

SIGNIFICANTLY INCREASE THE SERVICE LIFE OF EMBOSSING AND CUTTING DIES

Millions of strokes per day put tremendous stress on high-performance punching tools and their active components.

How can tool life be extended, thus minimizing downtimes and reducing costs?

How can automated measurement technology with AI simplify quality assurance?

How do you get stamps manufactured precisely and economically from batch size 1 to X?

This white paper provides all the answers.



INTRODUCTION

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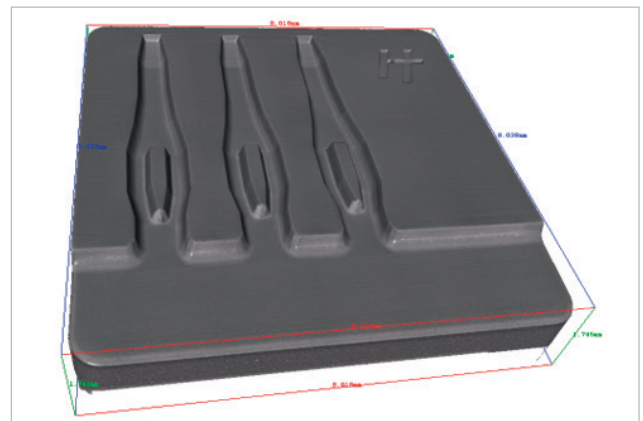
For producing embossed **contours in carbide tools**, die-sinking EDM has long been considered the first choice for creating precise and intricate contours in the carbide base material. Meanwhile, promising technologies such as ultrashort pulse laser machining (USP) have been developed.

A joint series of **tests conducted by Ceratizit Empfingen and HAILTEC** compares USP with the die-sinking EDM process. This white paper presents the **test results, technological details, and metal-lurgical tips** for practical use. Ceratizit Empfingen GmbH is part of the Ceratizit Group, technology leader in the carbide industry with locations world-wide.

In this USP white paper, we also present a **pilot project with Bruker Alicona**, demonstrating the **potential of AI-supported automated measurement technology** for fast, 100% quality control. Bruker Alicona is a specialist in optical measurement technology and a long-standing partner of HAILTEC.



As a pioneer in the industrial application of ultrashort laser pulses, we develop applications in close partnership with DMG Mori machines and TRUMPF lasers. In laser ablation, we cooperate with carbide specialist Ceratizit Empfingen GmbH, and for AI-supported measurement technology, we are a development partner of Bruker Alicona.



Carbide embossing dies for press-fit zones made from CERATIZIT CF-H40S+ material.

HAILTECs partner in ultra-short laser processing

DMG MORI

Bruker alicona





TECHNOLOGY OVERVIEW

Challenges in Carbide Machining:

Die-sinking EDM has traditionally been the preferred technology for creating embossing and cutting contours in carbide tools. Milling and grinding are also used. However, all three technologies present challenges, including:

TENSILE RESIDUAL STRESS

Die-sinking EDM typically introduces tensile residual stress into the outer layer of the carbide material. This creates thermally stressed zones that can lead to microcracks in the material's structure.

MICROSTRUCTURAL DAMAGE

When grinding or milling carbide, mechanical forces act on the material's fine grain structure. This can result in microstructural damage such as crack formation, increased surface roughness, or grain breakouts. Such damage can significantly reduce the tool's performance and service life.

WHITE LAYER

Another disadvantage of the EDM process is the melting zone that forms on the surface of the eroded contour, commonly known as the «white layer.» It weakens the base material and can lead to premature wear or even tool breakage.

