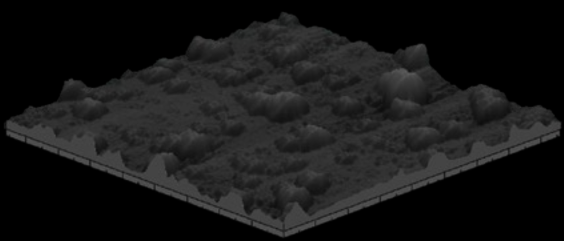
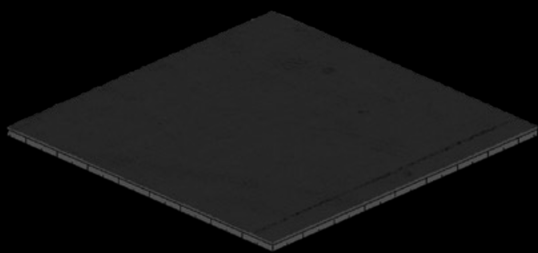
COATINGS





PLATIT® π - Series

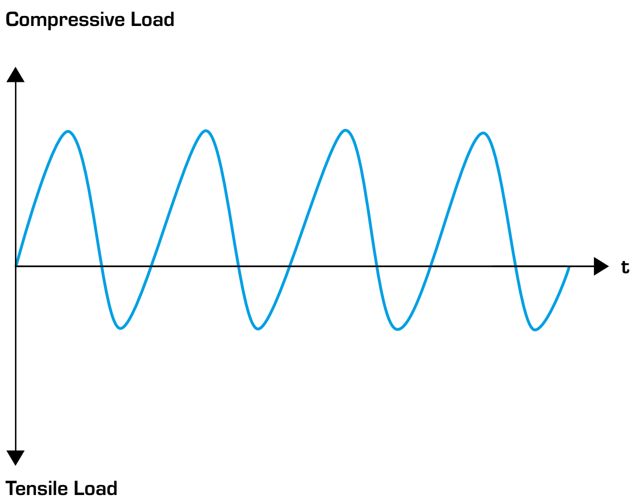
PLATIT®

Starting point

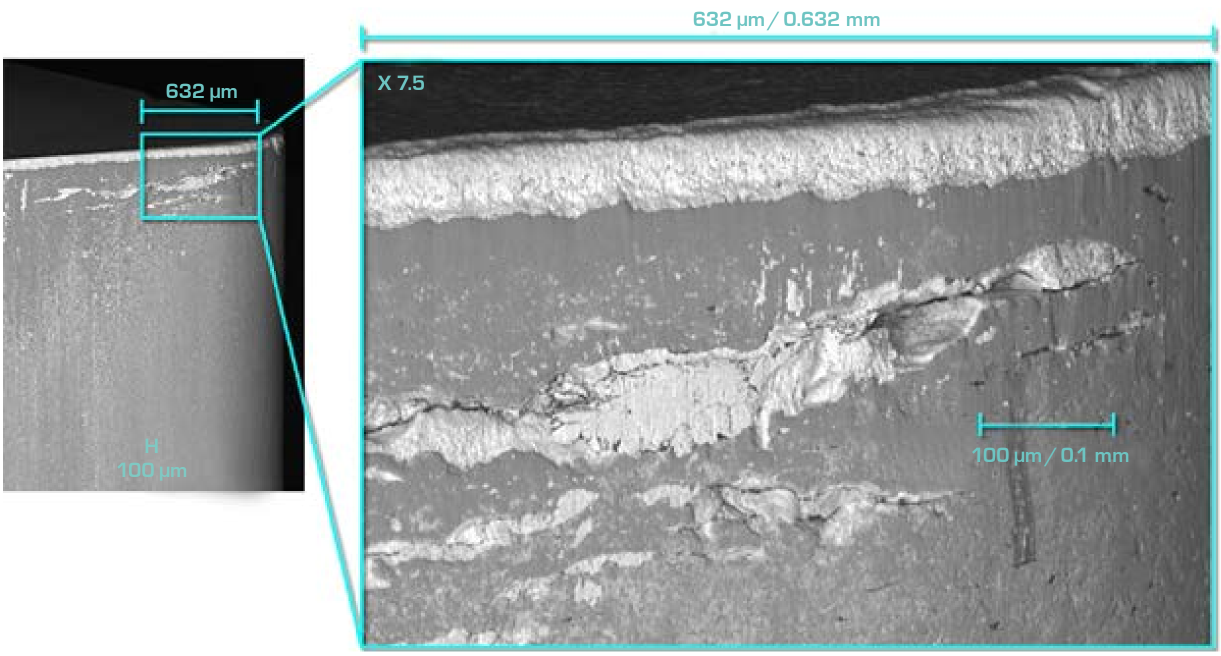
Fineblanking often places exceptionally high demands on tools and active elements (i.e. punches and die plates). Compressive and tensile loads on the cutting edges of active elements are much higher during fineblanking because the cutting gap is many times smaller than in conventional punching. Ejection of parts and / or grid removal causes tensile loads due to the friction on the lateral surfaces, while the actual cutting process causes high compressive loads. In production cycles, this leads to cyclical alternating loads on the cutting edges of active elements.

