Spreading the Knowledge

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”Characteristics of Bulk Material in Screw Type Conveyors”

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The following presentation wants to give you a brief overview on the characteristics of bulk material especially in screw type conveyors.

Before I will give you some information about the behaviour and the characteristics of bulk material in screw type conveyors, let me say just a few words about the characteristics of screw type conveyors.

Like most of conveyor-types the screw conveyor is not usable for any kind of material and massflow. But in specific application areas, for example for a mass flow less than 1200 t/h and free-flowing solids it is one of the best conveying systems because of some very important advantages of this system:

- One very important advantage of the screw conveyor is, that it is suitable for horizontal to vertical conveying directions.
- A lot of free-flowing bulk materials are conveyable
- The screw conveyor is a very simple construction with only one moving part, the screw itself. Except for the screw there are just a tube, some bearings and an electric motor.
- Thus the investment for the plant is very low compared with other conveying principles,
- The weight of the plant is low as well,
- And last but not least the requirement of space is low;

the last two points are especially important for on-board or off-shore plants.

But as you know, nothing is perfect, so there are some disadvantages as well:

- because the principle is based on friction in most cases a part of the particles would be crushed or chipped within the conveying process,
- another result of the friction is abrasion of the conveyor tube, this problem increases with the speed of the screw,
- the power requirement is higher than with other conveying principles, because the principle is based on friction,
- the possible mass flow and the power requirement strongly depends on the characteristics of the conveyed material.

For that reason it is very important for dimensioning and designing a screw type conveyor to know the characteristics of the material and their effects and influences on the conveying process.

Therefore a further problem lies in calculating the power rating for vertical conveyors, as used for example in the continuous unloading of bulk carriers. Our institute also conducted studies in this area and devel oped design models. It became apparent, however, that owing to marginal effects which do not lend themselves to theoretical quantification (splitting effect, clogging, transfer onto and discharge from the conveyor) the power ratings actually required differ distinctly from the values resulting from the movement of the bulk material which can be calculated with a good degree of accuracy. It has been possible to include these effects in the design methods by approximation. Owing to the considerable influence exerted by the properties of the material being conveyed on these marginal effects, however, characteristics specific to the bulk material are required in order to achieve a precise configuration, and these can only be obtained empirically.

Since 1996 Krupp Fördertechnik GmbH and the Institute for Material Handling, Material Flow and Logistics (fml) at the Technical University of Munich are working in close co-operation to study high-capacity screw conveyors. In the middle of 1997 Krupp Fördertechnik GmbH and our Institute started a research co-operation, aiming to improve the accuracy when rating and dimensioning large and efficient screw conveyors.

The most important objectives of the research in this co-operation should be:

- The possibility of a reliable prediction of the massflow and
- of the requirement of electrical power for plants with screw type conveyors
- Optimization of the operation-parameters of the machine
- Optimization of construction and design of the screw for different kinds of material.

- The result of the upper four objectives is leading to an optimized system of feeder, vertical-conveyor and horizontal conveyor with optimized interfaces between the components.

Within the frame of this close collaboration a pilot plant has been designed and developed, which was built and put into service at the beginning of the year 1998. It is equipped with a high-speed screw conveyor for vertical transport, a high-speed screw conveyor for horizontal transport and an open horizontal screw as feeding system (feeding screw conveyor).The space of our plant is about 150 m^2.

The vertical screw has a diameter of 260 mm, the maximum speed is 560 rpm and the length from inlet to outlet 7 m. The horizontal screw has a diameter of 315 mm, a maximum speed of 400 rpm and a conveying distance of twotimes 3 m. The diameter of the feeder screw is 400 mm, its maximum speed 100 rpm. The feeding device is 1.5 m wide.

Our experimental plant is designed for a capacity of 100 t/h, based on a density of the material of 1 t/m^3.

The feed drives allow a maximum velocity of 20 m/min into the material. Usually we use about 7 to 12 m/min because otherwise the period of one measurement is to short.

The experimental plant has almost real dimensions (mass flow 100 t/h) and thus allows very realistic studies of the handling equipment, but also of the bulk material to be handled and its behaviour during transport. Furthermore, the plant permits investigations of bulk materials, in particular with respect to their handling characteristics and power requirement, for the design of new plants.

In our research we want to investigate the influence of the operational parameters of the machine by working out a performance characteristic of the machine with a reference material, we used granulated PET, former bottles of Coke.This procedure allows to investigate changes of the components or constructive differences at any time. Afterwards we try to calculate the differences of other material with caracteristical values, which need not to be constant values, but curves.Thus we get performance characteristics of the machine, based on a certain material.

The influence of changing geometrical data will be investigated by measurements with other plants, a smaller one is part of our experimental plants at our institute. Bigger ones could be investigated with measurements on real unloading plants.

For designing new equipment with screw type conveyors the first question should be:

What are the optimal geometrical data for the new machine.

For our research this question means:

What is the maximum of the possible mass flow, depending on the parameters of operation and construction.

This was the first objective of our research, and we found out that the maximum mass flow strongly depends on the characteristics of the material, not only on the density and the friction. It was very interesting that the biggest problem to give an answer to this question was, that with some kind of material it was not possible to get enough material into the conveyor.

We had many problems with Potassiumchlorid. This material has the behaviour of consolidation in front of the conveyor-inlet as a result of giving pressure on the material from more than one direction. Instead of the necessary volumetric efficiency (also called „conveyor loading"), which means the volume of material in the conveyor divided by the theoretical volume of the screw, of about 45% we could reach a maximum of some 30%. It was not possible to get more material into the inlet of the conveyor.

Thus, the answer to our question about the maximum mass flow is not a question just about the procedure of transporting the material from inlet to outlet but also a question of the construction of the inlet and the behaviour of the material.

For free-flowing material, for example the prilled Sulfur that is used in the following graphs, the answer looks like this diagram. As you can see it is almost possible to get any mass flow with one machine with certain geometrical data, you just have to increase the speed of the screw. Because of physical reasons the mass flow is a little bit under-proportional to the speed of the screw.

The problem of not getting enough material through the inlet raises with the speed, because of the centrifugal force of the parts of material, which got already into the screw and try now to get out again.

So for recapitulation our result was, that in wide ranges it is possible to get high mass flow with small screw conveyors.

The next important question while designing should be:

How much energy would be required for the conveying process.

Responsible for the required power is the torque which is necessary for the conveying process. From the theoretical point of view the torque is a function of the volume of material, which is in the conveyor. In our evaluation of the measurements we obtained first the course of the torque during the conveying process. This is important, because if there are high amplitudes the requirement of power could be much higher than the average torque. Obviously there is an influence of the feeder-system on the vertical conveyor. The deviation of the torque is not a result of inhomogeneous mass flow. It is a result of the load of the bulk material on the screw, which effects like a break to the vertical screw and is caused by the feeder system. This influence is just important while conveying very low mass flow, in this graph about 19 t/h. Near the calculated capacity of the system the effect is not remarkable anymore.

Thus we are calculating with a satisfying accuracy using the average value of the torque as we did in the next figure.

The influence of the speed of the screw is theoretically very low compared with other influences. So we could see in our empirical research, that the torque strongly depends on the volumetric efficiency. With a speed of the screw higher than 350 rpm the torque increases as well.

