TOOLOX®

PREHARDENED TOOL & MACHINE STEEL

SURFACE ENGINEERING OF Q&T TOOL STEEL

SSAB OXELÖSUND

1. Introduction

When special properties are requested on a steel surface a large variety of solutions are available to establish such properties. Methods to create tailor-made surfaces will hereafter be regarded as different kinds of surface engineering. This overview describes some methods which are divided into four main groups:

- Surface hardening (induction hardening, laser hardening, nitriding etc…)
- Surface coating (CVD- and PVD-coating resp.)
- Polishing
- Etching/texturing.

Surface engineering is utilized pertaining to:

- Increase the component/mould/die surface abrasive wear resistance
- Increase the component/mould/die surface adhesive wear resistance, i.e to reduce the galling risk
- Increase the component/mould/die corrosion resistance
- Create mould/die conditions which give the correct surface aimed for at the finished component manufactured in the mould/die.

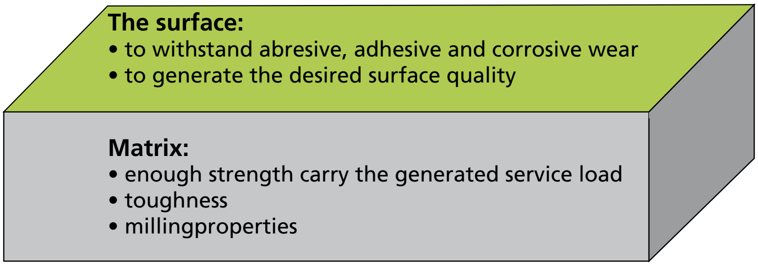

Figure 1.
The description given in Figure 1 summarizes the demands put on a component/mould/die made in TOOLOX.

The steel must have enough strength and toughness to carry the generated service load. It shall also possess milling properties enabling it to be machined into the desired shape. Furthermore, it shall also give the component/mould/die the surface properties which are required in the actual application.

TOOLOX is very well suited to different surface engineering methods, but as it is delivered in quenched & tempered (Q&T) condition from SSAB there is a limitation of surface engineering methods possible to use. This limitation is very simple and easy to remember:

- Almost any method which is carried out at temperatures below 590°C can be used!

Surface engineering methods which require temperatures above 590°C will destroy the properties given to TOOLOX in the various production steps at SSAB. If TOOLOX is heated to temperatures above 590°C no responsibility will be taken by SSAB for the steel and its function!

Attention must also be paid to whether hydrogen charging of the steel matrix is likely to occur with the actual surface engineering method used. If such charging occurs is the method not suitable for TOOLOX. An example is Q&T steel which shall not be subject to hot-dip-galvanizing as it embrittles (hydrogen charges) the steel matrix!

In applications which require extra high surface hardnesses can surface engineered TOOLOX be a more powerful solution than traditional tool steel heat treated to equal hardnesses. The explanation is that the component/mould/die steel matrix toughness is often forgotten and attention is only paid to the hardness. Depending on load conditions, constructive geometry etc. certain steel matrix toughness is required to avoid failure/breakdown of the component/mould/die during service. Figure 2 shows typical hardness and toughness levels in tool steel.

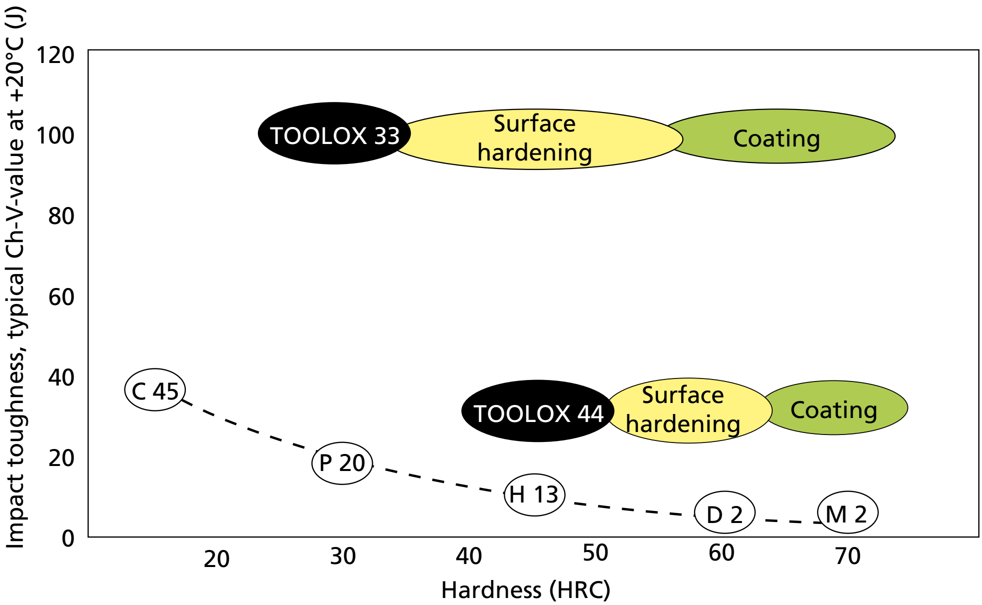

Figure 2.
Typical tool steel hardnesses and toughnesses

Figure 3 shows a die which was originally made in W.Nr 1.2379 (D2) Q&T to 58/60 HRC. This die often collapsed due to too low steel matrix toughness. The red arrow indicates one of the four areas where cracking generally occurred. Surface engineered (nitrided) TOOLOX 44 was chosen instead of the original tool steel choice pertaining to create a die with improved matrix toughness. This resulted in 1.5-2 times longer service life of the die. The steel subject to surface engineering must possess high enough toughness to have a crack arresting capability if cracks occur in the surface engineered layer! Traditional tool steel generally show low toughness values, see Figure 2, which makes them not so suitable for surface engineering. TOOLOX has, as earlier pointed out in Figure 2, much higher toughness and thereby better crack arresting capability when compared with traditional tool steel of similar hardness.