These compressive loads are close to the limit of tool steels (compressive yield point), and in some cases also beyond it, which can lead to local plastification. This process may then result in material fatigue and cracking during production.

Stress curve on the punch edge during production:



Scanning electron micrographs of a punch edge after 30,000 strokes. Fatigue cracks are visible in the area below the cutting edge:

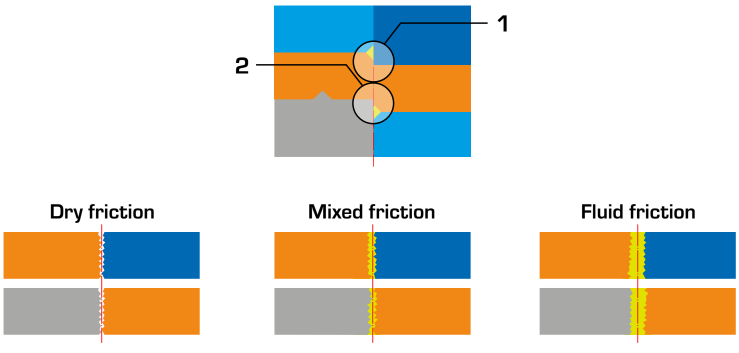


In addition to mechanical loads, increased temperatures also occur in the cutting edge area, mainly due to friction. There are indications that, depending on the thickness and strength of the punching material, temperatures exceeding 400 °C may briefly occur locally in the cutting edge areas.

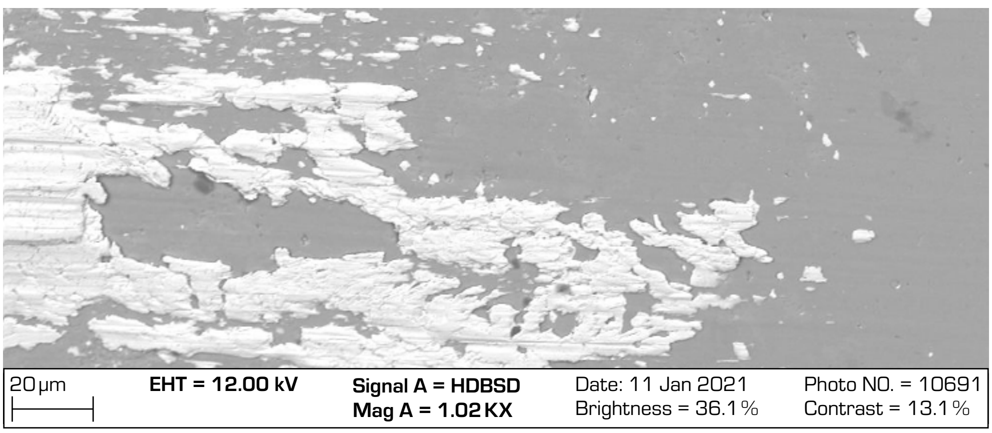
Surface finishes of active elements have a specific roughness profile due to the manufacturing process. This leads to "mixed friction" in the fineblanking process. The lubricant, which is applied to the surface of the punching material during fineblanking, is not able to completely separate the active elements from the punching material when cutting. This results in local contact between roughness peaks in the active elements and punching material.