INACCURACY

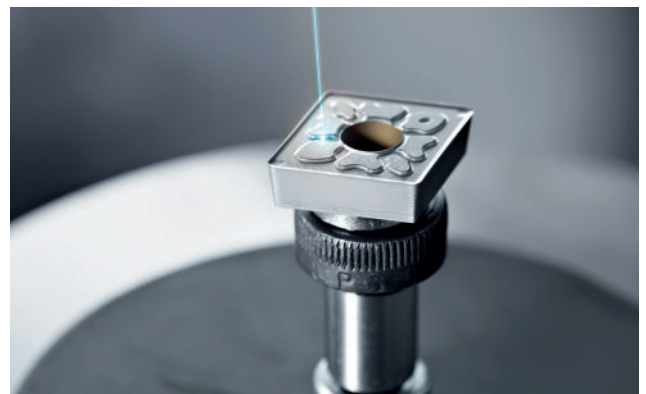
In milling, the contour must be set up in multiple steps, which can easily lead to deviations. Precision suffers as a result. Moreover, milling tools are very expensive and wear out over time. The result? Dies that differ from one another – a nightmare for quality assurance.

BENEFIT FROM THE UKP LASER TECHNOLOGY AT HAILTEC:

Nobel Prize-winning TRUMPF femtosecond laser sources with pulse peak powers exceeding 300 MW combined with state-of-the-art 5-axis laser systems from DMG MORI

Highest repeatability and reproducibility

Positioning of laser contours relative to the work-piece blank with precision up to ± 0.005 mm thanks to high-resolution CCD camera and integrated 3D measuring probe



Press dies made of carbide

ULTRASHORT PULSE LASER MACHINING

the ultrashort pulse laser can process even highly reflective surfaces. It operates with virtually no heat-affected zones and completely without process forces. The decisive advantage: **extensive post-processing or surface cleaning is largely eliminated.** This saves time, reduces costs, and ensures consistently high quality.

TEST SERIES AND RESULTS

How does ultrashort pulse laser machining compare to die-sinking EDM when it comes to creating intricate contours in embossing dies? Ceratizit Empfingen and HAILTEC investigated this question. In joint test series, they subjected all carbide grades of the CF series to ultrashort pulse laser ablation. Subsequently, they metallurgically examined the results for structural damage, residual stresses, and mechanical properties.

COMPARING RESULTS:

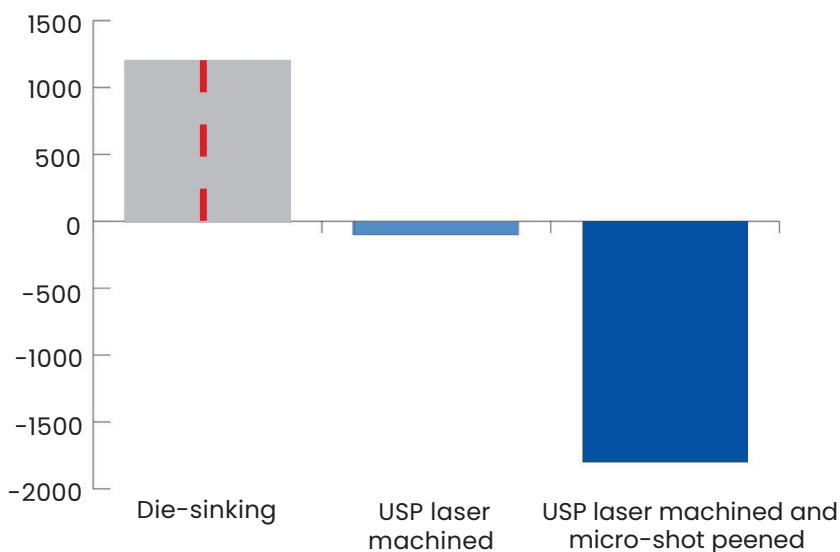
DIE-SINKING EDM VS USP LASER MACHINING

The test series shows clear results: The extremely short pulse durations of the femtosecond laser result in cold material removal. As a result, the 'micro-structure of the carbide remains virtually unaffected. Thermal cracks and other material damage are barely detectable or not detectable at all. «Laser ablation using USP lasers avoids known disadvantages of the die-sinking EDM process, such as tensile residual stresses in the outer layer of the material,» explains Maximilian Voigt, Team Leader Product Management at Ceratizit.

