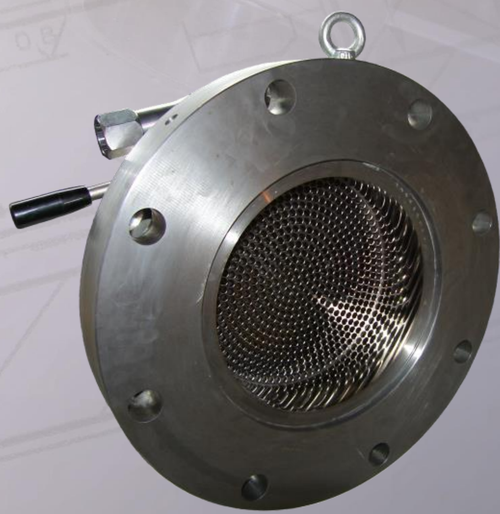
Plastic processing enhancements with Lunac coatings

Abstract:

Plastic processing machine parts such as screws, adaptors, screen changers, dies, etc. mostly have to deal with issues such as sticking/plastic degradation, wear or corrosion. Lunac coatings can in most cases alleviate or even totally eradicate these typical problems. The unique Lunac metallic glass coatings which are applied by means of special co-deposition processes offer the following features:



- Reduced surface energy and consequently mostly improved non-stick characteristic
- A weld-like coating-substrate bond
- No micro-crack formation
- Cleansing effort is almost without exception significantly diminished
- Good heat shock resistance
- Moderate wear resistance in the case of Lunac 1
- Ultimate wear and galling resistance in the case of Lunac 2 +
- Lunac 1 can be polished to extreme low values
- Lunac 2 + can moderately be polished
- Lunac 2+ generally offers ample corrosion protection. Both Lunac 2 hc + and Lunac 1 generally offer good corrosion protection. The latter two versions can even resist some fluor and chloride containing plastics and with that replace expensive nickel alloys

Observed effects with Lunac plated parts in detail:

- ***The risk of black particles or stripe formation of plastics explicitly susceptible to degradation (such as PVC or PC) is mostly highly counteracted with a Lunac 1 coating***
- ***The effort to polish Lunac 1 (HRc 65) is minimal and can deliver optically perfect surfaces (Ra 0.005 - 0.03 µm / 1.9E^{-4} - 1.2E^{-3} mil) starting from <Ra 0.2 µm / 7.9E^{-3} mil initial substrate roughness.***
- ***Lunac 2+ is very hard (Hv 1,150 (=HRc 72) /2,100) and highly resists abrasive wear. Wear resistance increase up to 80 x compared to brass (final dimension determining) parts has been recorded.***
- ***Almost without exception, parts can be cleaned with notably less effort. (However, also mild abrasive cleaning tools will nullify the high performance deeply polished Lunac 1 surface)***
- ***Lunac 2+ will strongly prevent sliding surfaces, as present in e.g. screen changers or adaptable dies, from galling and adhesive wear. Even tolerance reductions can sometimes be considered due to this explicit anti-galling characteristic.***

Lunac application:

Lunac 1 coated plastic processing machine parts mostly display the second best improved melt conveying characteristic (next to PTFE coatings). Usually the coating is locally applied to all melt flow surfaces and in the case of corrosive plastics also a few millimeters/0.15” around the edges. Lunac 1 coated parts are also resistant to many (not severely degrading) corrosive plastics. After plating, edges are mostly sharpened to prevent turbulence at interfaces. Plastics can, dissimilar to steel or hardchromium surfaces, hardly infiltrate a Lunac surface. For this reason steel or beforehand chromium plated surfaces, mostly need a deep mechanical clean up first (up to 40 µm/1.6 mil depth), if the part was already in contact with plastics, before the part can be (re)plated. The most common coating thickness is 35-60 µm/1.4-2.4 mil in the case of Lunac 1 and 45-120 µm/ 1.8-4.8 mil in the case of Lunac 2+. Most “black particle” issues with e.g. polycarbonate production are largely eradicated (mostly with Lunac 1), if the coating is applied to the screw and all downstream machine components (See figure 1). The reduction of sheet line formation and melt fracture is another important reason to apply Lunac 1 to plastic processing machine parts. Lunac 1 can be hardened up to HRc 65 and will offer a good scratch resistance. However, the generally moderate wear resistance limits its application to plastics free of abrasive particles. The very hard semi-ceramic Lunac 2+ version will offer the ultimate (abrasive and adhesive) wear and scratch resistance. Lunac 2+ coated parts are not as easy to polish to the ultimate values Lunac 1 could obtain and are mostly a bit less corrosion resistant. Although both Lunac 1 and 2+ can offer full substrate bond, care must still be taken with respect to the edges because of the hard and brittle structure.

