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# Recycling of Municipal and Industrial Waste

**KAHL plants for the production of fluff and pellets as alternative fuels**

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# Processing of Waste to Alternative Fuel

Michael Gursch



## 1. Introduction

For many years the German medium-sized family-owned company Amandus Kahl GmbH & Co. KG has been active in the field of waste treatment. The core components such as the flat die presses are used for pelleting and crushing of various bulk materials and the belt driers/coolers for gentle drying and cooling.

In connection with waste treatment, we spoke about 20 years ago about RDF (refuse derived fuel), while today so-called alternative fuels are produced, as described by the Life Cycle Management Law. The applications and requirements also have changed within the last years. In particular, the demand for waste pre-treatment in mid-2005 has brought the issue into the focus in Germany. Today, alternative fuels are utilised for example in cement kilns and power plants. At times, pyrolysis plants were also provided with conditioned waste materials. The operators and consumers have very specific ideas in terms of quality and throughput of alternative fuels, which manufacturers and suppliers of plant components must know very well. In the past, this resulted in the required plant technology, for example with mechanical-biological treatment technology or with stabilization processes for waste.

In recent years, the production of alternative fuels and their use have become an important topic in the sector of waste technology, not least due to the pricing of primary energy sources on the world market. However, it has shown that the waste quantities for the production of alternative fuels are limited and even declining in Germany. Nevertheless, due to the requirements of the various combustion systems the production of sophisticated and high-quality alternative fuels is a challenge for waste management companies and machine suppliers.

## 2. Production and recycling of waste materials

Waste management today means to minimise or even better prevent the production of waste in the community. At the same time dangerous substances in the waste must be eliminated, in order to exclude risks to humans and the environment. In the sector of waste management, several concepts for the recycling of waste materials are being pursued by policy and industry, the feedstock and energy recovery of which being mainly discussed. As far as packaging polymers are concerned, for example, first the mixed plastics are separated, the sorting residues mainly ending up in waste incineration plants and the unmixed fractions being returned to feedstock recycling.

Waste materials are available as heterogeneous bulk products, the handling of which often causes problems. In addition, the waste materials must be conditioned for further treatment or for the further recycling route. Objective is the production of a homogeneous product from a non-homogeneous waste or raw material. The agglomeration by compression or pelletization provides a solution for this. The flat die pelleting press can be used as a universal machine for different waste materials.

The following waste materials can be processed for example with a flat die press: Waste tyres, cotton waste, biomass, bleaching earth, DSD plastics, labels, filter cake, filter dust, flax, fly ash, industrial waste, household waste, blast furnace dust, wood, charcoal meal, cable waste, coffee waste, cardboard waste, sewage sludge, compost, plastic waste, paint residues, metal salts, garbage ( RDF), olive pulp, paper waste, paper sludge, petroleum coke, FGD gypsum, carbon black, sulphur pulp, sisal waste, stone wool waste, sawdust, carpet waste, textile waste, peat, pulp, fibrous web waste, nappy waste, cellulose dust and many more. The requirements on the plants for recycling these waste materials are very diverse.

To what extent the individual processes are appropriate for feedstock recycling and energy recovery with regard to environmental pollution and economic efficiency normally is shown by so-called ecological efficiency analyses.

**Feedstock recycling and energy recovery**

In the past, the following processes for feedstock recycling and energy recovery of various waste materials, particularly plastic waste, were discussed.

Recovery in the blast furnace: After agglomeration and transport the mixed plastics are ground again for being blown into the blast furnace as reductant. The resulting slag is further processed as slag sand, while the blast furnace sludge must be disposed of as hazardous waste.

Coal liquefaction: The agglomerated plastics, which must have a low ash content, are hydrogenated with hydrogen. In the hydrogenation, crude oil, bitumen, and lean gas are produced.

Pyrolysis: In the gasification, methanol is produced as synthesis gas. The steam and current required for recovery are also used in the processing plant itself.

