Next - Generation Plate Designs:
Taking Dispersion To A Higher Level of Performance

Ihalainen Ismo*, Gingras Luc* & Naik C.B.**

ABSTRACT

With the high price of virgin cellulose fibres, there is a need to extract the best value from secondary fibre sources. Successful processing of secondary fibres can significantly reduce operating costs for papermakers without compromising end product quality. Unfortunately, the overall quality of secondary fibre has gradually deteriorated, with more contaminants being included in the incoming raw materials. The effective and economical treatment of waste papers to remove and diminish these contaminants is critical for producing quality paper that runs smoothly on a paper machine while delivering excellent yields at low specific energy consumption.

This makes dispersion a key step in secondary fibre processing, since it has great influence over stickies and dirt removal. The dispersion process is quite mature and, while there have been some attempts to improve the technical performance of the disperser itself, little has been done to enhance the disperser plate design to make it more efficient and effective. That is, until now. Borrowing from applications knowledge gained in the development of refiner plates, new disperser plate designs are demonstrating improved dispersion results and/or improved energy efficiency. This paper discusses the new disperser plate technologies along with the results of studies in pilot plants and mills processing secondary fibres. The focus of the new technology is on optimizing the spacing between the surfaces of teeth, retaining sharpness of leading edges, and increasing the plate life, throughput, and energy efficiency.

The most important factor in determining the growth of the Indian Pulp & Paper industry is the availability of suitable raw materials, economically as well as on sustainable basis. Increasing the use of secondary fibre reduces the demand on virgin fibre resources, helping Indian producers overcome the acute shortage of conventional forest- based fibre. Stringent guidelines for environmental protection and government incentives to increase recycling are driving the industry to utilize wastepaper for long-term survival. Approximately 47% of production from Indian Paper industry is from recycled fibre.

With the development of technology for processing secondary fibres, the range of applications for wastepaper has widened significantly. At the same time, the industry is facing serious potential problems due to the inconsistent and heterogeneous quality of recycled fibres. Since papermaking is an integrated process where the effectiveness of one processing stage depends on the performance of the previous stage, the preparation of suitable paper machine stock depends on the removal of contaminants without cutting the good fibre. For high-quality printing and writing grades, the steps of pulping, screening, cleaning, flotation, and dispersion constitute the major processes. For brown grades where deinking is not a requirements, all other unit processes including hot dispersion are the conventional way of pulp preparation. This paper focuses on dispersion as being an important, but often overlooked, unit process for overcoming the potential problems (quality deterioration caused by dirt specks, stickies, and waxes) and contributing to the quality (fibre development) and cost efficiency (machine stability and energy efficiency) of stock preparation.

There are various dispersion solutions for many applications. For many years, there have been standard, generic solutions for disperser plates. Suppliers did little in R&D to enhance the plate designs based on current science and refiner theory. That has now changed. There is now disperser plate technology available, independent of the disperser manufacturer, which represents an improved next-generation solution. This solution helps paper producers offer higher quality end product to their customers with better visual aspects, reduce the cost of making the product, and increase yield -- especially if there are secondary loops after the dispersion stage.

The Role of Dispersion

When dispersion was introduced in wastepaper recycling in the 1970's, the primary goal was to improve the visual appearance of the paper sheet by reducing the size of contaminants so that they were no longer visible-essentially hidden in the pulp.

Today's requirements for pulp quality are much higher. Unfortunately, the quality of available waste paper has deteriorated as the recycling rate has increased. In addition to the raw material challenge, mills are closing water loops to reduce effluents so fresh water consumption is being reduced. This makes secondary fibre processing a more challenging task.

As opposed to just reducing contaminants in size and hiding those in the pulp as was done in early days, modern wastepaper

*ANDRITZ Ltd.,7, Gladstone Avenue, Chester, CH1 4JX, United Kingdom
**ANDRITZ Technologies Pvt. Ltd., Ekkatuthangal, Guindy, Chennai, (T.N.) India

processing systems rely upon the disperser to perform a series of tasks:

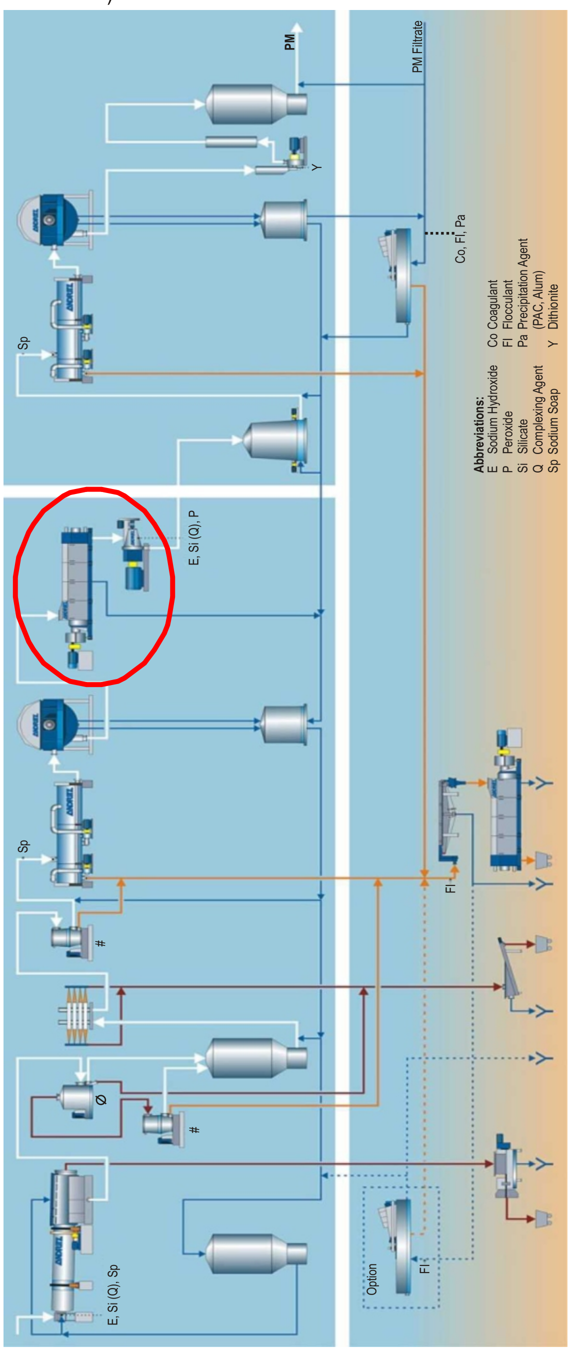
- Improve physical properties of the fibre
- Alter physical properties of the contaminants to facilitate removal in downstream process steps
- Detach printing inks from the fibre to facilitate removal in downstream process steps
- Disperse any contaminants which cannot be removed by other process steps
- Condition the pulp for the bleaching process
- Mix bleaching additives
- Destroy fungi and bacteria in the stock

Dispersion as such has been used by the industry since the late 1970's, Cellwood Machinery (2). All the major machinery suppliers (Metso (3), Voith (4), ANDRITZ (5)) offer dispersion solutions.

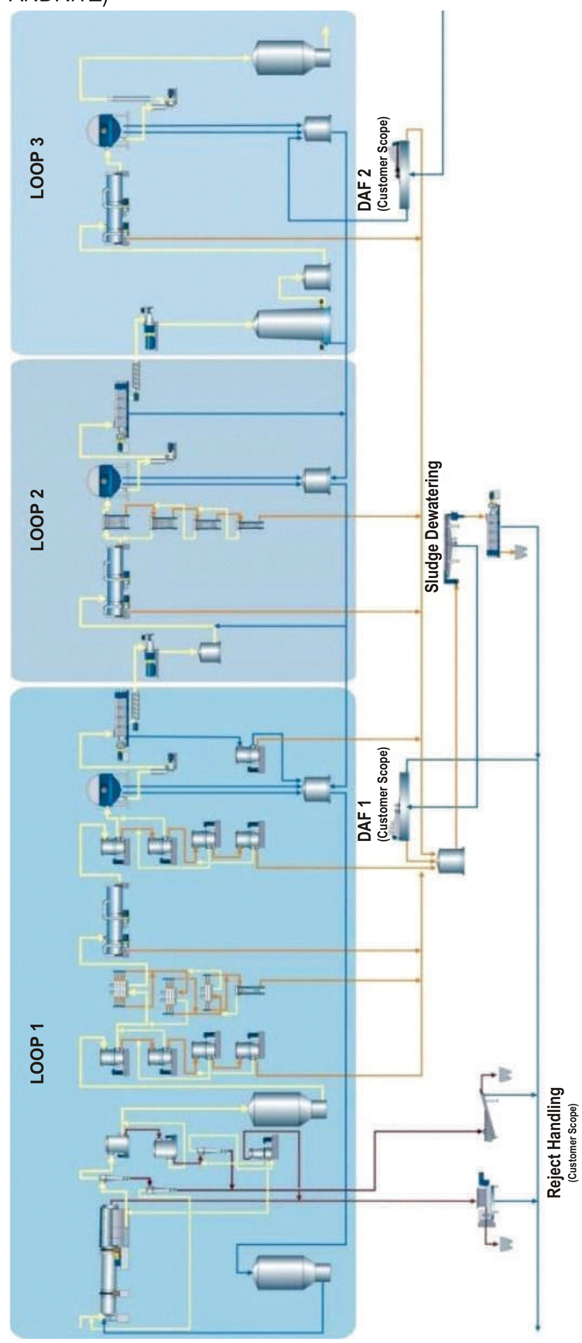
Before reaching the dispersion stage, the recycled fibre has been processed by a pulper to separate fibres, coarse screening to remove staples, and usually some flotation to remove inks and light particles. Some recent installations include fine screening prior to flotation, with the dispersion system typically installed after the first thickening stage. See **Appendix 1** for a typical two-loop system and **Appendix 2** for an example of a three-loop system.