While die-sinking EDM creates harmful tensile stresses, the laser introduces hardly any stresses into the material and can therefore be considered neutral. The stress diagram shows the harmful tensile stress created during die-sinking EDM (EDM) in red. Compressive residual stresses, on the other hand, counteract crack growth and are therefore desirable. These can be significantly increased by a shot peening process performed after laser machining.

STRESS DIAGRAM OF COMPRESSIVE RESIDUAL STRESS IN MPa

Material: Ceratizit CF-H40s+



Compressive residual stresses (- MPa in blue) counteract crack formation



WHAT DOES ULTRASHORT PULSE LASER MACHINING MEAN FOR CARBIDE PROCESSING?

Carbide is extremely wear-resistant and therefore difficult to machine. Until now, laser ablation with fiber lasers was not an alternative for carbide material, as the relatively long pulse durations and associated heat input literally destroyed the carbide material. «The breakthrough came with ultrashort pulse laser machining: The extremely short pulse durations of today's laser technology result in cold material removal, » explains Maximilian Voigt from Ceratizit.

LASER SIMPLIFIES PROCESS CHAIN

Compared to die-sinking EDM, ultrashort pulse laser machining requires no electrode production. This makes the manufacturing process simpler and more precise, as the carbide surface is not affected by wearing electrodes or the rougher surface quality resulting from die-sinking EDM. The laser creates the finished part directly from the 3D model, in a single setup and without applying processing forces. Furthermore, it operates with repeatable process parameters, ensuring that one die exactly matches another.

LASER IMPROVES SURFACE QUALITY

The test series shows clear results:

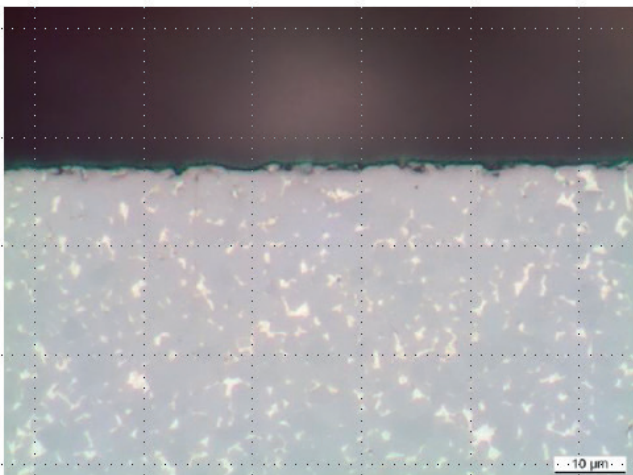
The images from Ceratizit Empfingen demonstrate the difference in surface quality between die-sinking EDM and femtosecond laser (USP).

Ultrashort pulse laser machining achieves surface quality up to Ra 0.1 µm without post-processing.

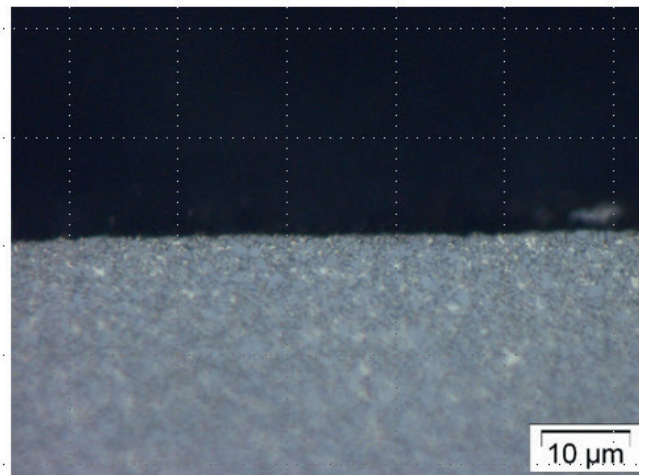
LASER INCREASES SERVICE LIFE BY FACTOR OF 10

From a metallurgist's perspective, Maximilian Voigt from Ceratizit Empfingen adds: «When you enhance a laser-machined contour in a carbide tool through a simple shot peening process followed by polishing, you achieve material properties that exceed even the as-delivered condition of unprocessed, sintered carbides. This allows you to fully utilize the advantages of USP laser ablation. Through this high-end processing, an increase in tool service life by a factor of 10 compared to EDM-processed carbide embossing dies is definitely possible.»

