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Evaporative cooling as a method for the reduction of the energy consumption on drying sand

Verdampfungskühlung als Verfahren zur Reduzierung des Energieverbrauchs beim Trocknen von Sand

M. Trojosky, R. Roller, M. Frey, Allgaier Process Technology GmbH, Uhingen, Germany

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M. Trojosky, R. Roller, M. Frey, Allgaier Process Technology GmbH, Uhingen, Germany

SUMMARY

Sand is one of the most widely used construction materials in the world. Among other products, it is used for the manufacture of mortar, tile cement, plaster and floor finishes, which are marketed as so-called "ready mix" products. In addition, sand is required for the manufacture of glass; particularly high-quality sand latterly in the form of so-called "frac sand" is used during natural gas extraction and in many other sectors of industry. It is necessary to dry the sand, e.g. so that it can be screened subsequently into different fractions with high selectivity. Cooling is necessary if required by the downstream process steps or due to the subsequent addition of temperature-sensitive additives, as well as for storage and packaging reasons. One technical solution for sand drying is the drum dryer system Mozer® from Allgaier Process Technology GmbH. In this system double-shell units are used. The drying takes place in the inner drum tube, while the cooling is undertaken in the outer tube on the same unit. Along with the proven, extremely robust and economical drying-cooling drum system TK in which the material to be dried is cooled by ambient air, Allgaier supplies the system TK+, which makes a very significant contribution to saving fuel and electrical energy by means of so-called evaporative cooling. The operation principal and the advantages of the mentioned system are described in the article.

ZUSAMMENFASSUNG

Sand ist einer der weltweit am meisten verwendeten Baustoffe. Er wird u.a. zur Herstellung von Mörteln, Fliesenklebern, Putzen, Estrichen verwendet, die als so genannte „Ready Mix"-Produkte in den Handel gelangen. Des Weiteren wird Sand zur Glasherstellung und besonders hochwertiger Quarzsand neuerdings als so genannter „Frac Sand" bei der Erdgasgewinnung und in vielen weiteren Industriezweigen eingesetzt. Das Trocknen der Sande ist notwendig, um z.B. nachfolgend die verschiedenen Fraktionen mit hoher Trennschärfe durch Sieben voneinander separieren zu können. Gekühlt werden muss dann, wenn die weiteren Prozessschritte es erfordern oder wegen der nachfolgenden Zugabe von temperaturempfindlichen Additiven oder aus Lager- und Verpackungsgründen. Die Allgaier Process Technology GmbH ist mit dem Trommeltrockner-System Mozer® Marktführer auf dem Gebiet der Sandtrocknung. Zum Einsatz kommen insbesondere zweischalige Apparate, bei denen die Trocknung im inneren Trommelrohr stattfindet, während die Kühlung im äußeren Rohr des gleichen Apparats ausgeführt wird. Neben der bewährten, robusten und preiswerten Trocken-Kühl-Trommel System TK, bei der die Kühlung des Trockenguts durch die Umgebungsluft erfolgt, liefert Allgaier das System TK+, welches durch Verdunstungskühlung zu einer signifikanten Einsparung von Brennstoff und Elektroenergie beiträgt. Die höheren Investitionskosten amortisieren sich durch die Energieeinsparung innerhalb kurzer Zeit. Die Funktionsweise und die Vorteile des genannten Systems werden in dem Beitrag beschrieben.

(English text supplied by the author)

Evaporative cooling as a method for the reduction of the energy consumption on drying sand

Verdampfungskühlung als Verfahren zur Reduzierung des Energieverbrauchs beim Trocknen von Sand

1 Introduction

In times of increasing energy prices the efficient use of resources is becoming an increasingly important method of improving cost-effectiveness and with it also the competitiveness of production. The protection of the environment, sustainable business management and energy saving have also become important issues for society. Because thermal drying requires up to ten times more energy compared to purely mechanical water removal, there is particular interest in using drying systems that are as energy-efficient as possible. As particularly in the construction material industry there is heavy pressure on prices at the producers along with high production quantities, energy-efficient design of the drying process is particularly important. With the combined drying and cooling drum system Mozer® TK+ (➧ Fig. 1), Allgaier has a concept that both effectively cools the dried sand by means of evaporative cooling and also realizes a fuel-saving of up to 20 %.