The dispersion system starts with a screw press to take the stock up to the 26-30% consistency. High consistency (30%) ensures

Appendix 1. Example of two-loop DIP system (source ANDRITZ)



Appendix 2. Example of three-loop DIP system (source ANDRITZ)



Appendix 3. Mill trial (Europe) using 100% Mixed Office Waste (MOW)

	Disperser Feed	Disperser Discharge	Difference
Specific Energy Consumption (kWh/ton)	N/A	65	
Freeness (ml CSF)	360	260	-100
Brightness (ISO) w.o.UV	66	72	+6
Breaking length [m]	3814	4926	+29%
Tensile [J/m²]	58,9	106,8	+81%
Tear Index (mN.m²/g)	9,1	9,3	+2%
Sticky Area [mm²/kg]	9203	2837	- 69%
Dirt Area [mm²/m²]	211	51	- 76%
Tappi dirt > 225 µm [-]	26	8,7	- 67%
Dirt Numbers [no/m²]	31567	8927	- 72%
Ash(525) [%]	13,7		

Appendix 4. Mill trial (Europe)
Furnish: 50% SOP, 13% Coated Books, 11% SBS, 10% Colored Broke, 9% Thermal Papers, 7% Carbonless material

	Disperser Feed	Disperser Discharge	Difference
Specific Energy Consumption (kWh/ton)	N/A	69	
Freeness (ml CSF)	486	407	-79
Brightness (ISO) w.o.UV	60,5	59,9	-0.6
Breaking length [m]	3359	3840	+15%
Tensile [J/m²]	45,7	65,8	+44%
Tear Index (mN.m²/g)	9,31	9,83	+6%
Bursting Strength {kPa}	148,9	182,5	+23%
Burst Index {kPa.m²/g }	1,93	2,31	+20%
Sticky Area [mm²/kg]	941,8	673,9	- 39%
Dirt Spec Area (mm²/kg)	2357	878	- 63%
Numbers (no / m²)	142.818	102.338	- 28%
Bulk Index (cm³/g)	1,78	1,73	-0.05
Bendtsen Porosity (ml/min)	2210	1590	-620 (-28%)

efficient dispersion. Heating of the stock takes place just before the disperser, or even in the disperser feeding screw or the entrance to the disperser's “refining zone.” Higher temperature improves stickies separation significantly, but long retention at high temperatures will result in brightness loss on unbleached chemical pulp and on mechanical pulp fibres. The energy applied is typically in the 30-150 kWh/t range, depending on furnish and final product demands. Some further flotation may be employed in some cases, and some systems will use a second stage of dispersion, sometimes followed by a third stage of flotation. **Table 1** shows the typical operating conditions for the most common recycled fibre sources.

For OCC (old corrugated containers), the visual aspects of the final product are not as high as publication grades, so there is less focus on ink dispersion. Stickies dispersion is the most important aspect of OCC dispersion, as the accumulation of stickies impairs

	OCC	DIP	MOW
Temperature	90-120° C	70-90° C	80-110° C
Specific Energy	30-50 kWh/t	40-80 kWh/t	80-150 kWh/t
Consistency	26-30%	26-30%	26-30%
Typical Focus	Stickies	Ink, Stickies, and Freeness	Ink and Stickies

Table 1. Common furnishes and operating conditions for dispersing systems / Gingras (6)

efficiency on the paper/board machine. Most systems use high temperature (there is usually no requirement to maintain brightness) so that dispersion efficiency is maximized with as little energy as possible. Many systems are pressurized in the feed zone in order to reach temperatures around 120° C. A few systems also have pressurized outlets as well. Energy input is usually 30-50 kWh/t.

