Hydrodynamic Couplings for Conveyor Drives

Klaus Maier

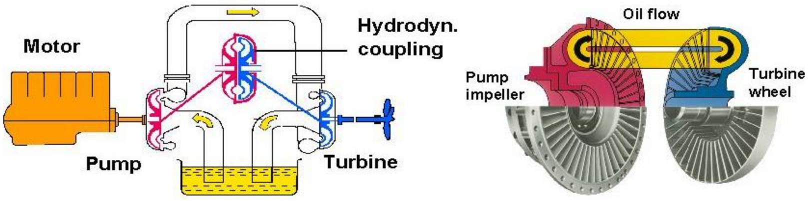
(1) <u>Information:</u>

This presentation is intended to discuss the issue how the requirements of a conveyor drive can be implemented and supported by the hydrodynamic coupling.

Below please find an example of a specific application of research, computation, test and field measurements. This paper is also intended to remove, to a great extent, any misunderstandings as to the functions of hydrodynamic coupling.

Increasing conveying capacities, longer distances / haulage tracks and increasing demands with regard to the reliability are resulting in varying requirements to be met by the drives of modern belt conveyors. To be able to use efficient and longer belt conveyors, modern drives are provided with high driving powers. At the same time, drive units need to support the units/machine components effectively and should be economical at low costs.

Main Features



- Wearfree
- Vibration damping/separation
- Rated operating slip 2...4%
- Compact design
- Good heat absorption capacity
- Excellent availability and reliability

- Power transmission depends on
- Working diameter ~D^5
- Motor speed ~n^3
- Density of Operating Fluid ~ρ
- Filling degree [%]

(2) <u>Basics:</u>

Today's requirements to be met by a conveyor drive are generally:

- load free motor start
- use of economically priced low-maintenance squirrel-cage motors
- smooth ramp torque
- start-up torque limitation
- Adaptation of start-up torque to the prevailing load condition
- Reduction / avoiding of longitudinal belt oscillations
- Load sharing with multi-motor drives

- staggered activation o motors with multi-motor drives in order to limit inrush loads on the mains

- Easy handling and compact design

- Low wear, low maintenance, long life

- Choice of using different operating fluids for individual applications.

These requirements as well as the technical and physical conditions of a hydrodynamic coupling, e.g. power transmission as a function of the

- diameter ~ D5
- motor speed ~ n^3
- density of operating fluid

  and fill level of coupling are basic conditions for considering the hydrodynamic solution in the drive train of a conveyor drive.

(3) <u>Research and Development</u>

A condition for the over the years increasing requirements to be met by a conveyor is also a further development of hydrodynamic coupling.

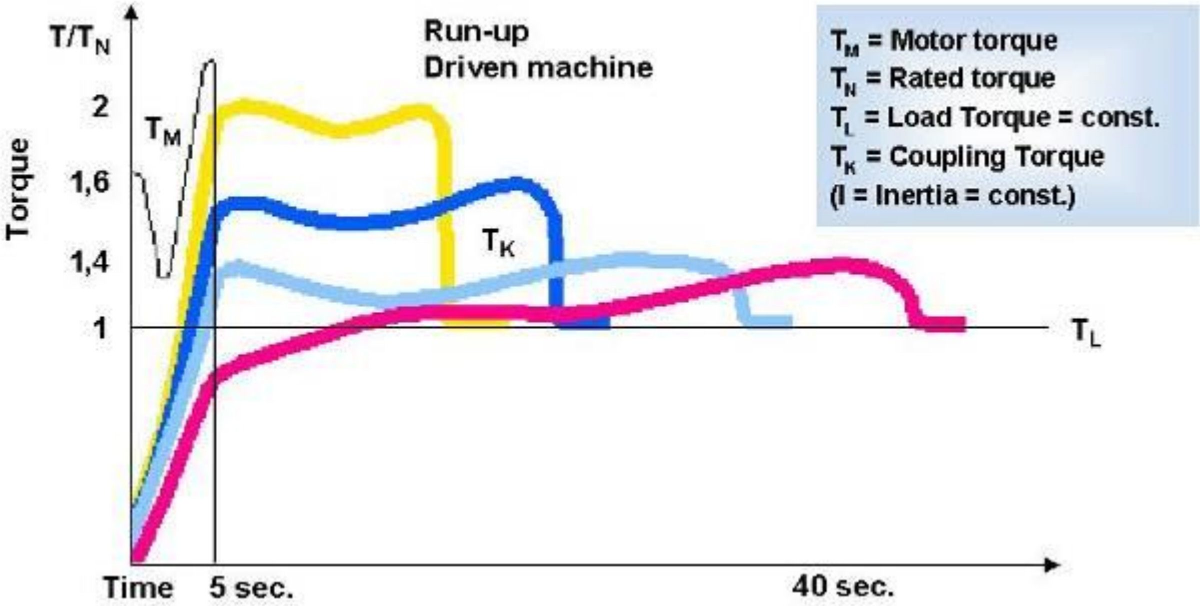
Based on the previously mentioned conditions or requirements the influential reach of power transmission is mainly limited to three (influential) parameters,

