Comminution – an Essential Component of Waste Treatment

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Note: in this article no difference is made between comminution, size reduction and shredding. These terms are considered to be interchangeable.

1. Waste Recovery and the Necessity of Comminution

1.1. Countries with High Developed Waste Recovery and Recycling Systems

Looking at the statistics of 2009 as published by EUWID, Re Nr. 8 v. 22.02.2011, concerning the treatment of municipal solid waste, we find for Germany:

Table 1: Waste quantities treated in Germany in 2009

Treatment in Germany (2009)	Quantity in 1,000 of Tons
Total quantity of municipal solid waste	48,101
Landfill	177
Incineration	15,535
Recycling	22,421
Composting	8,148
Not defined treatment	1,820

No general statistics for the comminution of waste depending on the treatment are available. The following data are therefore based on an approximation by the author.

Table 2: Percentages of waste comminution in relation with the waste treatment process

Treatment in Germany (2009)	% of waste, reduced in size	Quantity in 1,000 Tons
Landfill	< 2	3
Incineration, including incineration of RDF	20	3,107
Recycling	50	11,210
Composting	50	4,074
Not defined treatment	20	364

The above figures show that in Germany about 40 % of the total municipal solid waste is reduced in size during the treatment process.

The percentage of commercial and industrial waste (55 millions of tons in Germany) where the treatment process needs a size reduction is considered to be higher.

Please take into consideration that in the meantime in Germany the capacity of conventional incinerators increased to about 19 millions of tonnes per year, the yearly capacity of RDF incinerators to 5.7 millions of tons. RDF incinerators normally use only shredded waste, often derived from commercial and industrial waste.

1.2. EU 27

In 2009, in Europe (EU27), about 256 millions of tons of municipal solid waste were treated: 256 millions of tons by landfill, 50 millions of tons by incineration, 60 millions of tons were recycled, 45 millions of tons were treated by composting and for 5 millions of tons no treatment is defined in the statistics.

Based on the above numbers and on the assumptions already used for German waste, we get as a rough estimation that in 2009 20 % of the total European waste was reduced in size during the treatment process.

1.3. Poland

In 2009 in Poland 12 Millions of tons of municipal solid waste were treated: 8 millions of tonnes by landfill, 0,1 millions of tons by incineration, 1.4 millions of tons were recycled, 0.6 millions of tons were treated by composting and for 2 millions of tons, no treatment is indicated.

Based on the same assumptions as above, we get a 13% as estimation for the waste that was reduced in size.

1.4. Conclusion

About 20 % of the total quantity of the municipal solid waste in Europe is reduced in size nowadays. This figure is higher – about 40 % – for countries with a high developed waste recovery and recycling system.

That means the more waste is recovered or recycled, the more comminution is important.

2. Comminution and Logistics

No matter how the waste is finally treated, comminution can be advantageous for reasons of transport and material handling.

Reduction of Volume

Table 3: Examples of volume reduction percentages

Type of waste	Volume reduction %	Max. density for transport using suitable (press) containers without comminution To/m^3	Max. density for transport using suitable (press) containers after comminution To/m^3
Domestic waste	approx. 20	0.8	1.0
Bulky waste	approx. 50	0.1 – 0.3	0.3 – 0.6
Tyres	approx. 70	0.15	0.5

Potential Savings in Transportation Costs

Considering transportation costs of 0.05 to 0.1 EUR per kilometre and ton of transported waste and all over size reduction costs of 5 – 10 EUR per ton, we calculate a minimum transportation distance of several hundreds of kilometres in order to amortize comminution directly by the savings in transportation costs.

Exception: when transporting very light products (below 0.2 m^3/ton) comminution is cost efficient as it's easier to reach the max. transportation load. Cost savings in transport up to a factor 2 to 3 are possible.

Handling

Depending on the character of the waste, handling and conditioning can be significantly improved by the size reduction.

Examples:

- Pneumatic conveying,
- Conveying by belt conveyors or screws,
- Unloading by grab,
- Mixing.

