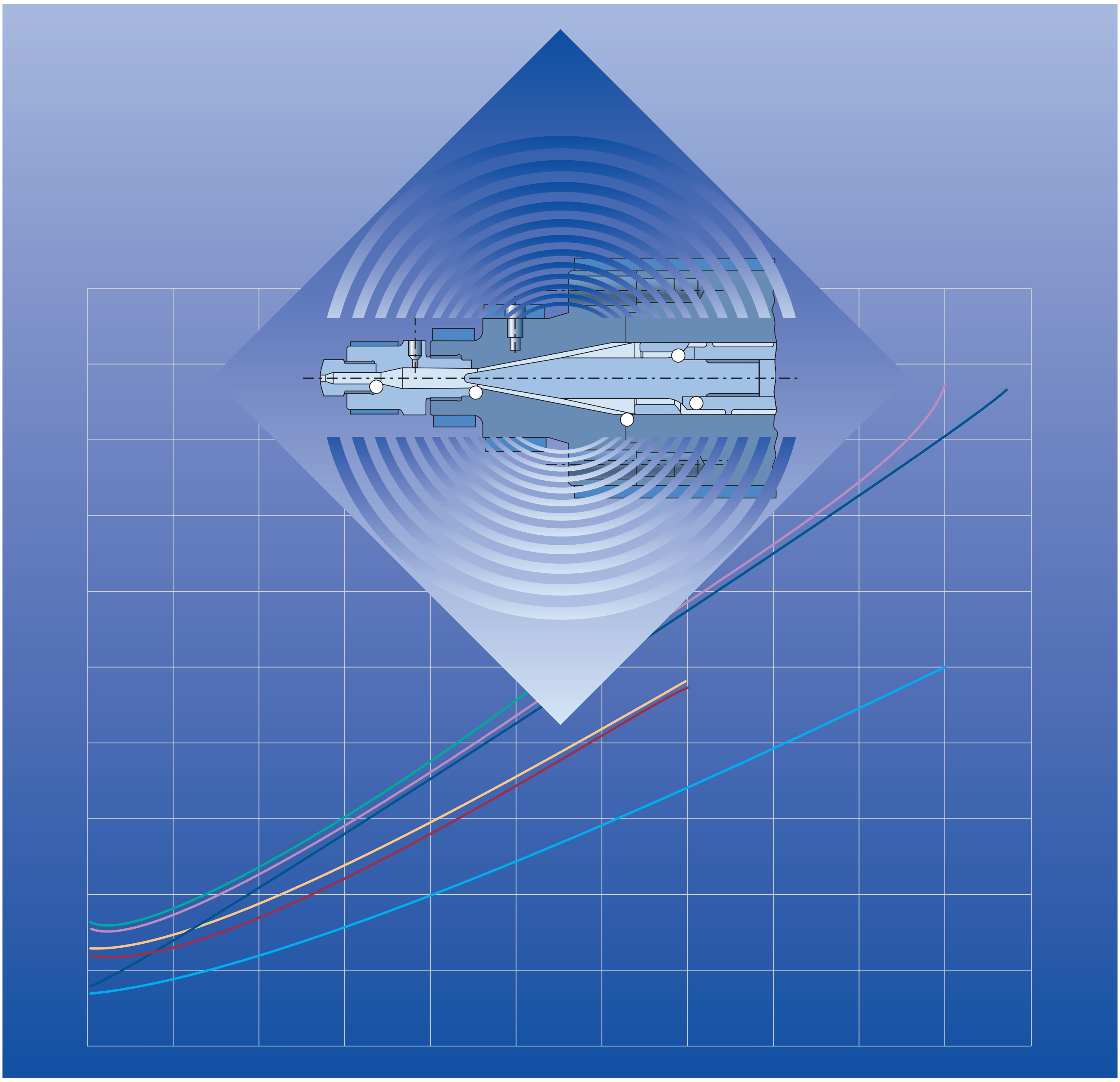
Injection molding of high-quality molded parts – Wear protection for the plasticating unit



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Wear has to be expected wherever surfaces move against each other without being separated by lubricants. This naturally also applies to the plasticating units of injection molding machines, where both metal surfaces and plastic granules, or molten plastic, rub against other metal surfaces.

This functional wear became even more severe midway through the 1960s when filler and reinforcing materials were added to thermoplastic molding compounds in order to improve on specific properties.

At the same time, an increasing number of new, highly functional and cost-efficient applications were opened up – especially for reinforced plastics – including applications which involved the substitution of metals (Fig. 1).

Apart from other advantages, such as

- lighter weight,
- efficient production without finishing work and
- electrical insulation

the reinforced plastics came close to achieving the same Young's modulus and flexural modulus as aluminum and magnesium alloys (Fig. 2).

Understandably, no one was prepared to dispense with the new group of materials, and hence the logical conclusion was to find means of providing additional protection against wear.

