Innovation at Hosokawa Alpine AG

Steffen Sander, Dr.-Ing.[a)], and Michael Heinecker, Dipl.-Ing. (FH) [b)]

a) Manager R&D - Powder and Particle Processing, Hosokawa Alpine AG
b) Manager R&D - Film Extrusion Technology, Hosokawa Alpine AG

Abstract

Hosokawa Alpine, founded in 1898 and based in Augsburg, Germany is one of the leading companies in the fields of "Powder and Particle Processing" and "Film Extrusion Technologies". The article highlights some of the many innovative products of Hosokawa Alpine. It is also shown, that once a product is introduced into the market, it is continuously further developed to meet the requirements of customers with a huge variety of applications.

The introduction of the air classifier ATP, for instance, was a milestone in powder processing enabling precise powder classifying with very fine cut points. However, it was developed further through the years in order to reach even finer top cuts, higher production rates and decreased pressure drop resulting in lower operating costs. Closely connected to the development of these air classifiers is the development of the fluidized bed opposed jet mill AFG and its related mills. Making use of the fact, that the feed material is comminuted autogenously by particle-particle collisions, this machine has become a working horse in fine grinding of all kind of materials.

The development of the internal recirculation classifier Ventoplex C was focused on the processing of mineral powders produced at very high production rates with reduced operating costs. In contrast to that, the picoline R is well suited for the processing of powders in very small quantities targeting the R&D labs of customers dealing with high value materials.

In film extrusion Hosokawa Alpine launched a new blown film line with up to 11 layers, extending the possibilities in blown film applications with a number of sophisticated solutions. The application of the new mono-axial film orientation lines MDO helps to further improve the cost efficiency in blown film production.

1. Introduction

The trade name "Alpine" acquired an excellent reputation in industry as early as the first half of the 20th century. And up to this day, Alpine - which celebrated its 100-year anniversary in 1998 - stands for state-of-the-art technology in leading-edge quality. Thanks to the confidence of customers all over the world, Hosokawa Alpine's two departments "Powder and Particle Processing" and "Film Extrusion Technology" are leaders in their respective fields.

Based at Augsburg, Germany the Hosokawa Alpine AG employs some 650 people. Since we believe that innovative products are necessary to meet our customers increasing requirements, R&D work is a vital part of the long term business strategy. Therefore, Hosokawa Alpine maintains well equipped test centers for both, the powder & particle processing as well as the film extrusion technology. Our experienced technicians and engineers develop cost-efficient systems and innovative processes for the future of process technology.

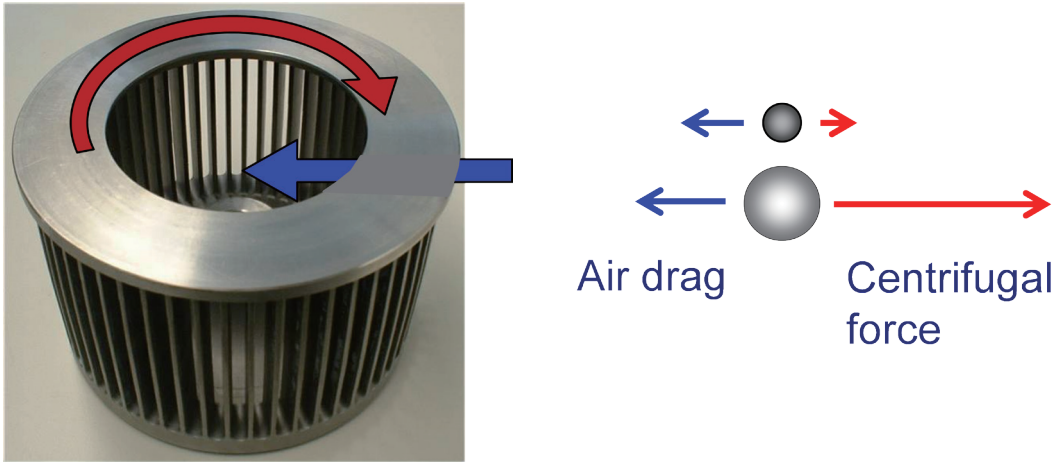


Fig. 1 Basic principle of a dynamic air classifier (ATP classifying wheel)

2.Powder and particle processing technology

The founding year of Alpine - 1898 - was very important in that with the design and construction of the "Triumph" universal mill, Holzhauer's company established itself on the sector of fine size reduction, the sector that is still today one of the core competences of the company.