Surface quality comparison: EDM vs femtosecond laser (Source: Ceratizit Empfingen GmbH)



EDM: Rough, damaged surface



Femtosecond laser: Homogeneous, undamaged surface

EMBOSSING DIES IN FOCUS

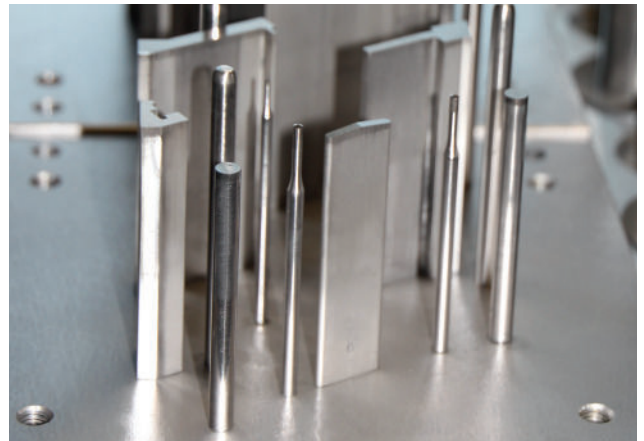
The ultrashort pulse laser technology shows great optimization potential particularly for wear-intensive tool components such as embossing dies for press-fit zones, connectors, or micro-number stamps, in terms of die service life, reproducibility, and replacement time. Laser-machined embossing dies minimize machine downtime, reduce costs, and shorten production time. The USP laser implements shapes, dies, bending punches, or cavities directly from the 3D model. It achieves surface qualities up to $Ra\ 0.1\ \mu\text{m}$ and avoids many disadvantages of die-sinking EDM (see previous pages).



Advantage of controlled edge rounding

CUTTING DIES IN FOCUS

For highly stressed tool components such as cutting dies, ultrashort pulse laser technology opens up remarkable optimization possibilities. The process achieves controlled edge rounding in carbide, ceramics, or PCD: Thanks to cold ablation, our ultrashort pulse laser process sublimates or halves the hard material particles instead of breaking them out of the binder material. The result is a significantly extended service life of the cutting dies.



Cutting die

Using expertise and ultrashort laser pulses, we extend the service life of your dies. When will you minimize downtime and reduce costs with HAILTEC?