Fig. 1: Examples of applications where injection molding technology is employed

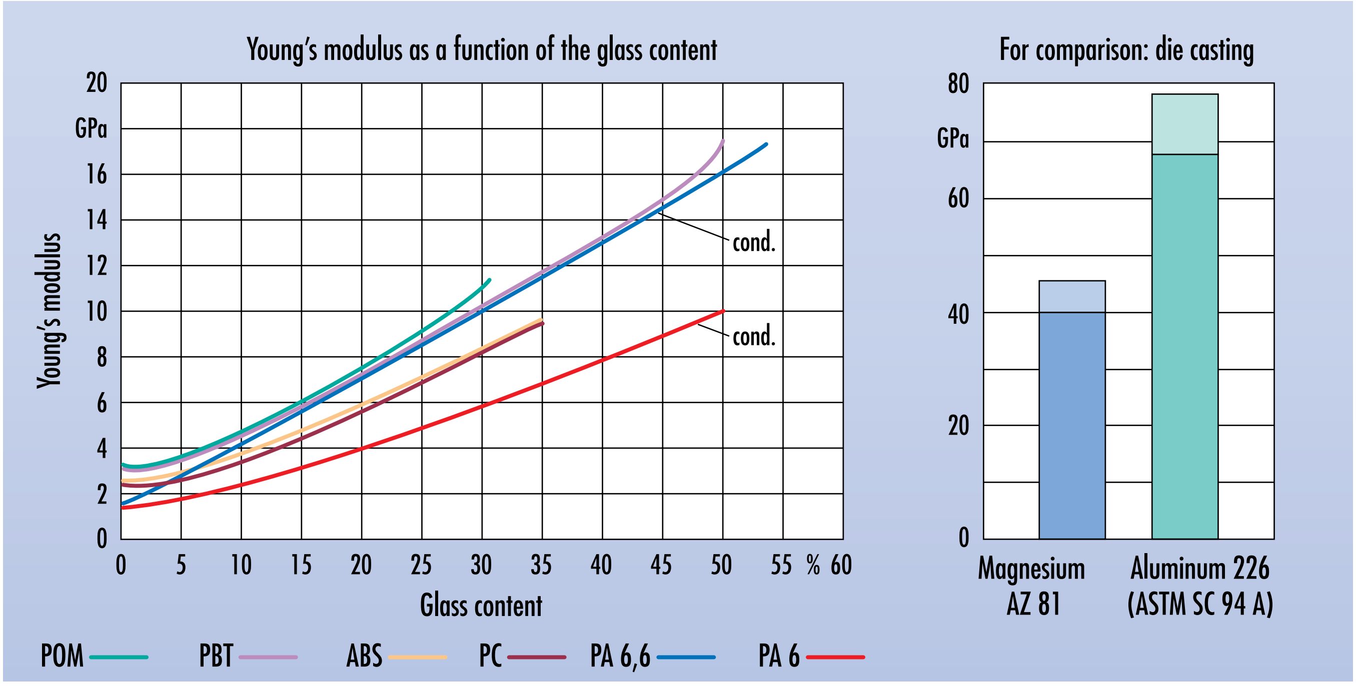

Fig. 2: Increasing the Young's modulus of different thermoplastic structural materials through glass fiber reinforcement

Apart from granular or fibrous filler and reinforcing materials, it is also possible for modifiers, additives, stabilizers and flame retardants to promote wear.

Added to this, for cost reasons, machines are generally operated close to their limits in terms of temperatures, pressures, velocities and plasticating capacity.

Wear during processing increases costs in two ways – firstly through machine stoppages and secondly through faulty molded parts (Fig. 3).

In Germany alone, the annual cost of purchasing replacement parts and producing moldings that have to be scrapped works out at almost Euro 1 billion.

Impact of wear phenomena

One criterion is the potential "service life" of the machine components in the plasticating unit up to the point where the level of metal wear produces malfunctions or breakdowns. Typical examples of this are leaky non-return valves (pressure build-up, leakage flow), extended metering times and a "doughy" consistency due to abrasion of the flights, expansion of the cylinder, or corrosion on surfaces and sealing faces that come into contact with the melt.

The wear on machine components has a direct influence on the quality of the molded parts towards the end of the components' service life. An increase will be seen in dimensional and weight fluctuations, and melt that has penetrated gaps or recesses and undergone degradation will lead to surface imperfections. Leakage flows extend the residence time to such an extent that thermally degraded molecule chains impair the properties of the molded parts.

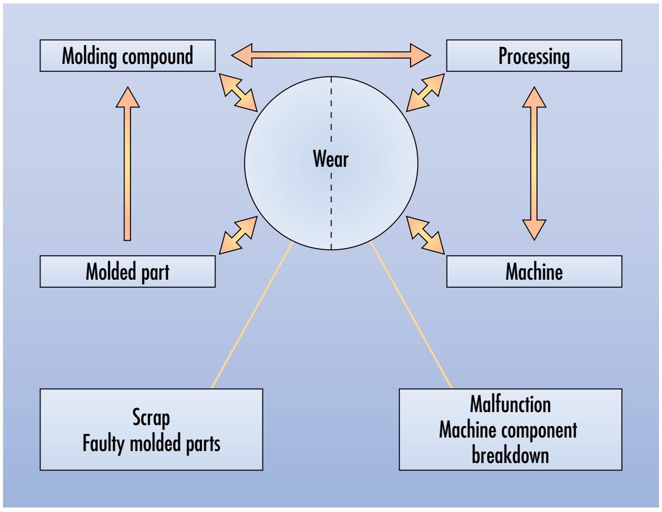

Fig. 3: Wear in injection molding

At the same time, just the smallest of wear phenomena in injection molding units which are otherwise in perfect working order can lead to faults in molded parts and the production of scrap. Mechanical, chemical and electro-chemical erosion and conversion reactions take place between steel surfaces and the plastic melt in the microscopic range, generating intensively colored reaction and abrasion products. When these are washed to the surface of the molded part, they produce undesirable color contrasts, such as streaks, dark stripes, silver streaks, dots, specks and cloudiness, even before macroscopic abrasion and corrosion damage becomes visible on the machine elements. These effects are even observed on new screws and cylinders and when non-reinforced molding compounds are processed.

Causes and types of wear

Wear phenomena cannot be analyzed on the basis of a simple cause-and-effect principle but are based on a complex tribological system. According to DIN 50 320, this system is made up of

- a solid basic substance suffering progressive material loss at its surface,
- a friction partner,
- the intermediate substance,
- the surrounding media and
- the corresponding boundary conditions, such as the forces that act, velocities, temperatures and loading times.

The effective surfaces of the injection molding machine constitute the basic substance, while the friction partner is the still solid molding compound which is generally in granular form. The intermediate substances are melt films, degradation and breakdown products and other media such as atmospheric oxygen, carbon dioxide, water and water vapor, etc. With the transition to the molten range, this system converts into a new system with a new friction partner (the melt) and different intermediate substances. This is why a distinction is generally drawn between the solid and the molten range, with the intensity of the wear varying as a function of the material pair involved.

Both systems are viewed in such a way as to include not only mechanical wear but also the superposition and mutual influence of chemical and electro-chemical processes. This is why the systems are also generally referred to as tribo-chemical systems.

Mechanical wear

The mechanical wear mechanisms are particularly complex in the case of plastication in the injection unit, since the tribosystem undergoes constant change as the polymer melts. Comprehensive descriptions of the types of wear, together with their causes and influencing parameters etc., may be found in the specialist literature. Only the key points will be touched upon here in order to make for easier understanding.

Figure 4 shows the standard types of wear that occur along the process axis on the melting model for thermoplastics. These are summed up once again in tabular form in Fig. 5. The different pairings involved are specified in each case, together with the location and nature of the wear, plus information on causes and influencing variables. The wear phenomena are additionally allocated to three principal zones:

- zone having no contact with the plastic,
- solids zone (non-melted polymers),
- molten zone.

