High-capacity screw conveyor –

Research Project of Krupp Fördertechnik and TU München

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Introduction

The work conducted by the Institute for Material Handling, Material Flow, Logistics (**fml**) includes the study of numerous processes which have a bearing on the industrial handling of a diverse range of goods.

The institute's research activities divide into:

- Crane construction
- Materials flow and logistics
- Movement of bulk materials
- Cable-way technology

The work in these four subject areas is shaped by three overarching fields of activity:

- Research into new design methods
- Development of planning methods and computer-aided planning tools
- Further development of technical systems.

The spectrum of research performed by the institute extends from publicly funded basic research and joint research with industry to contracts placed direct by business enterprises. Industrial funding accounts for well over 50% of the institute's resources, which guarantees that the research results are related to practical applications.

Movement of bulk materials

In its activities connected with the movement of bulk materials the institute has for many years conducted research work into handling processes, the behaviour of bulk materials, and the conveying equipment used.

In these investigations interest has for some time focused on the screw conveyor.

Because of its versatility this type of conveyor is used in all areas of bulk materials handling. Screw conveyors can, for instance, be deployed in horizontal, slightly inclined, steeply inclined and vertical configurations. They can be used to convey minimal volumes and to handle very large mass flows, including up to 2000 t/h in ship unloaders.

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These big differences in operating parameters, however, also result in completely different movement conditions for the material in the screw. It is therefore extremely difficult to find a generally applicable design, both for the handling behaviour of the material and, in particular, the power requirement of the equipment.

In numerous scientific studies carried out by the institute in recent years the movement of materials was researched and ultimately represented in mathematical models. As a result, for numerous applications it is now possible to calculate almost exactly in advance the handling behaviour and therefore the mass flow that can be handled.

This is the case for high-speed, steeply inclined to vertical conveyors and for horizontal or slightly inclined, low-speed units.

In order to increase capacity with the same unit size, efforts are being made to distinctly raise the rotational speed of horizontal screw conveyors too, but so far these efforts have failed to produce an applicable design method for this application - the horizontal high-capacity screw conveyor.

A further problem lies in calculating the power rating for vertical conveyors, as used for example in the continuous unloading of bulk carriers. The institute also conducted studies in this area and developed 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.

The institute has set itself the task of closing these research gaps. Currently, the changes in movement behaviour as a function of the incline of the screw axis are being investigated with the aim of calculating in advance the movement behaviour for any inclined path of the conveyor.

To carry out these investigations the institute has several test stands for bulk materials in its testing station and a complete range of instrumentation.

Another research aim is to investigate the marginal effects described above and their influence on the power requirement as well as to study quite generally the subject of high-capacity screw conveyors, i.e. high-speed screw conveyors for moving large mass flows with a small unit size.

It became evident that quantifying the marginal effects would be possible only to a limited extent on the basis of small screw conveyors as these effects are strongly dependent on the bulk materials being transported and in small screws only certain bulk materials can be studied.

High-capacity screw conveyor joint research project

Since 1996 Krupp Fördertechnik GmbH, St. Ingbert-Rohrbach, and the institute have been cooperating closely in research work on high-capacity screw conveyors. Mid-1997 saw the start of a collaborative research project between Krupp Fördertechnik GmbH and the institute with the aim of distinctly improving the design reliability of large, high-speed screw conveyors as required for the continuous unloading of ocean-going vessels.

Under the project the partners cooperated closely in the design and development of a test facility. In geometry and capacity this unit was to be much bigger than previous test units. Thus in the concept phase the volume flow of material to be conveyed was fixed at 100 m^3/h. The conveyor was designed using computational methods developed in the institute for vertical screw conveyors.

Further requirements to be met by the facility were

- realistic design both in terms of size and construction
- scope for studying a diverse range of bulk materials (mean grain size 0 mm to 20 mm)
- simple to operate for testing purposes
- -investigation of a vertical screw system with
  - feeder organ
  - intermediate bearing units
  - discharge

Test stand for high-capacity screw conveyor

- examination of a high-capacity horizontal screw system
- variable operating parameters for all individual units

This facility was built and commissioned on the institute's research ground at the beginning of 1998. It spans an area of 144 m^2 and has a maximum height of approx. 12 m.

Technical data and operating principle

While still in the commissioning phase the unit reached the projected volume flow, which proved the reliability of the design methods for use in operating practice.

The test unit was built with a rail-mounted moving gantry as load-bearing structure. The trolley supports a hoist frame and an electric wire rope hoist. The vertical conveyor installed in it has a conveying height of 7 m and is a self-supporting structure. It is moved by means of the rope hoist in the hoist frame, and this sets the height coordinates.

The horizontal high-capacity screw conveyor is fixed to the trolley and has a conveying length of twice 3 m. It is connected to the vertical conveyor by a telescopic chute.

A two-section container anchored to the ground serves as material store.

The bulk material in one half of the container is removed layer-wise by a feed unit and supplied to the entry of the vertical screw conveyor. The vertical screw picks up the material and carries it upwards. At the top end the bulk material is discharged into a chute and dropped down a pipe onto an impact plate weigher for measuring the mass flow. From there it drops down the telescopic chute onto the middle of the horizontal screw conveyor. This transports the material into the second half of the container. The trolley produces the main feed movement; the lifting gear controls the depth to which the feed unit penetrates the bulk material. These two movements make it possible to discretely set any desired mass flow.

The facility is designed for a nominal mass flow of 100 t/h when conveying material with a density of $p^{\underline{max}}$ 1000 kg/m^3.

The conveyors were dimensioned as follows:

- diameter of vertical screw: 260 mm
- diameter of horizontal screw: 315 mm

The horizontal screw conveyor can be operated at speeds up to 350 rpm, which is 3.5 times the maximum speed permissible to DIN for this size of unit. The vertical screw can be operated to speeds well in excess of 500 rpm.

All drives are frequency-converter-controlled three-phase a.c. asynchronous motors. The facility is controlled by means of a Siemens Simatic S5-95U programmable controller. This is connected to the frequency converters and the OP-7 operator's panel by a PROFIBUS-DP field bus. The test unit thus features modern control technology which is open to the needs of the future, permitting improvements in ease of operation and automation.

In the initial phase the test facility is being operated manually. The only controls applied automatically are those which are necessary in the interests of safety.

In the subsequent test period it is intended to implement partial to full automation of the test unit.

Research goals

On the test unit research work mainly focuses on the empirical examination of a diverse range of bulk materials as regards their:

- conveyability
- handling behaviour
- power requirement

This knowledge is needed for producing a practical high-capacity design optimised to customer-specific bulk materials, because as a result the very strong influence of the material being conveyed can be best reflected in calculating the equipment's power requirement.

To determine these factors it is necessary above all to achieve good reproducibility of the unit's different operating points as well as to be able to carry out numerous measurements in a short time. The initial experiences from test operation show that these objectives have been fulfilled with the existing plant concept.

Apart from the investigation of conveying behaviour with the aim of achieving a general design method suitable for use in operating practice, the declared aim of the research work includes optimising the conveyor and its individual components as a total system. Among other things, the aim here is to harmonise the interfaces between the components of the plant both design-wise and in terms of their operating parameters.