There are other influences than the transport of the material like local cloggings, material which is getting between the screw and the tube and the inlet and outlet processes which cause an additional requirement of power.

Thus once more the most important influence is the behaviour of the bulk material.

Because the parameters are changing a lot we tried to find an answer with our research to the question:

How much energy is required to transport one ton of a certain material in one hour over a distance of one meter and what are the parameters with the most important influences.

Therefore we worked out the specific power requirement.

As we could see after a lot of measurements this physical dimension is nearly a constant value in the ranges of the operational parameters which should be used. One of the results of our research was, that the requirement of power depends on the speed of the screw, on the construction of the screw and strongly on the conveyed material.

It is possible to have accurate predictions for the expected mass flow and the required power, if the screw is working in a certain range of operational parameter.

So it is possible to get a high mass flow with a small screw, but than you have to install maybe much more power than with a larger screw.

For the dimensioning of a new plant it is not necessary to work out the exact values of volumetric efficiency or speed, but it is important for an economical operation to use values in certain ranges. If you do so, it is possible to predict the requirement of power with the value of the specific power requirement. In that case it is possible to use the minimum value for the calculation because the maximum of the expected mass flow requires the minimum of the specific power. If the plant has to convey less material, the specific power requirement increases, but the true value of power requirement is lower.

Untill now we have investigated the following kind of material:

- granulated PET, which is not relevant for the practical use but is used for reference investigations because this material is very hard, with almost no changes of conditions during the investigations.
- crystalline Potassiumchlorid, KCl, kind of fertilizer,
- granulated Potassiumchloride, chemically the same, for conveying behaviour completly different,
- prilled Sulfur, which was described above.

For those kind of material we got all the results as given above. The most important value, the specific power requirement is compared in the next figure. With Sulfur we reached the highest mass flows and we needed less energy than with all the other kind of material. The value for the specific power requirement of Sulfur is about 19 Wh/tm.

Granulated Potassiumchloride has a value of about 27 Wh/tm. We could reach those values after the problem of not satisfying volumetric efficiency was solved by a reconstruction of the inlet-region of the vertical conveyor. We opened the tube wider and installed kind of feeding hopper at the interface between feeder and vertical screw. Before that reconstruction we never reached values less than 32 Wh/tm. The problem was the same, even worse with crystalline Potassiumchloride. So the specific power requirement was about 43 Wh/tm, with high deviations. The minimum we have ever reached with this material was more than 40 Wh/tm.

Our reference-material, the PET, reached values of about 22 Wh/tm. This curve is not included in this figure for better survey and because it was not a real material for investigation.

The next material we will investigate will be coal for power plants.

As given above one of the disadvantages of the screw type conveyor is the destruction of parts of the material. Some parts of the material get into the gap between the screw and the conveyor tube. Because of tolerances and inaccuracies of the parts of the machine this pieces are jammed and crushed. Other parts are grinded down because of the friction at the tube. In some cases it is very important for the owner of a plant that the unloaded material is not damaged or downsized while unloading.

Thus another objective of our research is to quantify the part of crushed or chipped material.

Therefore we did first measurements with the prilled Sulfur. We investigated the particle sizes before conveying and after conveying once. The result is shown in the next figure.

The “new” Sulfur at delivery conditions consisted of about 19% parts bigger than 4 mm diameter, 72% bigger than 2 mm. The other fractions were smaller than the gap between the screw and the tube. Therefore it is not probable that parts with this size are crushed. So we should compare the part of material bigger than 2 mm in the delivery conditions with the percentual part of the same size after one conveying process.

As you can see the part of material with more than 4 mm diameter decreased from 19% to 16%, the part between 4 mm and 2 mm decreased from 72% to 68%. Thus about 6% of the material was either crushed or chipped.

Material which is nearly from the same size like the gap between the screw and the tube would be strongly damaged. Very hard material which has a distinctly bigger diameter than the gap is no problem, just a small part of the material will be crushed.

Important for offering a plant is the possibility of the prediction of the degree of destruction of material, because some customers reject the screw conveyor, because they do not know what happens exactly and want to exclude the risc of heavy material destruction.

The situation might change in some cases, if it is possible to give quantifications for the percentual destruction of material or limits of it. Then it would be much easier to decide whether a conveying principle is suitable for the operational case or not.

Finally I want to summarize the results of our research.

The screw type conveyor is a very well known principle for conveying bulk solids. With the experiences of our measurements there is the background for a reliable method to predict the requirement of power and the possible mass flow of new plants.

The former disadvantages of the screw conveyor as the problems with dimensioning, especially of the vertical conveyors can be solved with the possibility of measurements with every material and characteristic values for the specific power requirement depending on the material.

The influence of the operational data of the conveyor could be predicted by characteristics of the conveyor.

Further on in our research we are searching for similarities between different bulk materials to predict its behaviour reliably without testing.

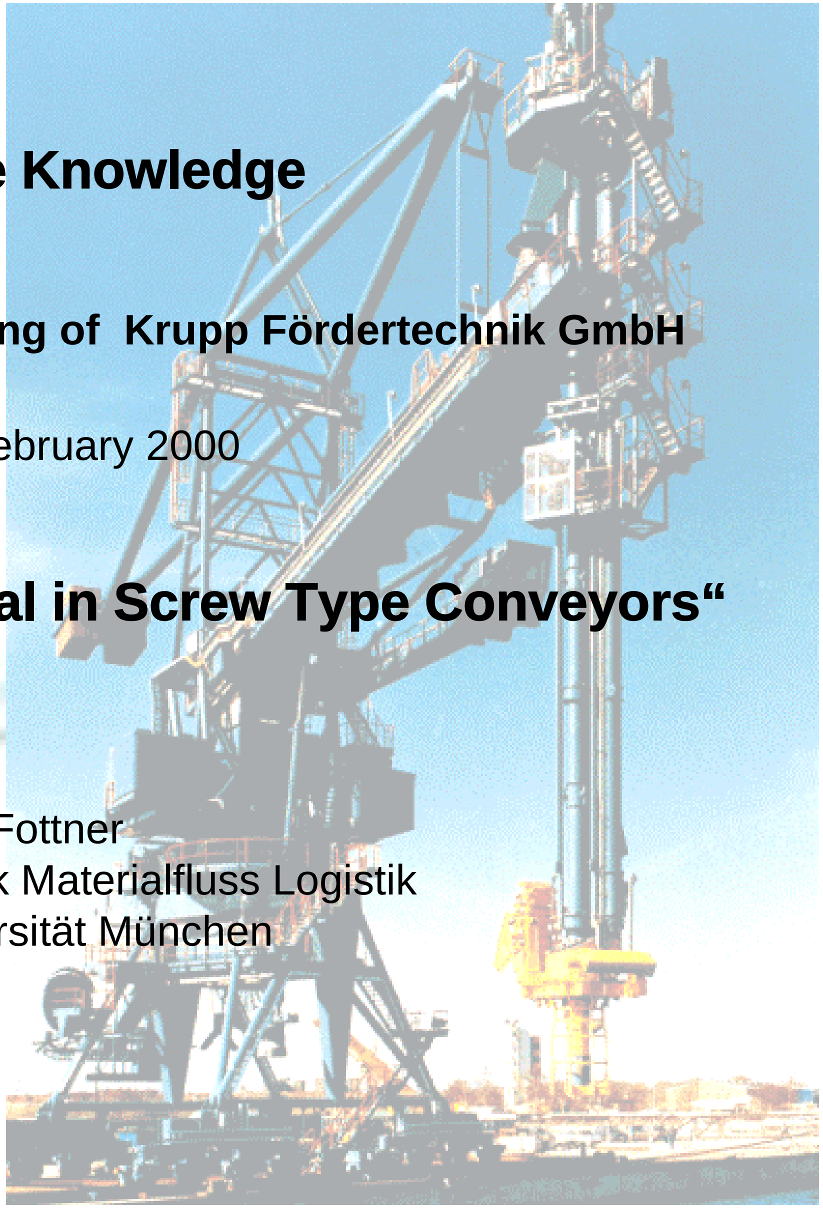
Effects of components inside the conveying stream should be investigated by measurements and be applicated in the dimensioning by characteristic values.