The transitions are, of course, fluid.

Unfilled molding compounds with a low pigment concentration do not cause any notable abrasion in the solid or molten zone, unless very high pressures are generated in the solid zone (through feed bushes). In most cases, these plastics can even be said to have an enveloping and lubricating effect in the molten state.

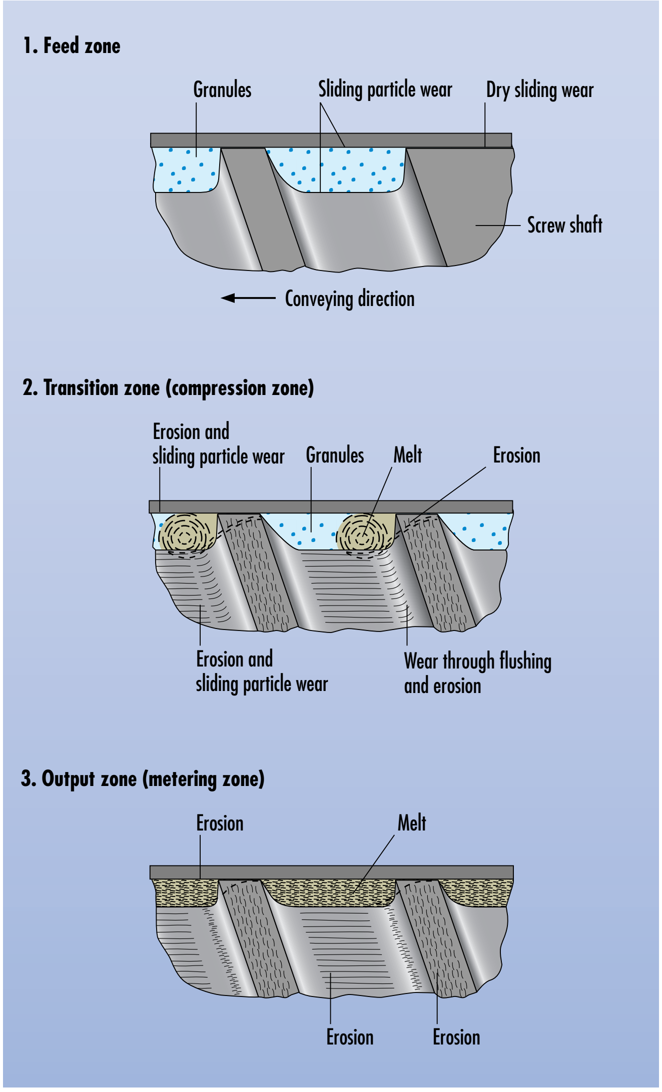

Fig. 4: Melting model for wall-adhering thermoplastics

Type	Pairing	Appearance	Location	Zone	Causes/Influencing variables
Dry sliding wear (adhesive)	Metal/metal (dry)	Seizure, chipping, craters	Screw shaft flight/feed zone	Without plastic	Partner material, hardness, weight,warpage, unilateral stressing (feed pockets, feed bushes)
Sliding particle wear Rolling wear	Metal/plastic Metal/filler	Furrows, scoring, rolling marks	Screw root surface in feed and compression zone		High pressure (unfilled polymers); hard (abrasive) pigments and fillers (dry), dry coloring
Sliding wear (abrasive)	Metal/filler	Furrows, scoring	Screw root surface in compression zone	Solid zone	High pressure; pigments and fillers in slightly melted polymers; "hedgehog" effect, masterbatch, pigment pastes
Flushing wear (abrasive)	Metal/filler	Furrows, scoring, washout	Flank in compression zone		
Erosive wear (abrasive)	Metal/filled plastic melt	Cracks, waves, channeling, orange peel	Screw flight, flank, root surface, end of compression and metering zone		Viscosity, mobility, filler hardness, forces, kinetic energy
Wet sliding wear (adhesive/ abrasive)	Metal/lubricated metal	Seizure, scoring, chipping	Cylinder/flight, cylinder/ locking ring, locking ring/tip	Melt zone	Pressure, forces, warpage, hardness, pairing, lubrication

Fig. 5: Types of mechanical wear in polymer plastication

Figures 6 and 7 show examples of frequent types of damage. “Sliding and flushing wear” often occurs with filled granules that are only melted on the outside (hedgehog-shaped friction partner) under a corresponding level of pressure.

“Erosion” is found on screw surfaces that are wetted with melt. Identical mechanisms also apply in the same way for the cylinder, although the intensity can vary in the different sections.

Inside the cylinder, the highest level of wear occurs abruptly in the transition zone, before decreasing towards the front and then rising again in the section over which the non-return valve moves.

With screw, it is generally wear in the output zone that predominates, with the wear becoming increasingly pronounced in the conveying direction. Particularly high abrasion rates are observed with leaky or missing non-return valves (in the case of thermoset processing).

On the screw root surface, the most severe wear is observed in the transition zone, which is caused by flushing wear (hedgehog effect) on the leading edge of the flight.

The cylinder will generally have a service life two to four times that of the screw.

Wear is regarded as normal for non-return valves and nozzles and is thus not rated negatively (wearing parts).

Special, less-frequent forms of damage are screw fractures and cracks in the nitrided layer which result from excessive torsional stressing of the screw (cold start-up, no overload protection).

Manufacturing defects can similarly cause damage: the flaking in Fig. 8 is caused by grinding notches that have been introduced through excessive final polishing. Dynamic load fluctuations undoubtedly promote wear here.

