DESIGN AND SIZING OF SCREW FEEDERS

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Abstract

This paper is concerned with the design criteria of screw feeders: a non proper design and selection of this device, which is present in large part of industrial processes, could mean poor performances, excessive power, severe wear of plant and degradation of the conveyed material.

In the past the performance of screw feeders has been based either on a semi-empirical approach (C.E.M.A.- like procedure) or on experimental studies using dynamic similarity to predict the performance of geometrically similar screws.
Both these procedures are somewhat limiting and are quite unuseful in industrial practice. A general procedure has been developed to predict the performance of screw feeders of any specific geometry: contrary to the approach of all the formulae present in literature which give the power at operating speed, industrial experience however clearly shows that the most important phenomenon as regards sizing the power is that of starting torque.

The operating torque is, in fact, usually 60-65% of the nominal torque, however, it is impossible to decrease the motor size as it will be unable to start.

This is why the sizing done in accordance with the actual standards and literature is quite reliable in screw conveyors; but it is not quite so precise in screw feeders.

Starting torque also has a direct influence on the correct selection of control devices, and the drive item is to be designed taking into consideration some specific features of this application: a proper selection could mean a reduction up to 10% of the total cost.

Screw devices and other systems.

Screw feeders are devices suitable for handling a wide variety of materials that have good flowability characteristics. The screw feeder has a helicoidal surface fitted on a shaft that rotates inside a fixed tube. The material which comes out of the silo is pushed by the helicoid flight along the base of the tube in the direction of transport. The advantages of the screw feeder include the possibility of having different openings, each with its own shut-off organ for unloading the material.

A number of years ago Rexnord proposed a set of selection guidelines, one for conveyors and the other for elevators that are useful for an indicative choice of conveyors on the basis of loading and unloading methods, the course of transport and the features of the material (flowability, composition granulometry, temperature, friability, abrasiveness and corrosivity).

In fact, the features of the material are a decisive factor in the selection of the conveyor/feeder device as regards both aspects: how the material affects the conveyor and,at the same time, how the conveyor affects the material.

That is why, in a correct application, experience plays a fundamental role [5].

There are, in fact, a number of devices that help and/or actually extract material in powder form from silos or hoppers: an initial classification is based on the fact that some of these merely aid the flow.

Fluidification devices or mechanical vibrators are typical examples.

These devices do not actually bring about extraction and can therefore be considered as accessories for correct functioning of the silo [1].

As a rule, these devices are associated with batching systems having the function of controlling the gravity flow (screw feeder, rotary cell or drag chain) which alone cannot bring about complete emptying of the silo.

Then there are specific devices, which are capable of ensuring complete emptying even in capacity batching conditions.

These are usually found to be more expensive than a system comprising a flow aid device (vibrator) and a batching device (screw feeder); however, these are generally much more effective and for this reason are indispensable in all applications involving products that do not flow easily.

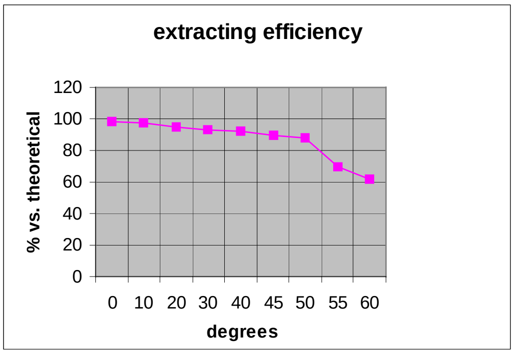
In brief, the strong points of the screw devices are:
Reduced risk of environmental pollution;
Flexibility of use;
Functional reliability;
Low investment costs;
Easy to install.

Flow, speed and dimensions

Calculation of the nominal flow can be done once the screw geometry, its rotation speed and the filling coefficient are known.

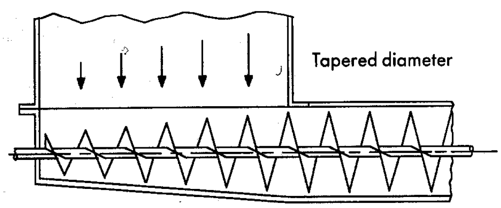
The flow rate of a screw conveyor or feeder depends on a number of interlinked factors:
- geometry of the screw
- rotation speed
- inclination
- geometry of the feed hopper and tube
- flowability of the material.

The risk of backflow increases with the inclination and with an inclination of 15°, there is already a reduction in conveying efficiency



There are several methods to increase screw capacity with length and to reduce the necessary starting torque.

