transmission from the design stage through the



Aluminum space component with M1.4 threads

Preventing burr formation in space

Minimizing burr formation is critical in space applications, as even small debris can endanger sensitive onboard electronics in a microgravity environment. Threading tool designs are focused on producing burr-free results to mitigate these risks and ensure system reliability. In this context, process security has a disproportionate role in the entire process:
small failures can lead to severe technical and economic consequences, with the complete failure of a satellite system in orbit as the ultimate negative effect.

entire production process to quality control and technical support for the end customer. German specialist company *Zoller* from Pleidelsheim was a close partner for the metrology section of this.

The core element of metrological monitoring is the contact-free method of continuously checking any decisive parameter, both in the geometry of the tool and in the surface treatment (roughness of the surface and defined rounding of the cutting edges). In the specific case of micro taps for aerospace components, the surface is monitored using a metrological process during the production process and after coating. These methods work optically without contact using laser light and a measuring microscope. The measuring spot measures 10 x 10 mm and even the smallest contours and geometries of less than 1 µm accurately. In addition the inspection devices handle complex geometries, such as cutting edges and thread flanks on cutting segments of taps with helixes of up to 45 °. Thanks to its large vertical working or positioning adjustment range (Z-axis), the unit measures very small tools flexibly and with repeatable accuracy.

Schumacher's service engineers supervise the application process and quality control with regard to surface finish and burr prevention. This process is important when setting up production for the first time, especially in the case of new regulations from the customer. Satellite technology is constantly exposed to new requirements and the components continue to develop accordingly. This affects both the workpiece materials and, above all, the design of the thread. Over the years the company has found that early involvement in the design phase is advantageous for the subsequent process.

further information: ***www.schumachertool.de***