Ejector Reduces Wear in Mould-making

Plasma Nitriding. Ejectors are the parts that undergo most movement in the injection mould, and therefore the determining factors in the lifetimes and maintenance frequency. The lifetime of the ejector pins depends on the structure and quality of the nitriding layer. Recent long-term studies call into question nitriding processes that are still used even though they are no longer state of the art.

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The lifetimes of moulds are all the longer and the maintenance frequency all the lower, the less wear there is on the ejectors. Even though they are regarded as standards, there are considerable differences between the designs of different manufacturers.

In general, a distinction is made between hardened and nitrided ejector pins. The hardened design is used at low temperatures in the mould when contours still have to be machined on the shaft. The ejector is through hardened to about 60 HRC and is ready to use after machining. Frictional wear can be reduced by the use of a lubricant or by coating. However, these methods have the drawback that the lubricant drips onto the surface of the part or the additional trip to a coater means a longer lead time and high costs for coating and transportation.

If the process requires a higher surface hardness or heat resistance, the designer or mould maker will use an ejector of hot-work steel. In contrast to the hardened ejector, which has a temper resistance up to 200 °C, the hot-work steel ejector is stable up to about 600 °C. The nitriding achieves a surface hardness of about 70 HRC (up to 1100 HV 0.3). The tough core material, whose hardness is still approx. 44 HRC, is elastic enough to accommodate the transverse and longitudinal forces that occur. The stability of the ejector thus crucially depends on the base material. However, the lifetime depends principally on the nitriding layer.

Old and New Nitriding Processes

The oldest method is salt bath nitriding. But the huge environmental and safety problems alone have almost caused it to fall out of use . From another point of view, too, salt bath nitriding also does not compare well: By virtue of the process, it does not permit good reproducibility. The bath concentration is too often affected by contamination. The nitriding result cannot be controlled. In salt-bath nitriding, a large number of deep pores are formed in the outer coating layer, which results in a very rough surface. These pores are now known to represent interruptions in the metal lattice, which significantly reduce its strength at the surface.

Studies conducted years ago showed that even with small contact loads and after a relatively low wear depth, particles are broken out or sheared off of the

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Process	Optimum	In salt bath	In gas	In plasma	Drei-S-Werk
Process control	Individually controllable	Via salt bath concentration	Via charging	Electronic via the pulse method	Electronic via the pulse method
Compound layer	Thin and even	Thick but porous and flaky	Can be thin, but porous and uneven	Can be even and thin	Thin and even
Nitriding depth with respect to fatigue strength	Thin and even	Thick but uneven	Can be thin, but uneven	Can be thin and even	Thin and even
Surface roughness	Without pores	Pores with a tendency to flake	Pores with a tendency to flake	Low pore	Low pore
Pore seam	No pore seam	Pore seam through high nitrogen content	Pore seam through high nitrogen content	No pore seam possible by control	No pore seam
Surface secondary finishing	None	Lapping, polishing or vibratory finishing	Lapping, polishing or vibratory finishing	None, or wiping with cloth	None, or wiping with cloth

Table 1. Decision structure for the use of different nitriding processes

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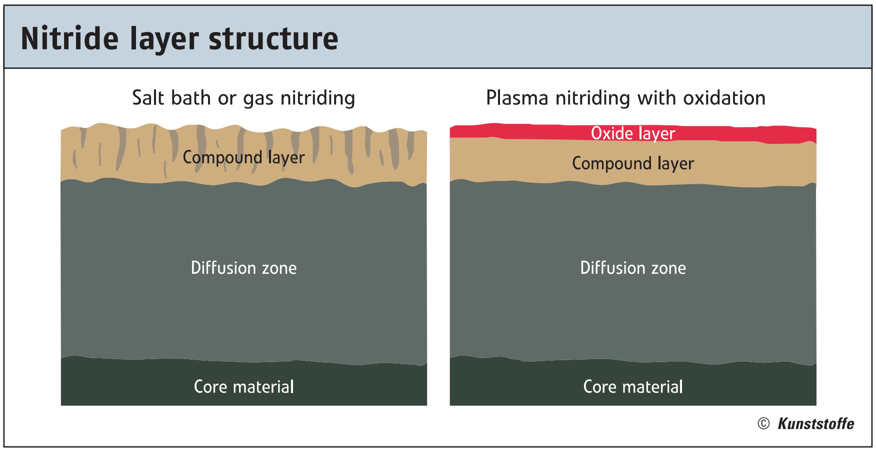

Fig. 1. Comparison of the schematic structures of nitrided layers of the salt bath or gas nitriding and of plasma nitriding, including oxidation (photos: Drei-S)

porous part of the compound layer and then form an abrasive medium together with the lubricant used [1]. Pores thus have a micronotch effect, which weakens the ejector. The short strokes and abrasive media contribute to the mould bore being prematurely enlarged and the ejector worn down. As a result, melt can penetrate into the gap between the ejector and bore – with the consequence that the mould fails.