For DIP (deinked pulp), the final product typically demands high brightness and good visual standards. Ink dispersion is very important, as is stickies dispersion. Most systems use medium temperatures to prevent brightness loss (since DIP contains a high percentage of mechanical pulp), typically in the 70-90° C range. High temperatures help prevent high freeness drops, which have an adverse effect on drainage of the pulp. Energy input is typically 40-80 kWh/t, but some mills add much more energy.

For MOW (mixed office waste), the final product typically demands very high brightness. Ink and stickies dispersion are usually critical. Most systems use high temperature, as MOW contains mostly bleached chemical pulps which will not darken at higher temperatures. Typical temperature in MOW systems is 80-110° C and energy applied is typically 80-150 kWh/t. Many systems will use two-stage dispersion, with a second flotation stage after the first disperser, and sometimes a third flotation after the second disperser.

Refining theory can be used to describe dispersers. In mechanical pulp refining, compressive and shearing forces are applied by the interaction between pulp and the crossing edge length of the bars in the refiner plates. The dispersion result depends on various factors such as specific energy applied, furnish, temperature, and consistency. All of these have been proven in practice and some in pilot plant trials. There are additional factors that are important such as crossing edge length of the teeth, open area of the plates, and retention time for the fibre between the plates.

Miles and May (7) developed a comprehensive theory relating the force applied per bar impact (refining intensity) and the number of impacts. Their analysis showed that the specific energy, coefficients of friction, and pulp consistency govern the residence time in a refiner which is using bar and groove design plates. The residence time determines the number of crossing edge length impacts on a specific fibre.

While the Miles and May theory for bar and groove designs explains the forces applied to fibres (resulting in feeding and energy transfer), pyramidal teeth design plates feed in a different way. With intermeshing teeth, the application and direction of forces are not the same. For example, the specific energy drops as the tooth spacing increases. For this reasons, we have used a similar method to arrive at our own explanation of disperser loading. The dispersion intensity can be altered by changing the tooth edge length, tooth spacing, plate gap, consistency, throughput, and temperature as per the following equation:

$$\text{Dispersing Load (DL)} \left(\frac{kWh}{ton}\right)$$
$$= \phi fn \left(\frac{f \text{ Teeth Edge Length } x \frac{1}{Gap} \ x \text{ Friction Coeff } x 1/\text{ToothSpacing}}{\text{Throughut}} \right) x\ fn \text{ (consistency, termperature)}$$

Where:

- Teeth Edge Length is the total length of all teeth edges on the working zone of the plates
- 1/Gap illustrates the ability to apply load to a given amount of pulp between tooth crossings
- The Friction Coefficient is derived from the teeth surface properties and the raw material surface areas
- Tooth Spacing is the open area between the teeth
- Throughput is the pulp throughput in tonnes per hour
- Consistency is the inlet consistency of the pulp
- Temperature is the inlet temperature of the pulp

There may be other factors that influence the dispersion load, but these represent the most common that can be measured, calculated, and controlled. There is a need to understand this part of the recycling process even further and the following text will show how some of these have an impact on each other.

Niggl (8) concluded that it is essential to keep the dispersion load above the 30 kWh/t, which seems to be in line with the findings of Gingras (6). Additionally Niggl claims that if it is desired to achieve a good dispersions result in terms of stickies count and dirt speck reductions, the applied load should be above 60 kWh/t. **Figure 1** shows the results of trials that Niggl conducted on an Escher Wyss disperser. The results of dispersing at higher loads are quite promising.

