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Series 11 Equipment with Four Coating Generations

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PLATIT AG, Selzach, Switzerland

Systematically developed coating equipment and coating spectra enable optimal selection of machines and layers.

Why the coating equipment and the coatings should be designed systematically? So that both small and large users can easily make the optimal choice for their production.

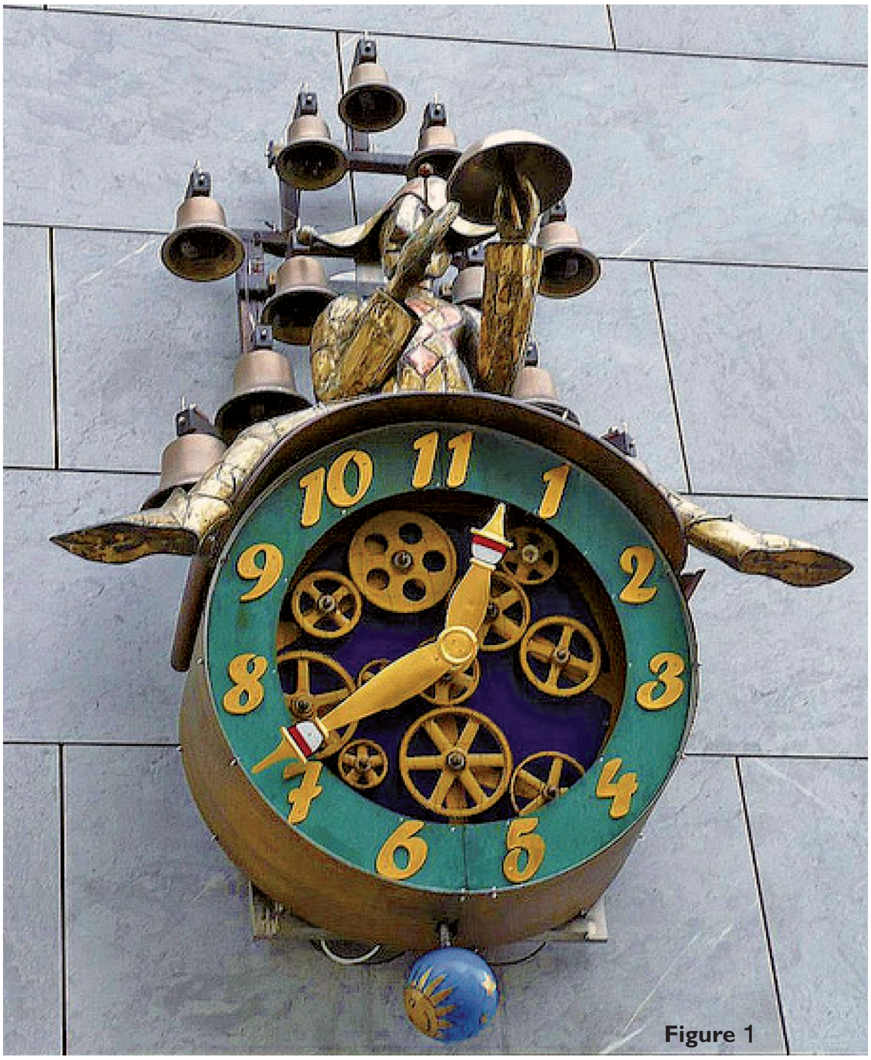


Figure 1

In the last 20 years, PLATIT has installed over 360 coating equipment, mainly as a basis for turnkey coating systems (**Figure 11**). In the last 4 years, machines of the 11 series have formed the backbone of these systems. They permit deposition of 4 coating generations. The article gives an overview of the machine series and its coating generations.

1. The 11 series of coating equipment

Why Series 11? PLATIT's parent company (Blösch) and headquarters work in the canton Solothurn, in northwest Switzerland. The most beautiful baroque city in Switzerland has strong ties to the "magic number 11". Here, for example, there are 11 museums, 11 fountains, 11 chapels, 11 churches and even a clock that shows only 11 hours (**Figure 1**).

All machines of the 11 series work with rotating cathodes, which meanwhile are employed by more than 130 users in 37 countries [1].