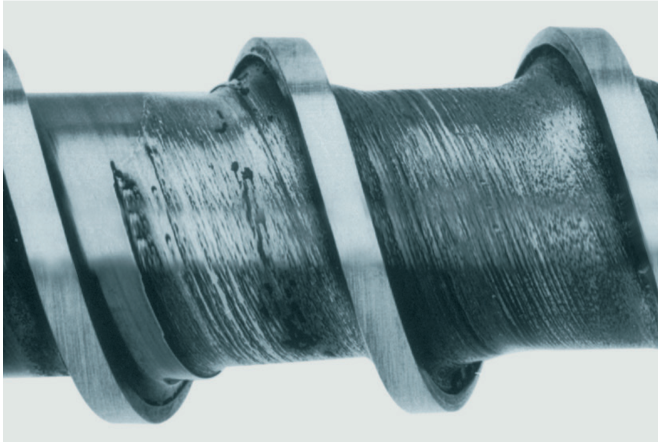

Fig. 6: Sliding and flushing wear in the transition zone

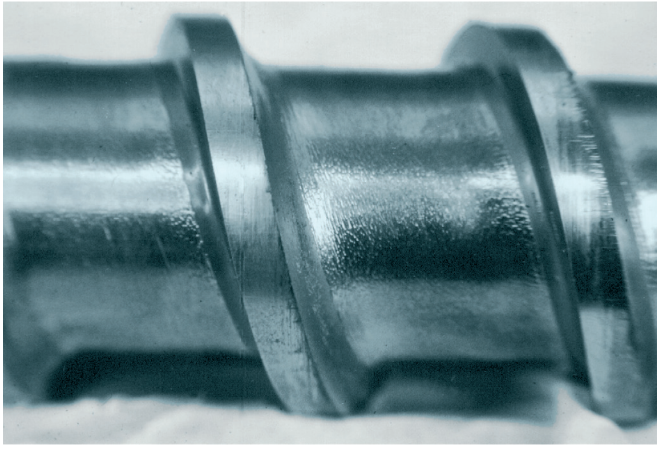

Fig. 7: Erosive wear in the output zone

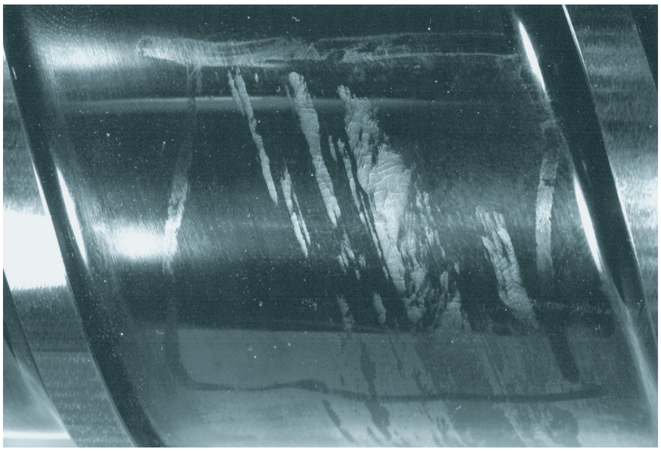

Fig. 8: Material that has flaked off the nitrided layer on account of notches introduced during the grinding and polishing processes

Corrosion

The chemically reactive or corrosive component of the interacting wear mechanisms is influenced by so many parameters that it is frequently impossible to evaluate this component. A few of the parameters that promote corrosion are listed below:

Water, air (oxygen, carbon dioxide), chlorine gases, acid residues, electrolytic solutions, hydrogen halides, impurities and degradation products. These come from:

- the environment (entering the system with the molding compound),
- additives, fillers, impurities (split off during melting),
- the plastic melts (splitting-off, degradation, crosslinking).

The processing conditions, such as temperatures, pressures and times, and also the dynamics of the process, obviously have a decisive influence on the level and speed of these reactions too.

The adhering, sliding and bonding properties of polymer melts influence the course of the reaction over time. In the case of ABS, lubricants can prevent melt from becoming stuck to metal surfaces, for example, and thus reduce corrosion phenomena.

Any damage to surfaces, in the form of notches, cracks, holes, unevenness and roughness, etc. will promote corrosion. This will need to be taken into account when looking at the steels employed and the treatment they receive.

Purely corrosive wear can take the form of both wide-area abrasion and pitting (Fig. 9). In cases where this is also influenced by interaction with mechanical wear, the damage can assume many different forms.

Influence and classification of molding compounds

The level and occurrence of mechanical and corrosive wear is influenced to a major extent by the composition and structure of plastics, together with their fillers and additives and also their melting, conveying and chemical reaction behavior. It is difficult to separate the two types of wear, since both processes take place simultaneously and mutually influence each other.

Corrosion, for example, destroys surfaces which are then more liable to suffer mechanical abrasion; passive layers can be subjected to mechanical abrasion, which means that the layer beneath is then attacked.

This results in “abrasive-corrosive overall wear” in the form of abrasion-corrosion (solids zone) or corrosion-erosion (melt zone).

Observed in purely mechanical terms, it is the micro-chipping process brought about by fillers and reinforcing materials that plays the decisive role. The intensity of the abrasion is essentially a function of:

– the type, quantity, form and hardness of the additives,
– the number of micro cutting edges,
– the forces that these materials are able to exert on the steel surface via the melt.

These forces, in turn, are determined first and foremost by the restraint, intrinsic mobility and kinetic energy of the particles. They are influenced to a major extent by the processing parameters that determine the temperature, viscosity, pressure and shear rate, and also the orientation.

Interesting examples of these correlations include:

a) the higher wear rates with thicker glass fibers and a correspondingly lower number of fibers by comparison with thin fibers, for an identical quantity of fiber by weight

b) the lower rates with shorter fibers, despite the corresponding increase in the number of cutting edges