TECHNOLOGICAL DETAILS AND FUNCTIONING OF USP

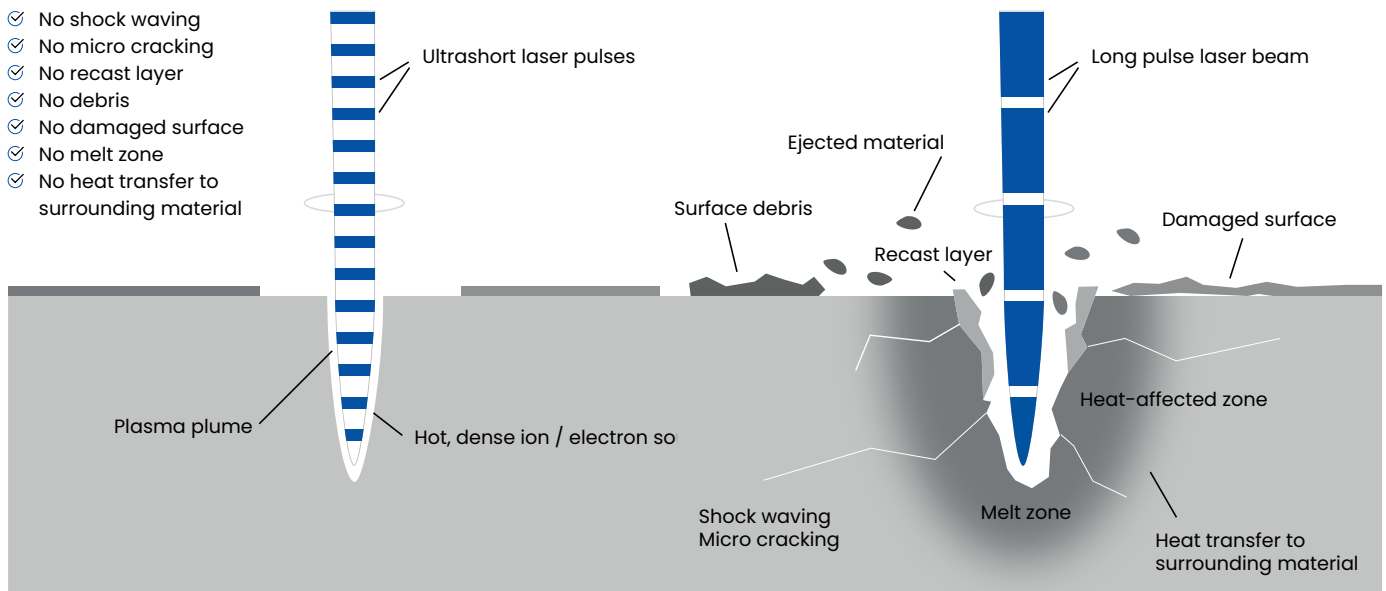
The ultrashort pulse laser offers significant advantages over conventional lasers, particularly in the precise and gentle machining of tools made from hard composite materials.



Forming and embossing tool made of hardened steel

COMPARISON TO CONVENTIONAL LASER

When using a conventional laser, also known as long-pulse laser, longer pulses lead to significant heat transfer to the surrounding material, damaging the surface and, depending on the material, causing the formation of microcracks and fragments. These thermal stresses weaken the material and can significantly reduce the service life of the processed tools.



TECHNOLOGICAL DETAILS AND FUNCTIONING OF USP

HOW DOES ULTRASHORT LASER PROCESSING WORK?

During laser ablation or cutting with the ultrashort pulse laser, laser pulses hit a component whose electrons absorb the immense energy. The electrons transfer the energy to the atomic nuclei. This results in highly precise heat localization. The material sublimates in this small zone before the surrounding material can heat up. This is why it's called «cold» laser processing.

HOW SHORT IS «ULTRASHORT»?

A femtosecond is imperceptible to the human eye and thus difficult to imagine. For comparison: A blink of an eye takes 300 to 400 milliseconds – making a femtosecond laser pulse a trillion times shorter than a human blink. Its extremely short and powerful pulses process the material faster than it can heat up. This is why the process is so gentle on materials, whether working with carbide, plastic, glass, ceramics, or semiconductors. The ultrashort pulse laser opens up unprecedented material freedom and thus new geometries.



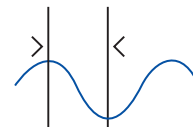
1 Second

300.000 km



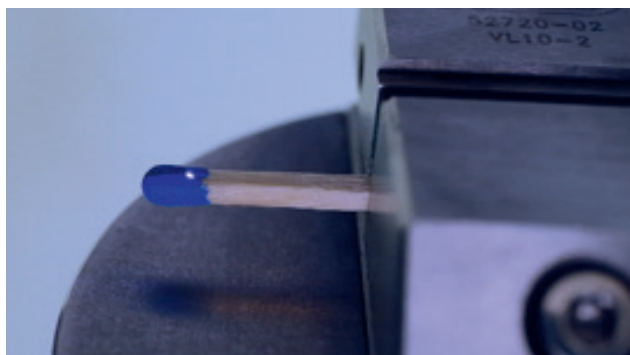
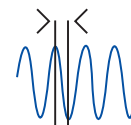
1 Pikosecond 10^{-12} s

0.3 mm



1 Femtosecond 10^{-15} s

0.3 μ m



The laser pulse is so short, we can engrave a matchhead without igniting it.