1.1 π111

The π111 is used especially in smaller companies, e.g. by tool grinders, but also in large coating centers as a flexible quick-reaction system. It was 4 years ago, in 2009, when the successor to the famous π80 was shipped for the first time. Its significant improvements compared to the π80 are primarily:

- The larger vacuum chamber, which provides 30% to 50% higher loading capacity with excellent coating thickness distribution,
- The higher load ability by a new drive system for heavier substrates (150 kg instead of 50 kg),
- Completely digital data transfer via Profibus, and above all
- The LGD® (LARC glow discharge), the new, stronger etching, through which an excellent coating adhesion can be achieved even with complicated, hidden surfaces (e.g. hob cutters, molds and dies etc.).
- The Nanocomposites are experiencing a renaissance due to these better "boundary conditions", even in smaller coating operations.

1.2 π211

The π211 will be introduced at the EMO 2013 as a worldwide innovation for dedicated deposition of hydrogen-free DLC coatings (ta-C coatings).

- It uses the chassis and chamber of the π111.
- It works mostly with a metallic (Cr, Ti) and a graphite cathode.
- For particle filtering, we developed a revolutionary new method and hardware πsCOAT® (π smooth Coating). The particles are guided through a straight-forward filter, which is pulsed controlled and saves space without the well-known “knee filtering” (90° filter).

The DLC coatings thus deposited have

- very high hardness (>60 GPa),
- low friction values (μ<0.1 measured against 100Cr6 steel).
- They are primarily used for coating components with high mechanical loads and for cutting of materials tending to form built-up edges (e.g. soft Al alloys).

Due to their very economical deposition, carbide tools with DLC coatings of the π211 series can be an alternative to expensive PCD- and CVD-diamond coated tools. This may be mainly valid for small- and medium-series production.

1.3 π311

The π311 was introduced 3 years ago in 2010 as a further development of the π300. It is the coating unit of choice for small and medium-sized operations.

- A central CERC® (central rotating cathode) and three lateral LARC® (lateral rotating cathodes) permit production of 30 coatings by software without any change of cathodes.
- This machine is the mother of the TripleCoatings^{3}®, which are used and imitated more and more.
- The π311-ECO, with only 3 LARC® cathodes, offers an economical entrance into the world of TripleCoatings^{3}®. But the lack of the central “booster” slows down the processes.

1.4 π411

The π411 was introduced at the AMB 2012. As a high-performance machine, it quickly finds its way into the coating centers of medium-sized and larger tool manufacturers and job coaters shortly after its introduction.

- The CERC- and three LARC-cathodes, which work simultaneously, are operated with high performance, enabling process times down to 3.5 hours.
- The QuadCoating^{4}® developed with its help contain an additional layer or feature compared to triple coatings.
- Instead of the CERC-cathode, a SCiL®-cathode (Sputtered Coating induced by LGD) can be employed. It permits production of (almost) droplet-free layers, which today are mainly used for coating of tools for threading.

Interim conclusion for Series 11 coating equipment

The Series 11 offers all users the corresponding capacity.

- The minimum is at ~250 tools, (one batch per day with the π111),
- The maximum is at ~3000 tools (six batches per day with the π411).
- Calculated for d × L =10 × 70 mm end mill cutter [1].

2. The 4 generations of coatings

Four generations of PVD coatings can be produced with the 11-Series systems. These include all coatings available in the market and much more (**Figure 2**).

2.1 Coatings of the 1st generation

The coatings of the 1st generation are monoblock coatings without any adhesion layer.