During the course of the company history, mills were developed for ever finer powders and today, particles with a diameter down to 1 µm are produced with Hosokawa Alpine systems. As a means of comparison: a human hair has a diameter of approx. 100 µm. At the same time as the mills, the company also engineered and built air classifiers to separate coarse and fine particles. In the process, Alpine's engineers achieved something of a world record in 1967: for the first time, a cut point of 1 µm was achieved.

2.1.Air classifiers for precise fine powder classifying

Alpine's good reputation in processing of fine to ultrafine powders is closely linked to the development of the TurboPlex® (ATP) classifiers. This is a dynamic air classifier, which applies a classifier wheel rotating at high speed. An air stream is sucked through the classifier wheel by means of a fan that is located downstream - in almost all cases subsequent to a filter. Any particles have to be well dispersed in the air stream. When entering the classifying zone they are subject to two competing forces (Fig. 1):

1) The centrifugal force acts from the centre radially outwards

2) The current force resulting from the air drag acts to the inner side of the classifier wheel.

For any set of parameters and given particle density these forces reach equilibrium at a certain particle diameter x_T. Bigger particles will be deflected by the classifier wheel and discharged in the coarse fraction. Particles having a smaller diameters then x_T will be drawn through the classifier wheel into the fines fraction.

The principal of operation of a ATP classifier can be seen in Fig. 2. After entering the process chamber, the classifying air is sucked through the wheel, which is horizontally mounted. The fines are extracted and transported to the filter. The coarse material rejected by the classifying wheel falls down to the discharge cone. Before it exits the classifier it is intensely rinsed by the upward air stream recirculating the remaining fines.

In order to process bigger quantities of material the classifiers have to be scaled up to bigger sizes. The smallest size available is the 50 ATP whereas the biggest one is the 1000 ATP (numbers give the classifier wheel diameter in mm), which is an enormous range. With a bigger diameter, the circumferential speed had to be increased to obtain the same cut point. For obvious reasons there are limits to the maximum speed of the classifying wheels. Therefore, the patented ATP multiwheel classifiers use up to six wheels in