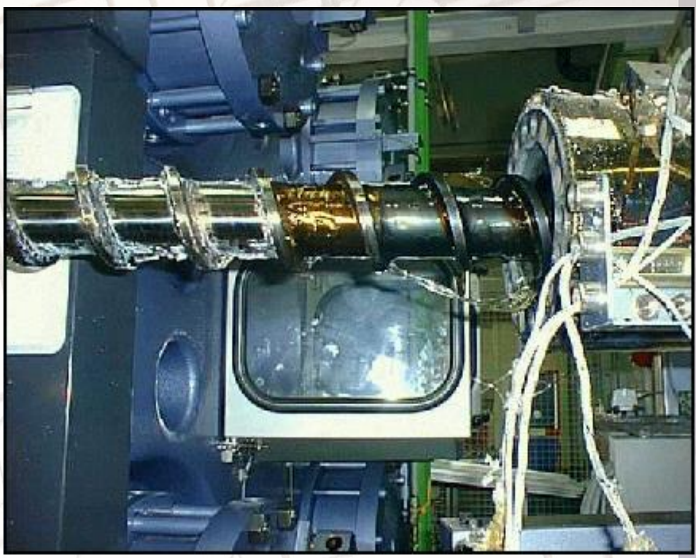


Fig. 1: Polycarbonate processing screw for car headlight shields. The left part of the screw has been coated with Lunac 1. The right side of the screw remained uncoated. The polymer on the left part of the screw did not tarnish/degrade, was easy to remove and did not emit black particles. Notice the discolouration of the polymer and steel at the level of the non-treated right entrance part of the screw. The new screw and adaptors treated with Lunac 1 has reduced the number of parts rejected because of black particles from 12% to 0%. The return of investment for the Lunac 1 coating was consequently short in this case. Lunac screw plating can be critical.

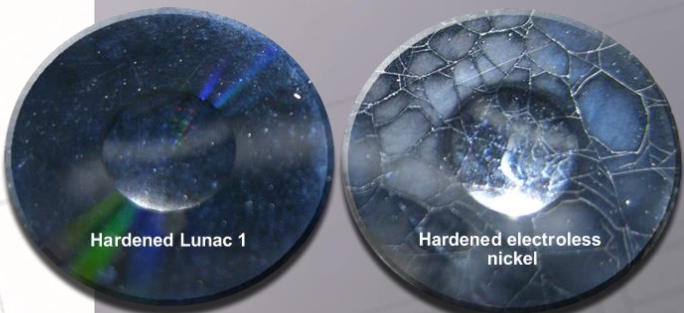
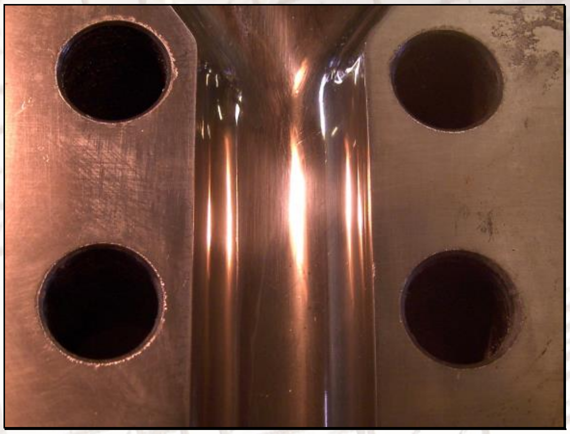


Figure 2. A multilayer die for corrosive PFA plastic processing (at +/- 400 °C/752°F) has completely been plated with 35- 60 µm /+/- 2 mil Lunac 1. Only micro-crack free corrosion resistant coatings could resist these conditions. This part was electroless nickel plated before. Electroless nickel tends to form micro-cracks on hardening (hardening takes automatically place starting from 290 °C/554°F. See picture above). On the other hand the electroless nickel coating distribution in the deeper structures is better than the coating distribution of hard chromium or to a lesser extent Lunac. Although the total Lunac-substrate bond is almost unrivalled, the coating itself is rather brittle and consequently care should be taken with respect to the edges.



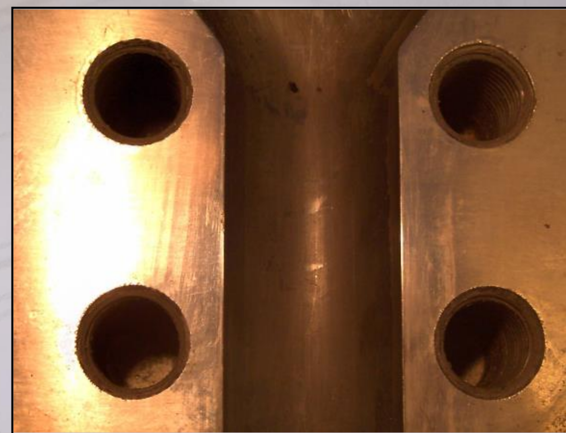


Figure 3. These upper pictures represent the main canal of a coated and non-coated sheet extrusion die (left). These dies processed the same HIPS for 3 years. The right not-coated carbon steel surface is dark and rough. This friction increasing effect notably influenced the plastic flow (stripe formation). The left picture displays a die exposed to similar conditions with a Lunac 1 coating. The improved melt flow as well as surface appearance have not changed since commissioning. Note: The possible bending of the flex lip has to be limited because of the brittleness of Lunac 1 i.e. 0.11% elongation to fracture. Flat die plating can be critical.