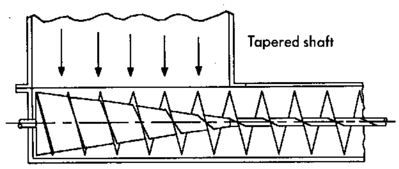
Tapered diameter screw



It is not recommended for most materials because the narrow back end is prone to having arches over it, besides it is difficult to properly fabricate the screw.

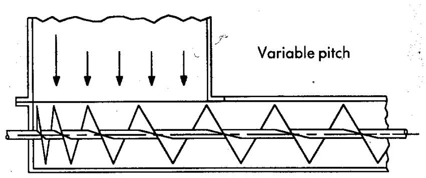
Tapered shaft and variable pitch

Poor fabrication tolerances are a frequent



problem the consequence is high power consumption and poor flow. Also, it is a quite expensive configuration.

Variable pitch



The minimum pitch must be no less than one-half the screw diameter (logging) , the maximum pitch approx. one screw diameter.

Constant pitch

A constant pitch in the feed section different from the constant one in the conveying section is a very cheap and common solution.
Typically: P= 2/3* D in the feed section , P=D in the conveying section.

Combination of b) – c) –d)

Motive power and starting torque

The formulae which express the power necessary for both the screw conveyors and feeders can be classified into two categories.

Analytical formulae

The first category includes formulae which express the power, for example, the single grain theory [3], the calculation procedure proposed by F.J.C. Rademacher [6], and Roberts [3] [8].

These start from a physical schematization of the phenomenon; actually none of these has actually found application in industry or design.

Semi-Empirical
The most known semi-empirical formulae for calculating the power of a screw are the C.E.M.A. formulae [12] which also constitute the basis of calculation of most European national standards [7].

These are semi-empirical formulae as they do not descend from a physical model of the phenomenon and use empirical coefficients which differ from product to product (fm) provided by industrial experience.

As against this simplicity of use, there exist a number of limitations:

The formulae for screw feeders are not very reliable, with differences as high as 30-40 % obtained from experimental tests.

All the formulae do not indicate the starting torque - a determining fact for correct sizing of the motor and drive organ.

It is also worthwhile nothing that laboratory tests clearly shows a reduction in the torque with increase in number of revolutions until a optimum speed is reached.

Investigations about the power requirement

The knowledge about the process in a screw conveyor is very good. It is possible to predict almost every geometrically or operational conditions with very good results. Another problem is the feeding part of the screw, where the volumetric efficiency or the filling degree is very high. Material pours out of a silo or is taken out by the screw itself of a bunker. Both situations mean a volumetric efficiency near 100 %. None of the existing calculating models allows to predict those conditions.

The same problem comes up with higher speed of the screw.
New investigations and research with a modern kind of experimental plant with high-capacity screw-conveyors are giving the opportunity to evaluate the results of new prediction-methods for different kinds of bulk material with data made in very realistic empiric way. So one result is, that there exists an optimum speed and an optimum volumetric value or filling degree where the requirement of power reaches a minimum. With higher speed or a higher value of filling degree the power that is required raises. The optimum point for operating depends strongly on the conveyed material, the operational parameter as speed, etc. and the filling degree of the system. But there are of course also influences by the designing parameters and the geometrical data of the conveying system. Very important especially for the prediction of the power requirement of feeder screws is the influence of very high filling degrees. This means a dramatically higher power requirement, depending also on the construction of the inlet part, the diameter of the shaft, etc. as given above.
(Annex #1 to #6).

The starting torque

Contrary to the approach of all the formulae present in literature which give the power at operating speed, industrial experience however clearly shows that the most important phenomenon as regards sizing the power is that of starting torque.

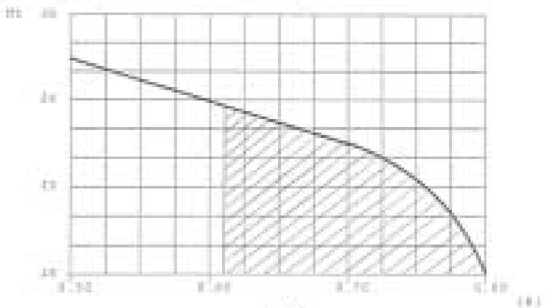
In fact, the operating torque is usually 60-65% of the nominal torque of the motor in screw conveyors, and even lower in screw feeders.

However, it is impossible to decrease the motor size as it will be unable to start.

This is why the sizing done in accordance with the C.E.M.A. standards is quite reliable in screw conveyors; however, it is not quite so precise in screw feeders; so it is always advisable to trust direct experience.