3. Cost of Comminution

Below is a list of costs for wear parts or repair work due to wear. Please pay attention to the fact that these costs extremely depend on the percentage of abrasive and *difficult* products. The degree of size reduction is also cost relevant.

Primary Reduction

Table 4: Wear costs for primary comminution systems

Product	**Min. wear costs**	**Max. wear costs**
	EUR/Ton	
Domestic waste (95 % < 150 mm)	1.0	3.5
Bulky waste, wood (95 % < 300 mm)	0.6	1.5
EBS Commercial waste, RDF (95 % < 200 mm for Product of stable shape)	1.5	2.5
Commercial waste, Industrial waste (95 % < 200 mm)	1.5	>> 10
Tyres (95 % < 200 mm)	2.5	5.0

The indicated dimensions refer to the maximum length. The other dimensions are significantly smaller. The costs for domestic and commercial waste are similar based on tons but not on volume, due to the different densities.

Depreciation of the machine is not taken into consideration in the above costs. Depreciation may vary a lot depending on machine type (sturdy stationary installation or easy to transport light mobile installation).

Secondary Reduction

Table 5: Wear costs for secondary (fine) comminution systems

Secondary reduction of preshredded waste or recirculation of waste	**Min. wear costs**	**Max. wear costs**
	EUR/Ton	
Domestic waste (95 % < 50 mm)	1.5	5.0
Bulky waste, wood (95 % < 50 mm)	1.0	2.0
Commercial waste, RDF (95 % < 50 mm)	2.0	3.5
Tyres (95 % < 70 mm)	2.5	5.0

4. Typology of Comminution

Note

In this chapter terms and definitions are used as applied by the actors in the waste business; this may differ from the general definitions in the mechanical process technology.

4.1. Comminution Speed

Comminution machines can be grouped into slow speed, average speed and high speed machines.

Comminution Speed and Application

Slow speed machines (rotary shears, hook shredders, wood crushers)

Rotation speed approx. 10 – 50 rpm

Linear speed 0.3 – 2.0 m/s

Main application: pre shredding of non defined products, shredding of inflammable products

Figure 1a: Cutting system of a rotary shear

Figure 1b: Hook shredder SID XLC 7300 with open ejection door for unshreddables

Figure 2:

Rotary shear SID I 185 with integrated ejection door for unshreddables

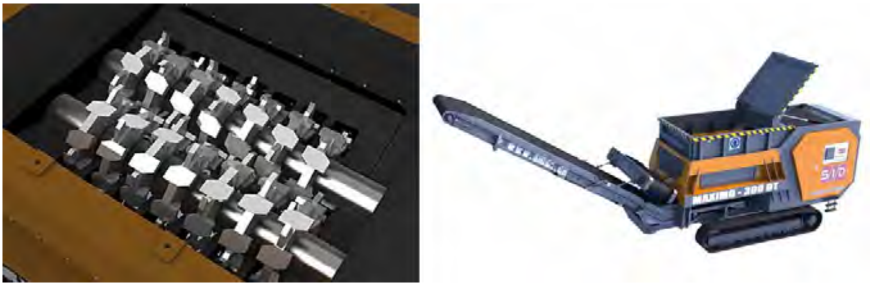

Figure 3: Mobile crusher MAXIMO

Average speed machines (*Grinder*)

Rotation speed approx. 100 – 200 rpm

Linear speed 4.0 – 8.0 m/s

Main application: pre shredding of more or less defined products, secondary shredding

High speed machines (granulators, hammer mills, impact mills)