Waste incineration: After having sorted out the recyclable components of the packaging plastics, further conditioning is not required. The mixed plastics are used in a modern refuse incineration plant with steam or current utilisation and downstream flue gas cleaning.

Utilisation in the cement plant: For combustion in the cement plant, the sorted mixed plastics must be conditioned and agglomerated. The compacted material is used as substitute for petrol coke in the cement kiln for primary firing.

Refuse incineration plants and cement plants offer advantages concerning the total costs compared with pyrolysis plants and blast furnaces. Hydrogenation plants are the least economic and cause the most environmental pollution. As for the environmental impact, the processes in the blast furnace and the pyrolysis perform best. It should be noted that in addition to the direct recover costs, the conditioning costs play a decisive role. Due to the high recovery prices the hydrogenation has the lowest ecological efficiency. Variations in the technical process design as well as political framework conditions and not least the recovery costs can lead to shifts of the presented eco-efficiency portfolio.

In the last few years the recovery and the use of alternative fuels in cement kilns and power plants have established themselves. The quality parameters of the product – and thus the required conditioning technology – are described and defined by the combustion technology used.

## 3. Production of alternative fuels

The cement industry has relied increasingly on alternative fuels (also referred to as secondary fuels) to meet the thermal energy demand in the clinker fabrication. In addition, secondary raw materials such as dry ash can be used to replace natural raw materials in the production of raw meal. The finely ground and well mixed raw meal, consisting of limestone, sand, alumina and iron oxide, is heated to sintering in a rotary kiln in order to achieve the characteristic hydraulic properties of cement. Then the so-called clinker is cooled abruptly and ground to ready cement with the addition of gypsum.

Since the cement production is a raw material and fuel-intensive process, this sector offers a high recycling potential. In addition to generating the necessary energy for example for the rotary kiln process, the combustion residues can simultaneously be used as raw material components. The alternative fuels for energy recovery in cement plants result for example from the recovery of waste paper as well as municipal and site waste. After all, about 1 ton of $CO_2$ can be saved through the use of 1 ton of alternative fuel.

As already indicated, quality-oriented products are the condition for the use of alternative fuels and secondary materials to meet the requirements of the customers. If the alternative fuels are used in power plants and cement plants, the following criteria are required for combustion:

- Lower heating value $H_u$ 11 – 25 MJ/kg,
- Ash content < 30 %
- Water content < 35 %,
- Granular size < 25 mm,
- Fine grain content (< 3 mm) < 5 %,
- Bulk density approx. 0.2 to 0.5 Mg/m$^3$.

In cement plants, the alternative fuel is used for the production of clinker. Similar alternative fuel qualities are required as in power plants. In this context, high quality and a trouble-free process must be ensured, too. The chlorine content is limited among others.

When waste materials (e.g. mixed plastics) are used for steel works, they are formed to 6 mm pellets. In the steel work, these pellets are then used as a reducing agent.

Besides, a good conveying and blowing capacity as well as sufficient mechanical and thermal stability are often required. In addition to the physical parameters, chemical parameters are of importance, too. The compliance with the limit values of pollutant levels such as cadmium, mercury, sulphur and the already described chlorine content is required. This means that quality assurance begins with the selection of the waste materials used for recycling.

**Conditioning with the flat die pelleting press**

Treatment of the waste materials plays an important role to achieve the required quality criteria, particularly size reduction, subsequent classification and sorting as well as conditioning of alternative fuels.

In recent years, the pelleting press has become increasingly important for the treatment of waste materials. The flat die pelleting press is used both for pelleting and for granulation.

In the treatment of waste, pelleting means slight compacting of bulk materials. The slightly pelleted material is also called fluff. The transition from fluff to the pellet can be smooth. For this reason, this form is often called soft pellet. Soft pellets are characterized by an increased bulk density with a narrow particle size spectrum.

Figure 1: Pellets and fluff

In the production of fluffy material, the input material is not only slightly compacted, but also conditioned to a homogeneous material with a narrow particle size spectrum. The die configuration as the central pelleting element of the flat die press determines the granular size of the fluffy material.