The Role of The Disperser Plate

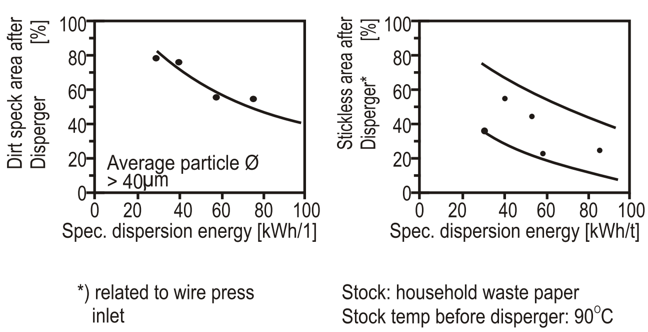


Figure 1. Dirt specks and stickies reduction as a function of disperser loading / Niggl (8)

According to McCarthy (1), there are two types of mechanical dispersers used on recycled furnishes: kneaders and disc-type dispersers. This review focuses on disc-type dispersers, which are similar to pulp refiners. Pulp is fed into the centre of the unit with a feed screw, then moves peripherally through the dispersing zone, which is the narrow gap between the rotating disc and the stationary stator disc. Disc-type dispersers have a shorter retention time than kneaders, but apply higher shear forces to the stock suspension. Rotational speed is generally between 1,200 and 1,800 rpm.

The dispersing action itself is achieved with well-proven toothed and bar patterns on the plates. The correct pattern produces maximum size reduction for dirt specks, while also providing the gentlest possible fibre treatment.

The primary role of the disperser plate is to transfer energy to the fibres during their passage through the unit. According to Gorton-Hülgerth (2), this energy transfer detaches printing inks from the fibres which can be removed in a subsequent flotation stage, and reduces the size of remaining dirt specks and stickies to below the visibility threshold.

The amount of energy applied in a disk-type disperser depends on the suspension rheology and consistency, operating temperature, rotating speed (peripheral speeds range from 50 to 100 m/s), and plate type. Two types of plates are commonly used: the pyramidal design having an intermeshing toothed pattern, and the refiner bar design that can have either fine or coarse bars.

For pyramidal designs, stock is forced radially through the small gaps created between the opposing teeth on rotor and stator plates. Pulp fibres experience high shear in their passage through dispersers caused by intense fibre-to-fibre and fibre-to-plate friction.

In terms of disperser plate design, it can be assumed that the greater the total length of the tooth edges available in the dispersing zone, the greater will be the number of fibres able to absorb a given load. This is because the pulp suspension is mostly collected on the tooth edges. The average number of crossing points where fibre flocs can be caught between opposing edges of the rotor and stator plates can be calculated based on the inner and outer diameter of the plates (number of rows of teeth), tooth and groove widths, and the average radial angle of the rotor and stator teeth. While the term “tooth edge length” is generally used to describe this factor, it is mathematically proportional to the average number of crossing points.

The gap between rotor and stator disks also plays an important role. The plate gap does not refer to disk position, but rather the space between the surfaces of the teeth. Too large of a gap leads to inefficient energy transfer; while too small of a gap leads to fibre refining and development, which increases energy consumption and reduces pulp freeness, resulting in less dispersion action per energy unit. It is critical to optimize the disperser plate design in order to operate at the right gap for given process parameters. The specific energy can be set according to the raw material requirements and the product quality required.

Another important design aspect is the durability/life of the plate. The pulp suspensions from recycled fibre can often be quite abrasive due to the level of sand, metals, and other hard contaminants remaining in the suspension. Given the high rotating speed of the disperser plate, the fibre-to-plate interactions, and the load employed, the plates are considered to be "wear parts" or consumables (a maintenance item). However, there are design characteristics such as the profile of the leading edge of the pyramidal tooth, the hydraulic flow patterns, and the metallurgies employed that can significantly extend the useful life of the plate.

Results - Pilot Plant Trials

Due to the large variations in raw material, it can sometimes be difficult to measure the efficiency and impact that dispersion has on final pulp quality. That is why some recycling operations do not fully utilize their dispersers, allowing them to operate at low loads, virtually unattended.

However, with just a minimum of attention to the disperser plate design and the correct operating range(s) for the disperser, it is possible to achieve significant improvements in contaminant reduction and energy consumption.

ANDRITZ has been a leading supplier of refiner plates for many years (marketed under the Durametal brand name). The company has long supplied disperser plates for ANDRITZ dispersers as well as those manufactured by other companies.

However, only recently, the company began an earnest R&D program to improve the performance and energy efficiency of its disperser plates - the foundation being the extensive development work already invested in a full line of refiner plates.