Starting torque also has a direct influence on the correct selection of control devices [9]

From this, it can be seen that, with the life being equal, the typical extracting screw-cycle allows an increase in load as compared to that of a general application (according to ISO standards) , which oscillates between 15 and 25%, taking account of the presumable values of R (dashed area).



R=ratio between the torque moment in the 2nd step (steady state) and in the 1st (starting) (Mty/Mtx)

A General Flow-chart for a Screw feeder design

(Annex #7)

Conclusions

Contrary to the common practice the design and sizing of a screw feeder is a highly complex procedure: for a correct and successful installation it's essential to have a proper understanding of the influence of all the system parameters.

Because the relative phenomena cannot be described in a deterministic way, the standards procedures must be integrated with suitable lab. Tests which are the only way to predict and optimize the system behaviour.

A general flow chart which is useful for designers and has been presented.

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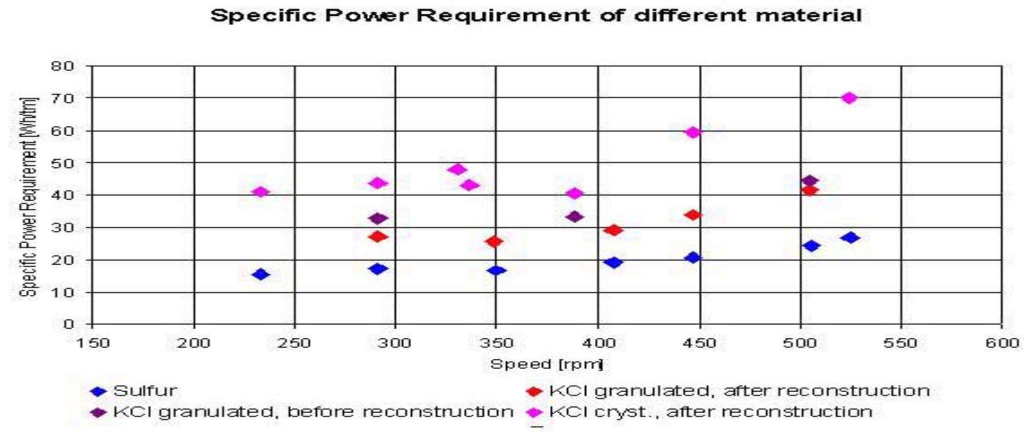

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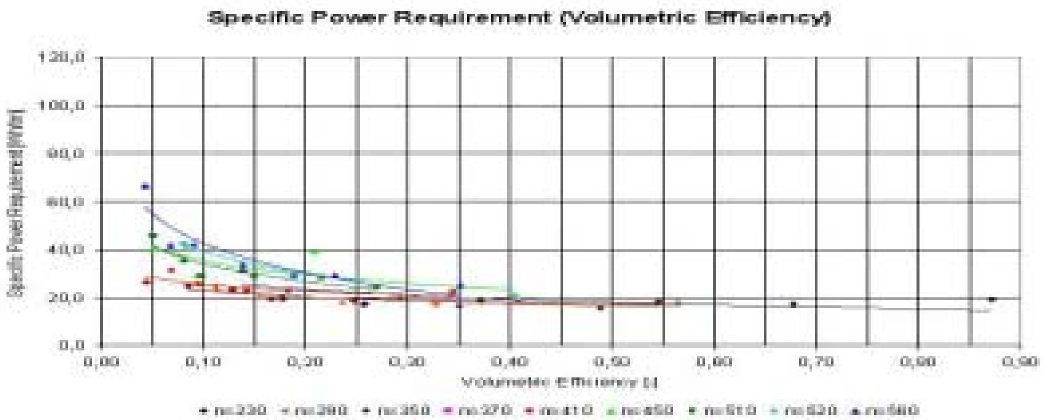

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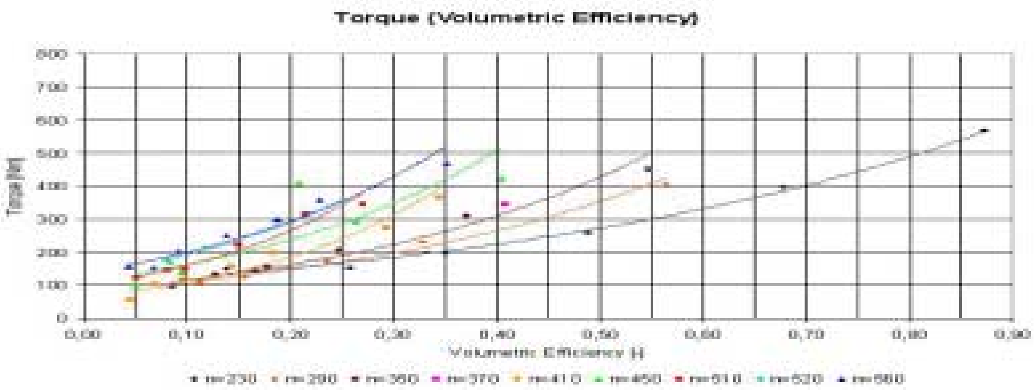