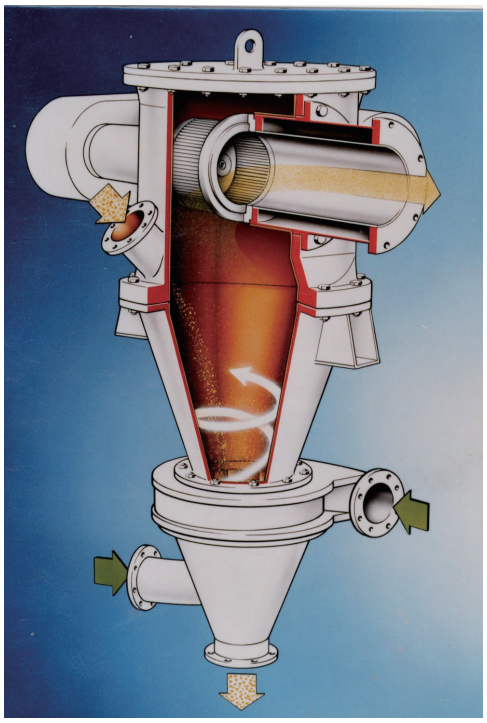


Fig. 2 Schematic view of a ATP classifier

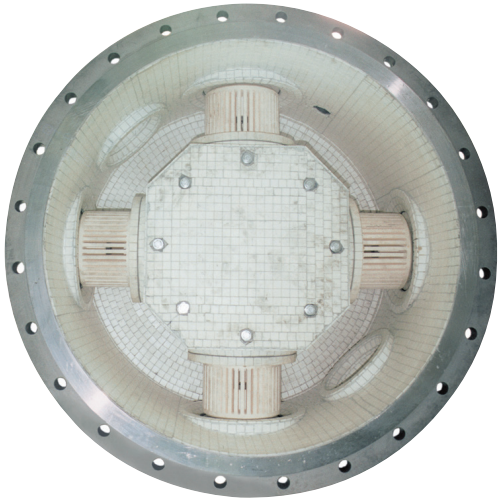
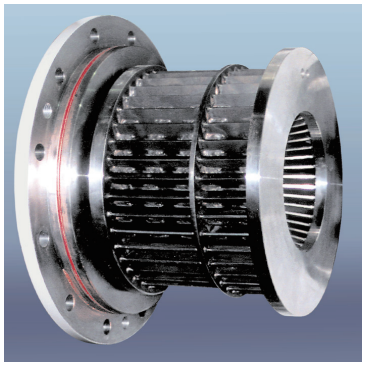


Fig. 3 Inside a 200/4 ATP multi wheel classifier (wheels in ceramics, inner walls with ceramic tiles)

one housing in order to maximize yields at fineness levels which can only be achieved with small classifier sizes. This design is often used also, if the material is abrasive or the application of the powder requires that contaminations with metallic particles are avoided during processing (Fig. 3).

However, the demand for even finer powder produced in high quantities at low operating costs lead to a further development known as ATP/NG (NG stands for New Generation). Using the conventional ATP wheel design a further improvement of fineness would have been achieved by higher wheel speeds, i.e. higher peripheral velocities. Since the ATP uses a wheel with a potential vortex, an augmentation of the rotor speed would have resulted in an increase of the pressure drop. Due to the relation between pressure drop and operating costs this increase had to be avoided, however. On the other hand the number of wheels that could be incorporated in a multiwheel classifier is not infinite. Space and costs for the drive units had to be considered.

Classifiers using a solid body rotation wheel exhibit an extremely low pressure drop. The disadvantage of these machines, however, is the limitation of the cut point at approx. 10 µm. Consequently, the design of the new