Rotation speed > 300 rpm

Linear speed > 10 m/s

Main application: secondary shredding of defined or sorted products

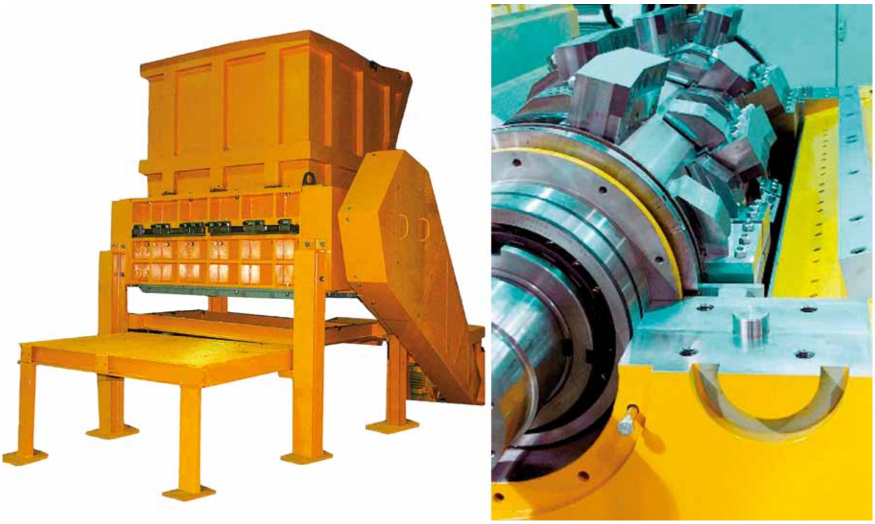

Figure 4: Granulator MR 200

General rules concerning comminution speed

The faster the machine runs, the smaller the output can be achieved, the more sensitive is the machine concerning unshreddable products. This is especially valid for machines based on size reduction by cutting. This means also that fast machines need sorted or well defined products.

Comminution Speed and Granulometry

Slow speed machines	**typical particle size**	**Exceptional cases**
Hook shredder and wood crushers	90 % ≤ 200 – 500 mm	≤ 100 mm
rotary shears	90 % ≤ 150 – 300 mm	≤ 50 mm
4-shafts rotary shears with sieve	90 % ≤ 30 – 60mm	≤ 20 mm
Average speed Machines		
Grinder and one rotor cutting machines	90 % ≤ 100 – 150 mm	≤ 20 mm
High speed machines		
Granulators	90 % ≤ 30 – 60 mm	≤ 10 mm

4.2. Comminution Effects

We can group machines according to the following criteria: breaking, tearing, cutting and pressing/crushing machines

Breaking

Comminution is a result of tensile and compression stresses („bending“); breaking works for dimensionally stable products

- Practical application: shredding of breakable products like wood;
- Typical machines: wood crushers.

Cutting, breaking, tearing combined

Comminution is a result of tensile, compression and shear stresses

- Practical application: primary reduction of mixed waste;
- Typical machines: hook shredders, some forms of rotary shears.

Pressing/Crushing

Comminution is a result of compression stresses

- Practical application: Primary shredders for breakable materials or for defribration;
- Typical machines: screw shredders, hammer mills and impact mills.

Cutting

Comminution is a result of shear stresses.

- Practical application: Primary and secondary reduction of mixed waste;
- Typical Machines: Rotary shears, grinders, granulators.

General rule concerning comminution effects

The more (viscous) elastic the material is, the better systems base on cutting effects work. The more dimensionally stable, the more *wood like* the products are, the better systems based on breaking effects work.

From a statistical point of view most cutting systems are used for fine shredding of waste.

For non defined waste or when a wide range of products has to be treated, systems combining different comminution effects should be preferred.

The more you cut, the more wear you have. Machines using tearing or braking principles are in general subject to less wear, but cannot be used for all products.

breakable		–>	(viscous) elastic
Crusher –>	Hook shredder	–> Rotary shear	–> Grinder/Grnulator

4.3. Driving Systems

Driving systems can be grouped into conventional electric drives, high torque drives and hydraulic drives.

Conventional electric drives (standardized asynchronous motors)

The comminution machine is driven by a standardized asynchronous motor via a multistage gearbox. Overload couplings and frequency variators may be used.

Application

- Small rotary shears,
- Grinders,
- Granulators, hammer mills, impact mills.

Advantages

- System price,
- Simple,
- High theoretical efficiency (> 90 %).

Disadvantages

- Maximum torque is limited by the installed power. Therefore conventional electric drives are often less efficient than hydraulic drives able to adapt speed versus torque according to the power installed.
- High inertia and therefore sensitive to unshreddables.
- High electric current peaks at start-up. Often high speed machines using conventional electric drives cannot be started when product is in the shredding chamber.