which is the diameter of coupling working circuit, the speed an the operating fluid.

Further development of wheel profiles had a significant influence on the coupling starting characteristics.

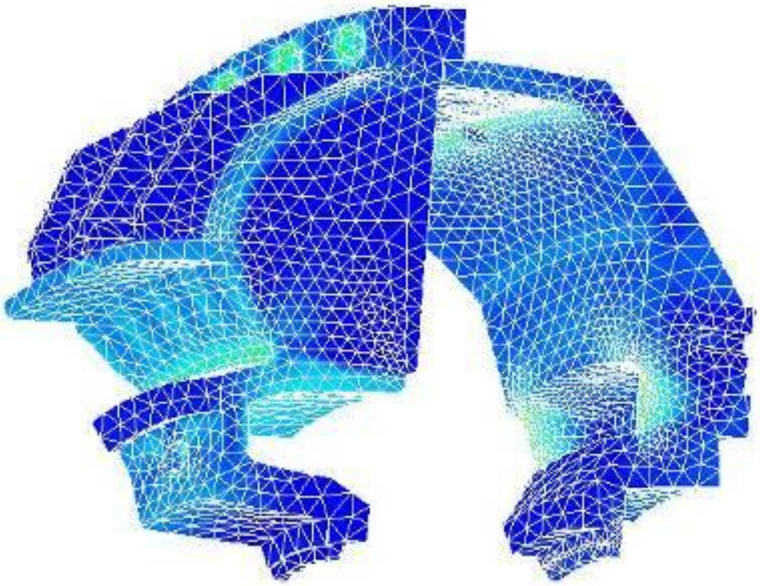
This means the starting torque was reduced from approx. 2 x N_M to 1.4 x N_M

Characteristic Curves

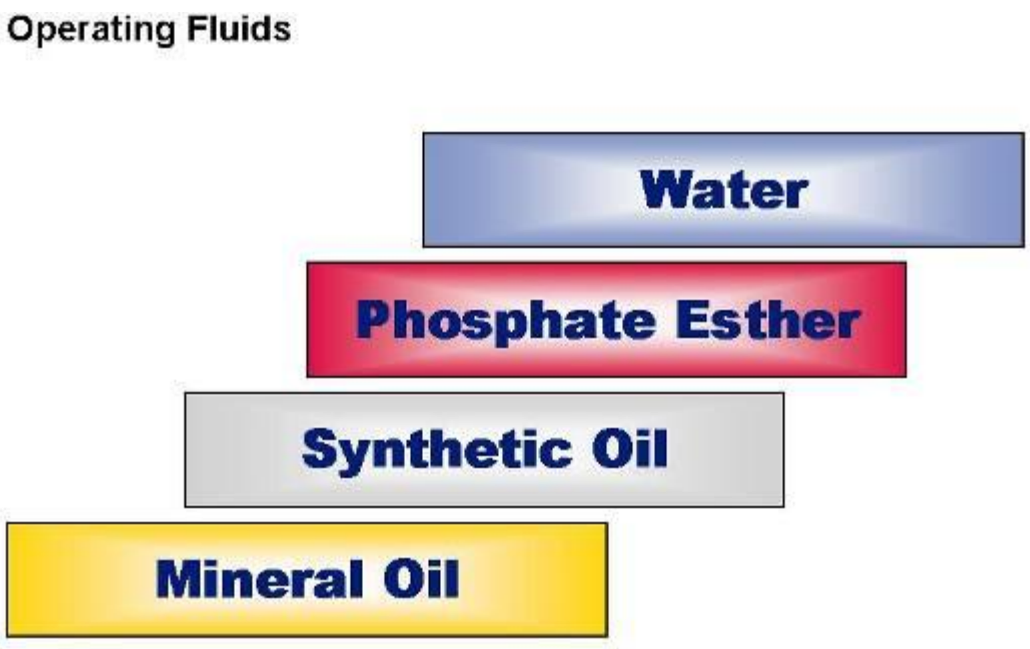


and with special designs of fill-controlled couplings to 1.1 x N_M. The finite element calculation used in this case is giving us an even greater safety concerning the stability of structure.