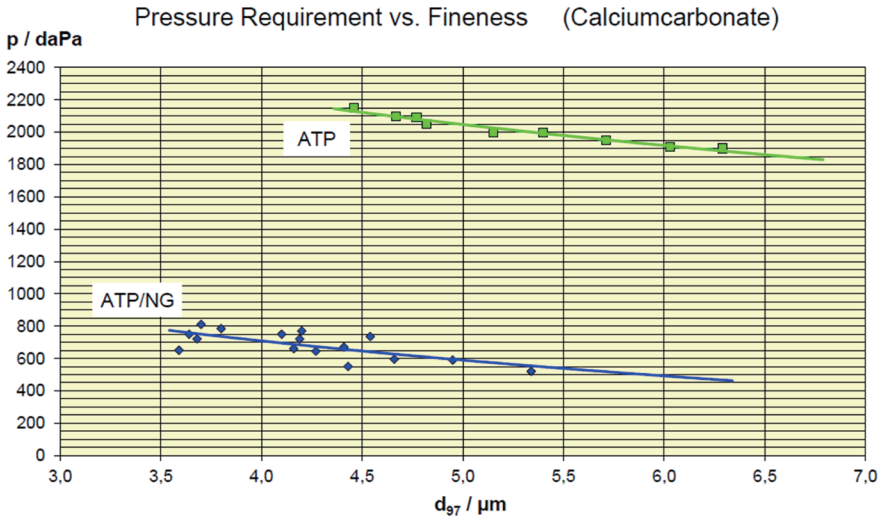


Fig. 4 ATP/NG classifier wheel and pressure drop vs. product fineness

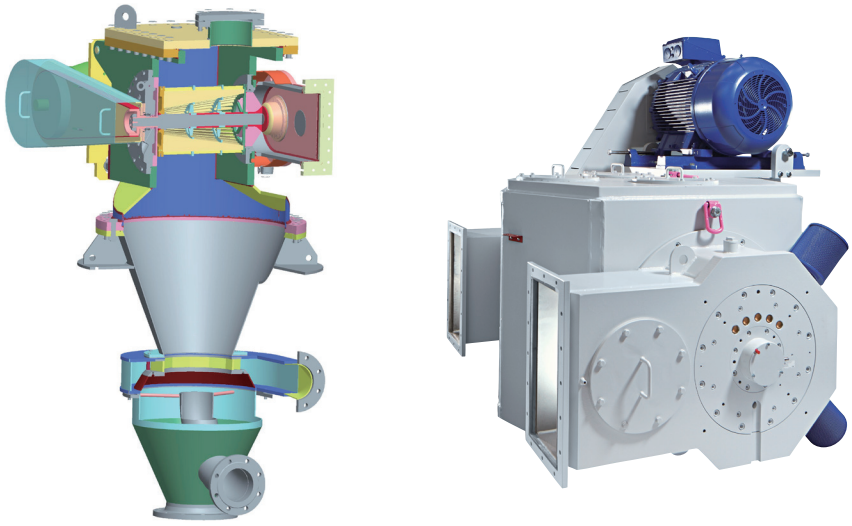


Fig. 5 TurboTwin classifiers: Schematic of a TTC and 630 TTD (head with two fines discharges)

classifier for finest cuts had to be a combination of both concepts. The housing of the ATP/NG uses the well proven design of the ATP as described above. In order to achieve the necessary small pressure drop a patented solid body rotation vortex wheel design is applied. As expected, the ATP/NG classifier wheel (Fig. 4) exhibits a much lower pressure drop than the conventional ATP. Moreover, it enables the production of finer products with a d_{50} at < 1 µm and a d_{95} at < 2 µm.

One key for obtaining finer products is the circumferential speed of the wheel and the radial velocity of the fluid. When developing the TurboTwin classifiers, in order to reduce the radial velocity the wheel height was increased and to achieve higher rotation speeds the wheel now had a bearing on each side. Consequently, the circumferential speed of the classifier is now in the range of 100 m/s. The lower radial velocity allows the use of higher airflows and thus enables the classifier to handle higher mass flows, thus combining the advantages of the ATP/NG technology with a low operating cost system suitable for producing large quantities of ultrafine mineral products (Fig. 5).

2.2. Fluidized bed opposed jet mills

The fluidized bed opposed jet mills AFG were introduced by Alpine in 1981 revolutionising the jet milling sector. This type of mill makes use of the fact, that the feed material is subject comminution by particle-particle collisions.

As the compressed grinding gas (air, nitrogene, argone etc.) exits the nozzles, it is accelerated to extremely high velocities transforming heat into kinetic energy. By using Laval nozzels the velocity of the gas jets can exceed speed of sound. As an example, compressed air at a temperature of 20 °C and at over-pressure of 6 bars leads to nozzle exit velocities of approx. 500 m/s. The particles inside the process chamber are accelerated by the jets and collide, i.e. at the point where the opposing jets intersect (Fig. 6). The high collision speed leads to very fine particles. However, a high concentration of particles is necessary to ensure an efficient comminution. The patented MegaJet nozzles were developed with this in mind, combining 4 small jets in close proximity, which results in an under-pressure in their centre and, thus, the particles are drawn from the fluidized bed into the centre of the jets.

The expanded gas stream flows upwards taking the material to the classifier section. In combination with an ATP or ATP-NG single or multi wheel classifier, the fineness of the product processed with an AFG can be precisely adjusted by means of the classifier speed. The particles too coarse are deflected and fall back into the fluidized bed and are ground further.

The basic principle of fluidized bed opposed jet mills may always be the same but there are many specific solutions for different purposes. Fig. 7 shows a solution for pharmaceutical applications ensuring superior cleanability. Cleanability was also one of the key issues