Electric drives using high torque motors

The machine is driven by a high torque motor which is electronically controlled concerning rotation speed, torque and power absorbed. The motor is usually liquid cooled.

Applications

- Rotary shears,
- Grinders,
- Granulators.

Advantages

- In certain cases the high torque drive combines the advantages of a conventional electric drive and an hydraulic drive;
- Theretical efficiency above 90 %.

Disadvantages

- In comparison to a hydraulic drives, inertia is high (so more sensitive to unshreddables);
- Usually, the regulation range for torque and speed is less wide than the regulation range of hydraulic drives for reasons of costs.

Hydraulic drives

The machine is driven by a hydraulic motor and a separate hydraulic power pack using hydraulic pumps and auxiliary systems as coolers, oil filter etc.

Advantages

- A wide range of torque and speed at limited installed power.
- Low inertia reduces damages when treating unshreddable products.
- Compact machine, as the hydraulic group may be placed apart.

Disadvantages

- Theoretical efficiency is low below 80 %;
- The System is more complex.

4.4. Stationary and Mobile Installations

All machine types mentioned above exist as stationary or mobile machines.

Mobile installations are more standardised and less expensive at comparable throughput. On the other hand, due to the fact that mobile machines have to be suitable for road transport limiting dimensions and weight, operation costs are higher and lifetime is shorter.

Based on a Diesel price of 1.5 Euros/litre and Electric power at 0.1 euro/kWH, the use of Diesel engines increases energy cost by a factor of 4.

5. Comminution and Waste Treatment Systems

5.1. Matrice: Where is Comminution Useful?

Table 6: Characteristics of comminution systems used in the main waste treatment systems

Waste	Landfill	Waste to energy: Incineration conventional	Waste to energy: Incineration non conventional, RDF (fluidised bed, cement kilns etc.)	Recycling	MBA Composting
Domestic waste	1	1	4	4	2, 4, 5, 6
Domestic waste from separate collection, recycling goods	–	–	4	4, 6	–
Compostable waste	1	1	4	–	5
Bulky waste	1	2	4	4, 6	–
Commercial waste, industrial waste	1	2	4, 6	4, 6	–
Hazardous waste	1	3	3, 4	3, 4	–

1 No comminution or only in special cases
2 Preshredding
3 Comminution including homogenisation or separation, safety systems
4 Comminution, multi stage comminution, including separation systems
5 Comminution for handling, increasing the surface
6 Comminution with special demands concerning products and post treatment

5.2. Landfill

Usually no comminution is necessary. If the waste is reduced in size, requirements concerning granulometry are not very demanding.

Purpose of comminution in the context of landfill

- Reduction of volume, the landfill site remains more stable;
- The waste closest to the lower sealing is shredded in order to avoid blessing the sealing.

Demands on the comminution system in the context of landfill

- Preshredding, large granulometry,
- Independent, self moving machines,
- Diesel engine,
- Comminution effects: mainly breaking/crushing and tearing, cutting only in exceptional cases.

Figure 5: SIDSA Standard Maximo 300 D

5.3. Waste to Energy: Conventional Incineration

In most incineration plants about 10 % of the incoming waste is shredded. In some plants, especially if the plants work together with mechanical pre-treatment plants no waste is shredded. On the other hand, in some incineration plants 100 % of the waste is shredded for logistic reasons.

What is shredded

- Bulky waste, commercial waste;
- Depending on the internal logistics in the incineration plant, also domestic waste is shredded.

Purpose of comminution in the context of conventional incineration

- The percentage of burnable material in the residues is lower;
- Better feeding and evacuation of material into resp. from the kiln;
- Mixing of products in the bunker is easier.

Requirements for the size reduction machines in the context of conventional incineration

- Preshredding. 90 % ≤ 300 – 500 mm;
- Immune to unshreddables and hard objects, as they are difficult to sort out by the bunker crane;
- Authorities responsible for labour safety often ask for automatic removing devices for unshreddable objects;
- Wide range of shreddable products as these installation are often contractually obliged to accept all kind of products;
- Automatic operation;
- High availability;
- Long lifetime;

- Dismountable in parts;
- Integration while respecting the standards valid for the all over installation.