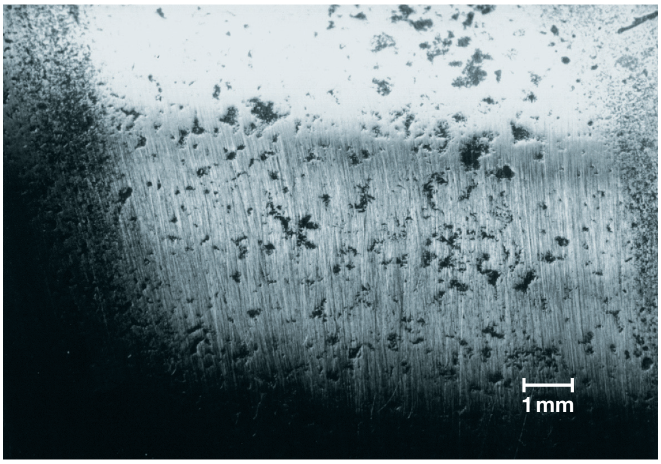

Fig. 9: Corrosion in the form of pitting on a nitrided steel surface

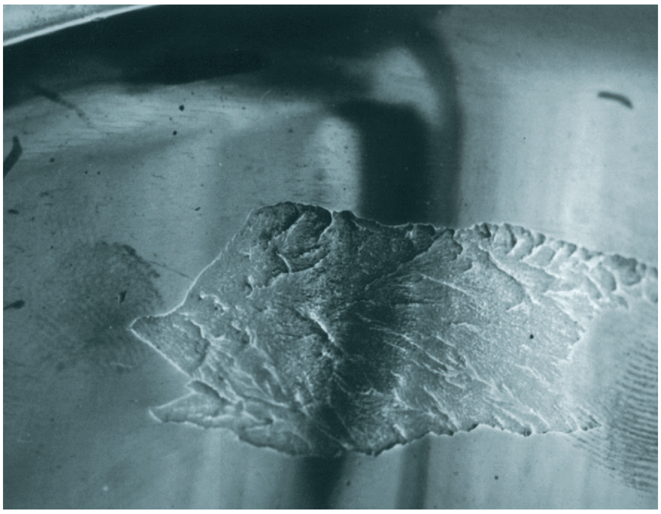

Fig. 10: Solidifying molten PC causes the nitrided layer to flake off

The shape and hardness of the abrasive materials can lead to varying intensity of wear depending on the process zone.

In the case of PA 66, glass fibers cause approximately 14 times more wear than glass spheres in the melt zone. In the solid zone, by contrast, the spheres exert greater Hertz-calculated stresses, which can then lead to greater wear values than with the fibers.

Finally, a number of molding compounds tend to display bonding or adhering effects when in contact with steel surfaces – at times only over certain temperature ranges. Typical examples of wear phenomena caused in this way are the flaking of nitrided surfaces caused by the adhesive forces that prevail between the nitrided layer and the PC melt that is solidifying and shrinking on to it. Fig. 10 shows damage of this type.

Direct coloring in the form of dry coloring using either hard pigments or pumpable liquids and pastes made up as masterbatch frequently leads to more pronounced abrasion in the feed and compression zones. The reason for this is the intensive dry friction, or insufficient lubricant effect of the paste or low-melting batch matrix, in conjunction with high pigment concentrations.

If the abrasive and corrosive components are added together to give the overall wear, then it would be possible to attempt a classification of the molding compounds on the basis of their behavior. Practical experience has indeed shown that pronounced wear is reported more frequently with certain molding compounds than with others. Model tests confirm the general trends observed. The following rank order is applies to thermoplastics:

PC-GF and SAN-GF:
low wear,

PA 6-GF
medium wear,

PA 66-GF
greater than PA 6.

The latest measurements suggest that PBTGF and POM-GF display even less favorable behavior; one surprising result was the high wear seen with PE-GF, which was not evident with PP-GF.

Influence of the materials used for the plasticating unit

In some cases, the gas- or bath-nitrided 34 Cr Al Ni 7 (1.8550) and 31 Cr Mo V 9 (1.8519) nitrided steels are still the standard materials used for screws and cylinders today, even though they have pronounced shortcomings. These were already classified as only suitable for unfilled PE and PS in the literature back in 1974. They no longer meet present-day requirements, since they do not offer sufficient protection against abrasive and corrosive wear.

As long ago as 1973, different authors set out the main causes of breakdown as being insufficient wear resistance, a low wear reserve through inadequate layer thickness, indentations of the nitrided layer with insufficient basic hardness and nitriding errors (such as embrittlement through over-nitriding).

Fig. 11 shows a micrograph of a brittle nitrided layer. The melt underwashes individual particles in cracks over the length of the grain boundaries, causing them to break out of the system. These gaps and holes act as nuclei for further abrasive and corrosive wear on the steel surface, as well as for the formation of what are generally dark to black degradation products from the plastic melts. Discoloration, gray streaks or stripes, and specks are the most frequent consequence (Fig. 12). An accumulation of Fe in the discolored areas points to metal abrasion in the majority of cases.

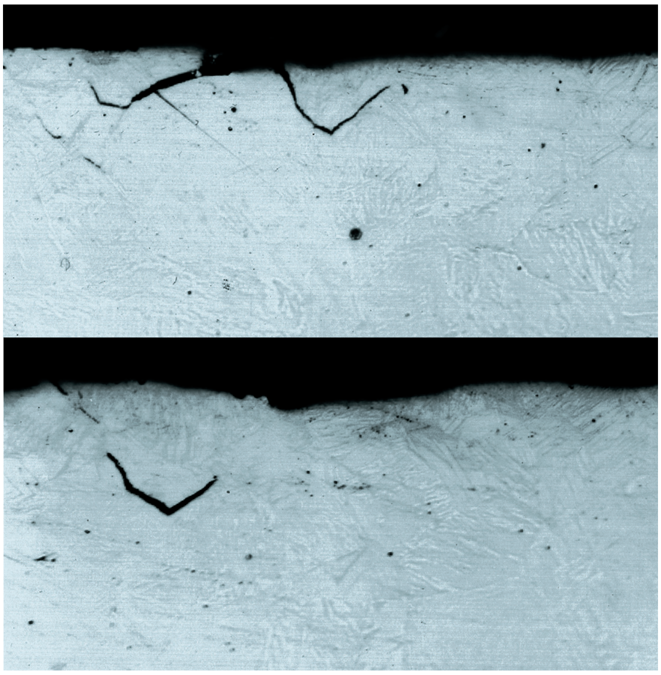

Fig. 11: Micrographs of the nitrided layer on an injection molding screw

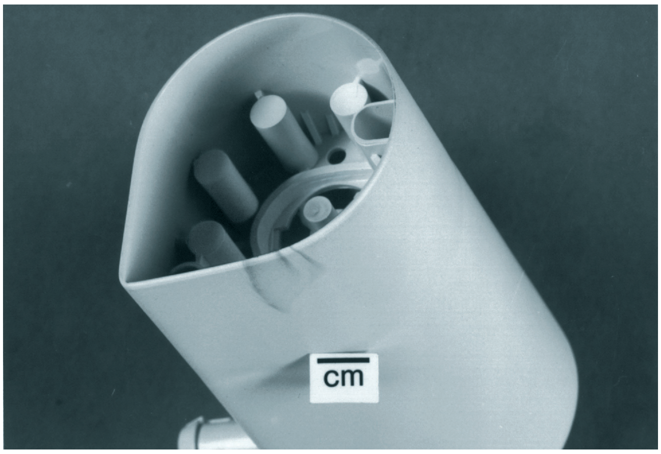

Fig. 12: "Gray streaks" on an ABS molded part due to metal abrasion

While ionitriding is claimed to improve the behavior of these steels a step at a time, they essentially not only have mechanical shortcomings (hardness, thickness, brittleness) but also insufficient corrosion resistance.