Gas nitriding does not produce as many pores as the salt bath. The layer structure can be better controlled. However, the uniformity of the layer thickness and the layer structure are problematical. Gaseous nitrogen is introduced between the parts to be nitrided. That causes many small sheltered zones during the gasifying of bulk parts. If the gas flows onto a workpiece, it is efficiently nitrided at this point. At the opposite side, in the sheltered zones, the amount of nitrogen reaching the workpiece surface is not uniform. When there are a large number of workpieces in a batch, very variable flow conditions prevail in the gas chamber. This discovery explains why the circumferential surface is fundamentally variably nitrided. Furthermore, nitriding defects (excess nitrogen concentration) result in a porous seam, which is as abrasive as sand in the guide.

Why Use Plasma Nitriding and Oxidising?

To make the best possible use of the wear resistance, a precise and uniform layer structure is required. In plasma nitriding, uniform electrical discharge takes place on the workpiece surface. A small electric arc forms, as in welding. This "glow seam" allows the gaseous nitrogen to penetrate into the surface of the steel. A thin nitriding layer, the "compound layer", thus forms on the workpiece. The compound layer is ideally very thin, not cracked or porous and bonds firmly to the diffusion zone, which contains nitrogen-enriched mixed crystals and deposited nitrides. A thin and low-porous compound layer can only be produced in pulsed plasma. The process can be very precisely electronically controlled. With some experience, the desired layer thicknesses can be manufactured very precisely and reproducibly (Fig. 1).

For a long time, the salt bath and gas nitriding were the conventional processes; subsequent processes in the manufacture of ejectors have been adapted to these processes. Since the almost black, dirty, porous and brittle surfaces were useless for injection moulding, the ejectors were polished after nitriding. However, polishing removed part of the nitriding layer. The broken compound layers produced in the salt bath and in gas nitriding were left with an uneven layer thickness or even removed completely. Although the ejector had a bright finish – the protective, wear-resistant compound layer had been removed. Drei-S-Werk therefore developed the bright, plasma-nitrided ejector (A004), which does not need to be polished. The pin has a bright finish with a light-grey, matt surface with a correspondingly optimised compound layer.

If an oxidation layer is additionally applied to the compound layer, the durability of the ejector is further improved (Fig. 2). Drei-S-Werk together with well-known nitriding institutes further developed this new process for ejector pins and launched the AV03 ejector on the market. The black oxide layer can be applied by various processes – however, the combination with plasma nitriding offers most technical advantages:

- The wear behaviour of the mould bore and ejector is improved.
- The oxide layer serves as an antiadhesion layer for melts.
- The corrosion resistance is increased.
- Dry running is made possible.
- The parts do not discolour during handling.

Concerns that the black layer of the AV03 may discolour can be dispelled by a simple test. If small slivers are abraded from a bright-finished ejector, a light grey one and a black-oxidised one (Fig. 3) by means of the diamond file and compared with one another, no colour differences can be seen. Whether bright or light grey, steel always oxidises at the surface. Under the microscope, the oxidised steel always has the same appearance – such as a black oxidation layer in the case of AV03. However, dry surfaces wear faster than lubricated surfaces. The AWF 1400 high-performance grease for ejectors, which can be used up to 1400 °C, is economical to use and suitable for low and high process temperatures.

