Surface Coating. Wear is unavoidable and system-inherent in counter-rotating twin-screw extruders. Apart from the material being extruded, the process parameters and the geometry of the parts, the right choice of friction partners plays a dominant role with respect to the service life of the process unit. The use of special surface coatings allows the service lives to be significantly prolonged.

Close-meshing twin screws (figures: KraussMaffei Berstorff)

Wear Protection on Twin Screws

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Counter-rotating twin-screw extruders are predestined for the processing of rigid PVC dryblend to semi-finished products of all kinds. Higher throughputs and the increasing use of fillers (in particular chalk) and regrind are the main reasons why screws and barrels are exposed to a steadily growing wear stress.

A fundamental distinction can be made between three types of wear in counter-rotating twin-screw extruders:

- Adhesive wear,
- Abrasive wear and,
- Corrosive wear.

Adhesive Wear

Due to the movement principle, counter-rotating twin-screw extruders are characterized by almost exclusively axial material transport in a closed chamber system **(Title figure)**. According to Menning [1], a "calendering effect" with flow conditions well-known from calenders with corresponding roll pairings is created in the meshing area of the screws due to the system-inherent speed and pressure conditions there. This calender flow under high surface pressures results in adhesive wear conditions in both the solid and melt conveying section, due to the forcing apart of the screw shafts which are supported only by the barrel wall **(Fig. 1)**. Adhesive wear is understood here as being the occurrence of atomic adhesive forces at surfaces without outer boundary layer which can reach the cohesiveness of the approximated solids surfaces under high surface pressure [1].

Abrasive Wear

The abrasive wear is caused by abrasive fillers, in particular chalk, on the screw flanks and at the screw root. Extreme erosion of the screw surfaces can occur here **(Fig. 2)**. Abrasive wear has increased considerably in recent years, in particular in pipe extruders, as the processors use more and more fillers. Not only the volume of the fillers employed, but more importantly the type and particle size play a crucial role with respect to the wear.

Corrosive Wear

Corrosive wear plays a less significant role in counter-rotating twin-screw extruders. This type of wear can occur predominantly when processing tin-stabilized blends. Due to its high tendency to stick, the melt can adhere to the screw surface with subsequent thermal degradation.

When the PVC burns, hydrochloric acid is given off. The hydrochloric acid then has a corrosive effect, attacking the steel surface.

In order to reduce the tendency of the PVC to stick, the screws and the parts coming into contact with the melt are hard chrome-plated.

With the various fields of application of rigid PVC intermediates production,

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widely differing wear values can be observed.

This is then reflected in particular in the service life of the process units.

The wear is primarily influenced by the following parameters:

- Material to be processed,
- Output of the extruder,
- Length of the process unit,
- Choice of screw geometry,
- Process parameters.

The demands on the surface quality of the window profiles prohibit the use of high filler contents and coarse fillers. As modifiers are added to the profile formulations, the profile extruder screws have lower compression values than the pipe extruder screws.

All this results in general in a significantly longer service life of the profile extruder screws compared with the pipe extruder screws.

In sheet extrusion, modified formulations are used as in profile extrusion. Sheet extruder screws therefore also have relatively low compression values. Due to the higher outputs compared with profile extruders, however, higher wear rates have to be expected.

In pelletization, a wide variety of pellets are produced starting from the ready mixed dryblend. The spectrum ranges from rigid PVC profile and fitting formu-