2 Principle of operation of drum dryers

In drum dryers the material is moved by the rotation of the drum and by the conveying action of the fittings in the drum. Lifting blades pick up the moist material from the bottom of the drum and allow it to drop again after lifting, as a result the damp material comes into contact with the hot drying air. The optimal design of the drum fittings for the intimate contact of the drying gas with the moist material is particularly important. Even today it is not possible to calculate completely the arrangement and the shape of the fittings or their number, instead a combination of experience, trials and calculation is required for the design.

In the majority of applications for drying, the material is conveyed in the same direction as the gas flow. In the past conventional drum dryers were often designed with a gradient in the direction of material discharge to convey the material in the drum. This design resulted in increased effort for positioning the drying drum during operation as well as related wear problems.

Allgaier double-shell drums are horizontal so that the material in the outer tube can be conveyed in the opposite direction to the material in the inner tube. The material is conveyed in horizontally erected drying drums by so-called guide blades.

A combination of parallel flow and cross flow between the drying gas and the material is produced in the dryer. The moist waste air is extracted from the dryer by a waste air fan, fed through a bag filter to remove the dust it is carrying and discharged to the environment via a chimney. The waste air pipework for a drum drying plant is of comparatively simple design, as it is only necessary to extract from one point in the dryer housing. Inlet air pipework, as necessary on fluidised or fluid bed dryers, is not normally required, as drum dryers can in many cases be operated with a flame burning directly in the dryer or a combustion chamber can be mounted directly on the dryer housing.

In the construction material industry, throughputs of material to be dried of between 20 and 150 t/h are common. A particular advantage of drum dryers is the broad insensitively to fluctuations in the initial moisture content of the sand to be dried due to the time of year or for production-related reasons, or due to fluctuations in the throughput and the

Figure 1: Dryer drum/cooler for sand

particle size of the material, or due to the addition of undesirable clumps or coarse material.

Dryer drums are suitable for both fine particle sizes, and also for coarse or very coarse bulk materials; it is not necessarily imperative to adjust the amount of air on a product change. Even on the failure of the drying air, the material in the dryer drum is reliably transported by the rotation of the drum. These characteristics mean that drum dryers can be operated with high reliability.

3 Evaporative cooling

After drying the sand heated by the drying is often cooled. The cooling is necessary, as the subsequent processing steps such as conveying, screening, storing, mixing or packing only permit specific maximum material temperatures. Cooling is also required if temperature-sensitive additives are to be added to the prepared sand, e.g. certain resins for the manufacture of high-quality "ready mix" dry construction materials. Finally, residual portions of remaining moisture are removed from the space between the particles in the bulk materials by the cooling with ambient air; this moisture is carried away by the moist dryer exhaust air. The dried materials are therefore subjected to a form of airing which stabilises the moisture content achieved in the material.

In the majority of cases the cooling of the hot sand is undertaken using dry ambient air. Very high quantities of air are required for this purpose.

As the equipment costs and the energy costs are related to the technological design of the cooling, cooling should only be undertaken to the actual temperature required. For applications in the construction material industry this temperature is often approx. 55 to 60 °C and less frequently approx. 40 to 45 °C.