Example installation of Stuttgart

- In Stuttgart Münster 100 % of the waste is shredded;
- All over annual comminution capacity: 500,000 tons;
- The waste is fed to the rotary shears by metal conveyors;
- Unshreddables can be easily removed via a hydraulic ejection door.

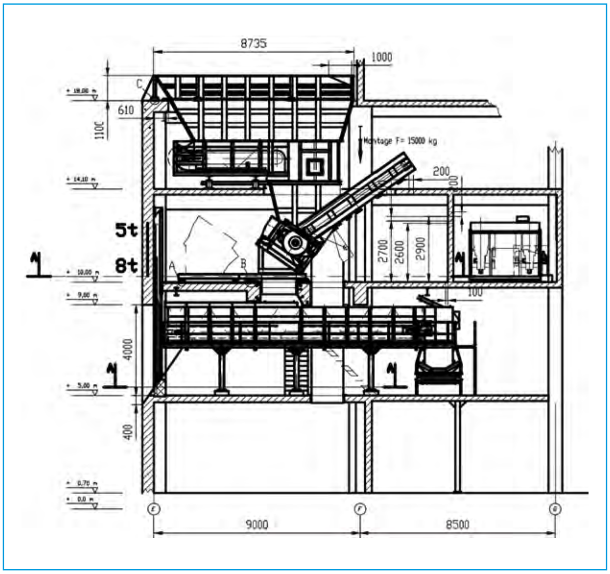

Figure 6:

Comminution installation Stuttgart with rotary shears S 350 XL

Example installation in lower austria

- Bulky and commercial waste is shredded by an hook shredder SID XLC7300;
- Hourly throughput of 50-250 tons, installed power 500 kW, Shredding surface 7.3 m^2;
- The waste is brought directly into the machine by the bunker crane, 5 – 8 Tons per cycle;
- Unshreddables can be easily removed via a hydraulical ejection door.

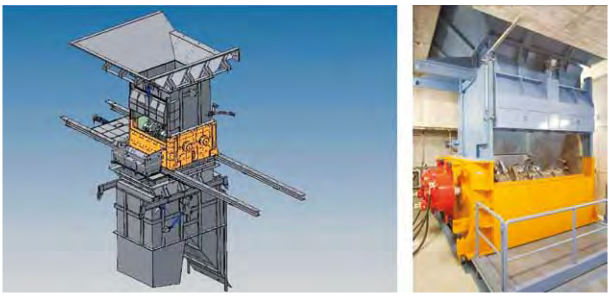

Figure 7:

Comminution installation with hook shredder SID XLC 7300

Example installation in Antwerpen

- Bulky waste and commercial waste are shredded by a rotary shear SID S300XL;
- Hourly throughput 20 – 80 To/H;
- The installation can fed by the bunker crane or directly from the lorries in the waste reception hall, allowing a certain control of the incoming waste.

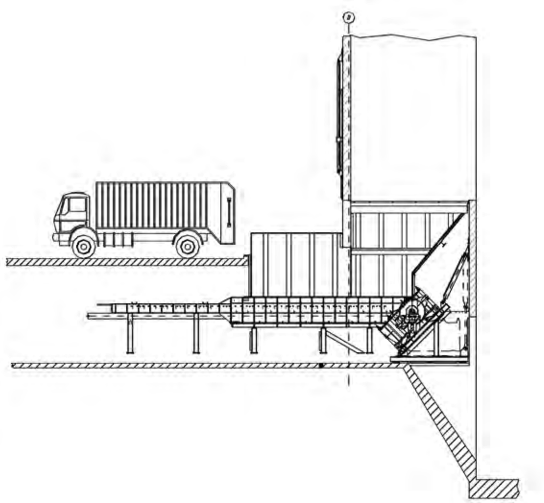

Figure 8: Comminution installation for feeding by lorries and bunker crane

5.4. Waste to Energy: Incineration of RDF

RDFs are used in fluidised bed incinerators, power plants, cement plants or steelworks. The waste is usually better defined than waste incinerated in conventional incineration plants, but has to be reduced to much smaller sizes. The comminution often works together with separation equipment, in most cases FE and NF removal equipment. Often the size reduction plant is geographically separated and independent from the enduser.