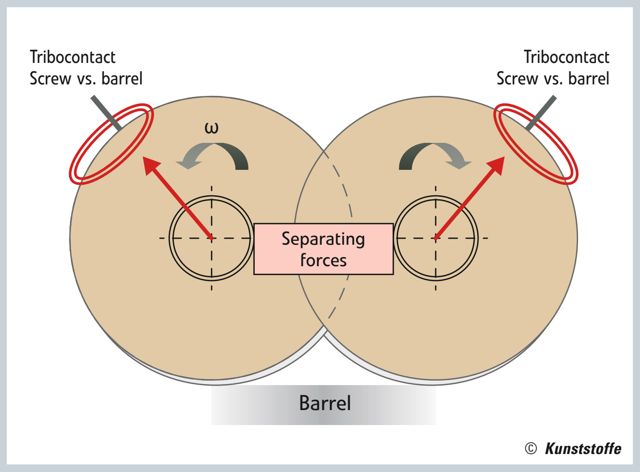

Fig. 1. Tribocontact screws versus barrel due to separating force

Fig. 2. Abrasive wear on twin screws

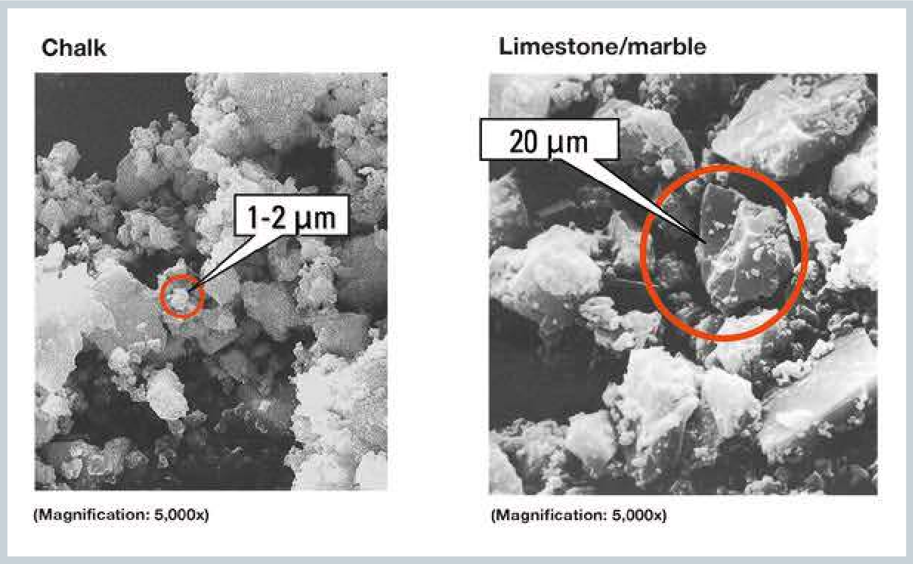

Fig. 3. Exemplary illustration of filler types and grain sizes

lations, through cable duct formulations right up to a vast array of flexible PVC formulations for the shoe and cable industry. The wide variety of formulations, screw geometries, machine configurations and process parameters can result in widely differing wear mechanisms.

Characteristic Wear in the Various Applications

Profile extrusion is used predominantly for the production of window main and secondary profiles. Due to the high quality demands on the semi-finished products, the profile extruders are operated with lower outputs and hence lower screw speeds compared with PVC pipe extruders.

Pipe extrusion generally employs unmodified formulations so that screw geometries with a relatively high compression have to be used. In addition, pipe extruders are operated at roughly twice to three times the output of profile extruders. A further problem is that materials with very high filler contents, and in some regions even with abrasive fillers, are increasingly being used for sewage pipes.

Factors that Influence Wear

The material being processed has a crucial influence on the wear. Counter-rotating twin-screw extruders are predestined for the processing of PVC dryblend. The filler content and the type of filler play a major role in determining the abrasive wear.

In addition to chalk which has a spherical, round structure, materials such as ground limestone and marble with a cuboid, rough structure are also used in some regions (**Fig. 3**). A dominant influence on the level of the abrasive wear, however, is the particle size of the filler which is characterized by the "top cut" (D98). From experience we know that this should not exceed a value of 8 µm.

In addition to premixed dryblends, coarse to finely ground PVC regrind and PVC pellets are also processed on the machines. The use of these materials can also increase the wear. In this case, too, se- →

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lected areas of the screws are hard chrome-plated as protection against abrasive wear.