Figure 3.
Die geometry and component produced. The red arrow shows where cracks in the die manufactured in W.Nr 1.2379 normally occurred.

2. Surface hardening/coating

2.1 General

Steel surface hardening/coating processes can be divided into two major groups:

1. Methods where the component/mould/die is subject to temperatures above the steel tempering temperature.
2. Methods operating at temperatures below the actual steel tempering temperature.

These are schematically shown in Figure 4. TOOLOX is not recommended to be subject to surface engineering methods indicated in the red sector of Figure 4. However, utilizing methods in the green sector in this figure are possible to use.

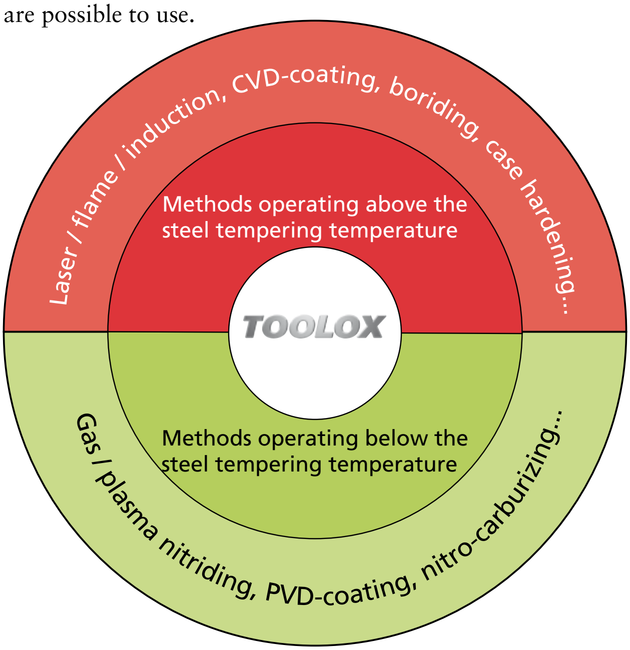

Figure 4
Schematic illustration of surface engineering methods.

2.2 Surface hardening using methods operating at temperatures above the steel tempering temperature

When using hardening methods such as laser/flame/induction hardening, QT-methods, the hardness in and the depth of the hardened layer depend on several factors such as:

- The heating rate to the austenitizing temperature
- The soaking time when the austenitizing temperature is achieved
- The quenching speed
- The steel chemical composition.

Regarding the steel chemical composition, carbon has the largest influence on the re-hardened layer hardness. This layer is also commonly very brittle and may easily crack in service.

When applying QT-methods an intermediate zone is also generated between the re-hardened layer and the un-affected matrix respectively, which has different properties when compared with the re-hardened layer and the matrix. How this zone may influence the function of a mould/die must be judged from case to case. No general recommendation or rule-of-thumb can be given. Generally, use of QT-methods is not recommended for TOOLOX as a hard and also brittle surface layer is then generated. The cracking risk in the re-hardened zone must also be taken into consideration.

Laser hardening tests have been carried out by one customer on both TOOLOX grades. They obtained surface hardnesses around 500 $HV_{0.3}$ in TOOLOX 33 and approximately 580 $HV_{0.3}$ in TOOLOX 44. In their tests they also noted TOOLOX to show much lower distortion after the laser hardening when compared with the traditional tool steel also used in the test.

Another company report, when using laser hardening, hardnesses of 51 HRC in TOOLOX 33 and 56 HRC in TOOLOX 44. The hardening depths were between 1 and 1.25 mm.

to summarize: TOOLOX should not be subject to re-austenitizing surface hardening methods due to the uncertainty of the obtained results. When higher surface hardness is requested methods such as nitriding, PVD-coating etc. are recommended.

2.3 Non re-austenitizing hardening methods

Pertaining to avoid the drawbacks related to QT-methods when surface hardening steel a variety of techniques have been developed such as:

- Gas nitriding
- Plasma nitriding
- Nitro-carburizing.

The basic idea of these methods is to use substrate temperatures operating below common steel tempering temperatures. The most used ones are summarized as follow:

- Gas nitriding, is commonly carried out at temperatures between 500-590°C. The steel sample to be nitrided is kept in an ammonia atmosphere. Ammonia decomposes at the steel surface where-after nitrogen diffuses into the steel matrix.
- Plasma nitriding, is carried out in an evacuated chamber where the steel sample acts as cathode and is sputtered with nitrogen ions. During sputtering is also a surface cleaning achieved.
- Nitro-carburizing, is usually carried out in a salt bath at temperatures around 540-580°C. The salt bath generally consists of a mixture of alkali-cyanide and alkali-carbonate.