What is shredded

Normally 100 % of the waste

Purpose of comminution in the context of RDF

Comminution is necessary for the incineration/combustion itself as for the feeding systems of the incinerator

Requirements for the size reduction machine in the context of RDF

- Size reduction to a granulometry of 50 – 100mm; steelworks often need 15 mm size, cement plant need sizes < 10 mm when the product is fed via the principal burner;
- High availability;
- Low operation costs as the pre-treatment companies operating the shredders are often in competition;
- Short payback periods as the companies operating the shredders are often not working on the basis of long time contracts.

Machines used

- Pre-shredders: Rotary shears, hook shredder, Grinders;
- Secondary size reduction: Rotary shears, grinders, granulators, hammer mills, impact mills.

Example installation close to Mulhouse

- 100 % of the waste is shredded, 160,000 tons per year, fluidised bed incinerator;
- Waste is fed by metal conveyors to the rotary shears;
- Unshreddables can be removed via a hydraulic ejection door;
- After size reduction FE and NF removal equipment is installed.

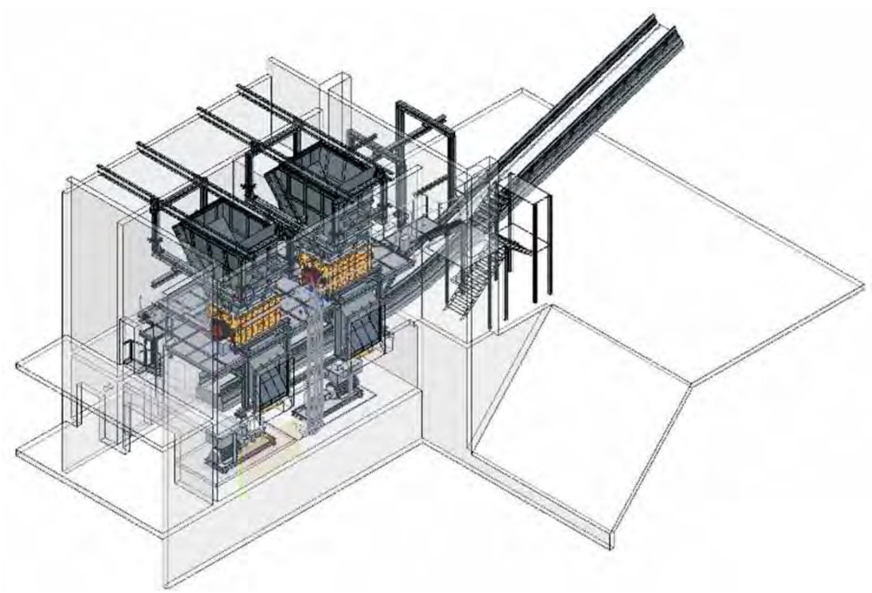

Figure 9: Communition installation with ferrous and non ferrous separating systems

Example installation close to Berlin

On the sketch below is a complete pre-treatment plant able to reduce size to 10 mm in three stages.