One only has to look at the basic pattern of the typical disperser plate (**Figure 2**) to surmise there is room for improvement. Plate designers often refer two different zones in the plate and address the functions in an integrated way. The function of the "feeding zone" (the first three to five rows of teeth near the inner diameter) is to transport and distribute the pulp suspension from the centre of the disperser to the outer diameter. The fibre suspension moves to the "working zone" (the five outer rows) where most of the work is

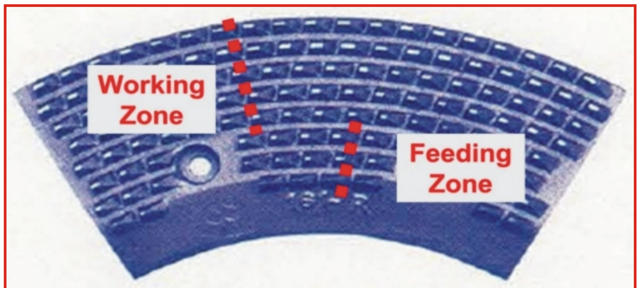


Figure 2. Typical OEM disperser plate showing two zones.

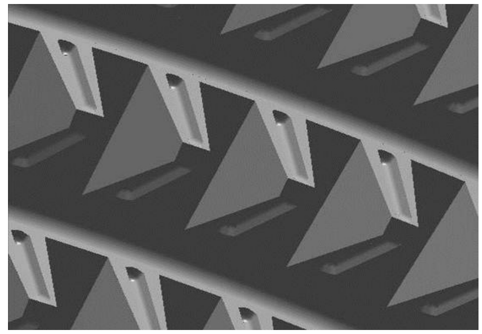


Figure 3. ANDRITZ plate with Dura-Pulse tooth geometry. The mini-groove creates additional pulses as the teeth intermesh.

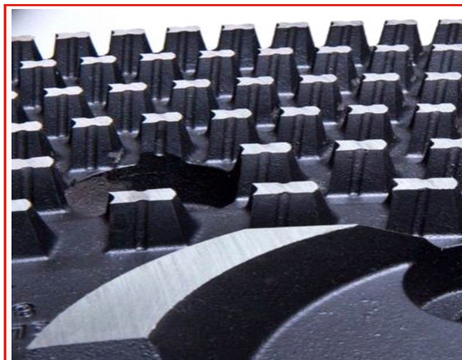


Figure 4. ANDRITZ plate with feed bar in foreground. The bars improve feed and distribution of fiber suspensions

performed.

For example, one of the major improvements that can be made to the "feeding zone" is the replacement of some of the individual teeth with feed bars **-** solid metal bars without gaps (straight or curved geometries depending upon the application) in order to improve the feeding/loading of the "working zone" teeth. **(Figure 3)**

A major improvement in the "working zone" is the patented DuraPulse mini-groove tooth geometry **(Figure 4).** The grooves in the teeth increase the number of pulses generated by the crossing teeth, providing increased dispersing effect for a given energy input level. In order to estimate the effect of a plate design on dispersing efficiency, an aggregate length ("total edge length" of crossing rotor and stator teeth leading edges) is calculated. The DuraPulse tooth geometry increases the number of impulses on a fibre by a factor of four while preserving critical open area. A conventional pattern showing a crossing edge length of intermeshing teeth of 18 km/rev is thereby elevated to 72 km/rev without any loss in production capacity. The DuraPulse design can be used on both rotor and stator, or only on one side. It can also be combined with other advanced technologies, such as the ANDRITZ V-Tooth or X-Tooth geometries.

Another improvement is the patented OptiPulse varying feed design concept for concentrating dispersing energy where needed **-** in the outer rows of the "working zone" **(Figure 5).** OptiPulse does this by increasing the holdback effect of each row of teeth moving towards the plate periphery. The holdback angles can be adjusted for each application, significantly increasing the loadability of the disperser for a given number of teeth. The designed-in pumping

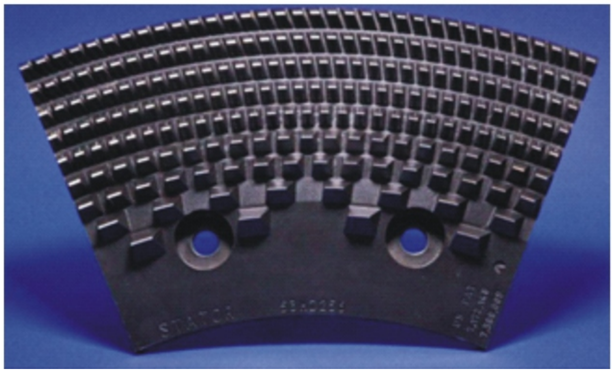


Figure 5. ANDRITZ plate with OptiPulse design to increase loading in the "working zone."