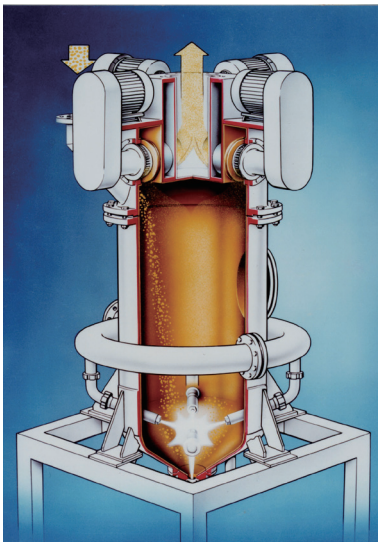


Fig. 6 Schematic of a AFG fluidized bed opposed jet mill

Fig. 7 200 AFG in pharma design

Fig. 8 TFG fluidized bed opposed jet mill with classifier in open position

when developing the TFG (Fig. 8), a fluidized bed opposed jet mill suitable for the processing of toners. The combination with the TSP classifier wheel results in extremely exact top cuts in the range of only a few µm. The mechanism used for opening the classifier ensures a quick access to the processing chamber and helps to reduce down time for cleaning. Today, the fluidized bed opposed jet mills can be combined with TTD classifiers, too. This helps to produce even finer powders, e.g. for talk or graphite.

2.3. Ventoplex C classifier for high production rates

The Ventoplex classifier type C is an internal recirculation classifier designed for high fines yields at low energy consumption. The fineness range can be simply varied between d_{97} = 24 to 200 µm. It is suitable for abrasive materials with a Mohs' hardness of up to 7-8.

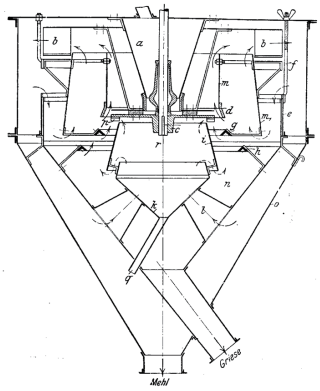
The development of this type of classifiers dates back to the year 1908, when Holzhauer's company received a patent for a recirculation air classifier (Fig. 9). After a continuous development process the Ventoplex type B was launched in 1970, which lead to a number of improvements. Still, there were a few disadvantages such as low separation efficiency, inconstant air flow rates and a limited cut sizes (not below 45 µm). Therefore, the development of the Ventoplex C was started in the middle of the 2000s years.

It has two separate drive units for the classifier and ventilator (the shafts are mounted coaxial), which ensures that they can be operated with different rotational speed (Fig. 9). The feed product enters the process chamber through a quill shaft and is distributed evenly by a distributing plate. Coarse particles fall down against the upward air stream and are collected inside the coarse material cone. They are discharged at the side of the housing.

Fine particles, however, are carried to the classifier wheel by the air stream. At the classifier wheel the particles are subject to two competing forces - centrifugal force and current force. Particles too coarse are deflected by the centrifugal force whereas the current force dominates for finer particles resulting in their passage of the classifier wheel. The fines side of the classifier wheel is mounted directly adjacent to the suction zone of the fan.

The fine particles are accelerated when passing the fan together with the air stream in peripheral direction. Similar to a cyclone the fines are separated from the air stream at the outer wall of the process chamber by the action of the centrifugal forces. The fines are discharged through the cone at the lower end. A rotary valve is used to seal the process chamber from outside air.

During the development and design process care was taken, that the all relevant parts can be protected against wear. Maintenance was improved by an easy access



SCHWEIZERISCHE EIDGENOSSENSCHAFT

EIDGEN. AMT FÜR GEISTIGES EIGENTUM

PATENTSCHRIFT

Nr. 43315 28. März 1908, 7½ Uhr p. Klasse 39 c

HAUPTPATENT

HOLZHÄUER'SCHE MASCHINENFABRIK-GESELLSCHAFT M. B. H., Augsburg-Göggingen (Deutschland).

Luftsichtmaschine zum Trennen von Mahlprodukten in Mehl und Griese.

Fig. 9 First sketch and patent for an Alpine recirculation air classifier from the year 1908
The Ventoplex C - as every internal recirculation classifier- combines 3 different functions (Classifier, Fan, Cyclone) in one machine:

Fig. 10 Section drawing of Ventoplax C and dismantling of a C21V

to all rotating parts (Fig. 10). But also the processing performance was improved significantly, as can be seen for a C9V in Fig. 11. Obviously, the fineness range now reaches very fine cut points whereas the capacity can be kept at high levels.