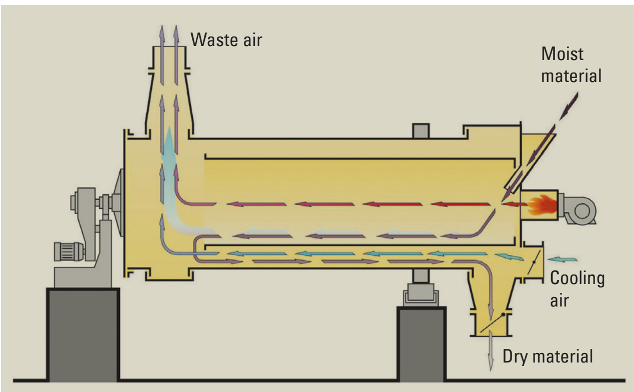

Figure 2: Allgaier drum dryer system Mozer® TK with air cooling

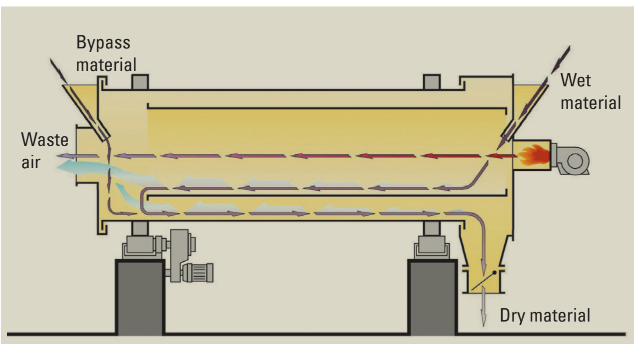

Figure 3: Principle of operation of an Allgaier drum dryer system Mozer® TK+ with evaporative cooling

Evaporative cooling is the cooling of the material using "latent" heat, that is the heat of evaporation or vaporisation of the water. While a certain defined residual moisture content in the dried material is dried by contact with cold or slightly preheated ambient air, the evaporation of water cools the material. The drying of the sand to the required residual moisture content is undertaken using the residual heat in the product and the water absorption capacity of the ambient air applied. Theoretically cooling to the so-called "wet bulb temperature" in accordance with the psychometric principle is possible.

As a consequence the process of evaporative cooling has the advantage that energy is saved during drying by using the residual heat in the material and the product is also cooled at the same time.

Evaporative cooling can be achieved in fluid bed dryers by designing the drying in the initial area of the dryer in such a way that the drying is not "completely finalised", instead the sand laden with residual moisture enters the cooling zone in which the drying of the residual moisture and the cooling are undertaken using the cooling air introduced. Particularly in fluid bed dryers with a high capacity, however, the control of such a drying plant can become a problem both in relation to the moisture in the product prior to cooling and in relation to the final moisture content, if too much moist sand "breaks through" into the cooling zone due to fluctuating initial moisture content, it is then no longer possible to control the required final moisture content.

The use of drum dryers has become established particularly in the last decade in particular for drying sand and other minerals, not least because Allgaier has offered the possibility of robust plant operation combined with high energy efficiency in the form of its modern, very robust drum dryers and combined drying-cooling drums.

While the standard model, the combined drying-cooling drum system Mozer® TK (❯ Fig. 2), uses the sensible heat in the ambient air for cooling, the further developed system TK+ (or "TKplus", ❯ Fig. 3) uses the method of evaporative cooling.

On the TK+ a primary flow of moist sand is dried in the inner tube of the two-shell dryer/cooler; after the drying in the inner tube the remaining sub-flow of moist sand is applied to the system in a controlled manner in such a way that the hot, dried sand is mixed with the cold sand that has not yet been dried (the so-called "bypass material", ❯ Fig. 4).

Both sub-flows, the hot, dry product from the inner drum and the bypass product, are intensively mixed in the outer drum by lifting plates and conveyed against a very small flow of cooler ambient air. During this process the water contained in the bypass material evaporates (turns into vapour), while at the same time the hot product is cooled by the effect of evaporative cooling.