- Its most important advantage is the high productivity in deposition (and

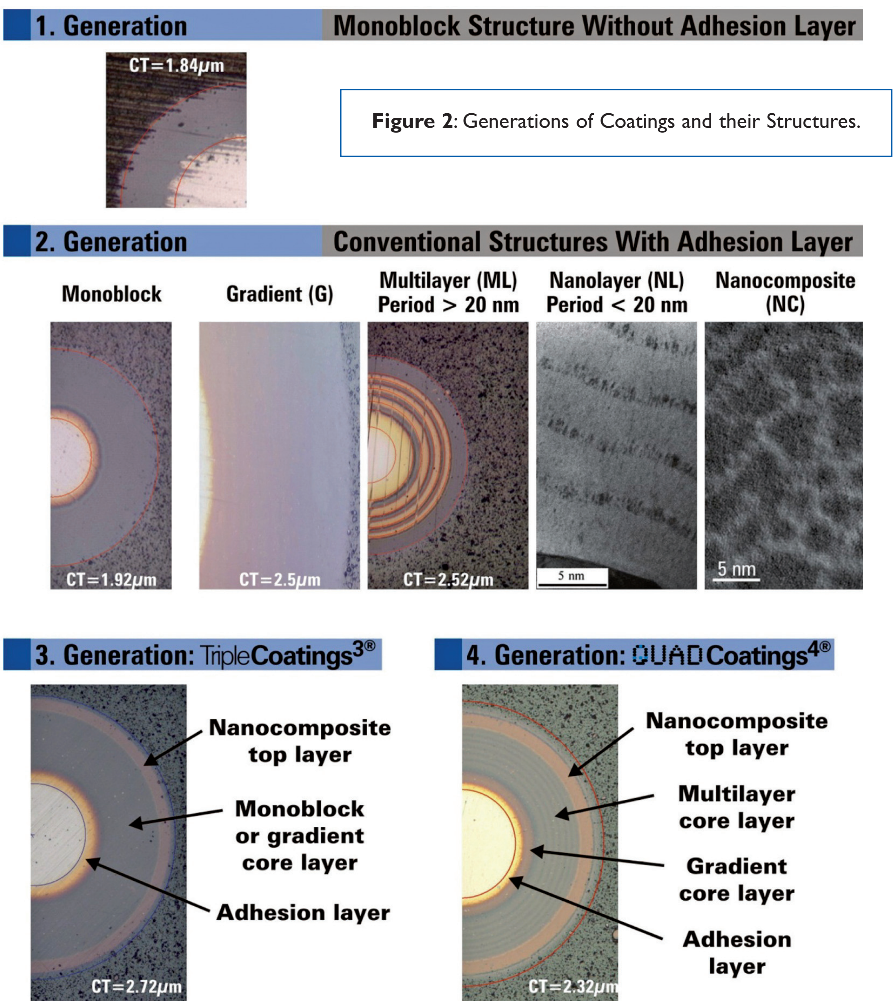
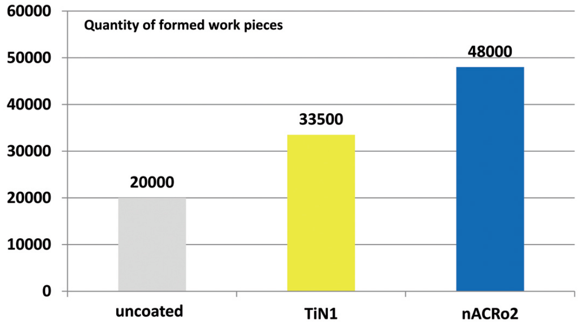


Figure 2: Generations of Coatings and their Structures.