Preventive measures

A range of different measures can be implemented to provide protection and prevent wear. These essentially relate to:

– the design of the component,
– the selection and treatment of the materials,
– the processing parameters.

Only when the individual measures are suitably coordinated will effective protection result.

Component design

Irrespective of the material selected and the processing conditions, it is possible to counter wear by paying attention to a number of design details.

Screw geometry

The top section of Fig. 13 shows a number of critical geometries.

Excessively short screws have too low a melting and homogenization capacity. Granules that have not fully broken up are conveyed at too early a stage into zones where a high pressure prevails. Feed zones that are too short, an excessively high level of compression, and compression zones that are not long enough all constitute aggravating factors. Screws with a constantly increasing root diameter lead to similar effects.

The proposed geometry for thermoplastics shown in the lower part of Fig. 13 can be expected to display more favorable wear behavior. With screw lengths of < 20 D, the pitch should be reduced to ensure gentle melting, so that 20 flights are available once again. The flight depths in Fig. 14 similarly constitute a tried-and-tested compromise for processing both semi-crystalline and amorphous thermoplastics. The dimensions should not deviate by more than 10 % from these figures.

The flight depths (h) can be converted into any required diameters (Dx) with the model law

$h_x = h_o\ (Dx/Do)^{0.74}$.

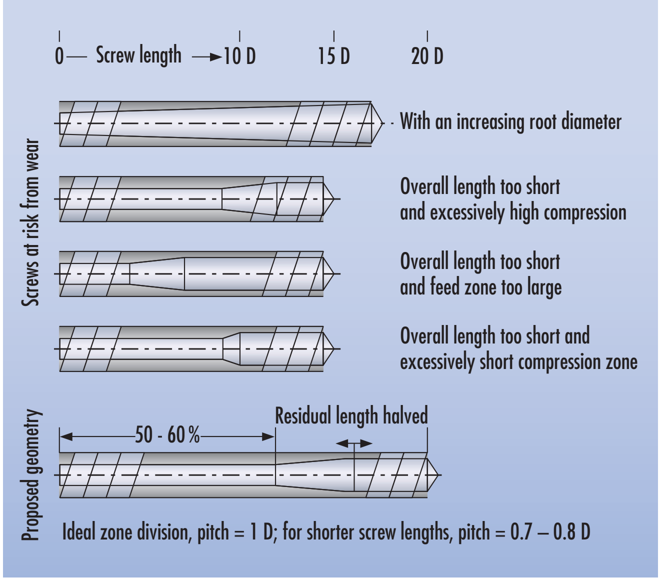

Fig. 13: Screw geometries at risk from wear and favorable screw geometries

Screw diameter (mm)	Flight depths (mm)			Flight depth ratios	
	Metering zones for amorphous and semi-crystalline thermoplastics	Feed zones			
		amorphous	semi-crystalline	amorphous	semi-crystalline
25	2.0	4.0	4.0	2.0:1	2.0:1
30	2.1	4.3	4.3	2.0:1	2.0:1
35	2.3	4.8	4.8	2.1:1	2.1:1
40	2.6	5.4	5.4	2.1:1	2.1:1
50	3.0	6.5	6.5	2.2:1	2.2:1
60	3.4	7.4	7.4	2.2:1	2.2:1
70	3.7	8.4	6.8	2.3:1	1.8:1
80	4.0	9.1	7.6	2.3:1	1.9:1
90	4.2	10.0	8.4	2.4:1	2.0:1
100	4.6	10.8	9.1	2.4:1	2.0:1
110	4.8	11.5	9.8	2.4:1	2.0:1
120	5.0	12.0	10.4	2.4:1	2.1:1
130	5.2	12.8	11.0	2.5:1	2.1:1
140	5.4	13.4	11.0	2.5:1	2.0:1
150	5.6	14.0	11.0	2.5:1	2.0:1

Fig. 14: Flight depths and flight depth ratios on injection molding machine screws for processing amorphous and semi-crystalline Bayer thermoplastics

Cylinder head

Two critical points have to be observed in the region of the cylinder head. First of all, the two sealing faces on the front end must be absolutely flat and undamaged so that they provide a gap-free seal with the surfaces they rest against. Material that penetrates cracks undergoes degradation, is carried along by the melt flow and can cause discoloration or specks in the molded part. Corrosion processes can also occur in gaps of this type which then destroy the sealing faces still further and make the problem worse. A surface pressure of up to 400 N/mm² will reinforce the sealing effect.

Secondly, care should be taken to ensure a favorable transition from the cylinder aperture diameter to the nozzle aperture diameter. Slim cones avoid the material stagnation in "dead spots" which can occur with onion-shaped or stepped transitions.

Non-return valve

The requirements for reducing wear here are:

- perfect sealing faces on the back-up ring between the tip and the front end of the screw (Fig. 16),
- flow cross-sections under the locking ring which are similar to those in the final screw flight (± 20 %),
- avoidance of sharp deflections in the melt flow,
- a sufficient guide length for the locking ring, which also has a sealing function (approx. 1D; 0.8D with a diameter of more than 70 mm),
- rapid closure of the valve to prevent any leakage flows,
- a hard facing on the flights at the screw tip which experience sliding friction against the locking ring.

In addition to this, the taper at the screw tip should, of course, be coordinated with that of the cylinder head. It is not possible to give a universally valid value for the maximum permitted play between the locking ring and the cylinder aperture that will avoid leakage. This will very much depend on the viscosity of the molding compound and the pressure required to fully shape the molded part. Excessive play can cause increased wear.

Material selection

The demands placed on the properties of materials used for the screw, the cylinder and the non-return valve, etc., can be derived from the familiar shortcomings of the standard nitrided steels and the loading types that will be encountered. In individual cases, it may be justified to choose a material that is specifically adapted to the main type of wear that prevails in the system being used (abrasion or corrosion). There are, however, three aspects which favor the use of universally applicable units:

- the processor intends to use the system to process a large number of different molding compounds over the long term,
- corrosion and abrasion frequently act together, without it being possible to establish or quantify the individual components,
- if there is protection against one type of wear only, then slight influences of the other type of wear, which has not been taken into account, can lead to faults and scrap molded parts.