In this way only a proportionally smaller amount, 80 to 90 %, of fuel (natural gas, light heating oil, liquefied petroleum gas) needs to be used to dry the reduced main flow of moist sand, while the quantity of cooling air required is significantly reduced due to the effect of evaporative cooling. The con-

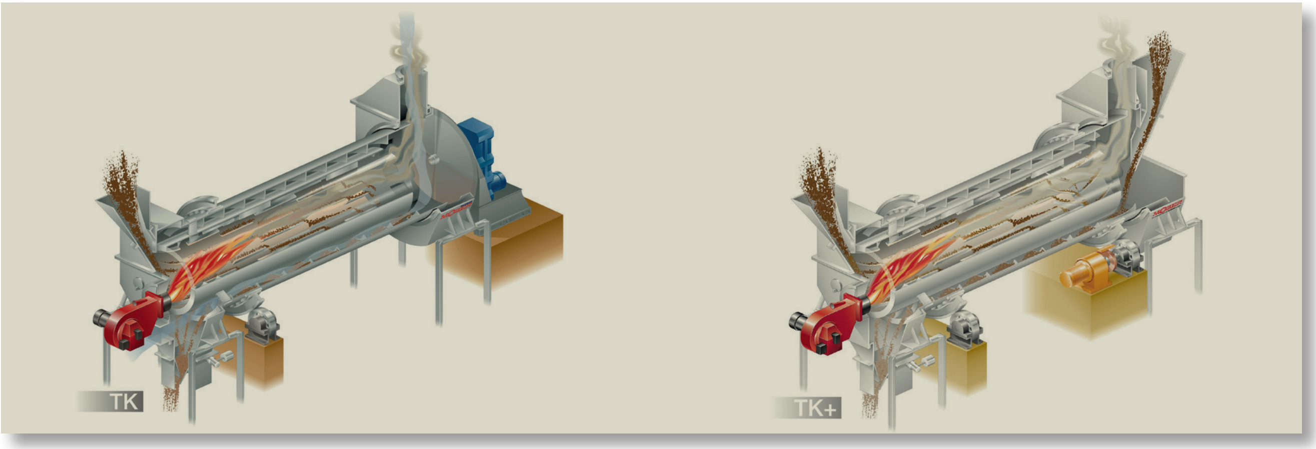

Figure 4: 3D section of a drying-cooling drum TK with air cooling and a TK+ with bypass feed and evaporative cooling

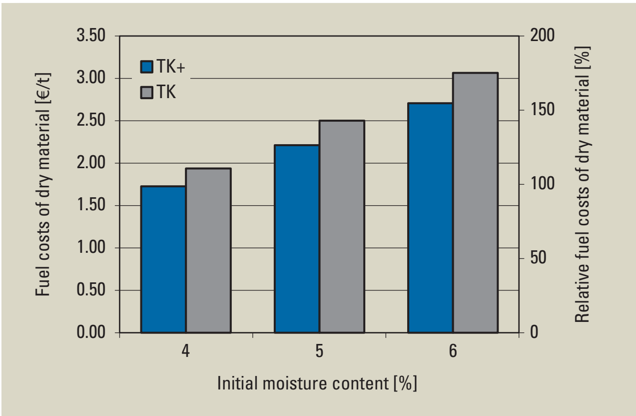

Figure 5: Fuel costs per metric tonne of dry material

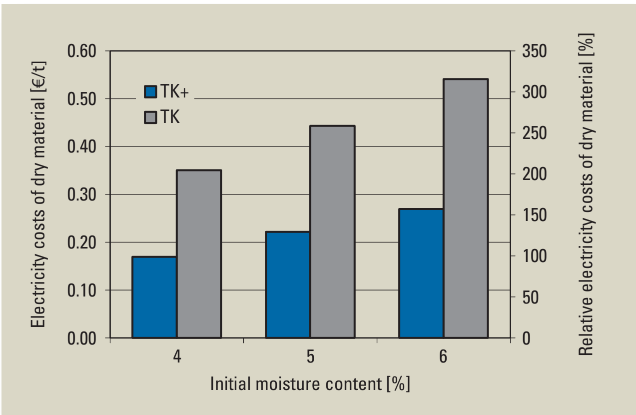

Figure 6: Electricity costs per metric tonne of dry material

sequence is that with the system TK+ significantly smaller waste air fans and waste filter plants are required. Along with the reduction in the amount of fuel required, there is also a reduction in the consumption of electrical energy.