See for yourself in the video:

https://www.youtube.com/watch?v=_BeEbjAbG8

Short pulse lasers, also known as picosecond lasers, generate pulses in the range of 10^{-12} seconds. In contrast, ultrashort pulse or femtosecond lasers operate in the range of 10^{-15} seconds (femtoseconds), resulting in more precise material processing with less heat influence.

TECHNOLOGICAL DETAILS AND FUNCTIONING OF USP

At HAILTEC, we use application-specifically enhanced, automated ultrashort pulse laser systems from DMG Mori and TRUMPF – partners with whom we have been advancing the industrial application of this technology for years.

ADVANTAGES FOR CARBIDE EMBOSSING DIES

The joint test series by HAILTEC and Ceratizit Empfingen confirms the enormous potential of USP laser ablation for the economical production of embossing tools.

The most important process advantages include:

1. High-precision process simplifies process chain
2. The microstructure remains virtually unaffected, thermal cracks and other material damage are practically undetectable
3. Very short process time (no electrode production necessary)
4. Very high reproducibility
5. Surface quality up to Ra 0.1 μm
6. High-precision cavities with flank angles up to 10°
7. Internal corner radii down to 0.03 mm
8. Enables material and geometric freedom





QUALITY ASSURANCE WITH AI-MEASUREMENT TECHNOLOGY

Advanced USP laser systems are an important component, but only the complete process guarantees consistent quality. This is why we rely on digital, validated processes and offer robot integration starting from batch size 1. In-process measurements and our own measurement laboratory document the required dimensions and tolerances.

PILOT PARTNER OF BRUKER ALICONA

Due to the high demand for ultrashort pulse laser applications, HAILTEC relies on automated processes in multi-shift operation. At the same time, we maintain our commitment to 100% quality control. Until now, measurement technology often proved to be a bottleneck. As a pilot customer of Bruker Alicona, HAILTEC has supported the development of powerful, AI-supported measurement technology. With success: The automated die measurement saves enormous amounts of time.



DIGITAL TWIN

Using the target-actual comparison of Bruker Alicona's AI-supported MetMax software, we can verify precise and reliable results just as quickly as we produce them. A digital twin with measurement simulation and collision detection supports operation and intelligent measurement planning.

MILLIONS OF MEASUREMENT POINTS IN SECONDS

In embossing die production, it is crucial that there are no deviations in the forming geometry with respect to the reference point. Traditional methods reach their limits here, especially with tight tolerances in the single-digit μm range.

"For customers, comprehensive quality control means lower costs and material usage, fast and process-reliable production even of high volumes, and absolute precision."

Lars Kloker
Ultrashort Pulse Laser Processing
Application Engineer



HAILTEC

FASTER 3D MEASUREMENTS

Bruker Alicona's systems are based on the Focus-Variation principle and enable purely optical, non-destructive, traceable, and repeatable 3D measurement. The advantages of this tactile measurement technology include 3D visualization and the fact that Bruker Alicona delivers millions of measurement points in just seconds, significantly reducing measurement time.