The same procedure will be used for the influences of different constructions of the interfaces between the conveyors, for example the construction of the inlet of the vertical screw as interface between feeder and vertical conveyor.

The influence of changing geometrical data of the conveyors on the power requirement will be obtained by investigating other plants and comparing the results with the results of our tests.

Last we want to quantify the percentual value for destructed material as given above because there are absolutely no investigations on this.

Thank you very much for your attention.



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„Characteristics of Bulk Material in Screw Type Conveyors“

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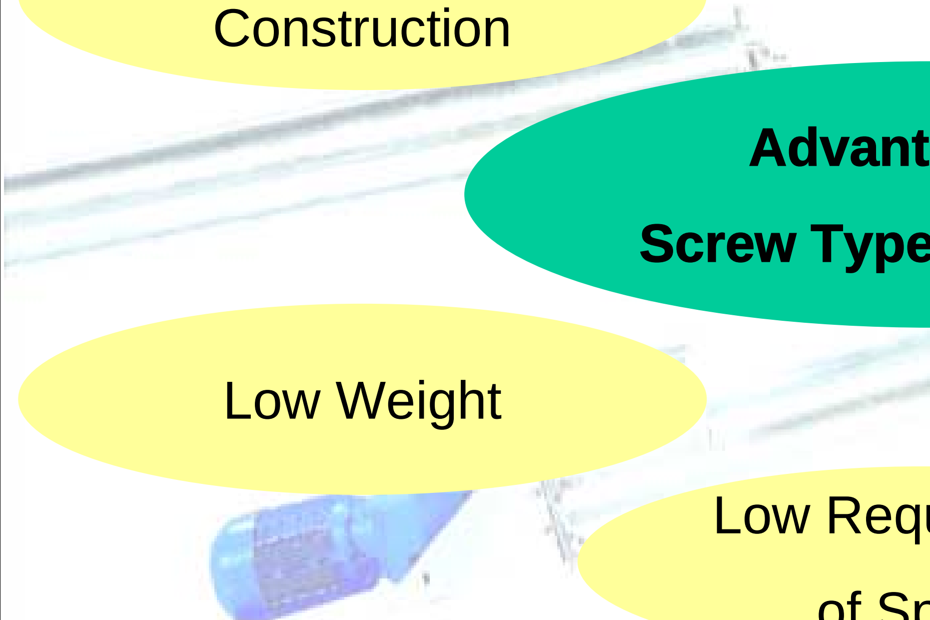
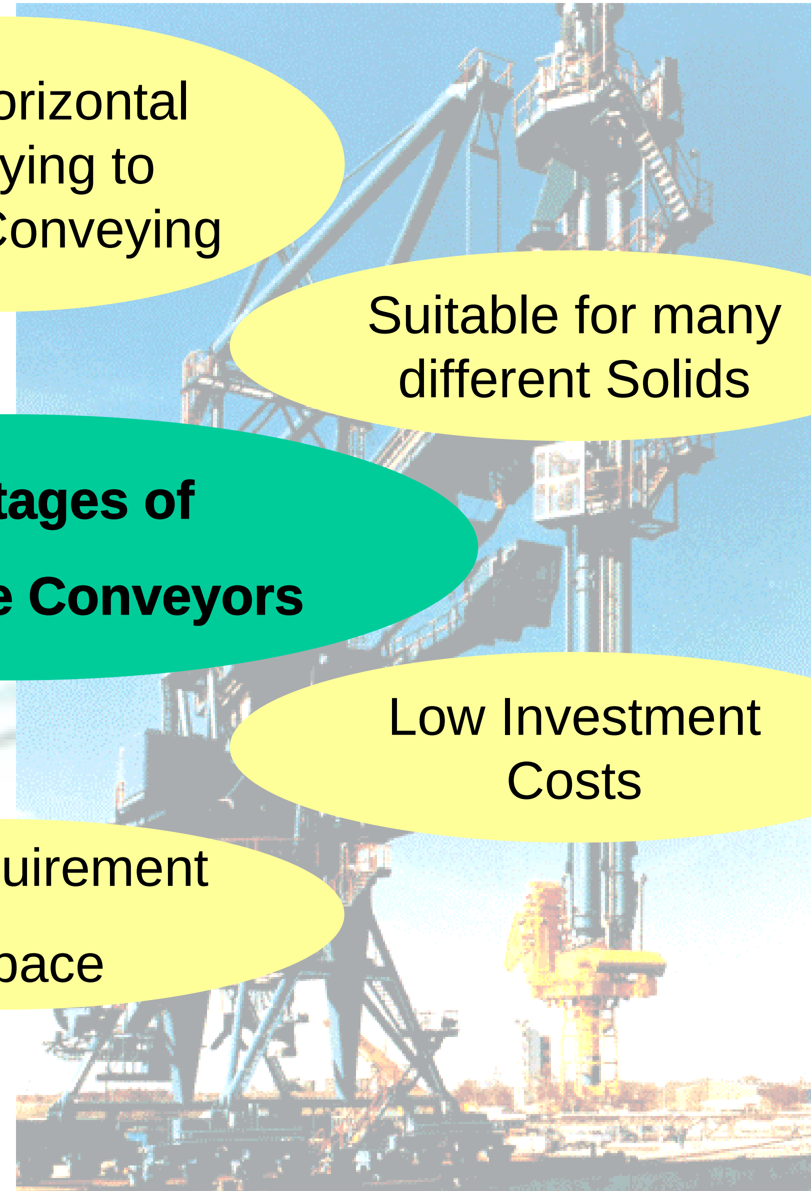