Meanwhile, the Ventoplex C classifiers are used in a wide range of sizes (Fig. 12) for a number of applications. It is mostly used for the cost efficient processing of industrial minerals, such as limestone, quick lime, fertilizer lime, bentonite, dolomite, gypsum, ores etc. But it is also used for the classifying of abrasive products (for example glass powder), food and feed ingredients and base chemicals.

2.4. Picoline system for very small quantities

The trend these days is more and more towards extremely expensive materials, e.g. in the fields of nanotechnology, pharmaceuticals and specialty chemicals, meaning that researchers often only have very small amounts of material to work with. And quite frequently, hundreds of product samples with minor variations are tested - leading to a further reduction of the amount of material available for each product variant. With the development of the picoline® (Fig. 13), very small machines are now also available for batches of under 1 g up to several grams.

The system consists of a platform in an ergonomic table-top design laid out to accommodate the picoline® function modules. The compact dimensions permit installation inside a laboratory fume hood. The controller (Fig. 15) is standardised for all picoline® function modules and contains all electric and mechanical components necessary for their operation. The media is supplied via an adapter, meaning that no tubes are necessary.

The series includes 10 function modules covering a wide range of unit operations:

- Size reduction: impact mill (Fig. 14), contraplex pin mill, classifier mill, fluidized bed opposed jet mill, spiral

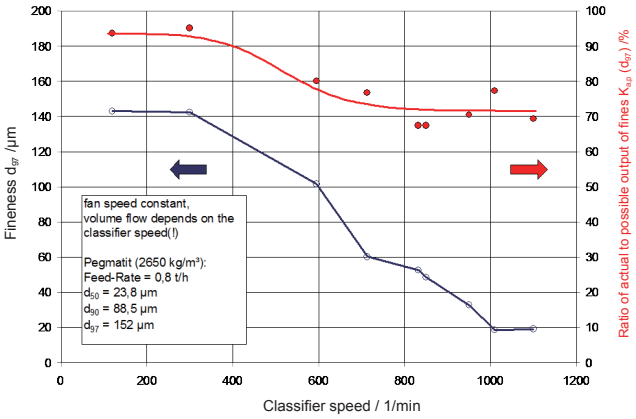


Fig. 11 Product fineness d_{97} and ratio of actual and possible output of fines as a function of classifier speed

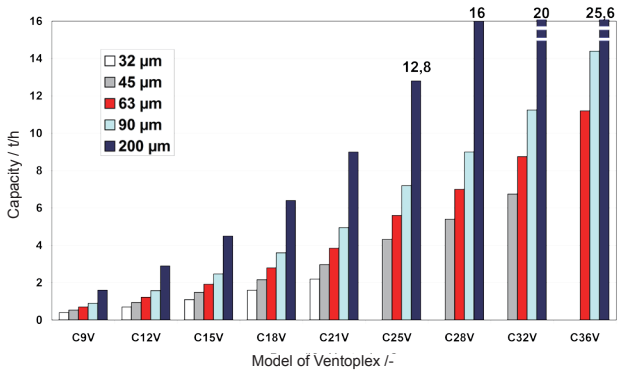


Fig. 12 Production rates for different sizes of the Ventoplex C at several fineness levels (GCC)

jet mill, wet stirred media mill, crusher for preparation of coarse materials

- Classifying: ultrafine classifier
- Mixing: batch mixer, high energy mixer

The picoline® is completed by accessories like dosing system and filter and is even available inside a containment system.

3. Film extrusion technology

The Film Extrusion Division is a global player and ranks high among the international suppliers of blown film lines (Fig. 16), film orientation lines (MDO) and film winders. Alpine blown film lines set new standards in film production and these systems are currently the most advanced on the market in terms of innovation and technology. The lines are characterized in particular by their flexible, economical and reliable operation. As a result, customers can achieve the desired quality and profit from the high degree of flexibility.