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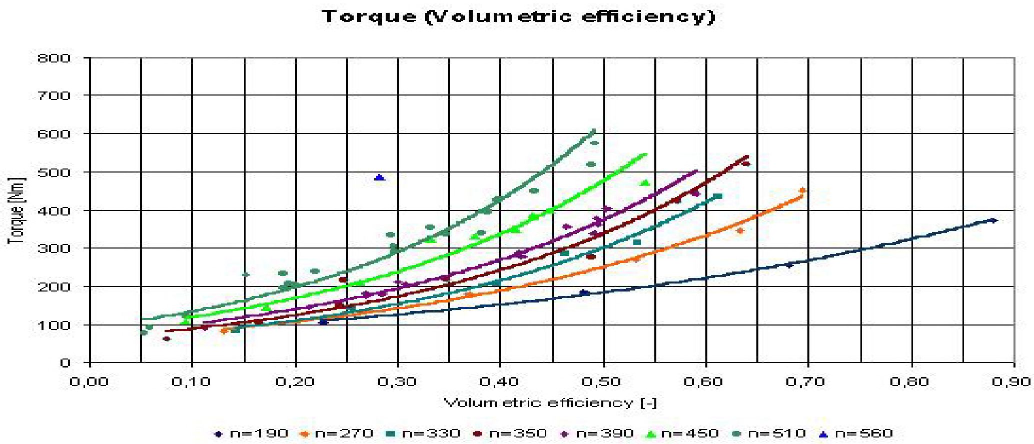

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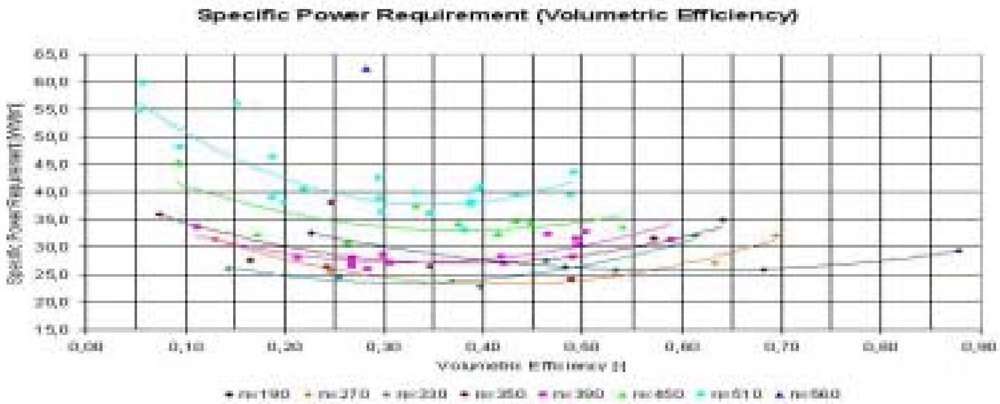

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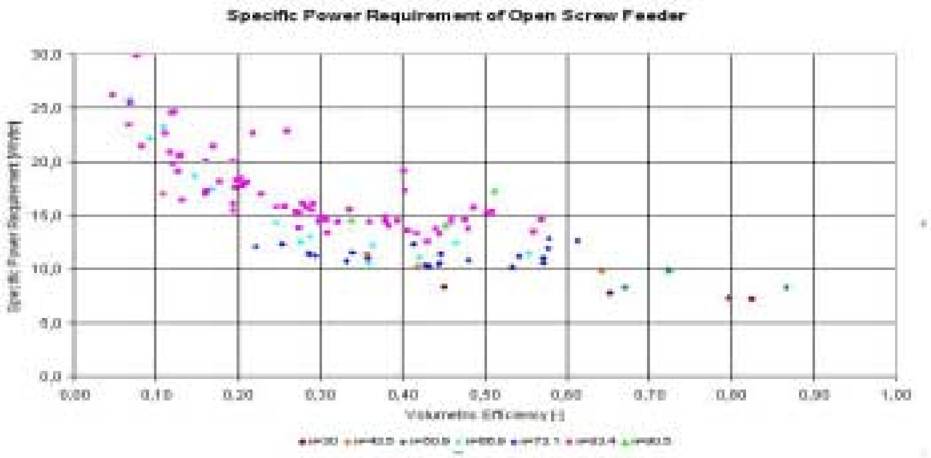