From Horizontal Conveying to Vertical Conveying

Very simple Construction

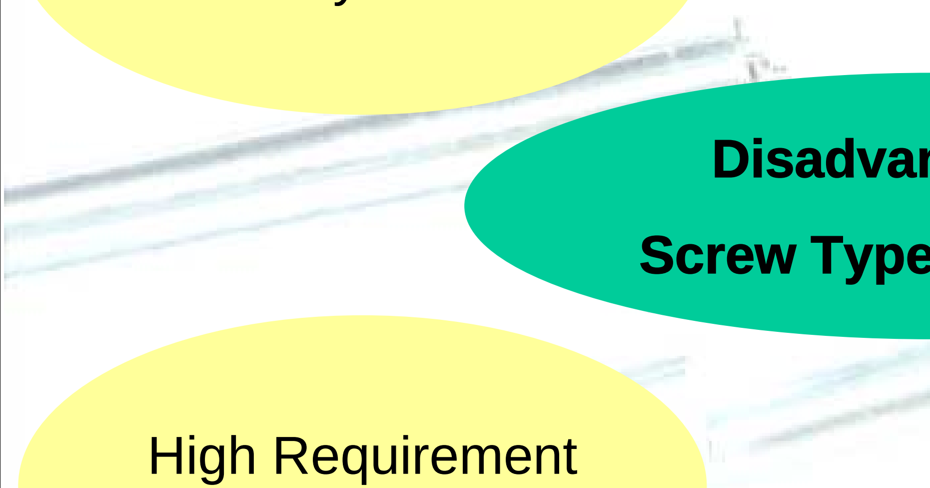
Suitable for many different Solids

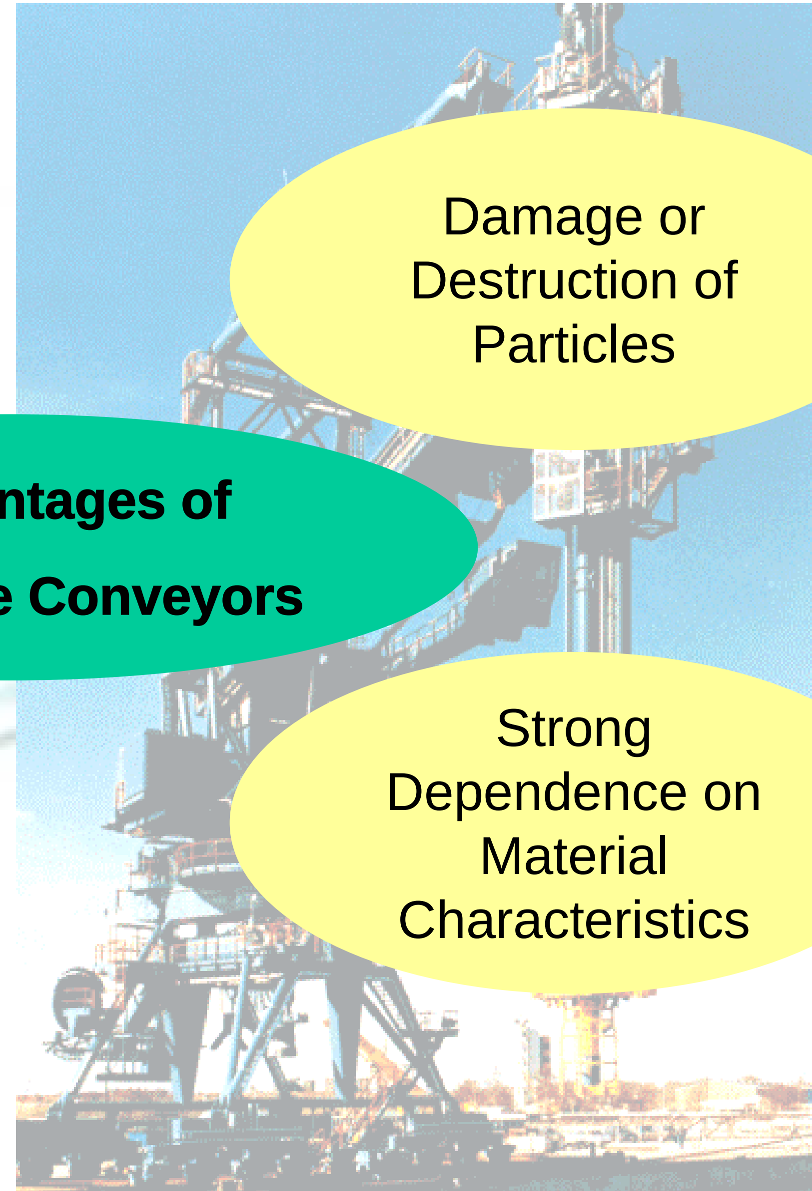
Advantages of Screw Type Conveyors

Low Weight

Low Investment Costs

Low Requirement of Space





Disadvantages of Screw Type Conveyors

- Abrasion of the Conveyor-Tube
- Damage or Destruction of Particles
- High Requirement of Power
- Strong Dependence on Material Characteristics

Research of High-Capacity Screw Conveyors

Krupp Fördertechnik GmbH
Umschlagtechnik

Lehrstuhl für
Fördertechnik Materialfluss Logistik
Technische Universität München