3.1. Wide range of applications

Blown film extrusion systems have been manufactured at Hosokawa Alpine since 1955. As a one-stop shopping partner, Alpine supplies complete systems for the production of blown films with up to 11-layers. Customers worldwide use these systems to produce tailored films for every conceivable blown film application. For example highly transparent label films with brilliant printing and good lamination properties, candy wrap films with excellent twist properties, co-extruded films for merchandise bags with handles, metal-laminated high-tech seal-peel films, cereal liners with a high water vapor barrier and good sealing properties, stand-up pouches, robust films for heavy duty sacks, compression film, stretch hoods for pallet packages, special surface protection and masking films with excellent adhesion properties - just to name a few (Fig. 17). Although we focus on the high quality end of the market we also supply blown film lines with high output rates for the commodity markets. In comparison to commodity packaging, high barrier films represent a relatively small market segment nevertheless this market offers not only the described outlook and growth perspectives but also very interesting profit margins and thus presents a good opportunity for investors. According to current estimates around 20 new barrier lines for blown film alone are installed every year.

3.2. A plus in flexibility with the new 11 layer concept

An investment in 11 layer technology instead of 9-layers is particularly suited for companies who wish to be ideally equipped for future new developments and market requirements. It offers flexibility, not only in respect of 5 to 11 layer barrier films but also in respect of the enormous versatility with regards to the raw materials. Primarily responsible for the high degree of flexibility is the new 11 layer die head of our patented X Series. An almost infinite variety of layer structures

Fig. 13 picoline® platform with picoplex® function module

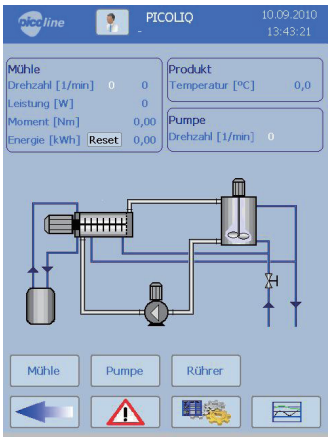


Fig. 14 View on the touch panel of the picoline®

Fig. 15 Grinding tools of picoplex® function module

is possible as the whole spectrum of suitable materials despite their very differing viscosities can be employed in any of the extruders and thus any layer without changing the screw. Both symmetrical and asymmetrical structures are possible as well as layer structures with equal or very differing layer thicknesses. To ensure that the enormous flexibility can be fully exploited under production conditions, short material change-over and purging times were given a great deal of attention in the design phase of the die head. To enable customers to verify this themselves we operate an 11 layer line in our test center (Fig. 18) which is available for customer tests. On this line, together with customers, new structures are implemented and, with raw material manufacturers, new materials and material combinations are developed and their process properties are investigated.

The heart of each Hosokawa Alpine blown film line is the patented Alpine X-die (Fig. 19). The die's innovative rheological design and high-precision components deliver superior film gauge tolerances, shortest purging times, and fastest material changes resulting in the most efficient Blown Film Lines in the industry. The spiral distributor system is specially conFig. d to ensure optimal individual layer distribution and film thickness tolerance, producing top-quality film. Thanks to rheological optimization, it was possible to define new, improved boundary values. We developed new processing methods so as to allow the production of specific parts that meet top quality standards. During the scaling of the flow geometries, self-cleaning effects could be taken into account which reduce the required purging times and positively affect the entire production process. The compact die head design allows a shorter flow distance, achieves minimum purging times, a long service life, a high line availability and significantly reduced material consumption. The sections where the melt flow merges were designed to ensure that laminar boundary layers are extruded without instabilities, even when the layer viscosity and thickness level vary significantly. The spiral distributor geometry in the outer layer is conFig. d to prevent port lines when critical materials are being processed.

Our HXS generation extruders are equipped with a versatile screw design that processes most polyolefin e.g. LDPE, LLDPE, HDPE, MDPE, mLLDPE, EVA and PP as well as barrier materials including PET, PA and EVOH. Other line components include innovative cooling system with a new generation of cooling rings that are flexible and adaptable to a wide range of film structures. An advanced profile control system achieves optimum point-to-point film thickness control. Alpine's ExVis Control System operates the entire Blown Film Line with process monitoring, recipe management and provides operators with complete line diagnostics. A smart-box drive concept in conjunction with motion control is implemented by means of state-of-the-art modular units.