Relative movement between the active element and punching material causes additional friction and increases in temperature. This can result in surface adhesions forming that are sheared off when the solid surfaces move relative to each other. This process is generally referred to in tribology as adhesive wear. In most cases, residues sheared from the punching material adhere to the surface of the active element. These residues in turn lead to increased friction, which continuously intensifies the wear process.

Friction states according to GfT worksheet 7:

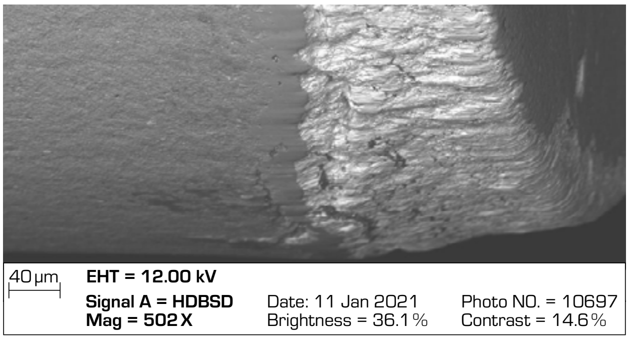


Adhesive wear phenomena on the surface of a fineblanking die:



In addition to adhesive wear, hard particles in the punching material (e.g. carbides, nitrides and impurities) lead to abrasive wear. These hard particles cause microchipping under the relative movement of active element and punching material during cutting and thus continuous removal of material from the active element surface.

Abrasive wear phenomena on the cutting edge of a fineblanking die:



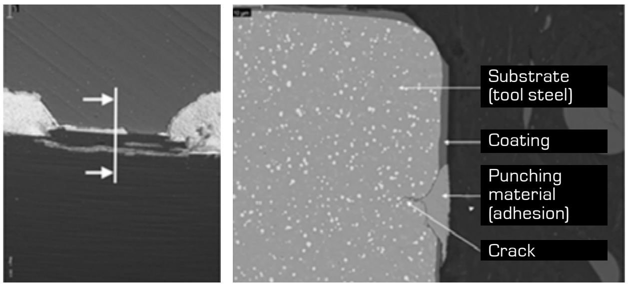
In most cases, active elements fail due to a combination of the main wear mechanisms: fatigue, adhesion and abrasion. Once a crack has started, crack propagation proceeds relatively quickly and leads to chipping of the cut edge. In brittle materials, chipping can occur over a large area. Such largescale damage usually requires immediate tool replacement or reworking.

It is assumed that crack formation in the tool coating can be considered the cause of the above failure. Punching material then adheres to the crack in the hard material layer, which leads to fatigue and crack initiation due to the resulting increased friction.

Cracking in the coating is probably due to the large differences in elasticity between the tool steel substrate and the coating. The elastic modulus of tool steel is around 230,000 MPa, while a common antiwear coating has around 500,000 MPa. The coating, which is relatively thin at around 2 µm, cannot withstand the elastic deformation of the tool steel under load and will therefore also deform. This will inevitably lead to the aforementioned cracking.

Our efforts in optimising wear patterns therefore focused mainly on homogenising the elasticity of the substrate-coating system and on the fracture behaviour of coatings.

Crack initiation due to fatigue and adhesive wear. Source: R&D project FeinAl Feintool / Platit, Dr. Marcus Morstein:



Objective

The FeinAl hard coating, with its dedicated coating design and seamless integration into a process chain consisting of pre- and post-treatment steps, has for years been setting market standards for PVD coatings for fineblanking tools. The bar was therefore set high for the further development of this already successful product.

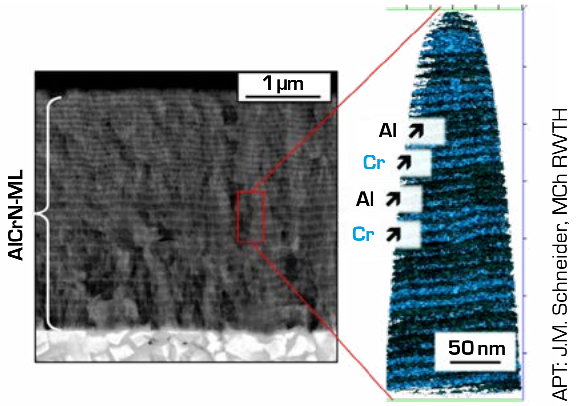
The approach for further optimisation of the coating system was based on a detailed examination of initial tool wear. The next generation of coatings for fineblanking tools needed to be even more efficient in counteracting the formation of cracks, the associated material adhesion in coating gaps and thus the risk of chipping. FeinAl's proven high abrasion resistance had to be maintained while further optimising the coating system's crack resistance.