Non stick properties:

The non-stick effect is not only governed by the surface energy but also by the inertness of the surface as well as its smoothness. The latter is often under estimated according to research. An important exception has been recorded in the case of perpendicular release of solidi(fied/fying) plastics which can particularly benefit from a Ra 0.4 µm / 0.0157 mil to 0.65 µm / 0.026 mil , accidented, smooth dome shape Lunac 1 RAD micro-structure.

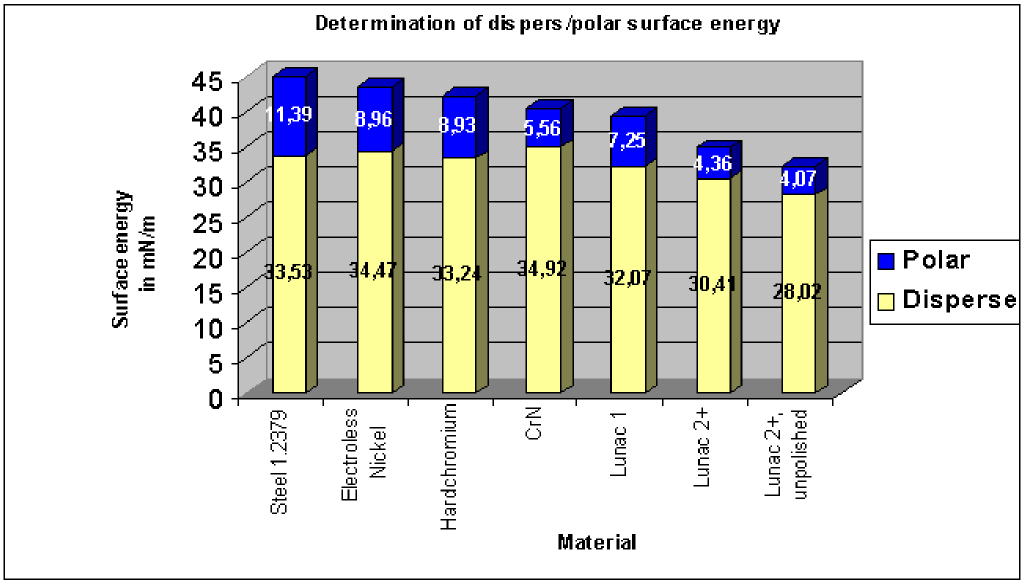
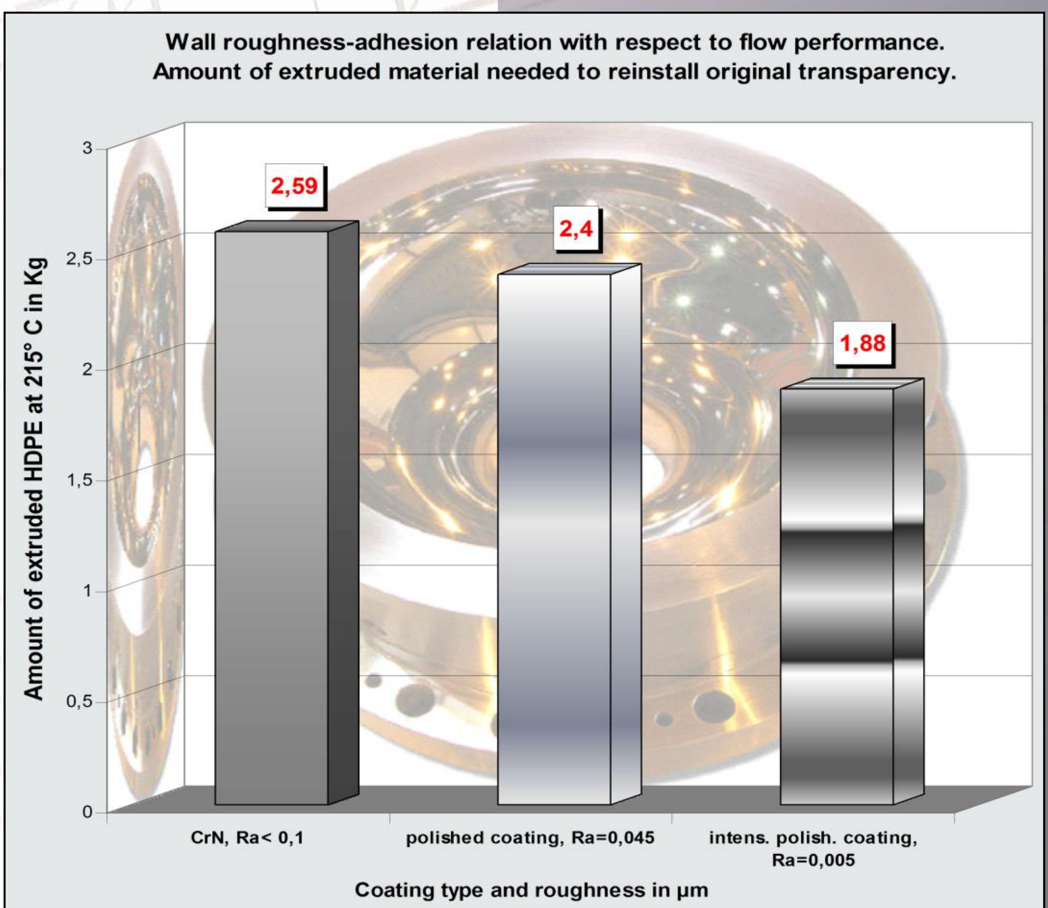