	Coating's Applications and their Main Characteristics		Coating Equipment of the 11 Series and their Coatings				
		"Parent" coatings	Pi111	Pi211	PI311-ECO	Pi311	Pi411
		Nitride					
1	Universal, also for decorative purposes, classical basic coating	TiN	TiN^1	TiN^1	TiN^1	TiN^1	TiN^1
2	Tapping and punching, classical basic coating based on TiN with carbon, high hardness. low friction coefficient , low heat resistance	TiCN-grey	$TiCN^2$-grey		$TiCN^2$-grey	$TiCN^2$-grey	$TiCN^2$-grey
3	Universal, especially for drilling, coating for cutting with HSS in the 90's, high heat resistance	TiAlN	$TiAlN^2$-ML		$TiAlN^2$-ML	$TiAlN^2$-ML	$TiAlN^2$-ML
4	Universal; for drilling, milling, hobbing, dry machining, coating for cutting with carbide in the 90's, with higher Al content and heat resistance	AlTiN	$AlTiN^2$		$AlTiN^2$	$AlTiN^2$	$AlTiN^2$
5	Molds, dies and components, for cutting wood, light metals, main basic coating for forming	CrN	CrN^1	CrN^1	CrN^1	CrN^1	CrN^1
6	Molds, dies and components, for cutting wood, light metals, improved CrN, combined with TiN as nanolayers	CrTiN	$CrTiN^2$-ML		$CrTiN^2$-ML	$CrTiN^2$-ML	$CrTiN^2$-ML
7	Minimizing build up edges at cutting light metals, also decorative purposes	ZrN	ZrN^2		ZrN^2	ZrN^2	ZrN^2
8	Milling and hobbing, mostly for dry machining, industrial star coating in the 00's, with high abrasive resistance	AlCrN	$AlCrN^3$		$AlCrN^3$	$AlCrN^3$	$AlCrN^3$
9	Dry and wet milling, hobbing, tapping, drilling, also for forming, more universal than AlCrN because of Ti	AlTiCrN			$AlTiCrN^3$	$AlTiCrN^3$	$AlTiCrN^4$
10	Universal, especially for drilling, reaming and turning, also for inserts, extended AlTiN with SiN based Nanocomposites	nACo	nACo®[2]		nACo®[3]	nACo®[3]	nACo®[4]
11	Cutting superalloys, for dry and wet milling, hobbing, punching, fine blanking, injection forming, AlCrN with SiN based Nanocomposites	nACRo	nACRo®[2]		nACRo®[2]	nACRo®[3]	nACRo®[4]
12	Hard milling and drilling, Nanocomposites with high Si content	TiXCo			TiXCo®[3]	TiXCo®[3]	TiXCo®[4]
		Oxi-Nitride					
13	Dry HSC turning and milling, especially for inserts, oxide coating with high heat resistance	nACoX				nACoX®[4]	nACoX®[4]
		DLC					
14	For wear components, very smooth Diamond Like Coating without nitride basis	Vlc	Vlc®[2]	Vlc®[3]	Vlc®[2]	Vlc®[2]	
15	For mold and dies at forming and for wear components, for cutting light metals without build up edge, DLC with TiN basis without Si	cViC	cViC®[1]	cViC®[3]	cViC®[1]	cViC®[1]	
16	For mold and dies at forming and for wear components, for cutting light metals without build up edge, DLC with CrN basis	CROMVlc	CROMVlc®[2]	CROMVlc®[3]	CROMVlc®[2]	CROMVlc®[2]	
17	For mold and dies at forming and for wear components, for cutting light metals without build up edge, DLC with CrTiN basis with Si	CROMTIVlc	CROMTIVlc®[2]		CROMTIVlc®[2]	CROMTIVlc®[2]	
18	For forming and punching, for cutting of high alloyed materials, nACRo with DLC top layer	nACVlc	nACVlc®[2]		nACVlc®[2]	nACVlc®[2]	
		SCiL®					
19	For tapping, sputtered coating	TiN-SCIL					TiN^1-SCiL®
20	For tapping of high alloyed materials, sputtered coating with low friction coefficient	TiCN-SCIL					$TiCN^1$-SCiL®

Figure 3: Standard Coatings of the Series 11 and their Applications.



Work piece material: 20G2P – Rm= 430-470 n/mm2
Tool-(stamp)-material: HSS - P6M5
Source: Technopolice, Moscow, Russia

Figure 4: Forming (Stamping) with Coatings of the 1st und 2nd Generation.

the related highest profit for the coater). All targets are the same and can be used during the entire process.

- Its most important disadvantage is the missing adhesion layer and the sub-optimal adhesion this entails. (If not the basic monoblock coatings TiN or CrN.)
- The coatings of the 1st generation are possible in all systems.
- PLATIT deposits the coatings of the 1st generation only for TiN and CrN.
- The most important application areas of the 1st generation coatings are HSS cutting and forming tools as well as simple components.

2.2 Coatings of the 2nd generation

The coatings of the 2nd generation have an adhesion layer and various structures for the functional layer.