With long process units, the percentage of shear energy in the total energy input can be reduced and the heating energy percentage increased. This makes it possible to use screws with lower compression. Apart from the greater flexibility of the machine in production, this also contributes to increasing the service life of the process unit.

The **choice of the right screw geometry** and the right balance between the geometry and the material to be extruded also has a significant influence on the wear behavior.

A geometry optimally matched to the material and the right operating parameters of the extruder result in practically uniform wear over the whole length of the screw – and hence a longer service life of the process unit.

Process parameters: The screw loading, i.e. the specific throughput in conjunction with the barrel temperature control, also play an important role with regard to the wear behavior of the screw.

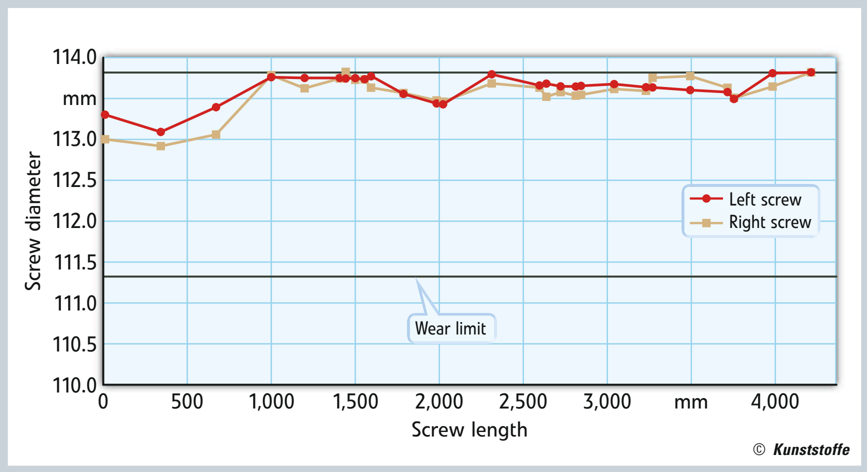

Fig. 4. Diagram for twin screw wear

Wear Analysis

Just as important as the regular maintenance of the machines is regular measurement of the wear in the process unit. With certain formulations, wear of the extruder is unavoidable. KraussMaffei Berstorff therefore offers wear measurements after which the customer receives wear diagrams showing the actual wear of the screw **(Fig. 4)** and barrel diameter and the maximum possible wear.

This makes long-term, timely and also cost-effective spare parts planning possible, and cost-intensive machine standstills can be significantly reduced (predictive maintenance). If above-average wear rates in the process unit are discovered during one of the measurements, the operating parameters and screw geometry need to be checked. As a result premature failure of the process unit, and hence greater technical and financial damage, can thus generally be avoided.

Measures for Reducing Wear

A lengthening of the process unit significantly reduces the wear on the screws and barrels. This can only be achieved, however, if the machine power is chosen in the right relationship to the installed screw torque and screw length. Whereas in the past the lengthening of the process units had the sole objective of boosting the output, great attention is paid today to increasing the processing engineering flexibility of twin-screw extruders. A balanced ratio of shear energy and heat energy together with the right extruder operating parameters are fundamental preconditions for the longest possible service life of the process unit.

As already described, adhesive wear is system-inherent in every counter-rotating twin-screw extruder. Apart from the material being extruded, the operating parameters and the geometry of the parts, the right choice of the friction partners (screws and barrels) plays a dominant role with respect to the service life of the process unit.

Whereas the screws wear around their whole circumference, the barrels are subject to only a single-sided, partial surface wear. Ever higher demands are made on a process unit. Apart from boosting the output of the extruders while maintaining the screw diameter, ever higher filler contents are being used. In order to further reduce costs, the percentage of reclaim used is also increasing steadily. With high-performance extruders, coating of the screw flights is therefore a necessity today.