Reliable Prediction of Mass Flow

Reliable Prediction of Power Requirement

Optimization of Operational Parameter

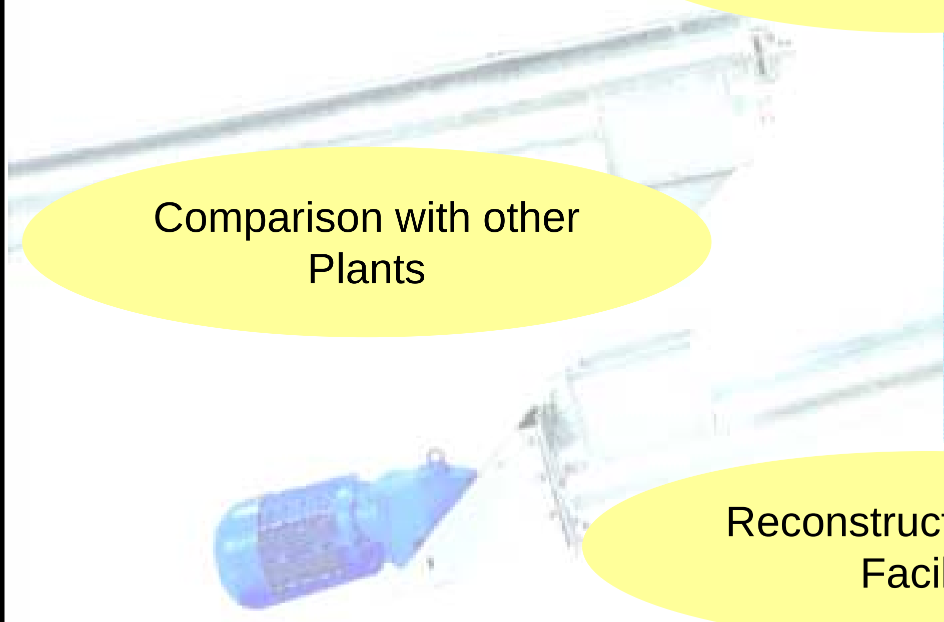
Optimization of Construction and Design

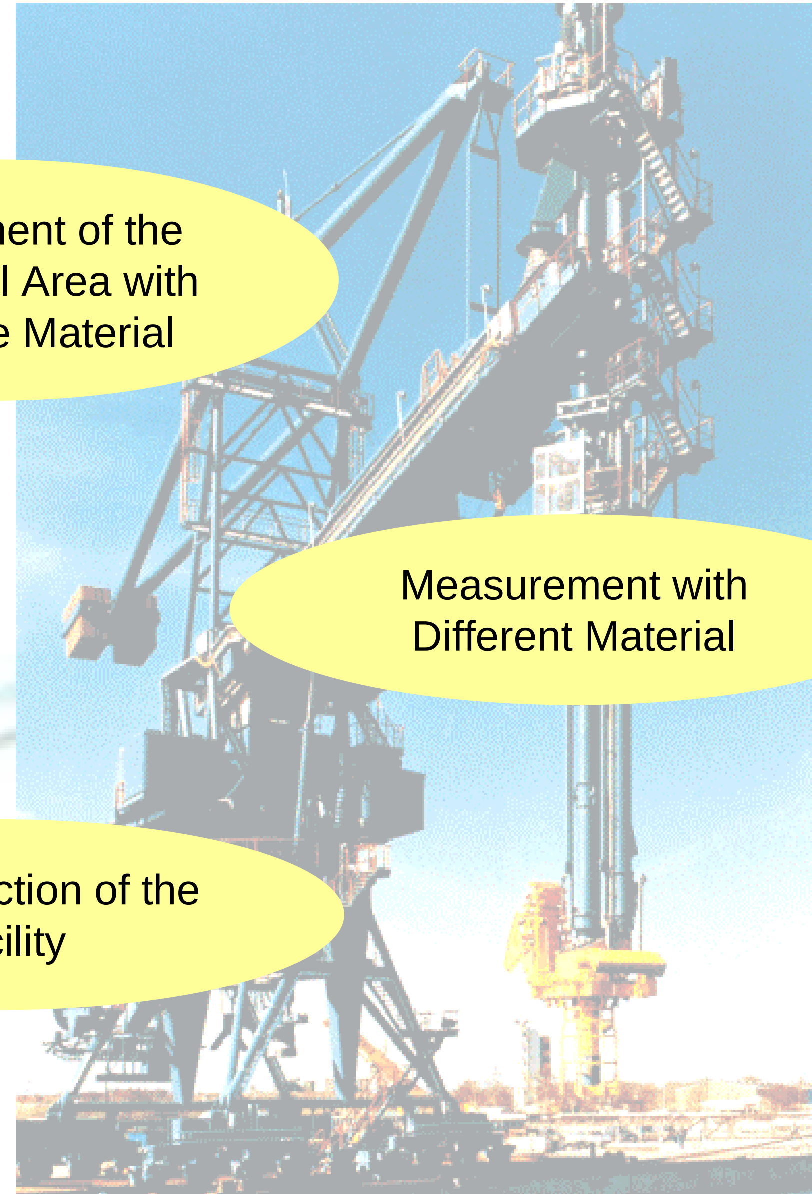
Optimized System of Feeder, Vertical Conveyor and Horizontal Conveyor

Technical Data

Diameter of Vertical Screw:	260 mm
Speed of Vertical Screw:	560 rpm
Length of Vertical Screw:	7m
Diameter of Horizontal Screw:	315 mm
Speed of Horizontal Screw:	400 rpm
Length of Horizontal Screw:	2 x 3 m
Diameter of Feeder Screw:	400 mm
Speed of Feeder Screw:	100 rpm
Length of Feeder Screw:	1.5 m
Calculated Mass Flow:	100 t/h
Max. Velocity of Portal Drive:	20 m/min
Max. Velocity of Feed Drive:	20 m/min

Procedure of the Investigation





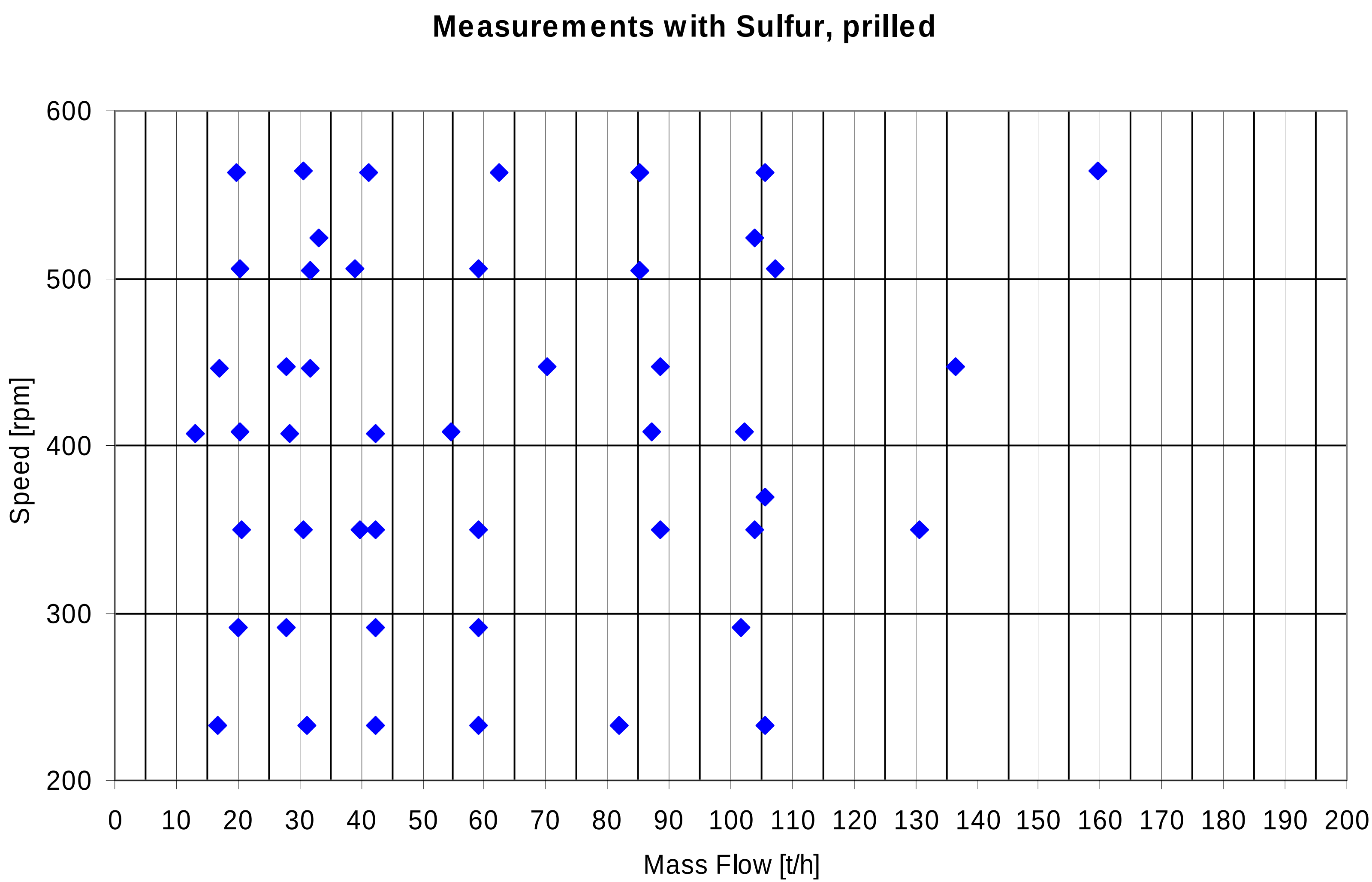
Measurement of the Operational Area with Reference Material