To achieve this, two different approaches were available: Counteracting crack propagation, e.g. by increasing the residual compressive stress in the top layer of the multiple layers; preventing cracks from forming in the first place, which was the approach we took rather than further inhibiting crack propagation.

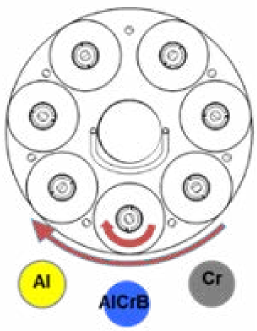
Implementation

Developing FeinAl Plus involved changing the coating composition and crystal structure of FeinAl, an AlCrN with a multilayer structure, to achieve overall lower residual stress in the coating structure. FeinAl's tried and tested multilayer structure was to be retained.

Left: SEM image showing the multi-layer structure of the hard coating. Middle: APT showing the substructure in the individual layers of the multilayer.



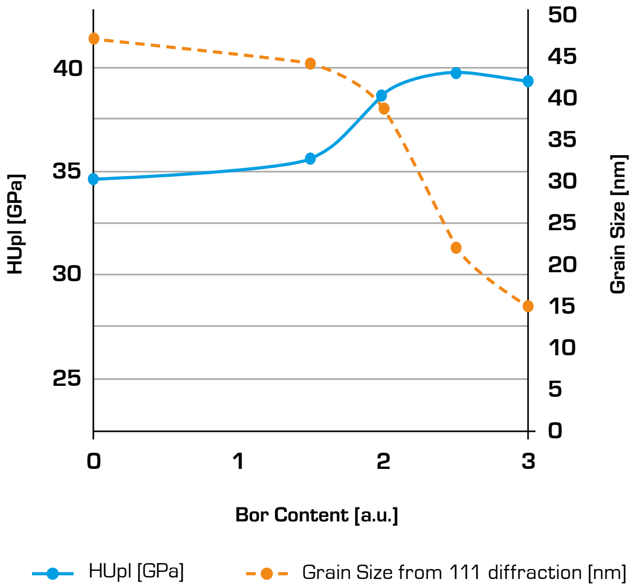
Right: Plan view of the PVD system: Nanostructure caused by rotation of the tools in the mounting along mostly metallic evaporators.



The SEM image above shows the layer structure in the micrograph, realised using arc control in the PVD system. Individual layers with different hardness and elasticity alternate over the entire layer thickness, with a periodicity of approx. 50–100 nm. As the atomic probe tomography next to it illustrates, each individual layer has a substructure. Al-rich and Cr-rich nanolayers alternate, realised by partly metallic evaporators in the coating system. These nanolayers of 5–15 nm thickness can be realised solely due to the deposition rate of the evaporators and the rotation speed in the mounting. The combination of nanolayers in the multilayer extends crack paths and thus impedes crack propagation in the coating system.