- All monoblock coatings of the 2nd generation start with an adhesion layer (with Ti or Cr).
- Among gradient coatings, the share of the second component (Zr, C, Al, etc.) is increased "continuously" (gradiently), normally to increase the hardness and/or temperature resistance of the coating toward the surface.
- Multilayers have a higher toughness thanks to the sandwich effect.
- Nanolayers can be harder than multilayers if the nanolayer period is correctly selected and deposited [1].
- Nanocomposites are super-hard layers with a fine structure. The hard grains (e.g. AlCrN) are embedded in an amorphous matrix (e.g. of Si3N4). The matrix prevents growth of the grains and thus increases the hardness of the coating [2].
- Approx. 60% of the coatings used today belong to the 2nd generation.

2.3 Coatings of the 3rd generation

The TripleCoatings3® ([3]) introduced by PLATIT in 2007 are combinations of the individual structures, where they can exercise their optimal effect.

- The first layer (TiN or CrN) ensures the most important criterion of a layer, adhesion.
- The medium core layer is responsible for the good durability of the coating.
- The purpose of the top layer is to achieve good wear resistance with a high degree of hardness.

2.4 Coatings of the 4th generation

PLATIT deposited the QuadCoatings4® [4] for the first time in 2012 in the π411 and brought them to industrial use. The quad layers have an additional layer, such as:

- a double core portion for higher toughness for hobbing,
- an oxide layer for thermal insulation at HSC and dry processing or
- a type of lubrication layer (e.g. CrCN) for reduction of the friction coefficients for forming tools.

3. Applications of the coating generations

How does the optimal coating spectrum look for a machine series with different capacities and, accordingly, with different users?

In such a way that the smallest and the medium-sized as well as the large-scale user can cover their machining needs. In doing so,

- the same selection criteria and coating assignments should apply for small and large, but
- it should also be possible to make use of the higher performance and broader options of the larger systems.

PLATIT solves this balancing act with the systematic help of the parent layers and their 4 generations (**Figure 3**).

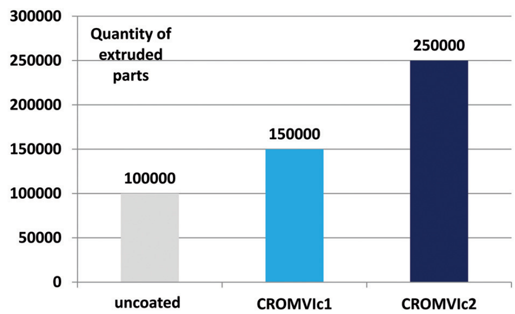
The "parent layers" are at the centre of the table.

- The application areas to the left depend primarily on the physical characteristics of the base materials of the coating, which are defined by the parent layer.

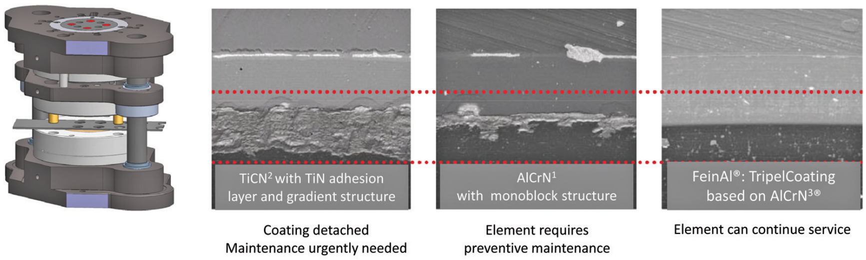
Figure 5: Extrusion with DLC Coatings of the 1st and 2nd Generation

Extruded aluminium parts

DLC coated tools for extrusion



Source: Coexal, Leinatal, Germany



Source: Feintool, Liss, Switzerland

Figure 6: Fine Blanking with Coatings of the 1st, 2nd and 3rd Generation - Comparative Analysis (SEM) after 30'000 Strokes.

– Which coating structures (which generation of the parent layer) are preferably deposited in the individual coating systems are recorded in the right half of the table.

Through this, all users see which coating they can or should apply for the respective use in their coating equipment.

– All four generations are represented in **Figure 7**. The most suitable QuadCoating4® for this drilling operation, TiXCo4®, has a very high silicon content in its top coating.