TOOLOX is very well suited for hardening methods, shown in the green sector in Figure 4. Attention must however be paid to the nitro-carburizing method to ensure that no hydrogen charging of the steel matrix occurs. An extensive study of surface hardening of TOOLOX has been carried out with the result given in Table 1.

Grade	Hardening method	Temp. (°C)	Soaking time (hrs)	Surface hardness (HV_1)	Hardening depth (mm)
TOOLOX 33	Nitro-carburizing in salt bath	580	0.75	790	0.18
TOOLOX 33	Nitro-carburizing in salt bath	580	1.5	800	0.19
TOOLOX 33	Gas Nitro-carburizing	580	4	780	0.27
TOOLOX 33	Gas nitriding	520	12	760	0.23
TOOLOX 33	Gas nitriding	520	30	720	0.64
TOOLOX 33	Plasma nitriding	540	8	780	0.55
TOOLOX 33	Plasma nitriding	540	12	800	0.44
TOOLOX 33	Plasma nitriding	540	30	810	0.51
TOOLOX 44	Nitro-carburizing in salt bath	580	0.75	870	0.16
TOOLOX 44	Nitro-carburizing in salt bath	580	1.5	820	0.18
TOOLOX 44	Gas Nitro-carburizing	580	4	840	0.27
TOOLOX 44	Gas nitriding	520	12	750	0.19
TOOLOX 44	Gas nitriding	520	30	660	0.55
TOOLOX 44	Plasma nitriding	540	8	840	0.31
TOOLOX 44	Plasma nitriding	540	12	880	0.28
TOOLOX 44	Plasma nitriding	540	30	760	0.41

Table 1.
Surface hardnesses and hardening depths obtained in TOOLOX 33 as well as in TOOLOX 44 after different surface hardening conditions.

This study shows very good results for the TOOLOX grades. Surface properties possible to achieve are briefly summarized in Table 2. The bulk hardnesses of both TOOLOX grades were, in the actual study, un-affected by the surface hardening methods and conditions used in this test.

	TOOLOX 33	TOOLOX 44
Surface hardness (HV_1)	800 ±50	850 ±50
Nitriding depth (mm)	0.5	0.5

Table 2.
Condensed summary of the nitriding propensities of TOOLOX.

Other tests carried out on gas-nitriding of TOOLOX 33 and TOOLOX 44 show results as given in Figure 5-6.

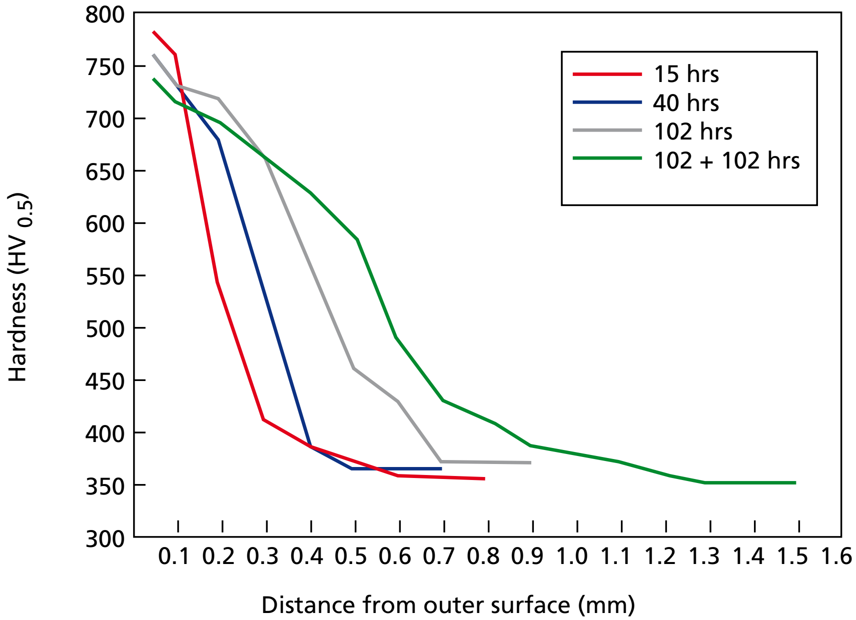

Figure 5.
Gas nitriding of TOOLOX 33.