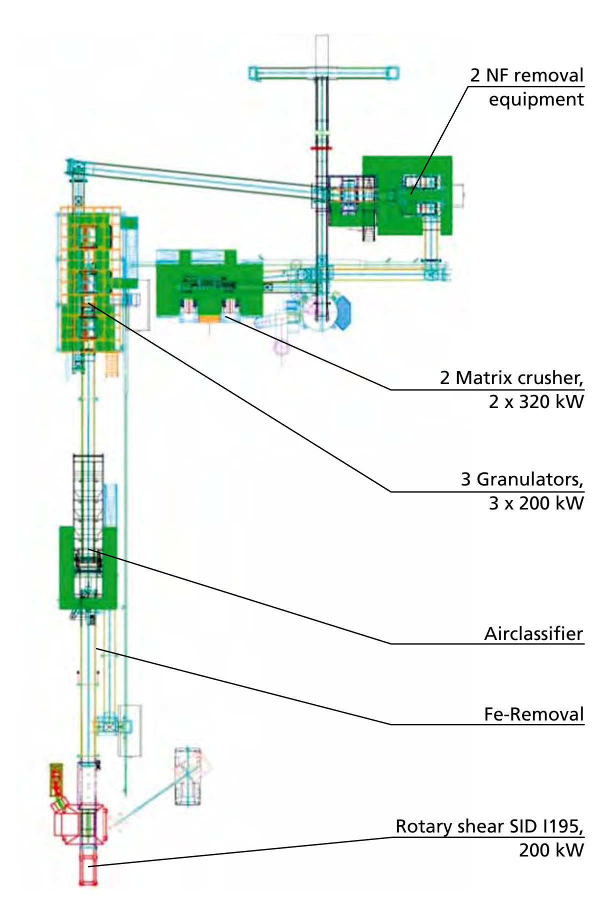

Figure 10:

Complete pre-treatment plant close to Berlin

Example installation Bejing

- The installation combines a *traditional* size reduction and pre-treatment plant with a hazardous waste shredding installation.
- Hazardous waste is shredded by a Rotary shear SID I185, afterwards homogenized/ mixed by a horizontal mixer of 10 m^3 and finally conveyed to the precalcinator by SPP 35 single piston pump from Solidpumps.
- Commercial waste is also reduced in size by the rotary shear SID I185, afterwards by a rotary shear D70 and finally by a granulator MR200. Fe and NF metals are removed. The end product of 10 mm is pneumatically conveyed to the principal burner of the cement plant

Figure 11:

Combination of a traditional size reduction and pre-treatment plant with a hazardous waste shredding installation

5.5. Hazardous Waste Incineration

In hazardous waste incineration plants – mostly high temperature incinerators using rotary kilns – safety aspects (ATEX, Exhaust air, man-waste contact) are most important for comminution.

SMP Installations, combining waste reduction with mixing/homogenisation equipment and direct feeding of the incinerator by a piston pump, are considered to be the state o the art.

Purpose oft the SMP plant

- Increases the incineration capacity up to 20% for a given incinerator;
- Improves emissions and slag quality;
- Lower operational costs.

Machines used for comminution in the context of hazardous waste shredding

As a very wide range of waste has to be reduced to approx. 10 cm size and in order to limit the risk of explosions, rotary shears are used.

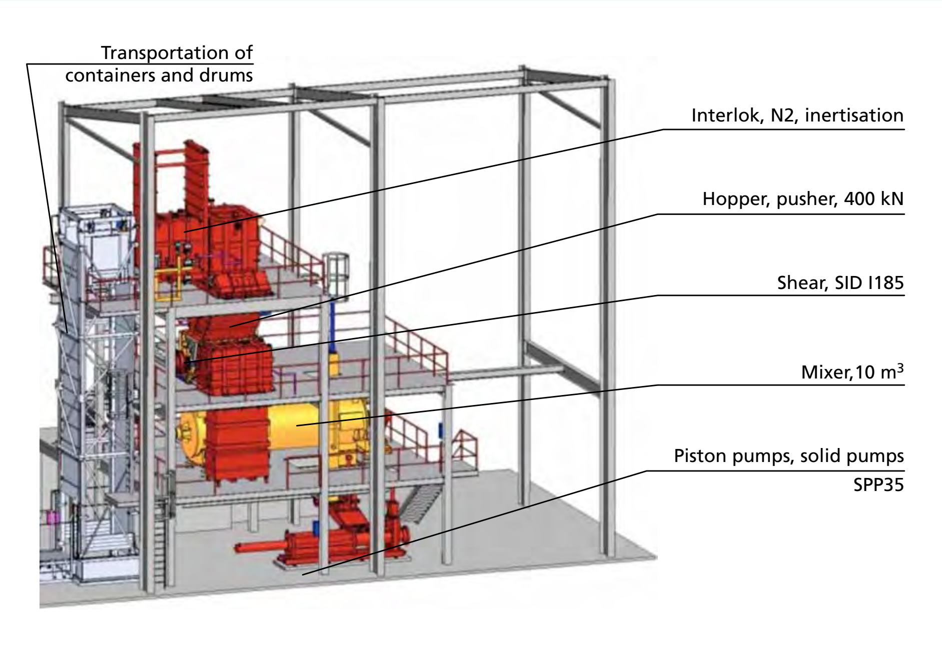

Figure 12: Shredding Mixing Pumping (SMP) installation for hazardous waste

5.6. Recycling

According to the product treated and the requirements of the final user of the recycled product, the demands on the size reduction equipment may vary a lot.