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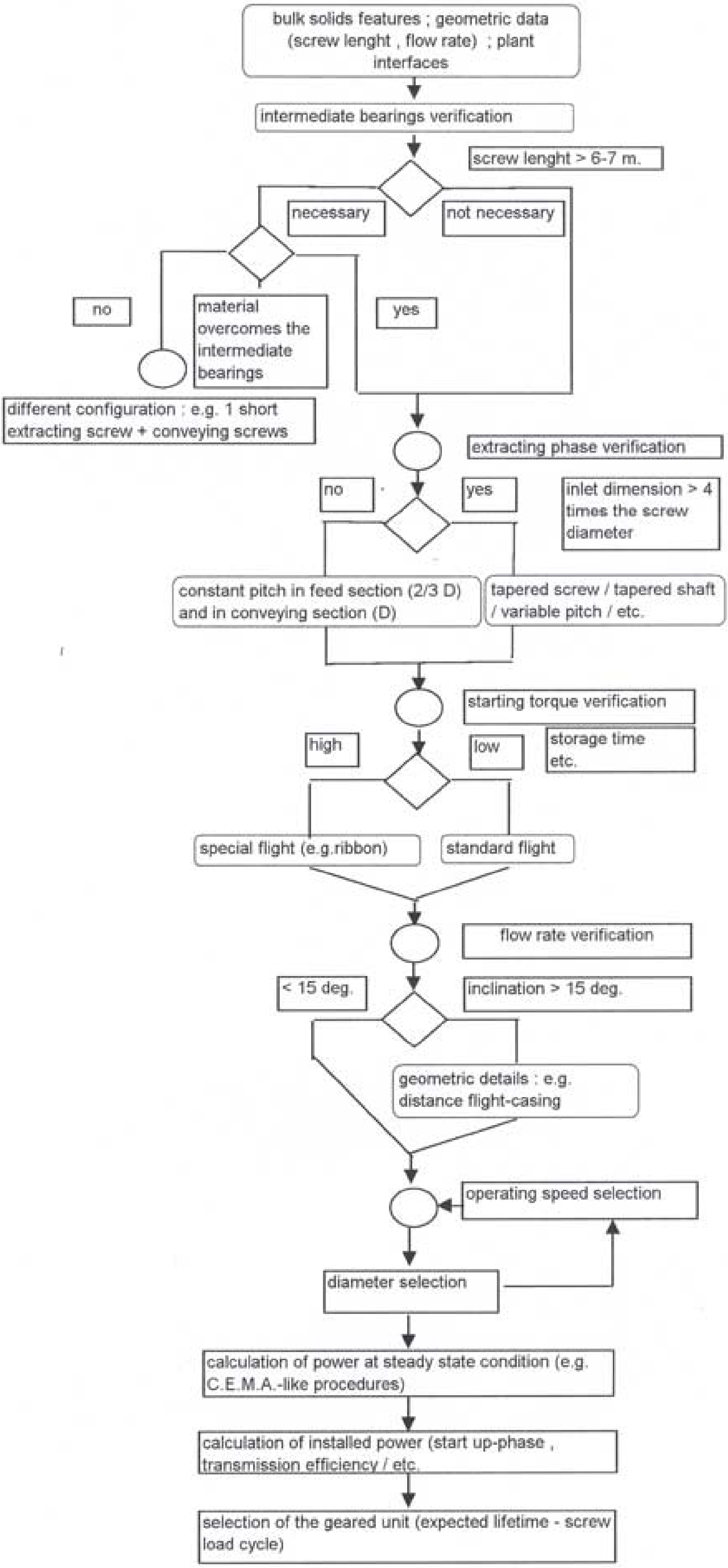
bulk solids features ; geometric data (screw lenght , flow rate) ; plant interfaces
intermediate bearings verification
screw lenght > 6-7 m.
necessary
not necessary
no
material overcomes the intermediate bearings
yes
different configuration ; e.g. 1 short extracting screw + conveying screws
extracting phase verification
no
yes
inlet dimension > 4 times the screw diameter
constant pitch in feed section (2/3 D) and in conveying section (D)
tapered screw / tapered shaft / variable pitch / etc.
starting torque verification
high
low
storage time etc.
special flight (e.g.ribbon)
standard flight
flow rate verification
< 15 deg.
inclination > 15 deg.
geometric details : e.g. distance flight-casing
operating speed selection
diameter selection
calculation of power at steady state condition (e.g. C.E.M.A.-like procedures)
calculation of installed power (start up-phase , transmission efficiency / etc.
selection of the geared unit (expected lifetime - screw load cycle)

annex#7

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