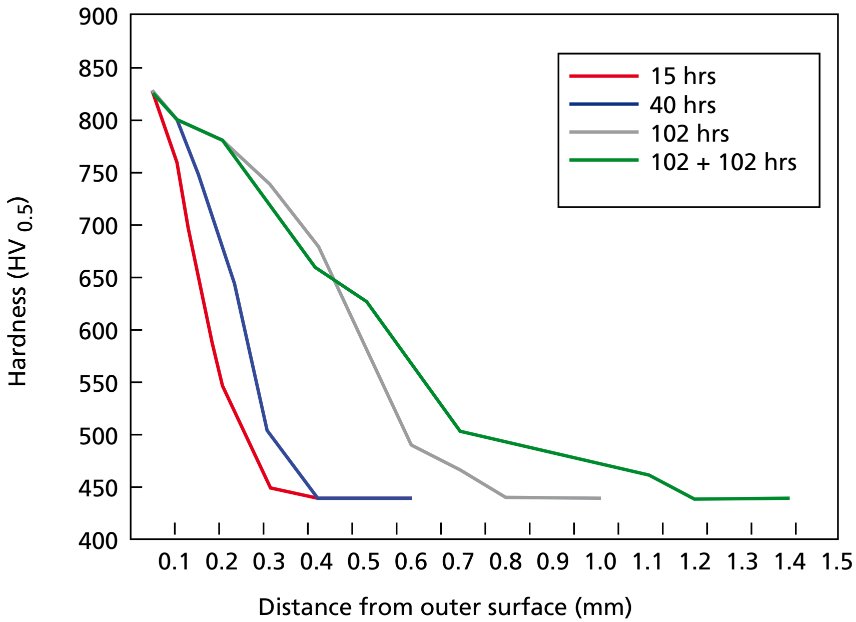

Figure 6.
Gas nitriding of TOOLOX 44.

2.4 Benefits of surface hardening

A method to compare and also rank, different combinations of mould/die/component surface hardness and abrasive wear material hardness has been worked out by SSAB Plate Division. This is an empiric method based on two main wear modes; severe abrasive wear and mild abrasive wear respectively. A schematic description is given in Figure 7. The severe wear mode prevails when the abrasive medium is much harder relative to the worn surface. The wear mode is gradually shifted into the mild regime with increasing hardness of the worn surface relative to the abrasive medium hardness. Do observe, as is shown in Figure 7, that a transition region between the two wear modes does exist. Attention must be paid to the shape (slope) of the relative service life curve in the transition interval, i.e. the transition zone width, when determining the minimum required surface hardness to obtain the mild abrasive wear mode in a given wear system. Also if deviations in relative hardness occur due to variations in the actual process parameters the mild wear mode shall dominate. The slope of the relative service life in the transition interval depends on the actual wear system and must be determined for each application.

One objective in mould design is to choose a mould surface hardness to ensure the mild wear to prevail. To make this choice must the relative hardness be evaluated of the actual wear system.

The relative hardness (HV_{rel}), defined as the ratio between the abrasive medium hardness and the mould surface hardness, is a vital parameter in the understanding of whether severe or mild abrasive wear will prevail. A transition between these wear modes takes place when $HV_{rel} = 1.6$ which is the point at the relative service life curve where the wear is 50% severe and 50% mild, indicated by the red arrow in Figure 7. The relative hardness is written as

$$HV_{rel} = \frac{HV\text{ (abrasive medium)}}{HV\text{ (mould surface)}}$$

With known abrasive medium hardness can the mould surface hardness where the shift in wear mode occurs be calculated as

$$HV\text{ (mould surface)} = \frac{HV\text{ (abrasive medium)}}{1.6}$$

Due to the width of the transition range between the two wear modes, see Figure 7, must the mould surface hardness be chosen to ensure an entirely mild wear mode to prevail, also if disturbances occur in the running component production.

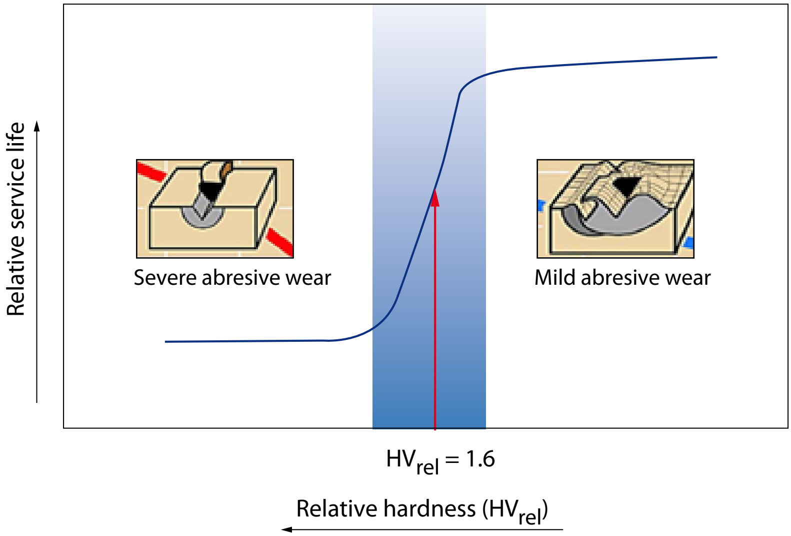

Figure 7.
Schematic presentation of abrasive wear and the relative wear life.

To demonstrate the powerful options surface hardening offers will be discussed the material choice for a mould producing a glass-fibre reinforced component. In the chosen example, the mould for production of glass-fibre reinforced nylon components, see Figure 8, will the mould wear be governed by the glass-fibre which has a hardness of approximately 1060 HV. This hardness shall be compared with the actual different mould surface hardnesses pertaining to clarify which wear regime governs the mould surface wear, see Table 3. The relative hardnesses are calculated using

$$HV_{rel} = \frac{1060}{HV\ (\text{mould surface})}$$

since the glass fibre has a hardness of 1060 HV. The relative hardness should, as discussed above, be kept well below 1.6 to ensure a mild surface wear mode to prevail.