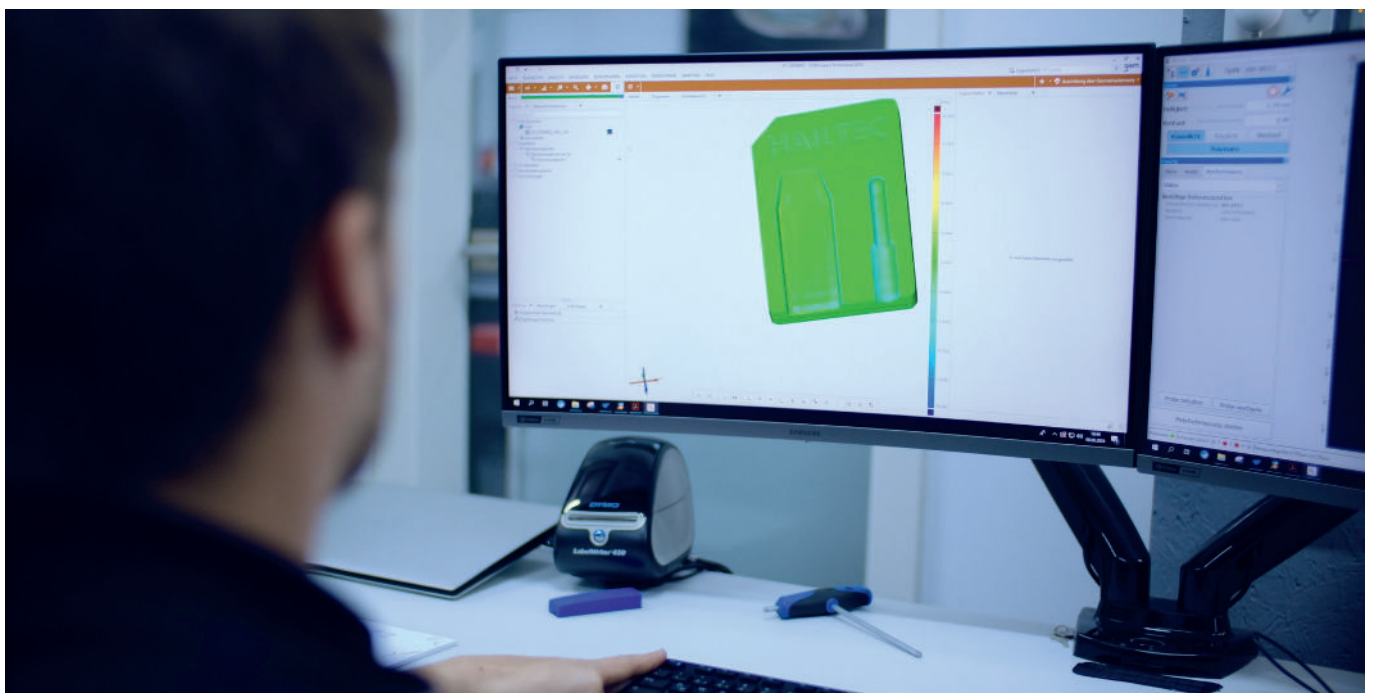
EASY QUALITY VERIFICATION

In the automated production of precision mechanical components, speed and precision are crucial. Automated measurement technology is a decisive factor here. Hailtec has achieved a level of automation that greatly simplifies measurement tasks, provides reliability, and enables optimal system utilization.

We simplify your quality assurance with automated, AI-supported measurement technology.

"The intelligent measurement technology is directly integrated into our production. This allows us to ensure quality without delay and provide clients with all relevant data"

Alexander Renz
CEO HAILTEC



3D measurement of an embossing die with false color representation of CAD deviation



QUALITY AND SERVICE

FOCUS ON ECONOMIC EFFICIENCY

Economic efficiency is at the core of our manufacturing strategy. As a specialized contract manufacturer, we have aligned our production capacities for batch sizes from one to hundreds of thousands. On highly automated production lines, optimized in collaboration with leading laser and system manufacturers, we integrate state-of-the-art measurement technology. An AI-supported in-line measuring system from Bruker Alicona enables immediate analysis of laser-processed components. This allows us at HAILTEC to execute even complex orders efficiently and precisely.



At HAILTEC, you receive your dies manufactured precisely and economically from batch size 1 to X². When urgent, also available as express service:

USP MACHINING AS 24H EXPRESS SERVICE

In emergencies, such as die breakage, HAILTEC manufactures replacements as an **express service**. Using precision systems from DMG MORI and TRUMPF, the job shop achieves manufacturing tolerances within +/- 0.005 mm.