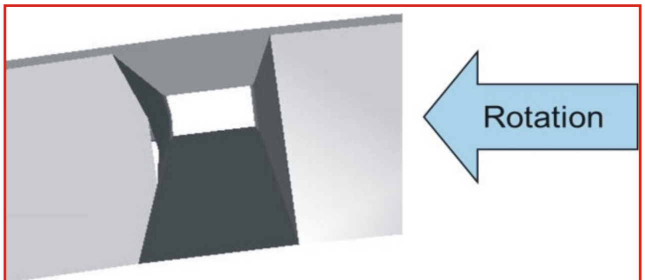


Figure 6. ANDRITZ V-Tooth geometry maintains a sharper leading edge leading to longer plate life.

angles accommodate increased throughputs and permit the use of finer plates at low energy levels.

The patented V-Tooth design **(Figure 6)** delivers extended plate life. While the new ANDRITZ designs have a sharper leading edge to retain their feeding efficiency longer than conventional plates, the teeth will still wear. But the V-Tooth increases plate life further (at least a 30% increase) by maintaining a sharp leading edge, even when it has started to wear.

Extensive trials were performed on some of these design concepts and other aspects of the disperser plate design at ANDRITZ's fully equipped Pilot Plant in Graz, Austria. The furnish for the trials was

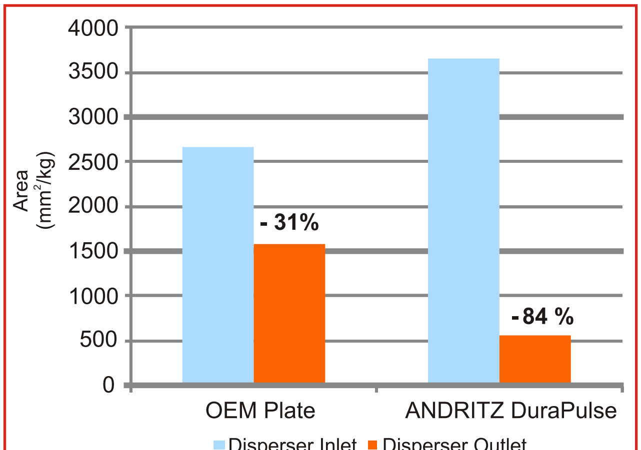


Figure 7. Comparison: Total stickies reduction (mm²/kg) reduction with OEM plate for Krima disperser vs. ANDRITZ plate with DuraPulse. MOW furnish. / ANDRITZ AG Pilot Plant, Graz, Austria.

Mixed Office Waste (MOW). Trials were performed against the standard OEM plate (Krima disperser in this case). The ANDRITZ plate featured the DuraPulse mini-groove design and tall teeth (23-30 mm height). Short teeth (7-15 mm) typically are utilized for

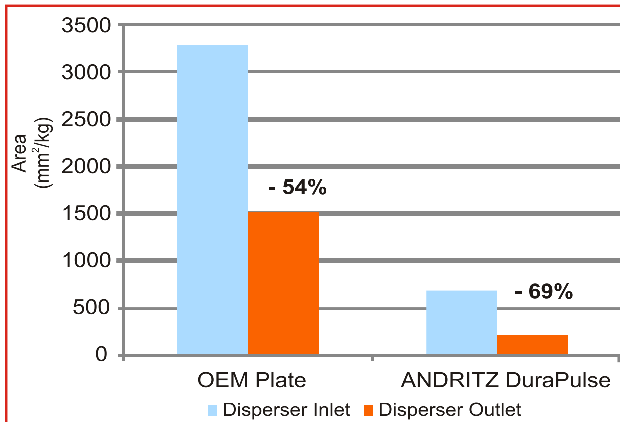


Figure 8. Comparison: Dirt speck area reduction (mm²/kg) reduction with OEM plate for Krima disperser vs. ANDRITZ plate with DuraPulse. MOW furnish. / ANDRITZ AG Pilot Plant, Graz, Austria.