– The e-beam coatings of the 1st and 2nd generation still have a monopoly in thread production. A new QuadCoating4®, AlTiCrN4®-Tribo, with all three main elements of today's PVD coatings (Ti, Al and Cr) and an additional lubricant coating, intends to break this monopoly (**Figure 8**) [5].

– Coating of hob cutters is a very complex task. The entire process - coating removal, regrinding, cutting edge preparation and coating – must have been optimized so that the coatings of the 3nd and 4th generation can achieve the good results (**Figure 9**) [6].

– Due to the high heat resistance, oxide coatings are recommended mainly for cutting inserts for dry HSC turning. The dedicated coating, NanomoldGold, was developed based on the QuadCoating4®, nACoX4®. It is establishing itself more and more for milling inserts as well (**Figure 10**).

4. Outlook

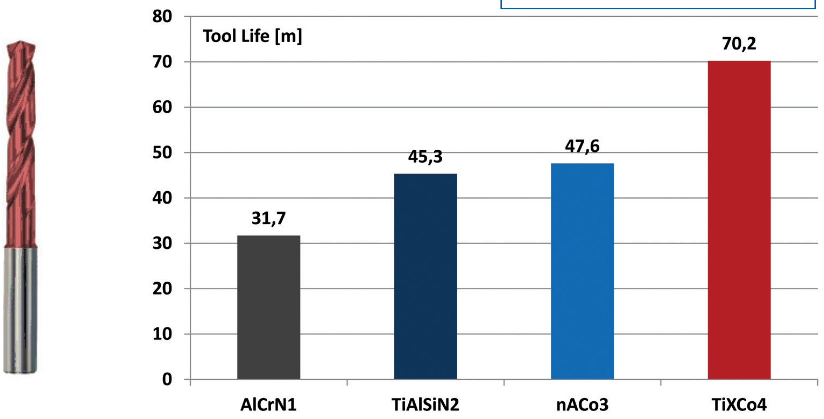
There is a great deal of movement in the coating industry [7].

– On the one hand, large corporations bought up several smaller coating unit manufacturers and coaters last year. Competition in job coating has been increasing and is pushing prices downward.

– On the other hand, large job coaters want to raise their revenue by performing regrinding themselves.

This is definitely a concern for medium-sized tool manufacturers and regrinders. As a result, their resistance toward integration of coating into their own production is clearly falling.

Figure 7: Drilling in High Strength Steel with 4 Generations of Coatings.

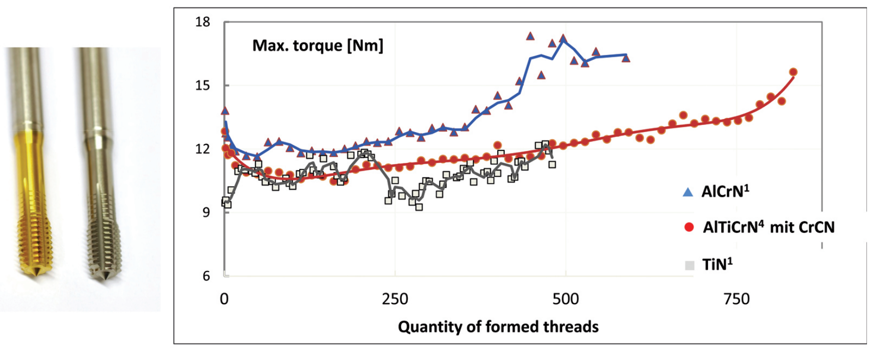


Work piece material: X155CrVMo12 - 1.2379 – Rm=1150 N/mm2 – Coolant emulsion 7%
Tool: solid carbide drill: Ø 6.8 mm; Edge preparation: 50 µm – Coating thickness: 3 µm
vc=70 m/min – f=0.16mm/rev - ap=15 mm – Tested at GFE, Schmalkalden, Germany

The **Figures 4 – 10** show typical application examples for how the coating performance can be improved through the higher generations.