Diagram 1 and 2: The positive influence of a coating with a reduced surface energy (diagram above, University of Duisburg Germany) on the melt flow is limited but measurable. In many cases the melt flow profits more from a surface that could be polished to extreme low values (diagram below). Method: a blue plastic shot was administered to the test die, the amount of transparent plastic to clear the blue colour out to an equal level was measured.



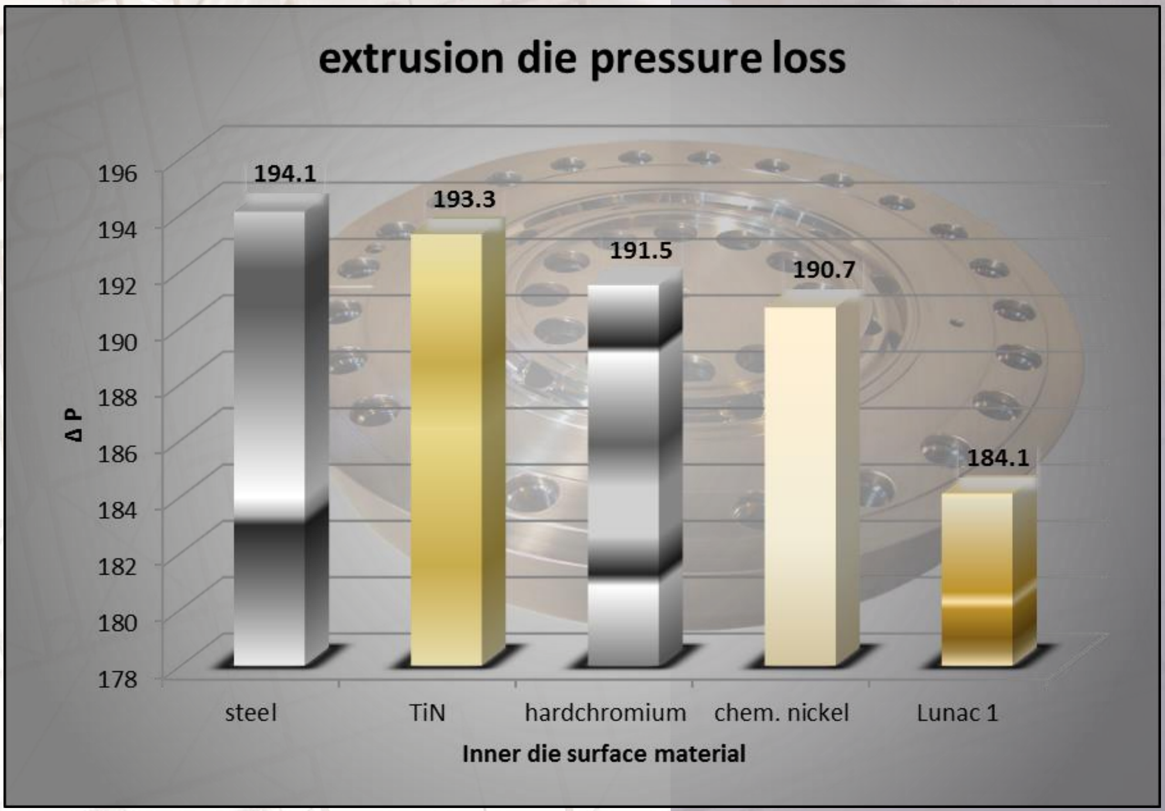


Diagram 3. This study represents the accumulated influence of various coatings (and optimally polished if feasible) on the melt flow in a full scale extrusion die.

Melt flow canal: 2,645 sq. mm/4.1 sq " **Temperature: 205° C /401° F** **Yield: 18 kg /40 pounds/hour**
Length canal: 196 mm/7.7" **Plastic: LDPE 5021**

Corrosion resistance:

Because of the very dense Lunac structure and generally very good corrosion resistance of Lunac 1 and the new Lunac 2hc+, an interesting possibility has risen (pictures 4 and 5). Instead of expensive nickel alloys, which are mostly hard to machine, (chromium) steel can be selected which is usually stronger and much better to machine. The improved corrosion resistance is covered by the Lunac 1 or 2hc+ coating. Lunac 1 will mostly tarnish starting at 340 °C / 644° F (but at higher temperatures in the case of fluoroplastics). Starting from 400 °C / 752° F, Lunac coatings will partly anneal, but will mostly still be able to deal with conditions prevailing during fluoroplastic processing.