Mould surface	Mould surface hardness (HV)	Relative hardness	Dominating wear mode
P20 / W.Nr 1.2311	340	3.1	Severe
TOOLOX 44	460	2.3	Severe
Regular 55 HRC	630	1.7	Severe
Nitrided TOOLOX 44	850	1.2	Mild

Table 3.
Abrasive wear of a mould when producing glass-fibre reinforced components.

Figure 8.
Glass-fibre reinforced nylon component.

In this specific case are the different surface hardnesses and their respective service life, relative to a mould made in P20 (= W.Nr 1.2311), shown in Figure 9. This clearly demonstrates when using moulds having surface hardnesses up to 650 HV (55 HRC) will the severe regime dominate. It is also shown that with mould surface hardnesses above approximately 750 HV (60 HRC) will the mould operate in the mild wear mode. Mould service life of about 30 times longer than with the severe wear mode can then be expected. When nitriding TOOLOX 44 is surface hardness around 850 HV (65 HRC) achieved. As is clearly demonstrated using this example does surface engineering offer a fast and reliable solution when to manufacture the actual mould.

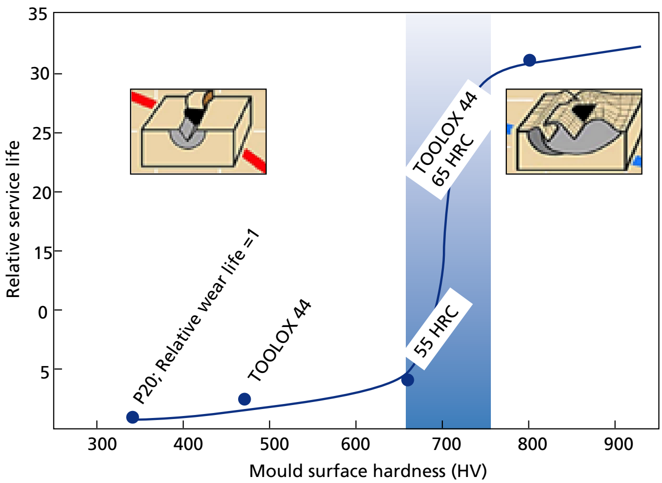

Figure 9.
Relative wear life of moulds worn by glass-fibre reinforced nylon.

Of course, also nitriding of the traditional 55 HRC tool steel gives surface hardnesses high enough to ensure mild wear of the mould. However, the mould manufacturing using TOOLOX 44 will be much faster when compared to using traditional tool steel as the heat treatment and the thereafter necessary dimensional adjustment steps which must be carried out are eliminated. Another important advantage using TOOLOX 44 is that the mould, directly after milling, can be test run for production of a limited number of components to verify that the correct shape and surface etc aimed for is obtained. Thereafter, when nitriding is made is the TOOLOX 44 mould then transferred into a production tool.

2.5 Surface coating

If surface hardnesses, above what can be achieved using nitriding etc., are required a large number of surface coating techniques are available on the market. SSAB is not an expert on coatings and contact shall always be taken with companies specialized in coatings when such questions have to be clarified.

The most common surface coating techniques used is CVD- and PVD-coatings resp. CVD-coatings are generally deposited at temperatures between 700 and 1000°C. This makes these coatings not suitable for TOOLOX since their deposition temperatures are above the tempering temperature of TOOLOX.

PVD-coatings, on the other hand, are developed to be deposited at temperatures below 600°C, commonly 200-500°C, which make them very well suited for surface engineering of TOOLOX. Applications where PVD-coating has been successfully used on TOOLOX are:

- Corrosive protection layer (Corr-I-Dur P® from Bodycote/IonBond)
- Corrosive protection layer (Blacknite® from Bodycote/IonBond)
- Chromium nitride layer having propensities counteracting galling in sheet forming.
- CrN PVD-coating to protect a TOOLOX 44 aluminium die casting die against corrosive chemical attack from the aluminium melt.

When using coatings to counteract wear on component/mould/die surfaces one of the basic ideas is to distribute the generated service surface load, see Figure 10.

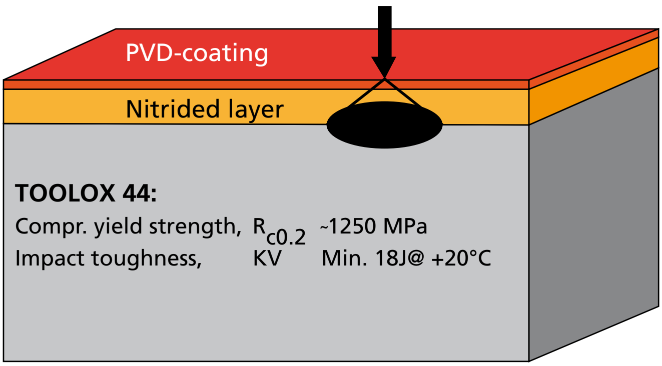

Figure 10.
Load distribution into matrix when applying surface engineering.

Do remember that the distributed load, when it enters matrix (tool steel), must be lower than the tool steel compressive yield strength! Otherwise will the component/mould/die be plastic deformed. PVD-layers can be brittle and if cracks occur in these is it of great importance to have as high steel matrix toughness as possible to arrest the crack when it reaches the tool steel matrix, see Figure 2.