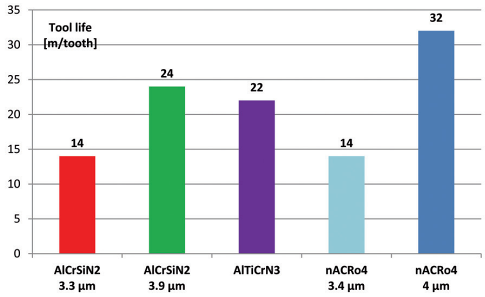
– **Figure 4 and Figure 5** present performance comparisons for non-cutting forming tools coated with 1st and 2nd generation coatings.

– **Figure 6** compares the wear characteristics of fine blanking tools coated with 1st, 2nd and 3rd generation coatings. The special core of the TripleCoating3®, AlCrN3®, is the basis for the good performance of the dedicated coating FeinAl®.



Work piece material: 40CrMnMo7 - Rm= 945 N/mm2
Tool: M8-6HX-InnoForm1-Z - HSSE 23/1 – Core hole: Ø7.4 mm
vc= 20 m/min - ap=1.5xd, MQL – Minimum lubrication – Tested at GFE, Schmalkalden, Germany

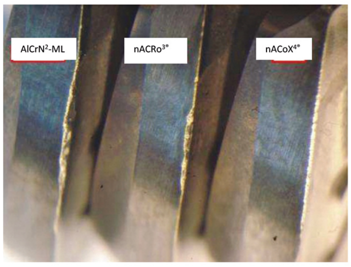
Figure 8: Fluteless Tapping in High Alloyed Steel by QuadCoatings with Lubricating Toplayer in Comparison to Reference Coatings.

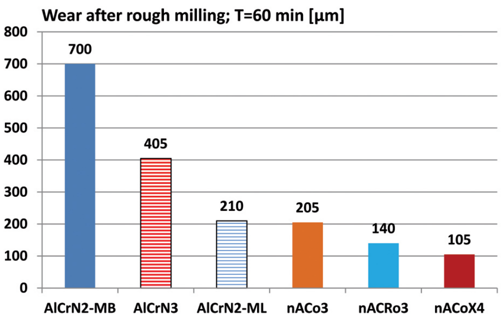


Gear material: 20MnCrB5 – m=2.7
Tool material: PM-HSS – vc=220 m/min - fa=3.6/work piece rev. – dry
Source: University Magdeburg, Germany

Figure 9: Hobbing with Coatings of the 2nd, 3rd and 4th Generation.

The hard competitive fight is pushing forward the development of the already innovative coaters. For that reason, the 5th coating generation is only a matter of time. It will perhaps not be characterized by a 5th layer, but by another additional feature. We are certainly curious.





Tools: Ball inserts - D=16mm
Work piece material: Cold working steel: 1.2379 – Rm=1000 N/mm2
vc=240 m/min – fz=0.4mm – ap=1.5mm ae=1mm – Coolant: internal air
Source: Insert manufacturer, Germany

Figure 10: Mold Milling with Coatings of the 2nd, 3rd and 4th Generation.

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Turnkey Coating System with the Equipment of the 11 Series