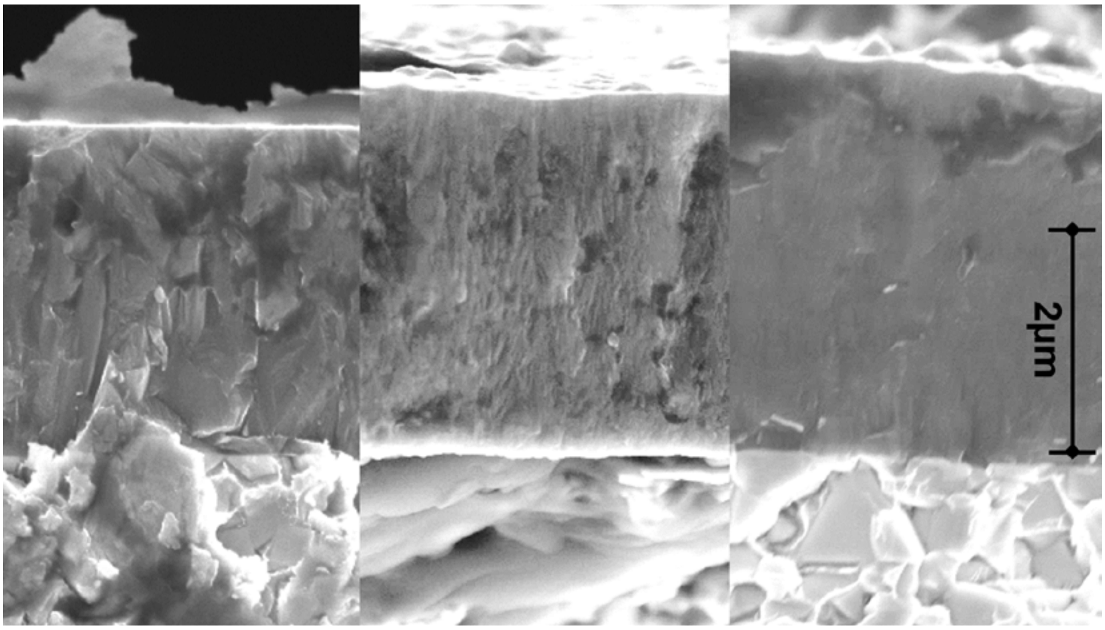
The mechanical properties of AlCr-based nitride coatings can also be very effectively influenced by adding further coating elements such as boron (Tritremmel et al. Surface & Coatings 213 (2012) 1–7). The following graph illustrates the influence of boron in AlCrBN with otherwise unchanged coating parameters.

Progression of layer hardness and grain sizes in AlCrBN with increasing boron content in the layer:



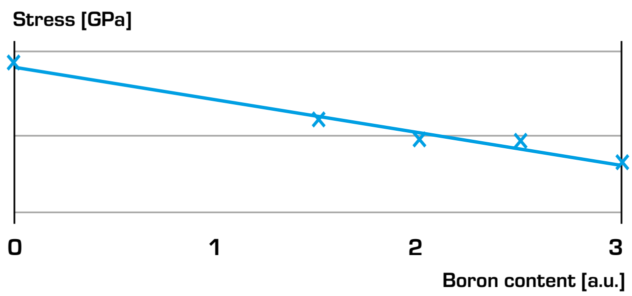
As boron content increases, layer hardness increases, with a simultaneous reduction in the structural units in the hard material layer. Crystallite grain sizes decrease from around 50 nm to around 15 nm (measured by X-ray structure analysis). This is clearly illustrated by the view of the layers in the fracture pattern. From left to right, the boron content increases, and the initially pronounced columnar layer structure becomes increasingly finer, appearing almost amorphous in the SEM image on the right.

Fracture images in SEM. From left to right: Boron content in AlCrBN increased:



However, the most interesting effect of boron in the AlCr-based layer relevant to fineblanking is the reduction in the residual stress of the layer. The addition of boron increases coating hardness by around 15 %, while virtually halving the residual compressive stress of the coating, as the following graph shows. The higher coating hardness has a positive effect on abrasion resistance. Low residual coating stress improves crack resistance.

Residual layer stress in [GPa] for AlCrBN according to boron content:



Results

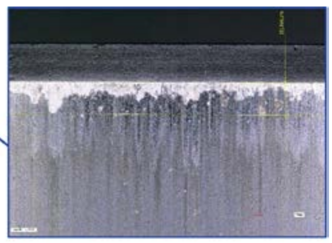
After several years of ongoing development, the project partners Feintool, Blösch and Platit can now present the next generation of coatings for fineblanking applications based on a proven concept: FeinAl Plus.

We take an example application and compare the wear behaviour of two fineblanking tools coated with a market reference product and with the new FeinAl Plus.