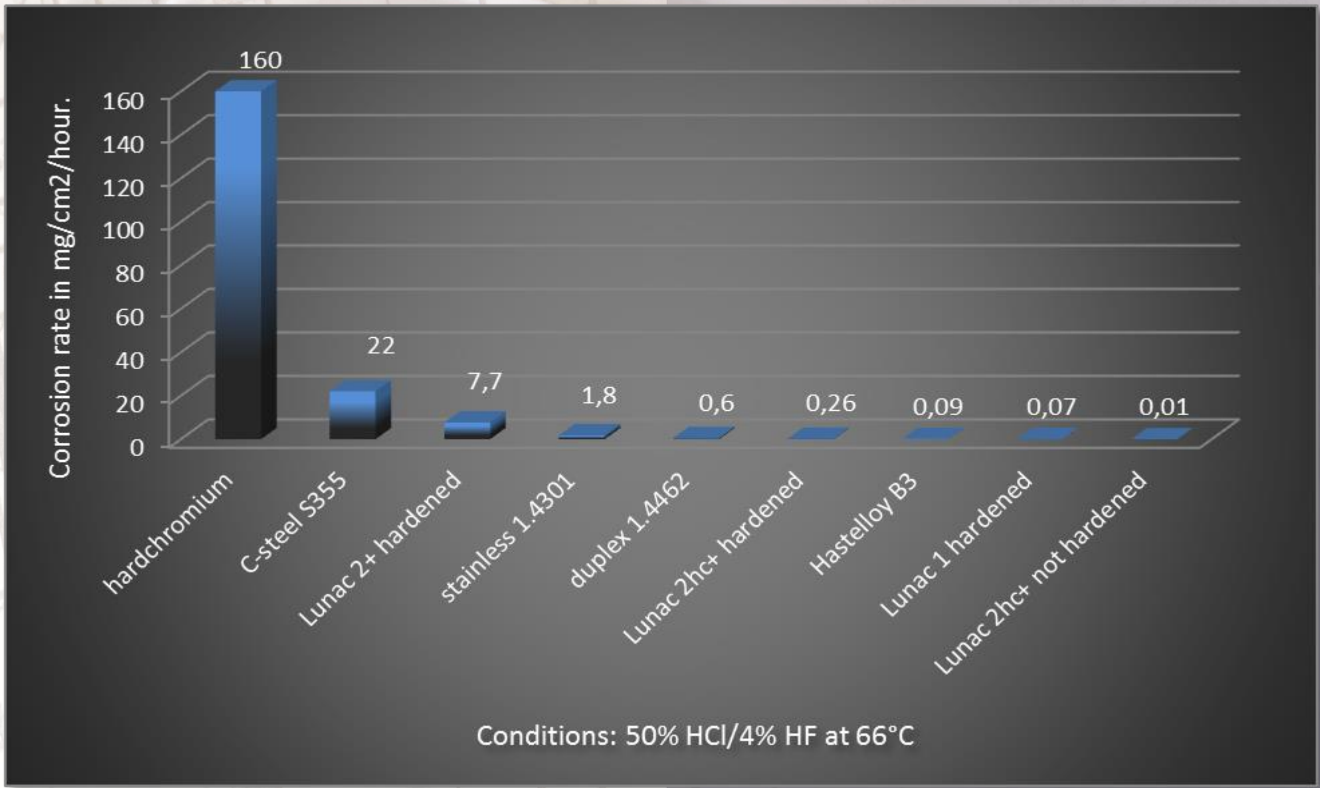


Diagram 4. Corrosion resistance diagram; Lunac compared to other common materials or coatings. (Note: Lunac 1 is 110 times more corrosion resistant than Lunac 2+ in this test)

Picture 4 and 5. high grade nickel alloy replacement by Lunac 1. New screw (left) and after 4 months (above) in a PFA fluoroplastic environment. No corrosion effect has been recorded. However, the applicant must be aware a local break-through cannot fully be excluded ever to happen. Basic material is PH 17-4 and stellite 12 flight tip armour in the case of screws larger than Ø 25 mm / 1 "

Wear resistance:

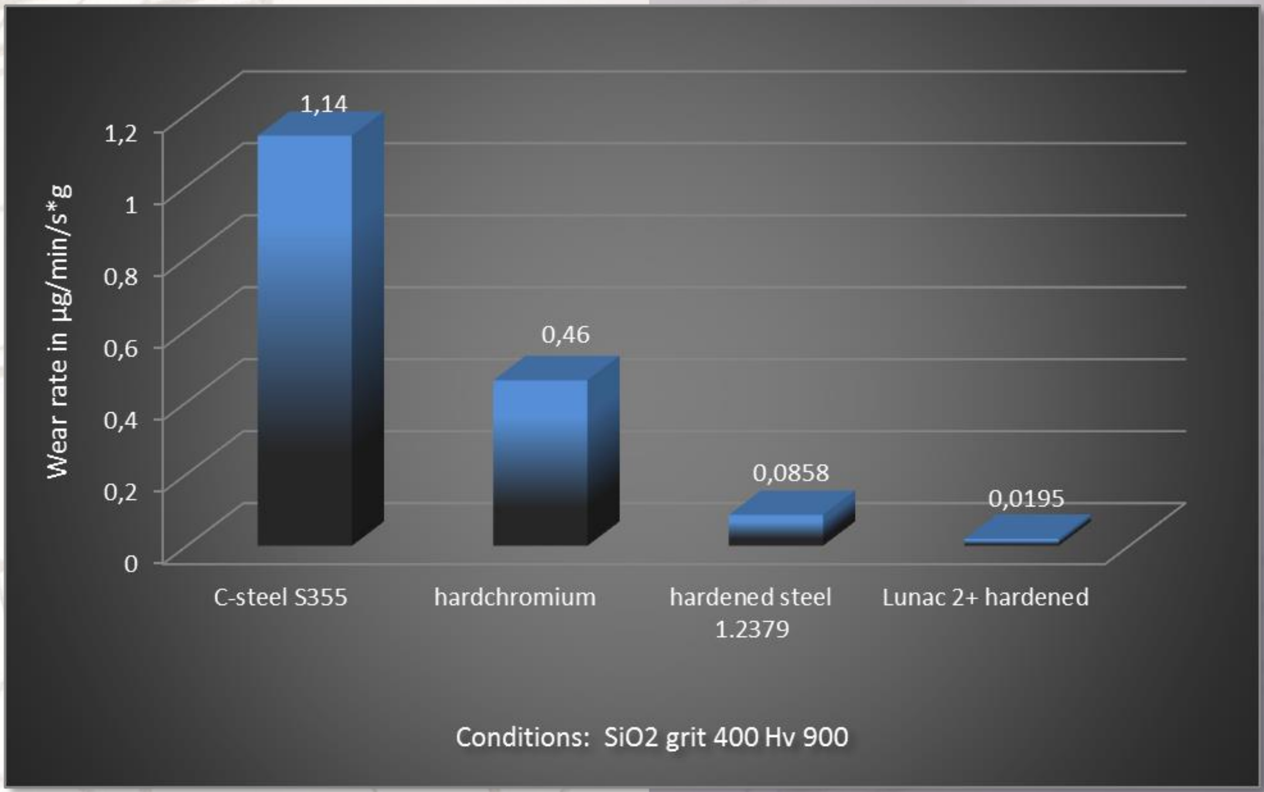


Diagram 5. Note: The wear rate of hardchromium depends highly on the nature of the abrasive. E.g. hardchromium could perform better in an abrasive wear test based on the harder SiC. Lunac 2+ hardly shows this dependancy. The wear resistance of Lunac 1 is moderate and mostly equals common carbon steel.

Coating distribution and internal plating:

Both Lunac 1 and 2+ show a +/- 6-fold better coating distribution than hard chromium and correspondingly suffer from less edge build up. Still an important part of the Lunac plating job is to create several current deflectors and in the case of deep internal plating, support anodes.

Lunac coatings can be applied to internal bores as small as 5 mm in the case of +/- 50 mm/2” total length. Ø 70 mm bores up to 3,000 mm length have successfully been plated with an accuracy of +/- 10% .

Screw plating and preparation:

High flight tip load screws

In the case of larger screws, a stellite 12 flight tip armour combined with a Lunac 1 / 2(hc)+ coating offers the most reliable Lunac screw plating system. Despite the full bond, due to the brittle nature of the Lunac coating, Lunac can often not deal with the very high loads in this outer diameter contact zone. These screws with flight tip replacement can deal with high flight tip load and prevent the flight tips from galling as well as offer all typical Lunac properties to the rest of the screw. Consequently, the Lunac coating will be available up to the flight tip edge, but **not on top** of the flights tips.

Procedure :

1. Preparation of a screw not harder than HRc 50 with still + 0.3 to 0.6 mm / 0.012-0.023" oversized flight tip diameter, but with already finished canals (Ra < 0.2 µm / 0.0079 mil)
2. After the 35-65 µm Lunac 1 or (2hc+) or 75-150 µm Lunac 2+ coating has been applied to the screw, the Lunac 1 coating will be polished to very low values and in the case of Lunac 2(hc)+ moderate values. The flight tips of the (rather not yet hardened) Lunac coating must be ground by the manufacturer to the final requested diameter. The Lunac coating will be penetrated and disappear on the flight tips by this operation. Most optimal would be to harden the Lunac coating after this final grinding to its ultimate hardness at 320 °C / 626 F for 5 hours or automatically in the barrel if the process temperature is higher than this temperature.

Only the smallest screws (< D25 / 1") with low flight tip load could be considered plated completely without flight tip replacement armour. However, brittle fracture can still occur on flight tip edges.