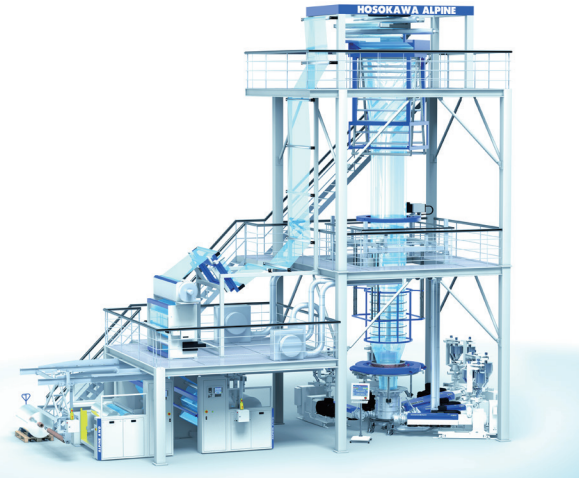


Fig. 16 CAD drawing of a complete line

Fig. 17 A few examples of blown film applications

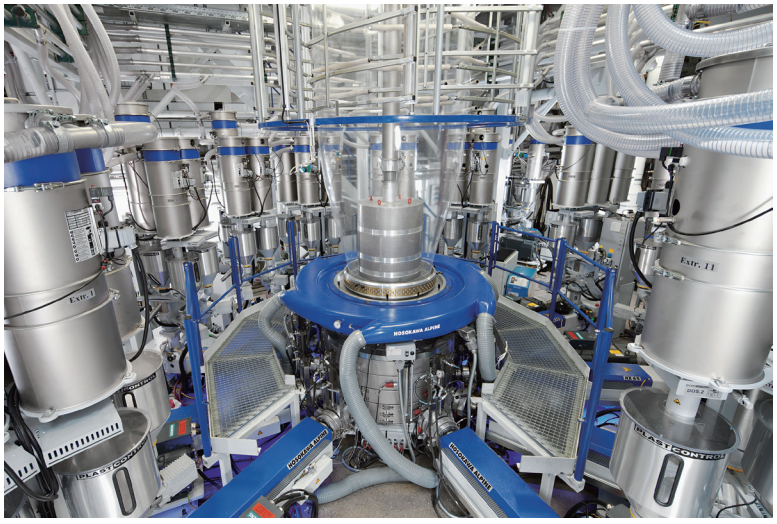


Fig. 18 The 11 layer blown film co-extrusion line in operation in our test center

Fig. 19 The patented X-Die (example of a 5-layer die)

3.3. Hosokawa Alpine film orientation lines (MDO) + TRIO make more of the film

Hosokawa Alpine is the market leader in mono-axial film orientation lines (MDO - Machine Direction Orientation). During the orientation process, a blown film is stretched between two rollers which run at different speeds according to the desired degree of stretch. Typical stretch ratios are between 1:3 and 1:10 depending on the material.

By means of mono-axial orientation the film properties such as thickness, strength, stiffness, puncture resistance, tear properties, Gloss, Transparency, Barrier properties and water vapor permeability, etc. can be optimized to meet the specific requirements of customer's application: During the orientation process, the film necks-in in the transverse direction and consequently reduces in width. This neck-in result in a thickness profile in the transverse direction which is biconcave, the oriented film becomes increasingly thick from the center of the film towards the film edges. In order to achieve sufficient film flatness and thickness distribution to enable the film to be processed on downstream equipment wide edge trims were required. In order to overcome these disadvantages of orientation technology, Hosokawa Alpine has developed the patented TRIO system (Trim Reduction for Inline

Fig. 20 Mono-axial film orientation line MDO

Orientation). Through the use of TRIO, the edge trim is markedly reduced, material is saved and the net output is increased. The efficiency of the entire process is enhanced. In comparison to MDO systems without TRIO the edge trim is reduced by approximately 50% with significantly improved film flatness.

4. Conclusions

Hosokawa Alpine with its two departments "Powder and Particle Processing" and "Film Extrusion Technology" has experienced continual economic growth ever since the company was founded and has also demonstrated quite impressively that it is possible to master even the most difficult times with constant innovation and flexibility. With the combination of modern facilities, and manufacturing equipment, highly educated, well trained and motivated staff coupled with the highest "Made in Germany" quality standards Hosokawa Alpine is ready to meet customer requirements every time.