If the flat die press is used for granulation, coarse input materials are crushed and ground. Due to the friction between the pelleting tools (die and pan grinder rollers) and the associated shearing and cutting effect, the raw materials are evenly crushed.

## 4. Operating principle of the flat die pelleting press

The press works as follows: The pelleting tools of the flat die press are the die and the pan grinder rollers. The die is a circular disk with holes. The shape of the holes determines the quality of the pellets or granulates. Depending on the configuration of the effective bores, the input product is pelleted, granulated, or crushed. A long effective bore is used for compaction or pelleting, a short one for crushing or granulating the input materials. The pan grinder rollers rotating on the die or the product layer on the die respectively press the product to be processed through the effective bores of the die. The die itself is mounted in the press. The product layer which forms is influenced by the proportioning quantity of the product to be processed as well as the gap between pan grinder rollers and die.

Figure 2:

Flat die pelleting press

Forces having shearing and cutting effects act between the pan grinder rollers and the die. Through this friction a combined pressure-shear load (shear forces) is produced. This positive and negative slippage effects a pre-compaction of the material and a reduction of the pressure force, an additional decomposition and a corresponding crushing of the material.

## 4.1. Crushing and pelleting with one machine

Because of this operating principle, the flat die press is universally applicable for the most diverse products with regard to their structure, bulk density, binding strength, particle size and moisture.

In addition to the afore-mentioned pelletable waste materials, the following products can be granulated or crushed: Sheep wool, rice husks, rice straw, barley, oat husks, nut shells, grass cuttings, peat, palm fibres, charcoal, PET waste, polyurethane foam, auto shredder light fraction, concrete aggregates, cable scrap, aluminium shavings, and last but not least waste tyre shreds and many other materials.

Today, pelleting and granulation processes are used in various production areas of the industry, and there are many reasons: Improvement of the flow and proportioning properties, improvement of the product handling and product properties, reduction and avoidance of dust and fines, reduction of the storage volume, suppression of segregation, increase of the dissolution properties, production of a high-quality sales product.

## 4.2. Product parameters and conditions in the processing of waste materials

Both process and mechanical parameters have an influence on the processing of waste materials with the flat die press. Process parameters are e.g. material composition, moisture, temperature, granular size, additives, retention time etc. Mechanical parameters are e.g. die geometry, die material, roller profile, number of rollers, roller speed, drive power, hydraulic pre-pressure, roller gap etc.

The waste to be processed must be specified as precisely as possible with regard to the material composition. The different components of plastic film, hard plastics, textiles, paper, cardboard, etc. and the corresponding moisture content, particle size, bulk density have a decisive influence on the processing - especially with regard to the requirements on the fluffy end product or the pellets.

The following product parameters for pelleting of waste materials would be optimal:

- Particle size distribution
  - approx. 90 % — 0 to 40 mm (in two dimensions)
  - approx. 8 % — 40 to 60 % (in 2 dimensions)
  - approx. 2 % — up to 200 mm (in 1 dimension)
- Product thickness
  - approx. 95 % by weight — max . thickness 5 mm
  - approx. 5 % by weight — max. thickness 12 mm
- Moisture
  - max. 13 % — for the production of hard pellets
  - max. 5 % — for the production of hard pellets from mixed plastics
  - approx. 20 to 30 % — for the production of fluff
- Bulk density
  - approx. 50 to 150 kg/m$^3$

Interfering substances include

- metals, glass, stones (granular size > 1/3 pellet diameter)
- hardwood with a thickness > 5 mm
- leather and hard rubber
- foams (for the production of hard pellets)
- shock-absorbing plastics
- wood and hard plastic with a granular size > pellet diameter
- inert materials (e.g. sand > 5 %)

Foreign and interfering substances influence the availability, the throughput, the service life of the pelleting elements, and the pellet quality.