It is also possible to convert the standard Mozer® TK system to the TK+ system without the need to modify or replace the existing dust removal plant.

4 Study confirms energy saving due to evaporative cooling

Many years of experience and sophisticated calculation programs mean it is possible to calculate in advance the effects described and therefore to be able to dependably design the plants to be delivered to customers.

To check, nevertheless, whether the plants supplied up to now by Allgaier confirm the predicted energy consumption figures in industrial practice, an intensive study has been undertaken on a total of eleven plants supplied by Allgaier, which in some cases have been in operation for many years, by measuring all available process and consumption parameters. Both Mozer® TK system dryer/coolers and also TK+ system plants were studied. Comparative assessments of the parameters determined using the existing design programs and the values measured on the plants have shown close agreement with the original, theoretical plant design.

The study confirms that fuel savings of between 10 and 20 % can be achieved with the aid of evaporative cooling with the use of the TK+ system plants. It has also been confirmed that the electrical power consumption on TK+ plants with evaporative cooling is almost halved, due to the reduced amounts of waste air.

❱ Fig. 5 shows the different fuel costs in absolute and relative terms (referred to a TK+ and 4 % sand moisture content) on the TK and TK+ systems with example sand moisture contents of 4, 5 and 6 %. ❱ Fig. 6 shows the electricity costs for both systems, resulting from the different amounts of air (shown in absolute and relative terms referred to a TK+ and 4 % sand moisture content). ❱ Fig. 7 shows the mean total energy costs for drying one metric tonne of sand based on the example of an initial sand moisture content of 5 %.

It therefore becomes clear that the potential savings with a system TK+ drying-cooling drum are dependent on the sand moisture content. A higher sand moisture content increases the advantages of a TK+.

At this point it should be noted that in general it should be attempted to start drying with the lowest possible sand moisture content. The initial sand moisture content can be influenced, e.g., by storage of the sand for several days for natural water drainage or by roofing the storage facility and the resulting protection against the rain.

5 Evaporative cooling or air cooling?

A decision as to which of the available dryer-cooler systems is optimal for a specific task must be made depending on several factors on a case-by-case basis. An amortisation calculation can be used to show which system is optimal for the related application. A drying plant based on the drying-cooling drum TK+ requires greater expenditure for the controlled feed of the main flow of moist sand and dosing the bypass flow. Several technical variants are available for this controlled moist material dosing. It is possible to use matched bucket conveyors or belt conveyors or a solution with a controlled material gate.

The additional expense for the material feed as well as the mature electronic control program and also the higher process-equipment related expenses for the manufacture of the combined drying-cooling drum TK+ result in a somewhat higher plant price for the TK+ systems compared to the standard TK systems.

In general it is known that investment costs diminish with increasing plant size. As the additional expense for the detailed aspects of a TK+ also reduce relative to plant size with increasing plant size, the additional costs for a system TK+ drying-cooling plant have less impact at higher capacities. ❱ Fig. 8 shows the procurement costs for both systems normalised to a system TK plant with a dry material throughput of 15 t/h.

Due to the significantly lower energy costs (fuel costs + costs for electrical energy) with the use of evaporative cooling, the additional costs for the bypass flow distribution and the control of TK+ plant can be amortised already after 5000 to 8000 operating hours. The greater the capacity of the plant and the higher the sand moisture content, the shorter the resulting amortisation period (❱ Fig. 9) for the additional costs of a TK+ compared to a TK. Here it is to be noted that a low sand moisture content reduces the absolute investment and energy costs for any drying plant.

The amortisation period was calculated using German energy prices from 2013. If energy costs continue to increase as expected, the amortisation period will reduce further. Particularly on plants with high throughput and high initial moisture content it is therefore worthwhile to use energy-saving technologies like that of the Mozer® TK+ system.