To demonstrate how surface hardening and PVD-coating (CrN) can be used to counteract galling was a sheet forming test carried out using two steels, W.Nr 1.2358 (55 HRC) and TOOLOX 44 (45 HRC). The W.Nr 1.2358 having a hardness of 55 HRC and a surface smoothness of R_a 0.2 was chosen as standard condition in the test, i.e having a relative service life of 1. Do observe that the relative life lengths are only valid for the actual test set-up, see Figure 11. Use of other sheet forming conditions will give other die life lengths!

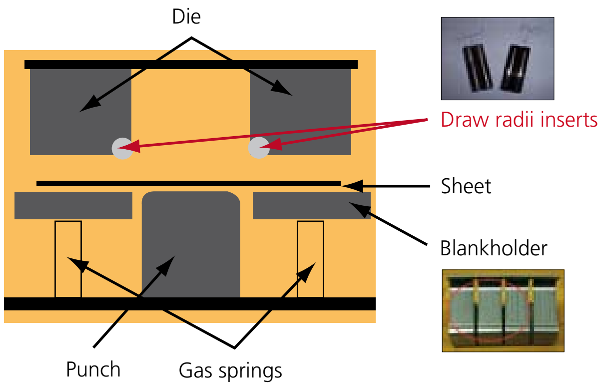

Figure 11.
Galling test set-up.

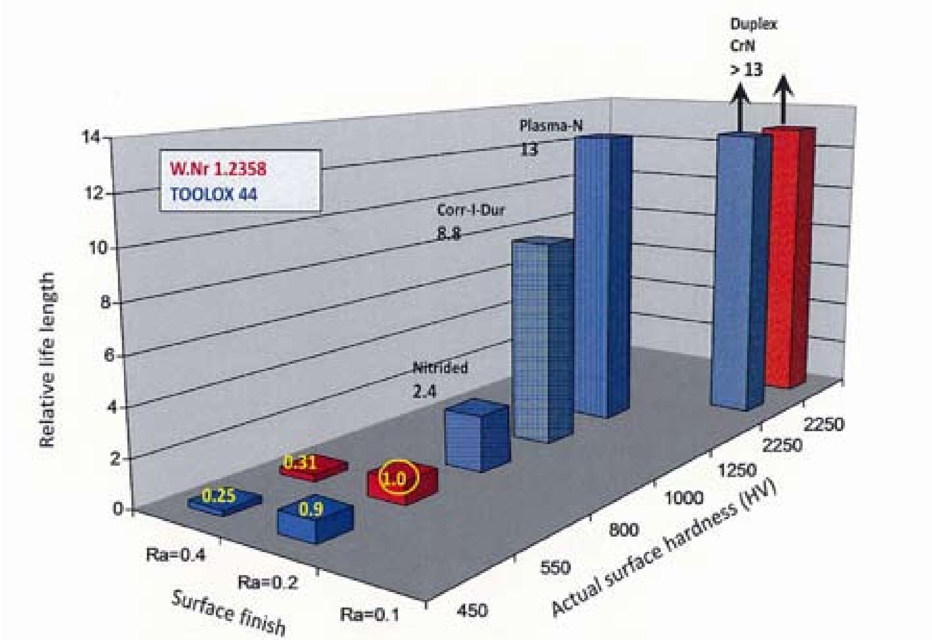

Figure 12.
Relative service life of different surface conditions in a sheet forming test.

Interesting to note is that there is only a small difference in relative life length between the W.Nr 1.2358 and TOOLOX 44 in plain conditions (without surface hardening/coating), see Figure 12. The test clearly shows that the surface roughness is one of the key parameters to counteract galling. Generally, the surface finish shall be kept as smooth as possible to minimize adhesive wear.

Surface hardening strongly increases the die life length relative to the standard condition. With the introduction of hardening layers on TOOLOX 44 (nitriding, Corr-I-Dur and plasma nitriding resp.) can relative life length up to 13 times longer than to the chosen standard condition be achieved, when keeping the surface roughness constant. A further relative life length increase was achieved by plasma nitriding plus PVD-coating, in combination with a surface refinement to R_a 0.1. This can be concluded as:

- When introducing surface hardening/coating techniques don’t communicate the steel bulk hardness. The wear medium is not in contact with the steel below the PVD-layer.
- The interesting point is the surface hardness of the layer, and its smoothness of course.
- When two steel grades have enough compressive yield strength to carry the surface load distributed into the steel matrix through the surface engineered layers the sheet sliding against the layer is not in contact with steel matrix! The outer layer will determine the die life length.

As pointed out earlier the steel subject to surface engineering must possess high enough toughness to show a crack arresting capability if cracks occur in the surface engineered layer! TOOLOX has, as is earlier pointed out in Figure 2, much higher toughness and thereby better crack arresting capability, when compared with traditional tool steel.

PVD-coating, CrN has also been successively used on an aluminium pressure-die-casting die, made in TOOLOX 44, to counteract the corrosive chemical attack on the mould steel from the liquid aluminium. More than 90,000 components have been produced in the actual die.

3. Polishing

Polishing of steel surfaces require great craftsmanship skills to achieve the desired result. The question is not as simple as if the surface ‘gloss’. A conditioned surface may also have a given design curvature. Special care must then be taken to maintain this curvature during the different steps towards the final prescribed surface quality.