## 5. Drying and cooling as supplementary process steps

Depending on the input material and the requirements on the pellets as the end product, the waste materials may have to be pre-dried. In the case of hard pellets, cooling is also required to store them.

For pre-drying belt driers can be used, which are assembled in modular design. Depending on the requirements, they can be executed in different belt widths and consist of several storeys.

The drying process for alternative fuels is divided into the following steps: Product supply, product storage with feeding, drying, and discharge, heat exchanger, inlet air and exhaust air system.

The belt drier (e.g. double-storey belt drier for 20 t/h) works on the basis of convection drying. Steam is used e.g. as drying energy and air is used as energy carrier of the drying heat. Via a storage bin or scraper floor/windlass, the alternative fuel is fed continuously to the first upper belt. A belt consisting of slotted plates moves in the drier housing. Via these slots the drying air flows through the alternative fuel to be dried. The heated drying air flows through the product from bottom to top in a cross-flow process and cools down due to the evaporation of the product moisture. The air enriched with moisture and fines is sucked off. A weak low pressure is produced which prevents the fines from escaping from the drier housing. Due to the design of the belt drier with several storeys, different temperature profiles can be adjusted in the individual sections. In addition, the product is turned and loosened when passing from one storey to the next. In total, this results in a gentle drying of the alternative fuel. The drier exhaust air laden with water and fine particles is cleaned by means of a filter system.

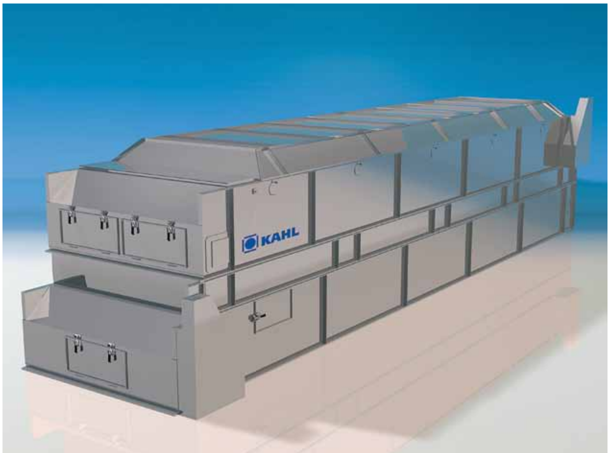


Figure 3:

Belt drier

The dried alternative fuel is subsequently fed into the pelleting presses. The fines discharged from the drier can also be fed into the presses.

The drying process depends on the composition, moisture content and granular size of the alternative fuel to be dried. This means that the process parameters such as throughput, required amount of heat and air mass flows are based on the input material and the desired final moisture. A drier produces always a certain evaporation rate at an exhaust air temperature with given air mass flow rates and their inlet temperatures. Varying throughputs or moistures change the exhaust air temperature. An intelligent control concept of the belt drier compensates these production fluctuations. Fire protection measures such as spark detectors and fire fighting equipment are part of the plant design to avoid ignition sources in the context of preventive explosion and fire protection in the drying plant.

The alternative fuels to be dried are already pre-crushed (e.g. granular size 90 % < 50 mm, granular and flat structure, particle thickness < 5 mm, input bulk density approx. 70 kg/m³, inlet moisture approx. 20 %, outlet moisture approx. 13 %, inlet air temperature approx. 90 °C) and are pre-dried for subsequent pelleting or for the production of fluffy material.

## 6. Examples of treatment plants for alternative fuels

In the following two plants for the production of alternative fuels (mechanical/physical stabilisation plant) are described. The alternative fuels are used in cement plants and power plants.

During processing of residual waste, more than 50 % (referred to the input material) of alternative fuels can be produced. The domestic and commercial waste passes through the process steps intake, processing, drying, sifting and conditioning.

In detail, this means: Pre-crushing to an edge length of about 300 mm, screening into several fractions, return of the coarse fractions, post-crushing to an edge length of about 60 mm, separation of ferrous and non-ferrous metals, drying for stabilising the waste to avoid aerobic and anaerobic degradation processes and to increase the calorific value, classification and separation of light and heavy fraction, post-treatment of the heavy fraction, pelleting of the light fraction, dust removal and treatment of the exhaust air.