Hardened screws (> HRc 50) are also frequently plated successfully, but we continue to warn for a possible unreliable coating-substrate bond (especially in the case of nitrided screws). If the nitride layer is ground off by at least 40 µm / 1.57mil an improved coating bond might be acquired again.

In the case of extrusion screws we developed special anodes to obtain thick coatings in the deeper structures as well to deal with highly abrasive plastics.

Observable shortcomings with current plastic processing machine parts (such as screw) which can be solved by Lunac coating:

1. Excessive adhesion and formation of (black) degradation products.
2. Corrosion of the (nitrited) steel as well as the welded armour transition zone.
3. (sub surface) corrosion of the optionally applied hard chromium, as chromium is less resistant to non-oxidizing acids (HCl or HF).
4. Insufficient wear resistance.

General notes on plastic processing machine parts (such as screws) treated with Lunac 1 and/or 2(HC)+:

- To preserve the low Lunac 1 adhesion coefficient, it is strongly recommended not to sand or clean a Lunac 1 surface with an abrasive medium such as scotch bright.

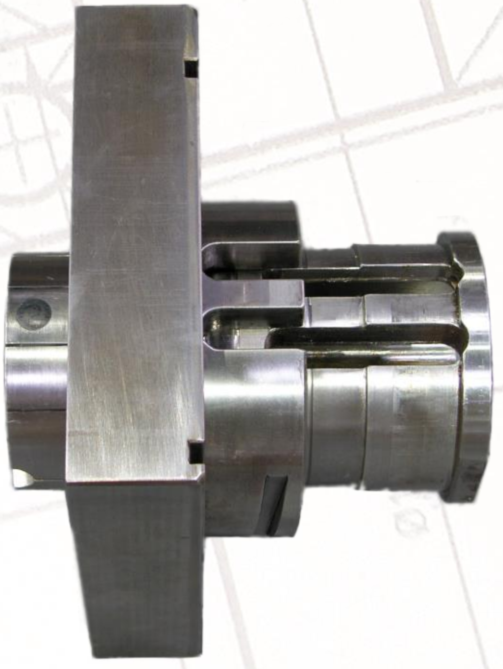
- Especially Lunac 1 shows a glass-like character and is thus susceptible to brittle fracture. Even though Lunac has a good adhesion up to the edges, this material is sensitive to shock and sliding loads on the edges.

- Lunac layers can be damaged by letting hard plastics (e.g. polycarbonate, nylon, polyester, etc.) cool down and solidify on this coating or start the machine without proper pre heating. Lunac layers can hereby suffer damage from internal (laminar) fractures through. Before cooling down, always remove the plastic from all melt flow canals or purge the machine with PE/PP/PS prior to cooling down or keep the machine on 200° C / 392° F in the case of non high corrosive plastics. Be aware the remaining solidified plastic on the screw in the screw-barrel system will shrink on cooling down and create an air gap between the outer plastic layer (e.g. a screw and the inner wall of the barrel). This will highly impede the heat transfer from the external heating elements to the screw. Extended pre-heating is necessary followed by careful screw torsion monitoring (e.g. by motor current control).

- In the case of (especially degrading) corrosive plastics, even the very good corrosion protective power of the Lunac 1 coating can fall short. The steel substrate must stay fully covered and highly twisting screws can locally crack the coating (rendering the screw partially unprotected). In the case of screw flight tips, inlay flight tip armour is not sufficient, because this will render small uncoated steel rims. These locations can consequently suffer from (sub-surface) corrosion.

Final product forming parts:

Granulator coated with 100 µm / 4 mil Lunac 2+ after grinding with diamond. The holes are blanked during the process. In this specific case the granulator lasted 45 times longer than the original nitrited steel concept. The adhesive wear of the non-coated knifes will generally also be reduced (according to laboratory tests 6.25 x). This concept is very competitive with hard metal inserts.



These sliding mould elements have largely been plated with Lunac 2+ (and ground by diamond afterwards to obtain a perfect fit). The typical galling problems of these parts were fully halted and the wear highly reduced. Moreover, the end products are now completely burr free.

Most preferred materials for Lunac treatment:

DIN 1.4122
DIN 1.2316
PH 17-4
H 13

However, nearly any non-nitrided steel could basically be plated

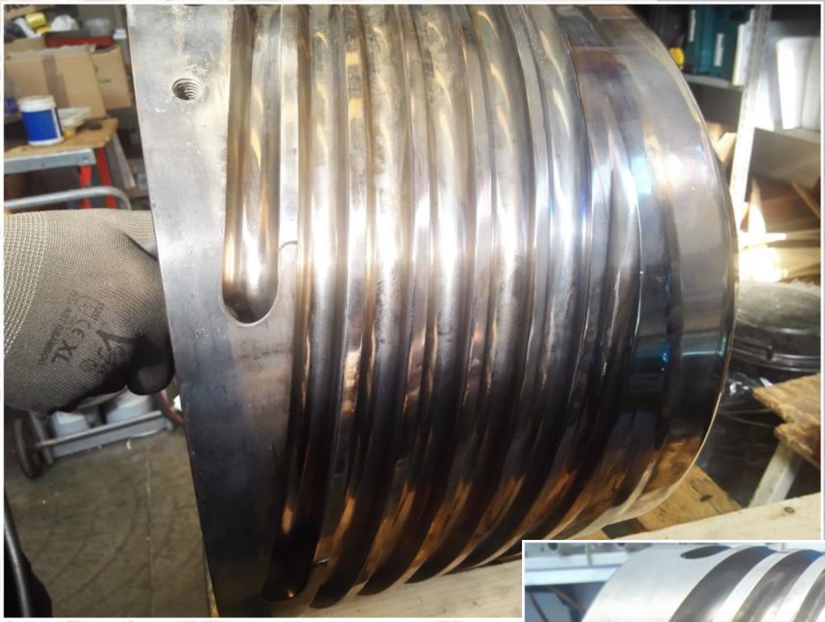
Maintenance Lunac 1 plated parts:

Routine cleaning or cleaning an extrusion tool covered with charred plastics

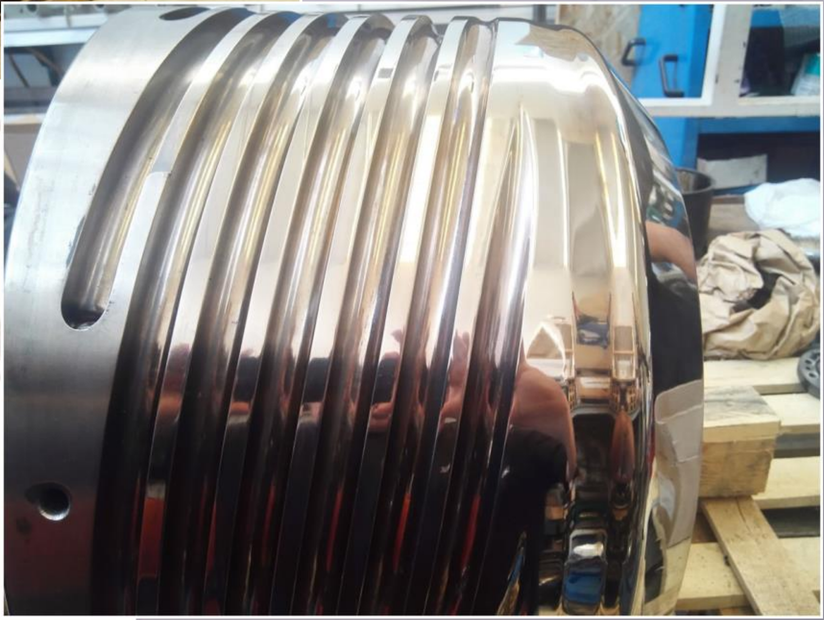
Almost without any exception Lunac 1 coated plastic processing machine parts are significantly easier to clean (cleaning spiral die, covered with non-degraded plastics, as displayed below; +/- ½ hour). We recommend applying brass tools (such as brushes) to complete this job and, if still needed, to apply minimal polish paste to regain the original shiny surface. We highly advice against applying an abrasive (cloth) medium or pyrolytic sand oven.

In the case plastic processing machine parts are covered with highly clinging charred plastics (e.g. after a machine has been overheated), the Lunac coating will still show its non-stick nature. However, more radical methods are mostly necessary. In these cases an N_2 oven can be applied at 400° C/752° K followed by removing the last remnant with a regular (short) cleaning polish action.

Spiral extrusion die covered with charred plastic (degraded PE). Before Lunac 1 plating the cleaning company needed 2 – 2 ½ days to restore the original shiny condition of this specific part.



Same spiral die after 2 hours N_2 oven treatment at 400° C / 752° F. Charred plastic remnants vanished. A discoloured surface remains



Same spiral die after 2 - 3 hours polishing to remove the discolourations. Reduction of cleaning time +/- 9 fold. See also the video clip on the Lunac 1 web page

Feed Back

We put a lot of effort in collecting feedback of our customers since 1984. The standard question is if they acquired the improvement with respect to non-stick and corrosion resistance they were looking for (and in the case of Lunac 2+ also the wear resistance). Check out the objective and continuously updated response of Lunac applicants on our website:

http://wmv.nl/downloads/Plastic_processing_experiences_2017_April.pdf

Plating capacity:

At this moment the maximum treatable length is 3,930 mm / 154.7" at Ø 750 mm / 29.5".

Naturally, circumstances can arise that are unknown to us and which could influence the noted results. Due to the complex nature of plastic processing the results with Lunac coatings cannot be guaranteed. However, the better cleansing capability is nearly always recorded.

The high level of quality is obtained by skilled operators that followed an internal education program. Their work is supported by an extensive technical database and a laboratory of material research. Coated parts will always be accompanied by measurement reports. All procedures per part are stored for reasons of reproducibility.

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More pictures and information on:
www.wmv.nl at Lunac 1 en 2+.