Comparison with other Plants

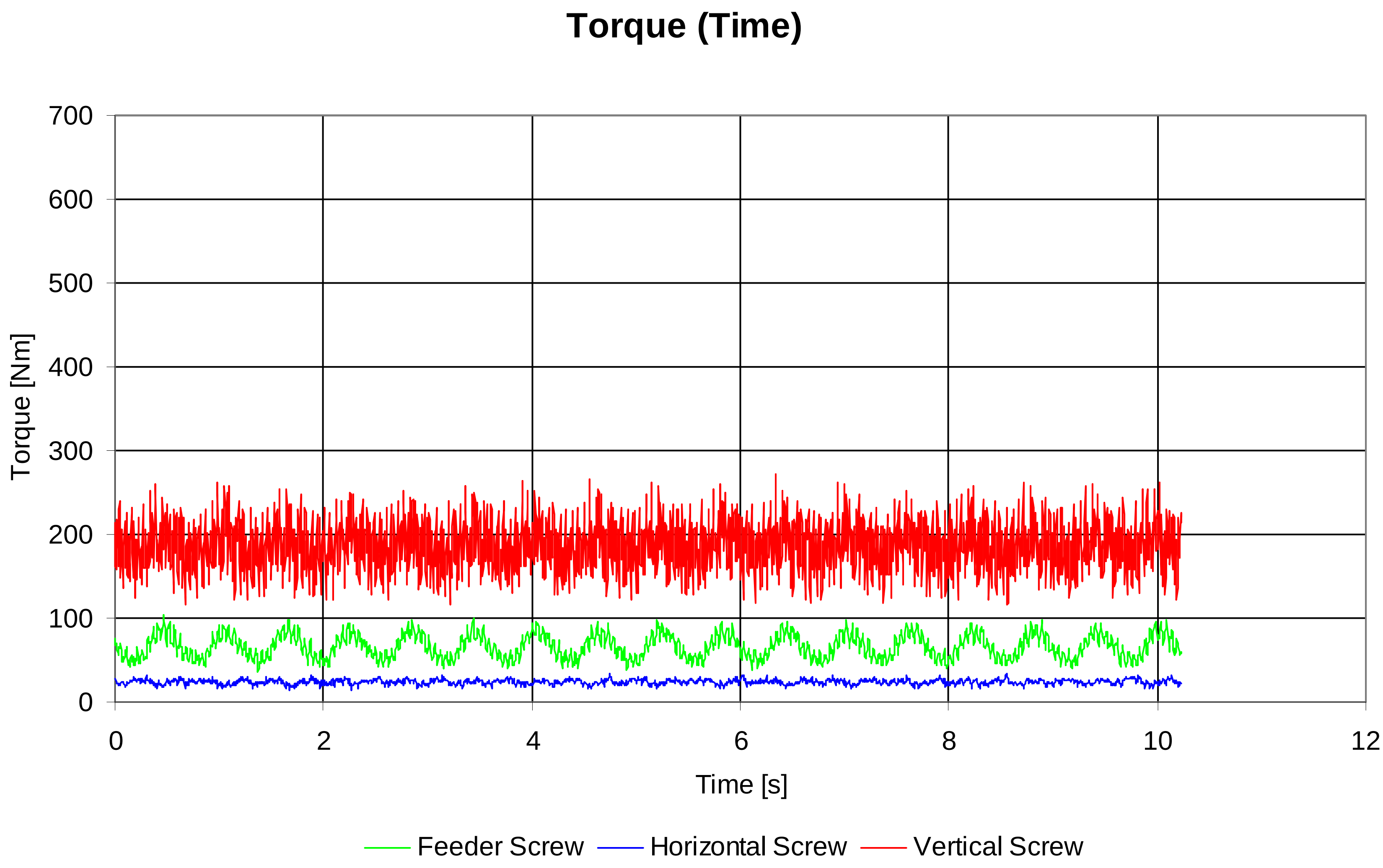
Measurement with Different Material

Reconstruction of the Facility

Results of Research 1: Possible Mass Flow

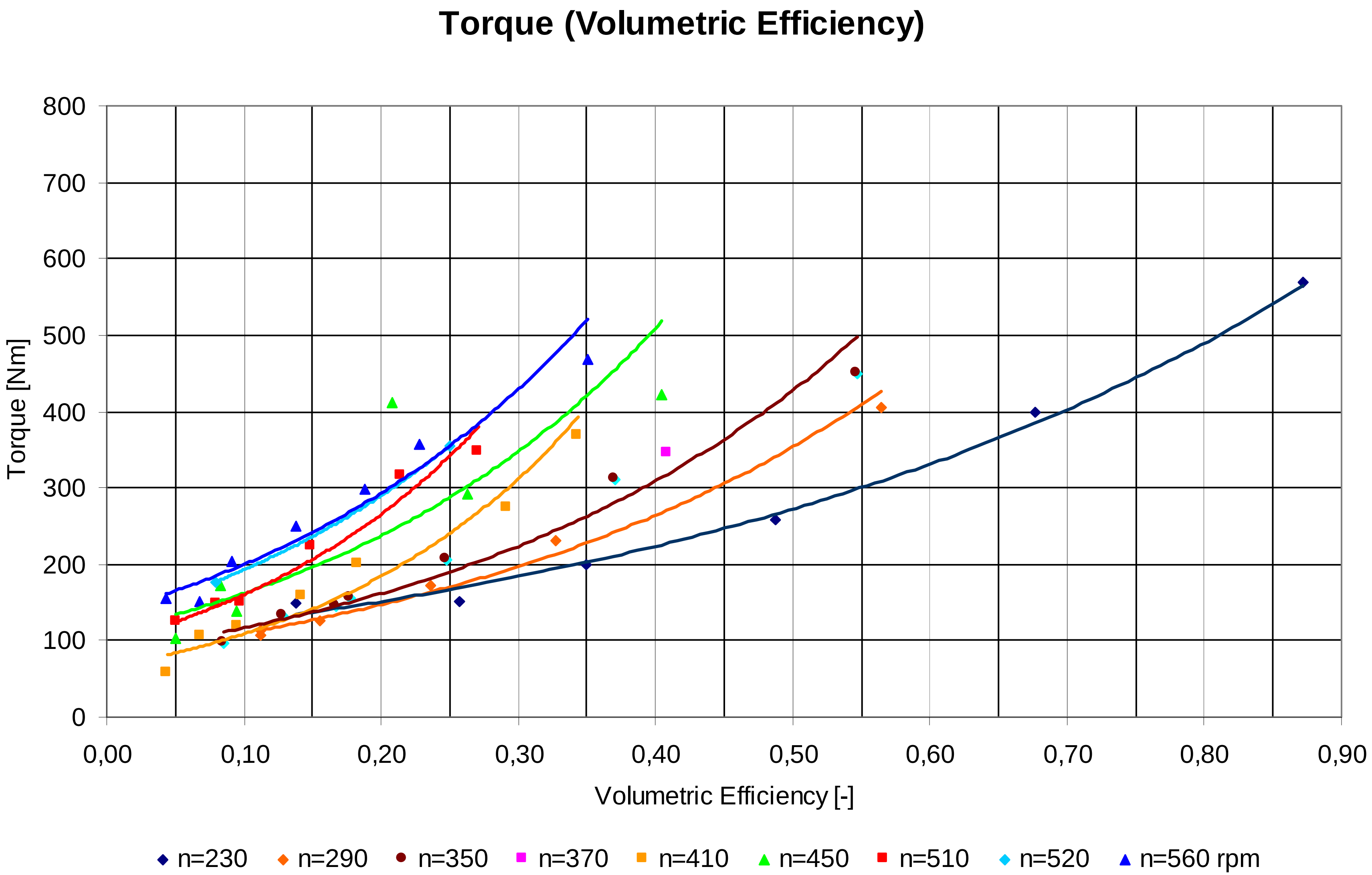