When considering surface roughness there are two standards normally referred to; DIN/ISO 1302 and SPI. Do observe that these are not compatible to each other. Table 4 and 5 summarize the respective demands.

Grade	Roughness R_a (µm)	Roughness R_{Max} (µm)
N 1	0.025	0.1-0.3
N 2	0.050	0.3-0.7
N 3	0.1	0.75-1.25
N 4	0.2	1.5-2.5
N 5	0.4	2-6
N 6	0.8	6-10
N 7	1.6	10-20
N 8	3.2	20-40
N 9	6.3	~60
N 10	12.5	~125
N 11	25	~250
N 12	50	~500

Table 4.
Surface roughness according to DIN/ISO 1302.

Grade	Achieved after grinding/polishing with
A-1	3 µm diamond paste
A-2	6 µm diamond paste
A-3	15 µm diamond paste
B-1	600 grit paper
B-2	400 grit paper
B-3	320 grit paper
C-1	600 grit stone
C-2	400 grit stone
C-3	320 grit stone
D-1	600 stone prior to dry blast glass beads #11
D-2	400 stone prior to dry blast #240 aluminium oxide
D-3	320 stone prior to dry blast #24 aluminium oxide

Table 5.
Surface roughness according to SPI.

Figure 13.
TOOLOX 33 polished to optical requirements.

The DIN/ISO 1302 has the advantage that the surface can be physically measured while the surface quality judged using SPI depends on the craftsmanship of the polisher! TOOLOX can be polished to highest optical demands, see Figure 13.

A description of how to polish TOOLOX, according to the procedure used at Svensk Industrigravyr, is given below. This description, polishing manual, gives the normal work-flow in order to achieve a surface roughness, R_a, of <0.3 µm on TOOLOX steel. The initial step may vary depending on the initial surface roughness, which governs whether a coarser or finer whetstone shall be chosen. However, in this description is it assumed that the chosen stone is correct for the initial surface roughness. Do also observe that the word “polishing” is not used except for the last steps. When talking polishing, the last step(s) in the process sequence towards a glossy surface is/are intended.

The designations used are:

Grinding Use of honing stones, whetstones, grinding papers etc.

Lapping The goal of the lapping is to keep the geometry/flatness, while at the same time step by step work down to a smoother surface. When using metallic lapping tools (normally brass) together with diamond paste is the procedure called "lapping". This is done using diamond paste having grain sizes of approximately 40, 25, 15, 10, 7 and 3 µm, together with a suitable fluid.

Polish-lapping As above but instead of brass tools; plastic, fibre or wooden tools are used as carriers for the diamond paste. The goal is a gentle material removal and also to achieve a semi-glossy surface at the same time.

Polishing All operations performed with soft diamond paste carriers such as soft wood, felt, leather or cloth are designated as polishing. After this step is the surface glossy.

The different steps necessary to carry out are as follow:

1. Honing with a coarse honing stone, for instance grain size 120. All remaining milling or EDM marks shall be completely removed. Vary the honing directions (in X-shape). This enable to achieve an even surface, and at the same time being efficient and time saving.

2. Honing acc. to above, but with a fine grained whetstone, for instance grain size 320. All remaining marks from the previous step (Step 1) shall be completely removed!

3. Lapping with diamond paste, grain size 45 µm, on a brass carrier. This continues until all remaining traces of the previous step (Step 2) are completely removed.

4. According to Step 3, but with 25 µm diamond paste. Continue until all remaining traces from Step 3 are removed!

5. Repeat acc. to Step 3 with 15 µm, 10 µm and 7 µm diamond paste. Each time until remaining traces from the previously used diamond paste is removed.

6. Polish-lapping with 3 µm diamond paste on fibre, wooden or plastic carrier. This operation is "dry", i.e without any fluid. Continue until all remaining traces from the 7 µm diamond paste are removed!

7. Final polishing with 3 µm diamond paste and felt carrier (or similar). This is manual work, and now is the final gloss given. Also here the diamond paste is used without any fluid. Work along the surface in one direction until all dull areas remaining from the previous operation are removed. Continue until an even gloss is achieved over the entire surface!

To consider when polishing TOOLOX:

Be thoughtful! For each step performed, remaining marks and scratches from the previous one must be completely removed. An example: Assume that Step 3 above is not made good enough, and you in the following Step (4) see scratches remaining from Step 2. Any attempt to remove these will fail. The one and only solution is to go back to previous step (Step 3) and repeat this step until it is completed. There are no short cuts!

Keep clean! Between each step shall the work piece, and everything which comes in contact with it, be completely cleaned ensuring that no coarse particles from the previous step, or from the surrounding, comes in contact with the surface. For example: If diamond paste from Step 4 (15 µm) remains as the polishing in Step 5 begins (with 7 µm paste), the coarse grains from the 15 µm paste will give scratches, no matter how much polishing is made using the finer paste.

Don't over-polish! Excess polishing with a soft carrier (felt, for example) can easily cause an "orange peel" surface. It is often tempting to polish "a little extra" on areas where perhaps remaining scratches from previous steps are revealed in order to eliminate them. Such behaviour usually creates an orange peel surface in this area. Furthermore, also the finest diamond pastes works off some material, and it means that a local - more intensive - polishing, also will generate waviness on the surface.

This condensed description gives the basics regarding polishing. It is in some cases possible to rationalize the procedure via short-cuts without jeopardizing the final result, but that is something only experience can tell.