The combustible components (high-calorific light fraction) can be processed to fluff as well as to pellets if required.

In the case of fluff production, after treatment with the flat die press the material is conveyed to the pressing station for loading. In the case of pellet production, the pellets are cooled, screened and intermediately stored in silos prior to loading/discharge by truck.

Figure 4:

Flat die presses for the production of alternative fuel

In a further conditioning plant alternative fuels are also produced for cement plants. The plant operates in three shifts. Domestic waste as well as combined industrial and site waste are pre-crushed and screened first. Then the high-calorific fractions are dried in a belt drier to approx. 15 %.

Via several conveying belts the pre-crushed product with a bulk density of 50 to 110 kg/m³, a moisture of 10 to 20 %, and a granular size of 90 % < 40 mm is fed to a scraper conveyor for distribution to the flat-die pelleting presses. Interfering substances such as metals, glass, stones, etc. are previously separated. Outlet slides as well as the actual proportioning elements consisting of proportioning wheels and screws are mounted below the scraper conveyor. The speed of the respective proportioning element is controlled by a frequency converter depending on the current consumption of the three-phase motor of the flat die press. It is a load-dependent control system to ensure an optimum throughput. Several flat die presses are placed in parallel, with the presses being operated in a so-called *overflow*. The product which is not drawn-in by the proportioning elements is transported by the scraper conveyor to a buffer belt, from which it is returned to the pelleting plant. Thus temporary production fluctuations in the upstream and downstream line can be compensated.

The flat die presses are reinforced for the treatment of waste materials. In addition, the presses are provided with a large pelleting chamber and an elevated upper part for optimum feeding of voluminous products.

## 7. Other application examples of bulk products worldwide

A variety of bulk materials can be compacted and granulated with the flat die press.

In addition to the waste management and recycling industry (waste tyres, waste materials, sludge, filter dusts, etc.) the following sectors are of great importance:

- Renewable raw materials (biomass, wood etc.),
- Compound feed industry,
- Food and sugar industry,
- Chemical and pharmaceutical industry,
- Mineral industry,
- Petfood industry.

Plants for processing bulk materials are designed and built world-wide according to customer requirements. For new products, the compaction, granulation and drying processes are tested and analysed in detail and the machines and plants are tailored to the requirements of the particular product being processed. Following the motto *We adapt the machine to the product* a tailor-made solution is reached. The variety of types available from the laboratory equipment to the production machine ensures a high degree of flexibility and variation in plant design. The application areas of the machines described range from raw material conditioning for subsequent processing to manufacturing of finished products.

## 8. Summary

The flat die pelleting press is a universal unit for the treatment of various bulk materials. Due to the equipment options, most requirements are covered.

In recent years, the flat die press for the production of alternative fuels has been improved continuously. The pan grinder roller principle, according to which the flat die press works, is suitable for many applications, particularly for the processing of waste materials. Depending on the design, both compaction and granulation is possible with one machine, i.e. different qualities of alternative fuels can be produced depending on the needs. The combined pressure-shear load (shear forces) produced in the flat die pelleting press on the product to be processed is an important feature. The flat die press is integrated in a chain of processing steps and is used for conditioning of alternative fuels. This conditioning step will be supplemented if necessary by a pre-drying and subsequent cooling step.

The processing steps to produce high-quality alternative fuels, however, are always connected with investment and operating costs. Despite both relatively low wear and operating costs, which are provided by the flat die press, a corresponding acceptance and reasonable cost structure is required on the market. The market is under pressure. Over-capacity and low-cost combustion in incinerators support this situation. The challenge is to produce a homogeneous product with virtually identical parameters from a non-homogeneous raw material, as waste happens to be. The flat die pelleting press offers you the possibility to produce a sophisticated and high-quality alternative fuel.