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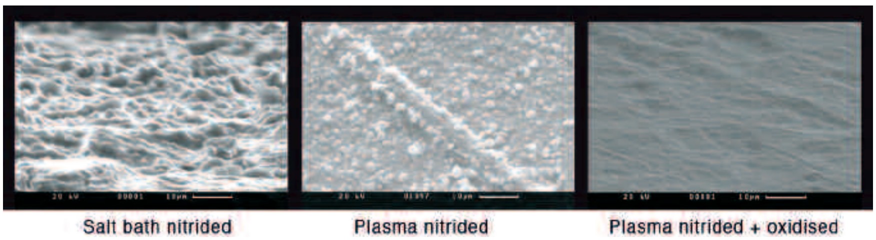

Fig. 2. Comparison of the surfaces of the differently nitrided ejectors

Comparative Tests for Wear

A comparative test on wear behaviour was performed to determine which surface treatment leads to a long lifetime of ejectors. To make the results as realistic as possible, an independent consulting engineering practice was contracted to simulate the standard test conditions as follows:

- test mould with standard bushes made of 1.2343 steel: three ejector pins in each case;
- stroke: 30 mm;
- lateral force on bushes: 10 N on a projected area of 30×8 mm^2.

The lateral forces that actually occur in a mould depends first and foremost on how precisely the mould and bearing tolerances of the guide bores and the ejector plates have been maintained.

The bushes were polished to a bright finish at the loaded surface regions by the friction of the ejector pins after just a short service time. The abrasion increases with time. There was no sign of the process stopping after a particular surface area had been abraded to a bright finish. Instead, the ejectors gradually wore further into the bush and produced abraded material continuously. This abraded material is the actual cause of the ejector seizing up.

The three best selling ejector models of Drei-S-Werk were subject to several test series with 100 000 strokes. Then the test moulds were completely dismantled. The results:

1. Black, nitrided ejector with MoS_2 (formerly used in pressure casting): The coating of MoS_2 antifriction paint of about 15 µm thick produced much higher frictional force between the ejector and bore wall, which additionally heated the test mould and greatly increased the wear of the ejector and bush.

2. Plasma-nitrided bright-finish ejector with lubricant (used in conventional injection moulding): Because of the short stroke movement, there was an accumulation of abraded material, that in some cases entered into a relatively firm bond with the substrate and significantly roughened it. The uniformity of the bright-finished zone, beyond the joint of the two bushes, appears to indicate that the abraded material together with the lubricant acted as an abrasive paste.

3. Plasma-nitrided and black-oxidised ejector with lubricant (new model for injection moulding and die casting): After 100 000 strokes, the oxidation layer was no longer apparent at the friction zone, but wear and abrasion still only took place at a relatively low level. The mould contour remained practically constant.

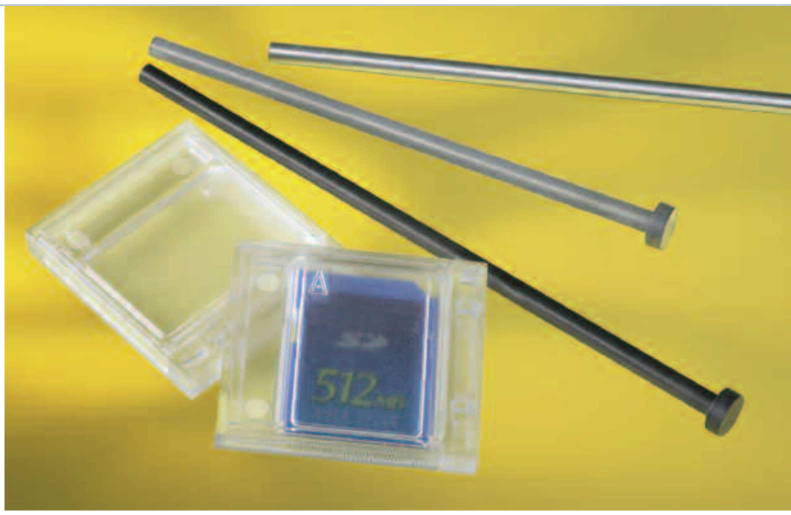

Fig. 3. AV03 (black), A004 and hardened ejector (from bottom to top)

An Ejector Pin that Protects the Mould

According to the present state of knowledge and the state of the art, the plasma-nitrided and oxidised ejector pin (AV03, Title photo) can be regarded as protective of the mould. It can be used as a lifetime-lubricated (AWF 1400) or dry.

From a tribological point of view, mould makers should avoid using two frictional counterparts made of the same material. It would result in uncontrolled wear and seizing up. Derived from this key statement, Drei-S-Werk, in a series of tests, established that the application of an Fe_3O_4 oxide layer, the sliding and emergency dry running properties are generally improved. The process is used for similar purposes in other industries. The camshafts of modern automotive engines are also oxidised. Mechanical engineers have made use of the corrosion resistance and dry-running properties for years in pistons in lifting cylinders. ■

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