Requirements for comminution in the context of recycling

- The comminution effect has to be specifically adapted to the product treated – often machines used are not universal machines as installed for example in a conventional incineration plant.
- As the waste is pre sorted and usually well defined, the number of unshreddable or hard to shred objects is limited. Therefore the machines are usually less robust.
- The final product size is normally well defined.
- Size reduction often works in connection with separation equipment and communition prepares the product for the following treatment steps.

Machines used in the context of recycling

- All machines based on all comminution effects are used. Statistically mostly cutting machines are used for fine shredding of waste.

Example: Cable recycling, tyre recycling, plastic recycling, electronic waste

Nearly all recycling plants, except when special products where easy dismantling is possible are using size reduction equipment.

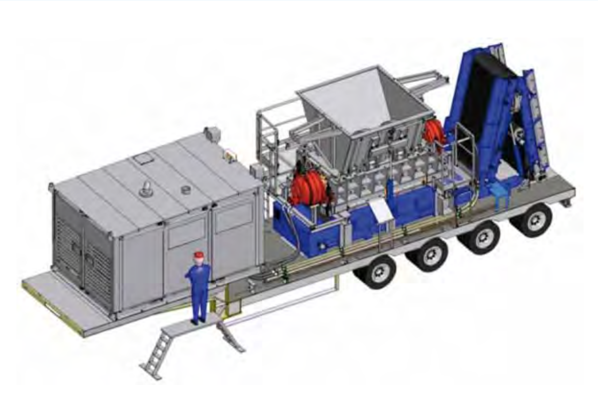

Figure 13:

Mobile shredding installation plant using a rotary shear S350

5.7. Composting

Comminution not only makes the sieving and the handling of the product easier, but also improves the composting process by increasing the surface and defibration of the input.

Statistically, screw mills and hammer mills are used most of the time; in some cases we find also rotary shears and hook shredders.

6. Abstract

About 20 % of the total quantity of municipal solid waste in Europe is shredded today. This figure is higher – about 40 % – for countries with a high developed waste recovery and recycling system and lower for countries with a developing waste industry.

Reduction of size also leads to a reduction of volume of 20 % (for example domestic waste) to 70 % (for example tyres). In order to pay size reduction by the savings in transport costs, transport distances have to be quite long, usually several hundreds of kilometres or the density of the product before shredding has to be low.

Cost of wear parts or repair work for a given size reduction varies by a factor of 10 or more for different sorts of waste and by a factor of 3 for comparable input under the same product definition.

The more (viscous) elastic the products are, the better systems based on cutting effects like rotary shears or granulators are suitable. The more dimensionally stable (*wood like*) the products are, the more we recommend the use of systems based on breaking effects. In general, small granulometries can be reached easier with fast running machines, which are unfortunately more sensitive to hard or unshreddable objects. Therefore, pre-sorting is more important when using these machines.

Lifetime of mobile size reduction equipment is usually shorter, wear costs higher and energy costs when using Diesel engines are 4 x higher than energy costs caused by electrical motors.

Size reduction equipment hast to follow different requirements according to the final use and the product treated. Shredders in conventional waste to energy (incineration) plants or typical pre-shredders before sorting have to able to treat a very wide range of products;

removal of unshreddables has to be easy. Non conventional waste to energy (incineration) systems, RDF plants (fluidised bed incinerators, power plants, cement plants, steelworks) and recycling applications have more stringent requirements concerning the size of the waste and other characteristics like separability. On the other hand, waste is much better defined and therefore the machines can be more easily adapted to the specific need.