If additional information, or assistance, is needed please don't hesitate to contact:

info@industrigravyr.se

www.industrigravyr.se

4. Photo-etching

Today the texture on a plastic detail often has more than a purely aesthetical function. Depending on field of use, it shall perhaps be; durable, easy to clean, ensure a good grip, being non-reflective etc. Furthermore - and this is not least important – the parts must be able to be produced in the tool without risk for surface damages.

Texturing is carried out pertaining to create;

- A desired surface on a finished product
- Optimum friction conditions
- Surfaces which will function together with a given lubricant

The most common use of texturing plastic moulds is to give the produced component a correct surface pattern. To enhance the texturing properties of tool steel there are important steel properties to control, such as:

- Segregation levels, which must be kept at a minimum
- Steel cleanliness
- Steel microstructure, which shall be as consistent as possible.

Furthermore it is also important to control the mould functioning. Figure 14 shows a component where the ejector pins have caused imperfections on the component surface. If the component surface will be exposed during its service care must be taken to eliminate such surface imperfections. In the actual case shown in Figure 14 is the component not visible in service and the ejector pin marks are of no interest.

Figure 14.
Imperfection on plastic surface generated by the ejector pin.

When texturing, commonly using photo-etching, a mould surface is it desired that the mould steel has a capability to give surfaces having a large range of gloss values. TOOLOX has turned out to show excellent etching capability. When performing tests at Svensk Industrigravyr (www.industrigravyr.se) gloss values from 1.5 to 45, depending on the actual texture pattern, have been achieved. Test has been carried out where a leather grain surface was etched on TOOLOX 33, see Figure 15a. The arrow in Figure 15b indicates that the surface is extremely even, enabling the surface etching companies to carefully control both texture depth and gloss value.

Figure 15a.
Leather grain surface on TOOLOX 33.

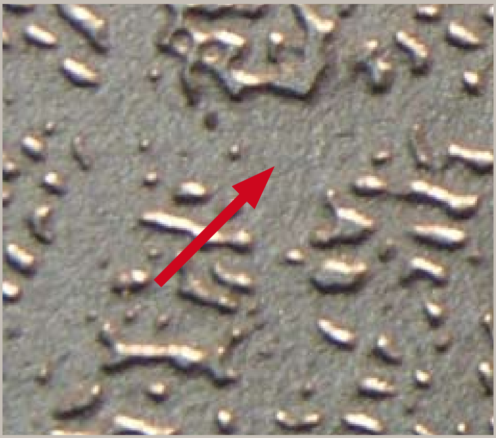

Figure 15b.
Magnification of the texture shown in Figure 15a.

Figure 16a shows a texture, twist grain, which is generated in six (6) different etching steps. The 'waviness', see Figure 16b, is created in different height levels at the same time as the bottom part of the texture intentionally was given a grainy structure.

Figure 16a.
Twist grain texture.

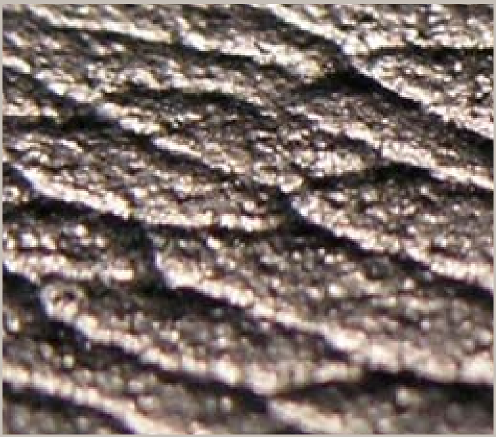

Figure 16b.
Detailed twist grain texture.

Figure 17.
Certificates of TOOLOX etching capabilities from Standex Int. Gmbh.

The etching/texturing company Standex International Gmbh has also tested the texturing capabilities of both TOOLOX grades and found them to meet their highest demands, see Figure 17.

5. Links

Additional information can be found on:

- www.ionbond.com, regarding surface coatings
- www.oerlikon.com/balzers/, regarding surface coatings
- www.industrigravyr.se, regarding polishing and texturing
- www.novapax.de, regarding polishing equipment etc.

07-TOOLOX SURFACE ENGINEERING OF Q&T TOOL STEEL - UK-V1-2008. Charlotte Bäckström, Nyköping

SSAB Oxelösund – a subsidiary of SSAB Swedish Steel Group – is the world's leading manufacturer of quenched and tempered heavy plate, marketed under the well known brand names of HARDOX® Wear Plate, WELDOX® Structural Steel Plate, ARMOX® Protection Plate and TOOLOX® Prehardened Tool & Machine Steel. The steels are characterised by the combination of high strength and toughness, derived from the clean steel composition and a unique production process.

SSAB Oxelösund focuses exclusively on developing quenched and tempered steels. With a strong local presence in more than 45 countries we provide our customers with high quality steel as well as commercial and technical support.

For more information, contact us or visit www.ssabox.com.

SSAB Oxelösund
SE-613 80 Oxelösund
Sweden

Phone: +46 155 25 40 00
Fax: +46 155 25 40 73
E-mail: contact@ssab.com
www.ssabox.com
www.toolox.com

SSAB OXELÖSUND