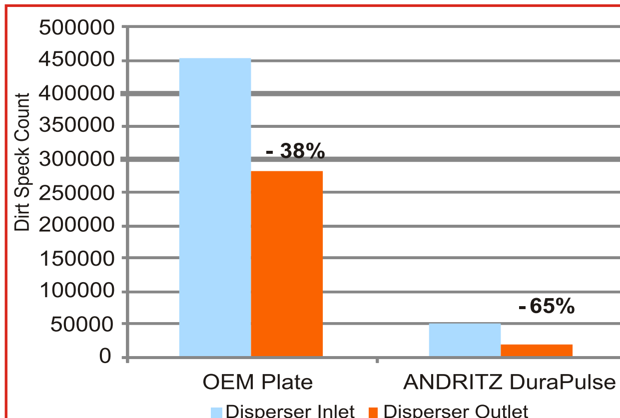


Figure 9. Comparison: Dirt speck reduction (total count) with OEM plate for Krima disperser vs. ANDRITZ plate with DuraPulse. MOW furnish. / ANDRITZ AG Pilot Plant, Graz, Austria.

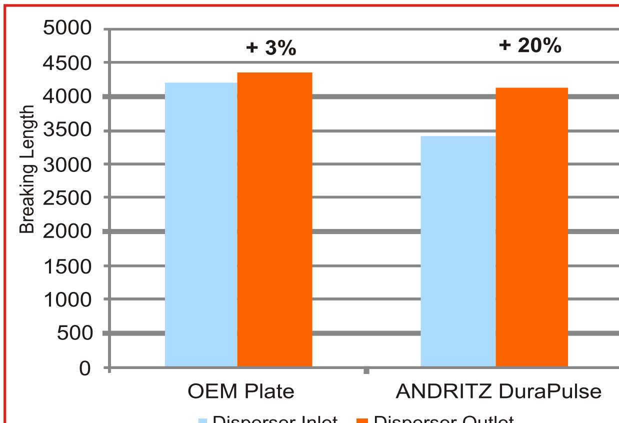


Figure 10. Comparison: Breaking length improvement with OEM plate for Krima disperser vs. ANDRITZ plate with DuraPulse. MOW furnish. / ANDRITZ AG Pilot Plant, Graz, Austria.

OCC application (up to about 400 t/d) where the applied load is 30-60 kWh/t. Tall teeth are used in production lines of 680-1000 t/d where the applied load is 50 kWh/t minimum, and more typically in the 80-90 kWh/t range. In trials of the OptiPulse design at the ANDRITZ Pilot Plant, the plate was able to accept loads up to 200 kWh/t in some applications. This far exceeds the capabilities of the OEM plate for the Krima disperser.

Figures 7, 8, 9, and 10 show the direction of improvement with the ANDRITZ plate (with DuraPulse mini-grooves) comparing stickies and dirt speck reductions in the Pilot Plant.

Results - Mill Trial

The reduction of energy consumption is a universal concern in the industry. In mills where there are reasonably large motors installed (e.g. 1.5 - 4.4 MW), the new design ANDRITZ disperser plates have contributed significantly to energy reduction.

For a newsprint mill in Europe, ANDRITZ was asked to design a plate to lower dispersion energy without impacting throughput. The solution combined the DuraPulse mini-groove tooth geometry with the OptiPulse feeding geometry. The OptiPulse introduces holdback angles for various rows of teeth in the "working zone" to increase retention time allowing for more dispersion throughput at the same energy input. This allowed the mill to keep throughput at the desired target while reducing the total power required. For this mill, the Dura-Pulse/OptiPulse combination reduced energy by 15 kWh/t, reducing the cost of purchased energy by almost US$ 500.000 annually for the dispersion process.

Conclusions

Dispersion is a key step in secondary fibre processing since it has great influence over stickies and dirt removal. The efficiency and effectiveness of the dispersion process relies to a great extent on the performance of the disperser plates. Recent advances in plate technology, some of it gathered from extensive experience in refiner plate development, are now making it possible for the dispersion process to reach new levels of performance in terms of contaminant removal or destruction, throughput, and energy efficiency.

Key, and often patented, enhancements to disperser plates by ANDRITZ will allow paper producers utilizing dispersers to improve the operation of virtually any disperser, regardless of the original manufacturers. New features such as improved feeding, innovative tooth geometries, and greatly improved methods for increasing retention time to obtain the targeted dispersion effect at less energy usage are now a reality.

These features have been tested and verified during extensive trials at ANDRITZ's fully equipped Pilot Plant in Graz, Austria using Mixed Office Waste, and in a few limited mill installations. While the actual experience base is still at its early stages, the concepts are proven.

While there are some installations where the dispersion stage is not fully utilised, and other installations where the disperser runs basically ignored, it is now quite evident that the correct disperser plate pattern and proper loading can make a significant positive impact on final pulp quality and energy consumption.

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