With HAILTEC, your samples and series match exactly – thanks to validated processes and comprehensive quality controls.

Zero-defect philosophy in practice:

- In-process measurements guarantee consistent quality
- Batch traceability in ERP system
- Initial sample test report available



Facing downtime? We help immediately: As soon as your blank arrives, we manufacture your die – your courier can enjoy a coffee and take the finished part right away.

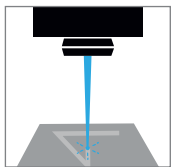


Taktils Einmessen des Werkstücks

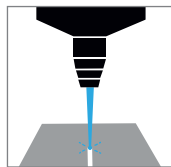
CONCLUSION AND OUTLOOK

In collaboration with research and industry partners, we continue to drive forward the industrialization of ultrashort pulse laser processing. Furthermore, we offer clients synergy effects through our unique technological range and the associated expertise.

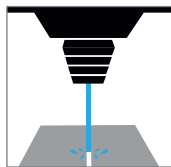
HIGH-TECH ARSENAL



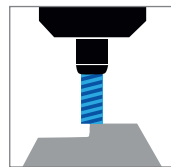
Ultra-Short Pulse
Laser Processing



Laser Fine Cutting



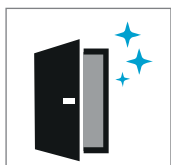
Micro Water Jet
Cutting



CNC Precision
Manufacturing



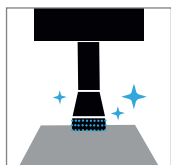
Precision Forming
Technology



Cleaning and
Cleanroom



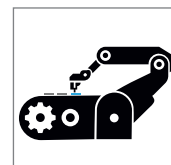
Metrology



Finishing
(Surface Finish)



Toolmaking and
Construction



Automated
Production Systems

MENTIONED PARTNER COMPANIES:

CERATIZIT Empfingen GmbH

For over 95 years, Ceratizit has been a pioneer in the field of sophisticated hard material solutions, including highly specialized cutting tools, indexable inserts, hard material rods, and wear protection parts. As a technology leader in the carbide industry, Ceratizit holds more than 1,000 patents and utility models. The hard materials specialist employs over 200 people worldwide in Research & Development and collaborates with leading universities and research centers throughout Europe. www.ceratizit.com

BRUKER ALICONA

Bruker Alicona's systems are recognized worldwide as a major export in measurement technology. Since 2019, the Styrian provider of industrial, optical measurement technology Alicona has been under the umbrella of the American Bruker Group. Founded in 2001, measuring systems are developed, produced, and distributed worldwide from the headquarters in Raaba near Graz. Over 90% are sold abroad. Based on Focus-Variation technology, Bruker Alicona's measuring systems bridge the gap between classical coordinate measurement and surface measurement technology. www.alicon.com/de

HAILTEC



HAILTEC GMBH

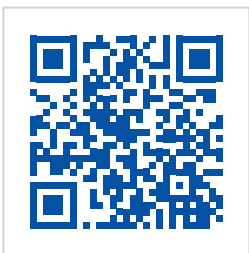
HAILTEC sees the future in new technologies and reliable partnerships. Founded in 2004 in the Swabian Alb Biosphere Region, the contract manufacturer invests in people, expertise, and high-tech. Under one roof, HAILTEC and its more than 40 employees produce precision mechanical prototypes and metal series for all those requiring intricate solutions with the highest precision. HAILTEC is certified according to DIN EN ISO 13485, DIN EN ISO 9001, and DIN EN ISO 14001.



»The material-friendly processing combined with the high precision of the ultrashort pulse laser process opens up unprecedented potential of the new technology for the fast and reproducible manufacturing of embossing and cutting tools»

Alexander Renz
CEO HAILTEC

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Read more:
USP brochure from HAILTEC