PLATIT®

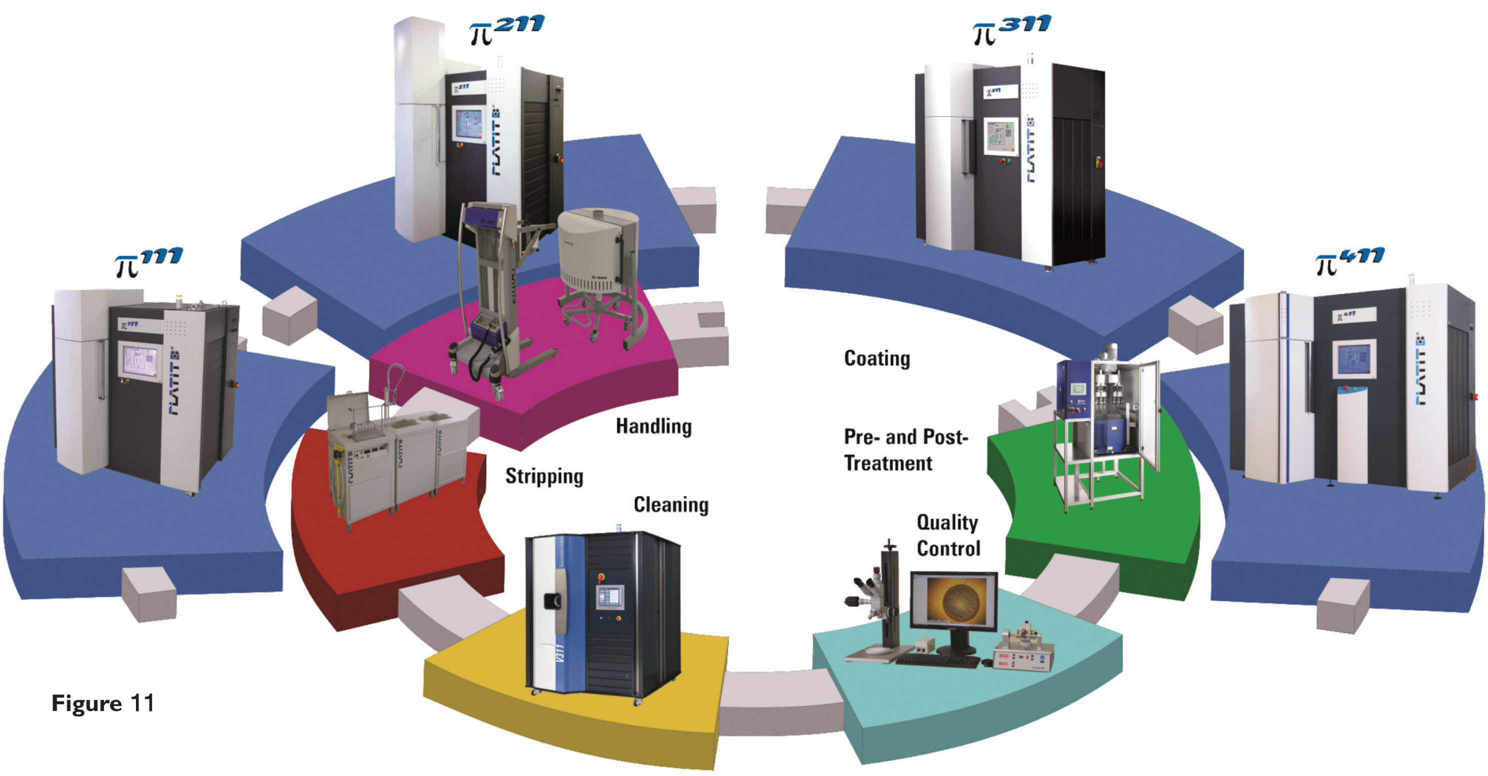

Figure 11

Two New Machines at the EMO 2013 from PLATIT's 11 Series

DLC

QUADCoatings$^{4®}$

π211

π411

Dedicated Coating Unit for DLC^3 (ta-C) Coatings with πsCOAT® Technology

2 × LARC® (LAteral Rotating Cathodes)

- Cr or Ti for basic layer
- Graphite for ta-C layer
- πsCOAT® straight forward ARC filtering
- Configurations for nitride coatings in development

DLC^3 coatings: VIc$^{3®}$, cVIc$^{3®}$, CROMVic$^{3®}$

- extremly high hardness >60 GPa
- low roughness and friction values
- for machine components
- for cutting wood and light metals
  - especially aluminium with low built edges

The High Performance Coating Unit

4 cathodes run simultaneously

- 3×LARC® 1×CERC® (CEntral Rotating Cathode)
  - high deposition rate; up to 6 batches / day
- LGD® (LARC® Glow Discharge) etching
  - for optimal adhesion
- OXI, DLC, SCiL® options
  └→ Sputtered Coatings induced by LGD
- All conventional coatings like TiN, TiCN, AlTiN, AlCrN, TiB$_2$
- All TripleCoatings$^{3®}$
- QuadCoatings$^{4®}$
  - nACo$^{4®}$, nACRo$^{4®}$, TiXCo$^{4®}$, nACoX$^{4®}$, AlTiCrN$^{4®}$, AlTiCrN$^{4®}$-Tribo, TiBN$^{4®}$