6 Advantages of the systems at a glance

The general features of drum drying can be summarized as follows:

- Suitable for both coarse and fine materials
- Also insensitive to very coarse or heavy materials
- Low expenditure for the inlet air equipment due to direct burner mounting
- Insensitive to
  - Change in the material particle size
  - Fluctuations in the moisture content and the throughput
  - Failure of the drying air
- Low specific electrical energy requirement
- High drying air temperatures in conjunction with low heat losses
- Low heating energy requirement also in the partial load area due to adjustment of the amount of waste air
- Straightforward installation and quick commissioning
- Tolerant of operating errors
- Very robust thick-walled equipment with long service life
- Can be installed outdoors in harshest conditions
- Moderate wear and low spare parts requirement

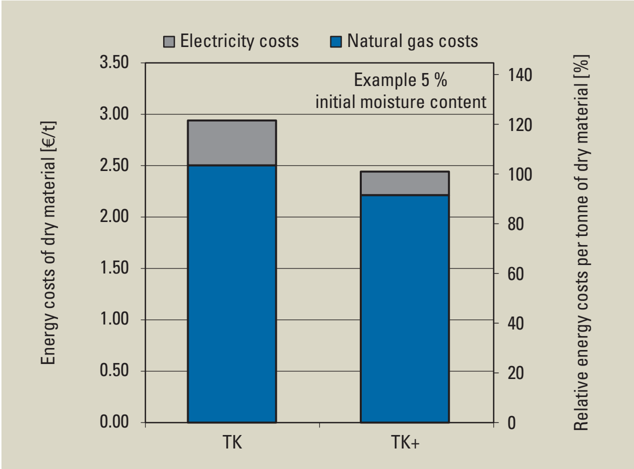

Figure 7: Energy costs per tonne with sand moisture content of 5 % in comparison

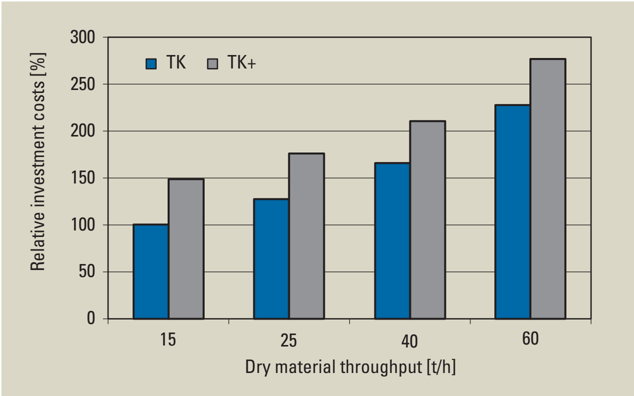

Figure 8: Investment costs compared (normalised)

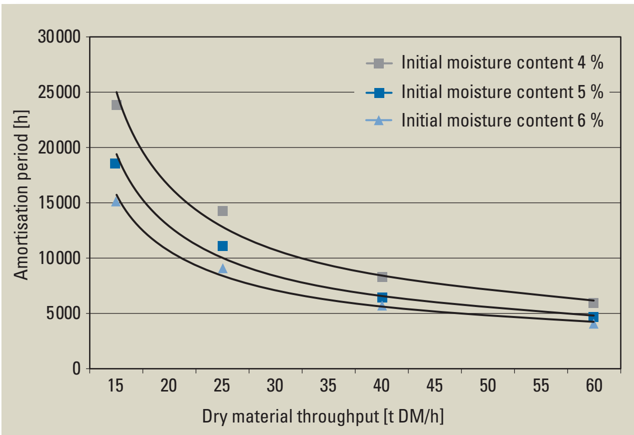

Figure 9: Amortisation period as a function of the dry material throughput

The advantages of dryer/cooler with air cooling based on the Mozer® TK system are:

- Tried-and-tested technology
- Low investment requirement

The advantages of dryer/cooler with evaporative cooling based on the Mozer® TK+ system are:

- Halving of the amount of waste air compared to air cooling
- Halving of the electrical consumption compared to air cooling
- 15 % lower natural gas consumption on average