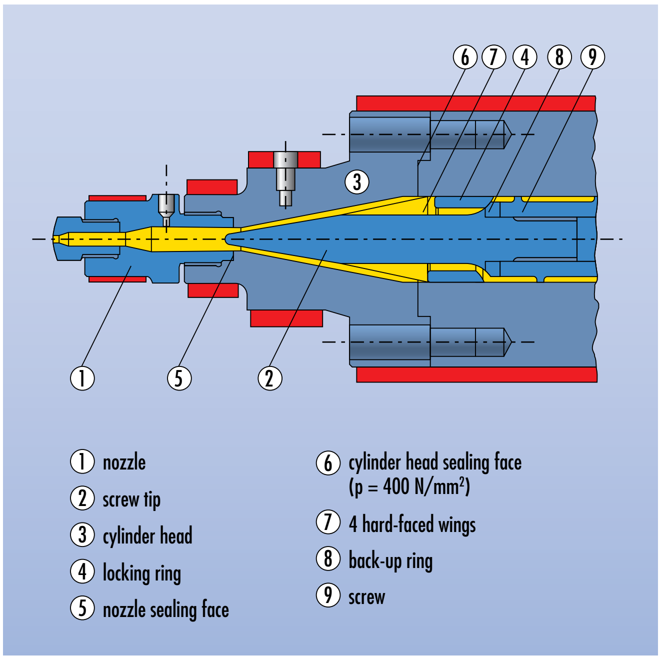

Fig. 15: Proposed design for the cylinder head/non-return valve and nozzle

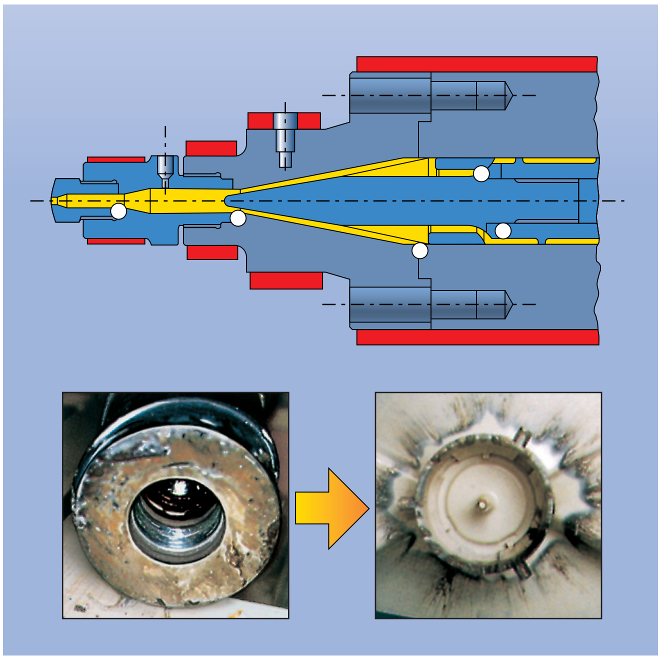

Fig. 16: Faults due to worn or corroded sealing faces

The materials used for a “universal” unit of this type must fulfil the following requirements:

– a sufficient surface hardness with the greatest possible layer thickness (wear reserve),
– a sufficient ductility in this layer (susceptibility to cracking, dynamic loading),
– the layer must be supported on a stable, compression-proof substrate,
– high-temperature strength and hardness for high processing temperatures,
– good surface-slip characteristics, low tendency to bond and adhere when in contact with plastic melts,
– sufficient chemical resistance to suppress corrosion problems,
– homogeneous properties,
– low tendency to warp,
– good mechanical load-bearing capacity.

There are doubtless a whole series of ways in which this catalog of requirements can be fulfilled. The most common approaches are listed in Fig. 17, divided up according to the main system components. This does not claim to be an exhaustive list and will naturally be subject to change as a function of future experience.

“Bimetal” cylinder tubes which have had a suitable wear-resistant coating some 2 mm thick applied to the inside by means of centrifugal deposition are gaining increasing ground. These provide sufficient protection against both corrosion and abrasion. At times, centrifugally coated bushes are shrunk into a supporting tube, especially when repairs are carried out.

Various solutions are adopted in the case of screws. To achieve combined protection against abrasion and corrosion, use is frequently made of high Cr-alloyed depth-hardened steels. These surfaces do not tend to flake off as a result of adhering, solidifying plastic melts (a heat soak at 180 °C is not necessary during stoppages when Makrolon® is being processed) and have a lesser tendency to form boundary layers (specks, discoloration). Tempered Cr-steels with stellite hard facings for the particularly endangered screw flights and additional ionitriding of the entire surface have proved successful. “Standard” nitrided steels with a hard facing for the flights and a chromium-plated root surface are similarly somewhat sensitive to rough handling and abrasion. It is possible for the Cr-layer to break out.

Positive experience has recently been reported with PVD surface coatings (e.g. titanium nitride), particularly for the production of optically demanding parts (e.g. CDs, DVDs, optical lenses).

With small diameters, use is also made of borided structural elements. Boride diffusion layers are said to offer not only hardness but also good corrosion resistance.

Stellite coatings on flights or full-surface stellite coatings are frequently applied when so-called standard units are being repaired or overhauled. The reliability of these coatings is assessed in different ways; in many cases, cracks, flaking and warpage are observed, which impairs cost-efficiency in comparison with new screws.

More recent protective measures include currentless deposition of Ni or NiSi carbide layers, wear protection layers deposited chemically or physically from the gas phase (CVD/PVD process) and structural elements made of hard materials, hard-metal coverings over the entire screw contour and screws and cylinders made of PM-HIP materials.

Material selection for the cylinder head and non-return valve is based on similar criteria as for the screws (Fig. 17).

Cylinders

a) Centrifugal deposition of a suitable wear-resistant coating; generally Fe-Cr-Ni-B-based; unalloyed C steels and Cr-V-alloyed special steels for the supporting tubes
b) Insertion of centrifugally coated bushes;
supporting tube in nitrided steels, e.g. 34 Cr Al Ni 7 (1.8550)
31 Cr Mo V 9 (1.8519)
c) Boride diffusion layers; small diameter
d) PM-HIP materials

Screws

a) High Cr-alloyed depth-hardened (up to about 60 mm in diameter and 1500 mm in length), additionally ionitrided in some cases, e.g.