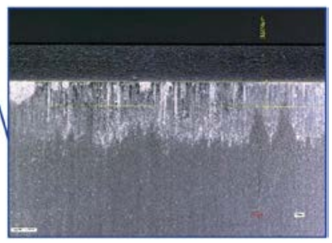
The tool type under consideration is an internal forming punch made of high-speed steel S390 with a hardness of 66 HRC. The properties of the punching material are as follows:

- Quality C60E
- Thickness 3 mm
- Tensile strength 560 MPa

Wear on inner forming punch after 23,500 strokes:



Coating: Market reference

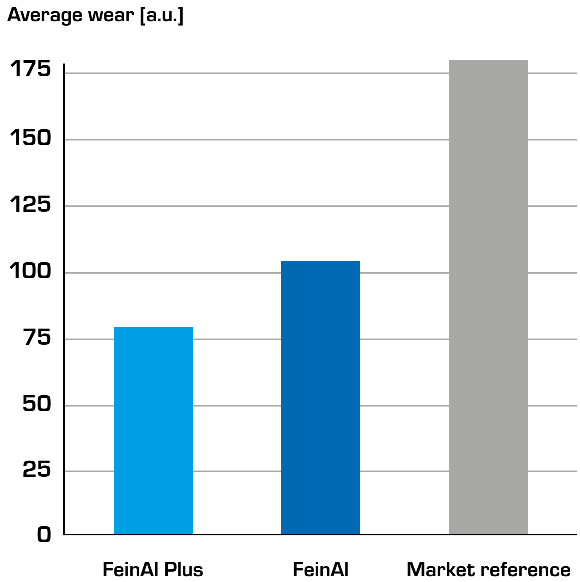


Coating: FeinAl Plus

The wear images shown above were taken after 23,500 strokes. The two microscope images show wear patterns. Compared to the market reference, a reduction in cold welds is found with FeinAl Plus. This is associated with reduced fatigue cracks and consequently less visible wear on the inner punch.

This positive effect on wear performance for FeinAl Plus was reproduced in all field tests conducted during the project. FeinAl Plus has confirmed this increase in performance, averaged over four different test series after a period of use of up to 30,000 strokes. Compared to the already proven FeinAl, FeinAl Plus can reduce wear even further and thus further increase process reliability in fineblanking.

Comparison of results:
Average measured wear on tools from four different test series after up to 30,000 strokes.



The characteristic properties of FeinAl Plus are as follows:

- PVD layer of three ARC cathodes deposited simultaneously, maintaining the crack-inhibiting multilayer structure.
- Boron added to AlCrN to increase plastic layer hardness while simultaneously decreasing residual stress in the coating system.
- Result: Less material build-up, higher crack resistance and a noticeably longer service life of fineblanking tools.
- FeinAl Plus can be optionally provided with a friction-reducing top layer for optimum run-in properties for fineblanking tools.

Acknowledgements

The authors would like to conclude by expressing their gratitude to all project partners and colleagues involved. Special mention goes to Stefan Scholl, head of hard coating at Blösch AG, for his tireless efforts.

Dr. A. Lümkemann, Platit AG
Mr. C. Maurer, Feintool Technologie AG

PLATIT AG
Headquarters
Eichholzstrasse 9
CH-2545 Selzach
info@platit.com
+ 41 32 544 62 00

PLATIT AG
Custom Coating Solutions (CCS)
Champ-Paccot 21
CH-1627 Vaulruz
info@platit.com
+41 32 544 62 00

PLATIT a.s.
Production, R&D, Service, CEC
Průmyslová 3020/3
CZ-78701 Šumperk
info@platit.com
+ 420 583 241 588

PLATIT Advanced Coating Systems (Shanghai) Co., Ltd
Sales, Service, CEC
No. 161 Rijing Road (Shanghai) PFTZ
CN-200131 Pudong Shanghai
china@platit.com
+ 86 2158 6739 76

PLATIT Inc.
Sales, Service, CEC
1840 Industrial Drive, Suite 220
Libertyville, IL 60048, US
usa@platit.com
+ 1 847 680 5270
Fax: + 1 847 680 5271

PLATIT Scandinavia ApS
Sales
Rabalderstraede 7
DK-4000 Roskilde
scandinavia@platit.com
+ 45 46 74 02 38

PLATIT®
Advanced Coating Systems
SWISS QUALITY