Results of Research 2: Requirement of Torque

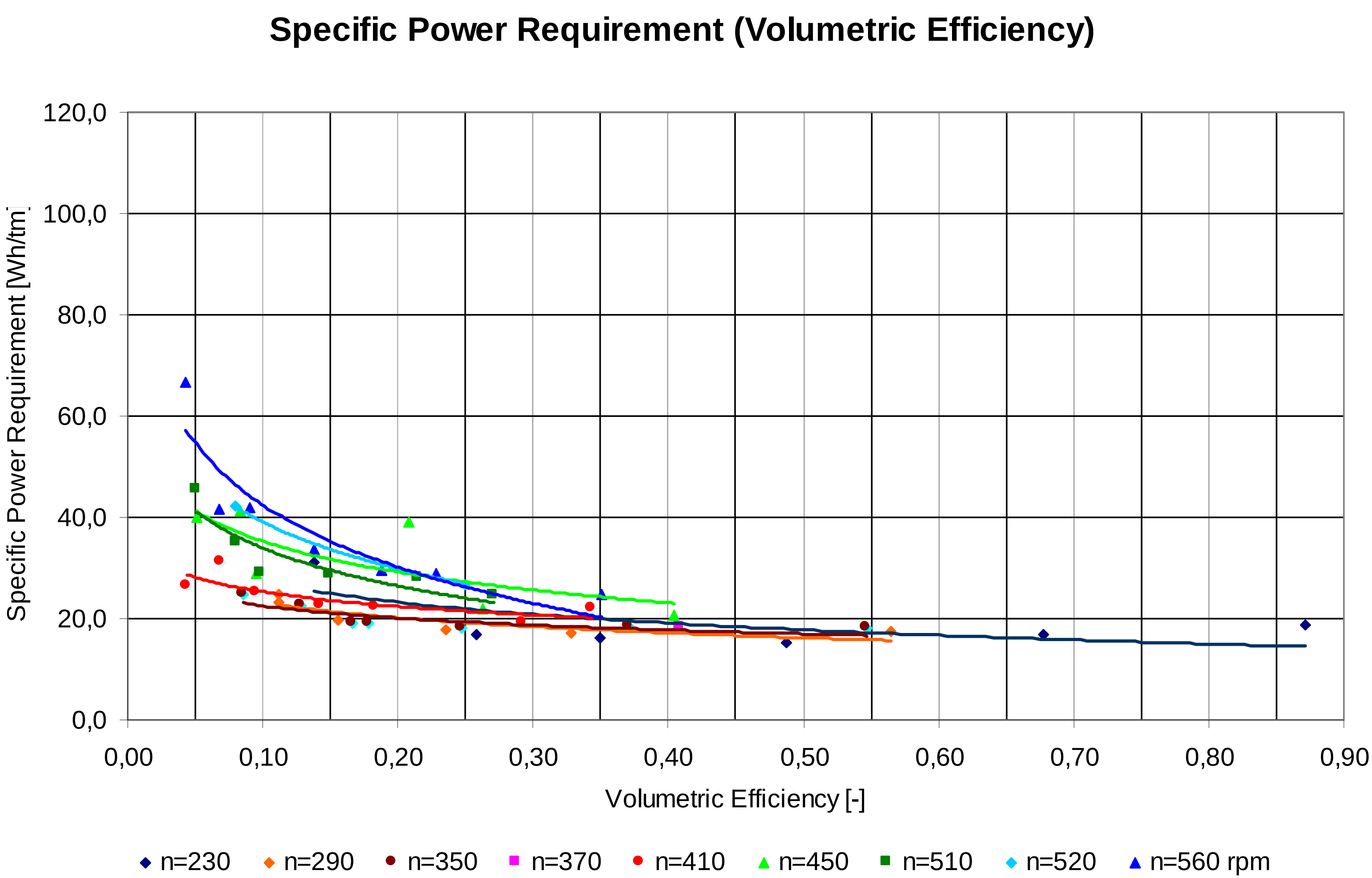


Massflow: 19,09 t/h   n (Vert.) = 505 rpm   n (Horiz.) = 190 rpm   n (Feed.) = 50 rpm

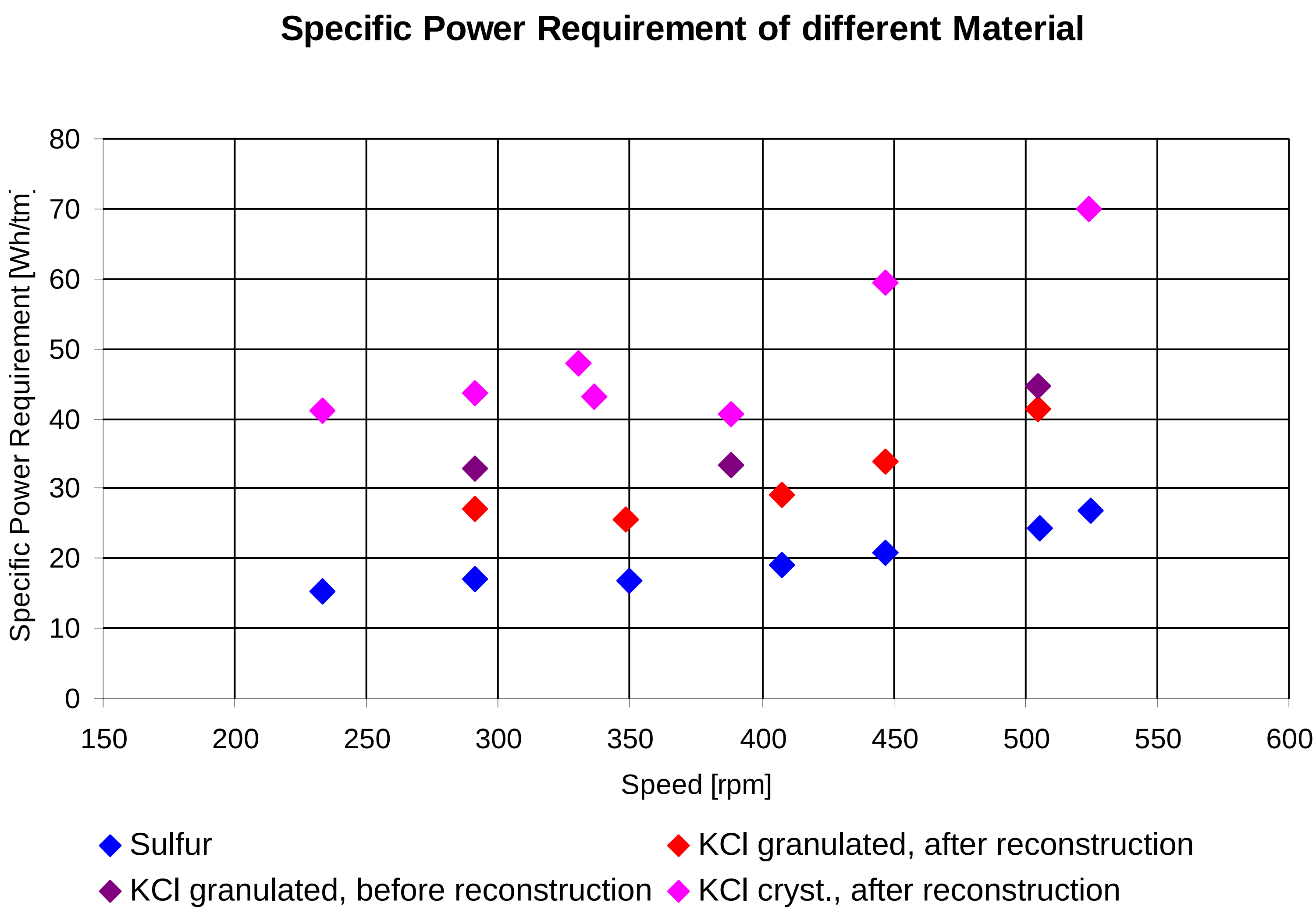
Results of Research 3: Requirement of Torque