Fig. 5. Plasma-powder overlay welding machine

Flight Surface Protection Based on Molybdenum alloy

As standard wear protection, KraussMaffei Berstorff offers Plasma-Powder deposit welding (PTA coating) of the flight outer edges on all parallel and conical twin screws in the diameter range

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from 43 to 184 mm based on a MoNiFe alloy with a molybdenum content of up to 50 % w/w **(Fig. 5)**. A special Ni steel is used as barrel material, and hence as tribological friction partner. The chemical composition, grain size and reduction ratio of the forgings used for this are precisely defined in a KraussMaffei Berstorff standard. The inner surface of the barrel is case-nitrided to a depth of 0.5 mm. After extensive analyses and subsequent

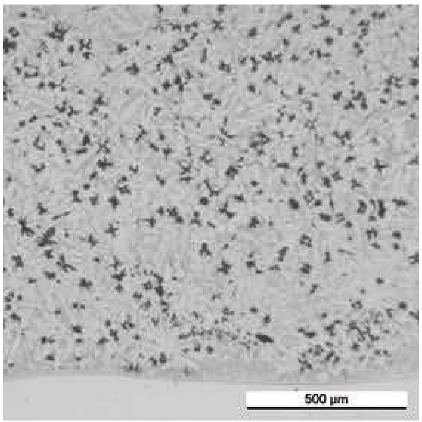

Fig. 6. Finely disperse, isotropic microstructure of an Mo overlay weld, surface hardness approx. 52-55 HRC

modifications to the welding parameters, such as the amperage in relation to the outside diameter and/or track width, and a corresponding heat input into the part at various work steps, a practically crack-free PTA Mo coating with low dilution is achieved, particularly in the edge zones of the welding area **(Fig. 6)**. This improved welding technology leads to a significant increase in the service life, the process availability is improved and minor damage such as localized breakouts are practically eliminated.

Flight Surface Protection Based on Tungsten Carbide

Coating of the flight outer edges with tungsten carbide has been known for years. The PTA WC welding technology was qualified in the same way as for the Mo coating, with determination of the welding current amperages for the respective outside diameters and/or track widths and of the heat inputs in the various work steps, and additionally the selection of a suitable WC welding flux. All test series were documented metallographically with micrographs and hardness measurements and then evaluated and assessed as to their suitability. The WC content of the weld metal in the NiCrBSi matrix was up to 70 % w/w. **(Fig. 7)**. A NiCrSi-based cylinder inner liner with a hardness of 58-66 HRC is used as tribological friction partner for the parallel twin screws. With this technology it was possible to produce twin screws in a diameter range from 75 to 164 mm with a WC coating of the flights.

In combination with the high-performance coating of the barrel, these screws are used as a highly wear-resistant tribological system, particularly for applications with high adhesive wear, such as in the processing of WPC for the production of decking profiles. The service lives achieved with WC coating – depending on the formulation and assuming operation of the machines according to specification – lie between 6,000 and 20,000 h. As process units with Mo coating exhibit premature failure in some cases after only a few hundred operating hours due to the formulation, a comparison or forecast of service life factors is not really possible as Mo coatings are not economically suitable for this process application. Even with the PVC formulations with high filler contents >50 phr and average filler grain size distributions of >10 µm encountered more and more frequently, twin-screw extruders are increasingly being equipped with WC-coated screws with the aim of reliably achieving the demanded service lives of > 12,000–18,000 h. ■

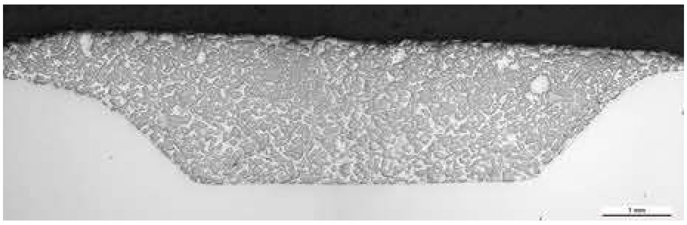

Fig. 7. Homogeneous, isotropic carbide distribution of a WC overlay weld, surface hardness approx. 58 HRC

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