X 155 Cr V Mo 12 1	(1.2379)	X 165 Cr Mo V 12	(1.2601);
X 210 Cr 12	(1.2080)	X 220 Cr Mo 12 2	(1.2378);
X 210 Cr W 12	(1.2436)		

b) Stellite hard facing for screw flights with ionitrided Cr steels for all diameters, e.g.

X 35 Cr Mo 17	(1.4122)	tempered
X 22 Cr Ni 17	(1.4057)	tempered
X 5 Cr Ni 13 4	(1.4313)	tempered

c) Stellite hard facing for flights and chromium-plated root surface and flanks, e.g. 31 Cr Mo V 9 (1.8519)
d) Boride diffusion layers, small diameter
e) All-hard-metal-coated screw contour and PM-HIP materials

Cylinder head

a) High-alloy Cr steels, ionitrided (see b) under Screws)
b) Standard nitrided steels, hard-chromed, e.g. 31 Cr Mo V 9 (1.8519)

Non-return valve

A Tip and back-up ring
- flights of wing tip always hard-faced with a Cr-Ni-B alloy with added carbide
a) high-alloy Cr steels, ionitrided if necessary (see b) under Screws)
b) Cr-alloyed depth-hardened steels (see a) under Screws)

B Locking ring
a) high Cr-alloyed steels with good toughness, through-hardened or tempered/ionitrided, e.g.

X 155	Cr V Mo 12 1	(1.2379)
X 40	Cr Mo V 51	(1.2344)
X 35	Cr Mo 17	(1.4122)

C All structural elements made of
– hard materials or
– borided or
– CVD[1]/PVD[2]-coated

Fig. 17: Suggested materials for the manufacture of wear- and corrosion-protected elements on the plasticating unit

[1] Chemical Vapor Deposition
[2] Physical Vapor Deposition

Influencing wear through the processing parameters

The chief influencing variables are

– pressure,
– velocity,
– shear,
– temperature,
– residence time.

Since these parameters act simultaneously and mutually influence each other, they cannot be quantified, but it is possible to estimate the correct trends for reducing the amount of wear. Certain tendencies run in opposite directions, however – the speed of the chemical reaction can double through a difference of 10 °C, while the shear is considerably reduced. On the other hand, the possibilities for intervention are already greatly restricted by other boundary conditions. Certain mold filling resistances, for example, call for specific minimum pressures and velocities at high processing temperatures, perhaps at the very limit of what is still permissible. Cost-efficiency considerations may make it necessary to select a high circumferential velocity in order to shorten the metering time.

As a rule, therefore, the processing conditions are not optimized in respect of wear, but on the basis of other target parameters, such as quality or cost-efficiency criteria for the finished part.

Wear protection for injection molding units should thus incorporate sufficient reserves to ensure that the processing influences that occur within the processing range employed in practice do not have any impact.

Practical experience and cost-efficiency

As has been mentioned several times, the assessment of wear-protected injection molding units used in industry cannot be based solely on cost-efficiency criteria as a function of the cost-to-service-life ratio. An overall economic appraisal must also take in factors such as scrap due to impaired quality and a reduced level of usage through breakdown and repair time.

The not infrequent experience of scrap rates accounting for more than 50 % of overall production makes it clear that production costs can increase many times over as a result.

At the same time, virtually no quantitative data is available on scrap rates or on breakdown times that are occasioned by inadequate wear protection. It can thus simply be stated in general terms that the equipment and treatment described will reduce or eliminate this cost source and hence increase the overall cost efficiency above and beyond the cost-to-service-life ratio.

A further aspect of cost-efficiency is that the solution selected should be universally deployable for as many molding compounds as possible. Even just looking at the service life and production costs in comparison with so-called standard equipment, however, it is evident that wear-protected units offer considerable advantages. Fig. 18 shows this on the basis of five typical cases.

All the cylinders on the units were protected against wear by means of a universally applicable centrifugally coated layer. The screws were made of depth-hardened steels, or hard facings were employed for the flights, using ionitrided Cr steels and chromium-plated standard steels. Irrespective of the material combination and molding compound employed, the service lives of the wear-protected units were some six to ten times longer. These factors constitute intermediate values in all the examples quoted, since all the units are still available for further use. The definitive factors will thus doubtless be even more favorable, so that the orders of magnitude set out above can be regarded as minimum general service life reference values. Units of this type are some 50 to 80 % more expensive than “standard units”.

Example	Treatment	Molding compound	Diameter	Service life factor “S”	Cost factor “C”	Cost-efficiency factor “S/C”	Comments
A	Cylinder: centrifugal deposition Screw: depth-hardened	PA 6 + 30% GF	60	> 5	1.5	> 3.3	still in use after 200 d
B	Cylinder: centrifugal deposition Screw: hard facing on flights + chromium plating	PA 6 + 35% GF	60	> 6	1.8	> 3.3	still in use after 250 d
C	Cylinder: centrifugal deposition Screw: hard facing on flights + ionitriding	PA 66 + 35% GF	60	>10	1.7	> 5.9	still in use after 215 d
D	Cylinder: centrifugal deposition Screw: hard facing on flights + ionitriding	PA 6 + 30% GF	60	> 8	1.7	> 4.7	still in use after 4 years
E	Cylinder: centrifugal deposition Screw: hard facing on flights + ionitriding	PC + 30% filler	60	> 7	1.7	> 4.1	still in use after 70 d

Fig. 18: Comparison of costs, running time and cost-efficiency

The service life and cost factors constitute a direct comparison with “standard” nitrided steel equipment that was observed previously.

When use is made of non-return valves that have also been wear-protected, similar running time and cost factors result.

If the service life and costs are expressed in the form of a ratio, then the cost efficiency is seen to improve by a factor of three to six. These are figures that speak for themselves. When additional allowance is made for the reduced cost of scrap, so many advantages ultimately become apparent that wear-protected injection molding units of this type will certainly become established over the long term.

The machinery producers are now responding more effectively to this state of affairs than in the past. Virtually all producers now offer universal wear-protected units as special accessories, for an extra charge. On some machines, these wear-protected units gratifyingly already come as standard.

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