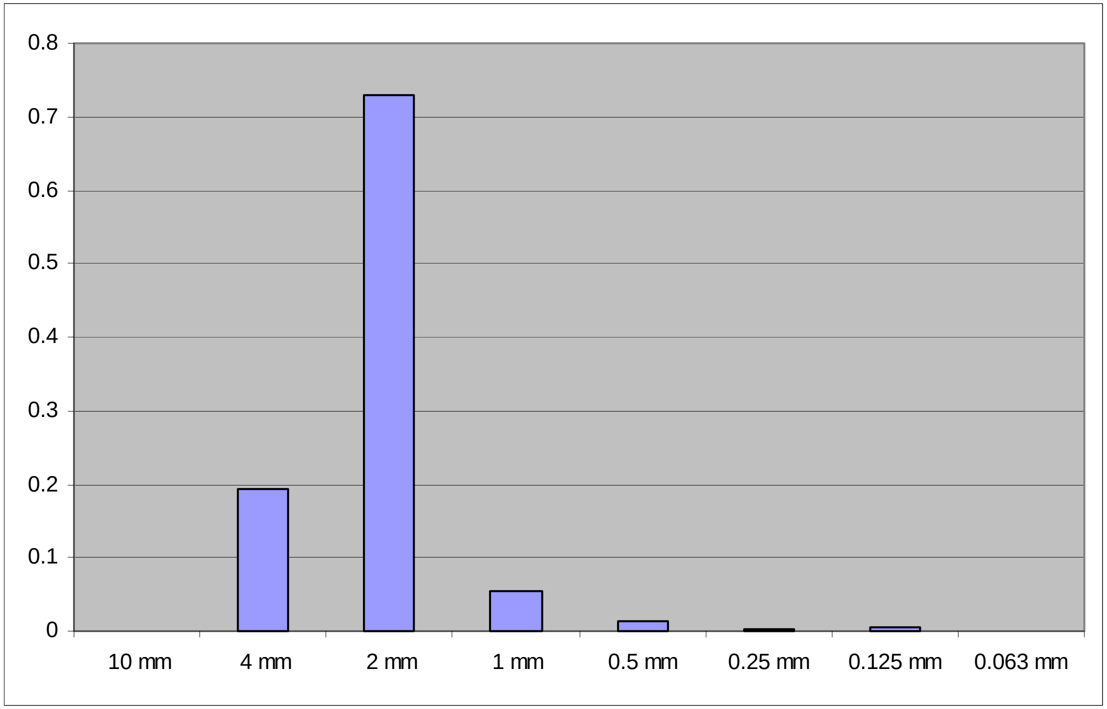
Results of Research 4: Specific Requirement of Power




Specific Power Requirement (Speed)
Specific Power Requirement [Wh/tm]
80
70
60
50
40
30
20
10
0
150
200
250
300
350
400
450
500
550
600
Speed [rpm]

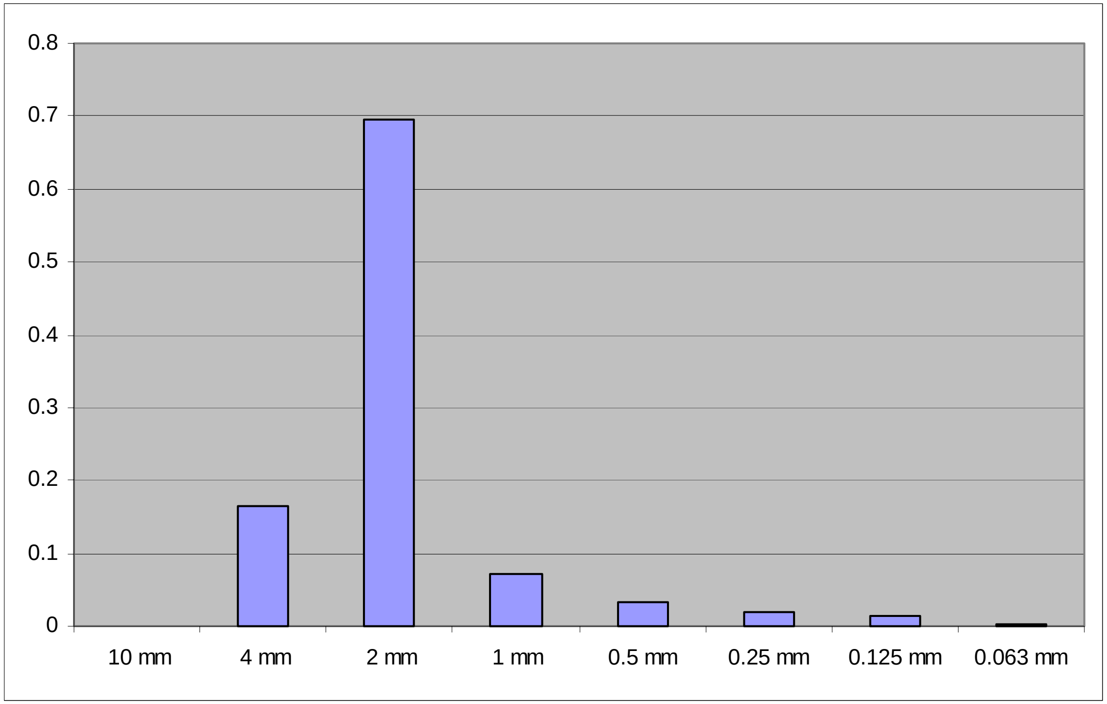

Specific Power Requirement of different Material
Specific Power Requirement [Wh/tm]
0
10
20
30
40
50
60
70
80
150
200
250
300
350
400
450
500
550
600
Speed [rpm]
Sulfur
KCl granulated, after reconstruction
KCl granulated, before reconstruction
KCl cryst., after reconstruction

Prilled Sulfur, Delivery Conditions



Particle sizes

Prilled Sulfur, after one Conveying-Process



Particle sizes

Result: About 6% of the particles were crushed or chipped

Conclusions