FEM design



As the operating fluid not only has a technical aspect, but also has a safety aspect, above all, in underground mining, it is today possible to use all kinds of operating fluids, from mineral oil over synthetic oils, phosphate ester to water.

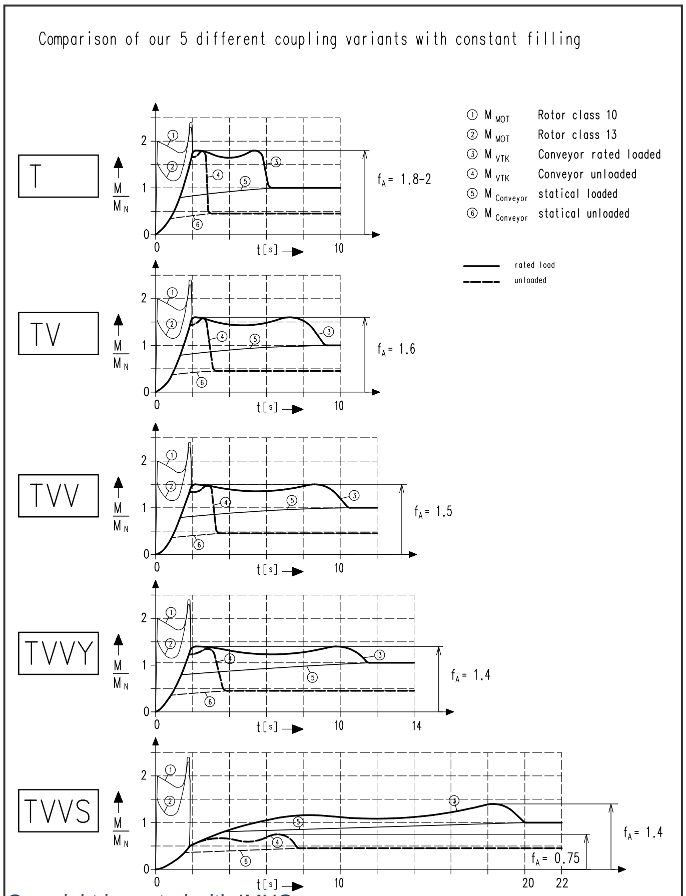


These operating fluids are hardly changing the starting characteristic, however, provide a large flexible field of applications for the hydrodynamic coupling.

(4) Constant Fill Couplings

At first there was the simple hydrodynamic coupling, called T-coupling, used as conveyor drive.

With increasing requirements these developed into hydrodynamic couplings with delay chamber and additional annular chamber.



The figure on the left shows the conditions for a conveyor drive when using different designs.

In case of changed operating conditions it is possible to adapt the turbo coupling, within its application limits, to the changed operating conditions by changing the fill level and the nozzle cross sections.

If the requirements are not covered by the above standard couplings, the use of special designs will be reviewed, as, for example, machining, installations or attachments. Special profiles are developed for special applications.

Designation:

T = constant fill coupling

TV = constant fill coupling with delay chamber

TVV = constant fill coupling with larger delay chamber

TVVY = constant fill coupling with larger delay chamber and refill hole

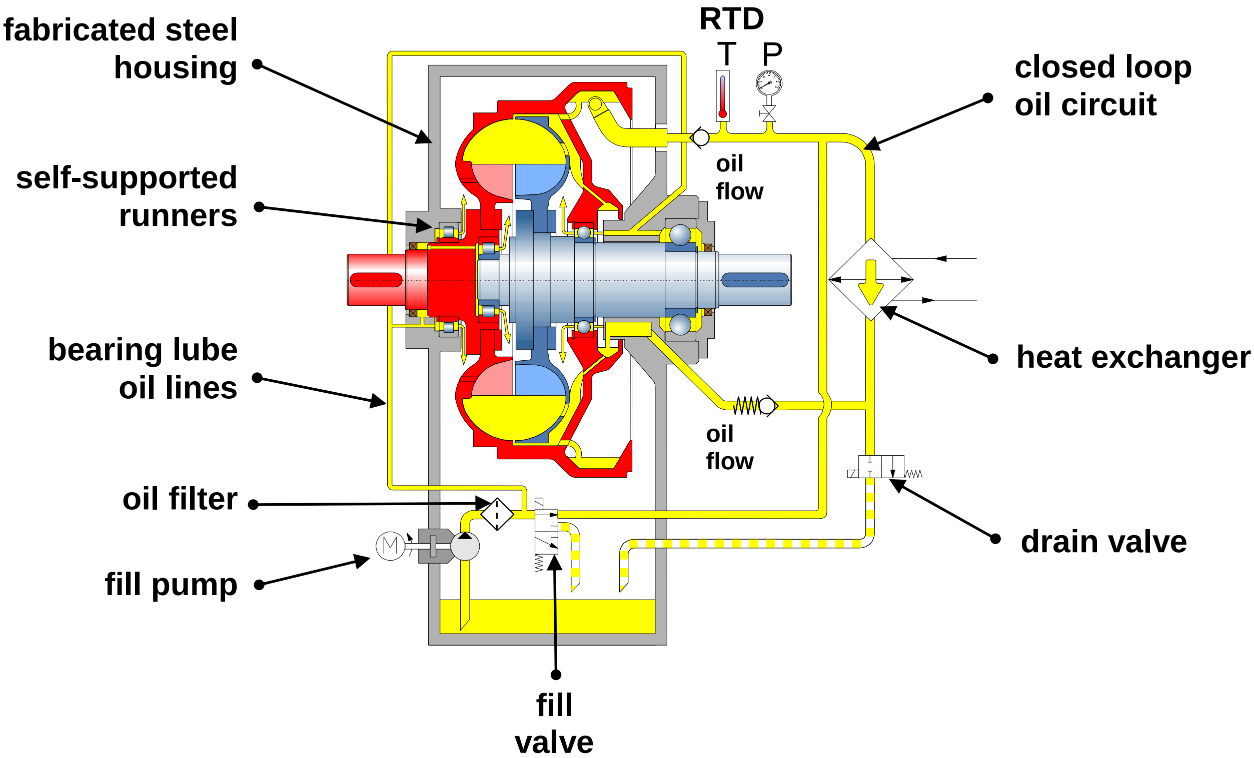
TVVS = constant fill coupling with larger delay chamber and annular chamber

(5) Fill-Controlled Coupling

Should you have reached your application limits for constant fill couplings, then one or several of the following points listed below apply:

- run-up time over a minute or longer
- very high starting frequency
- starting factors below 130 %, relative to the current power required
- load-independent, always the same run-up time
- delayed slowing-down time
- partial speed (inspection run)
- high motor powers.

For these additional requirements we developed the fill-controlled coupling type TPKL.



Power is transmitted in the couplings in the well-known hydrodynamic mode.

The working circuit (impeller / turbine wheel) is superimposed by an external cooling circuit.

For this purpose, hot operating medium is flowing from the nozzles, located at the coupling runner periphery, into the pump ring rotating at motor speed, where it is absorbed by means of a discharge pump pointing against the flow. In this so-called discharge pump the kinetic energy of fluid is converted into flow and pressure.

The hot fluid flow is flowing through an external cooler directly back into the coupling, very high starting frequencies can be realized.

A housing integrated oil supply system feeds fluid into or takes fluid from this circuit. Normally this process is controlled by solenoid valves.

This way the coupling fill is infinitely adjustable between 0 and 100 %, i.e. between empty and full.

The cooler is selected individually for the relevant drive configuration.

The torque transmitted depends directly on the coupling fill level and the relevant output speed.

Contrary to the constant fill coupling, the fill level of fill-controlled coupling is actively adjusted during operation.

The following applies basically:

A control system takes over this level control.

The higher the fill level, the higher the torque transmitted.

This means that it is necessary to increase the fill level appropriately from 0 to 100 %, without exceeding a set torque value.

<u>Available are three basic starts:</u>

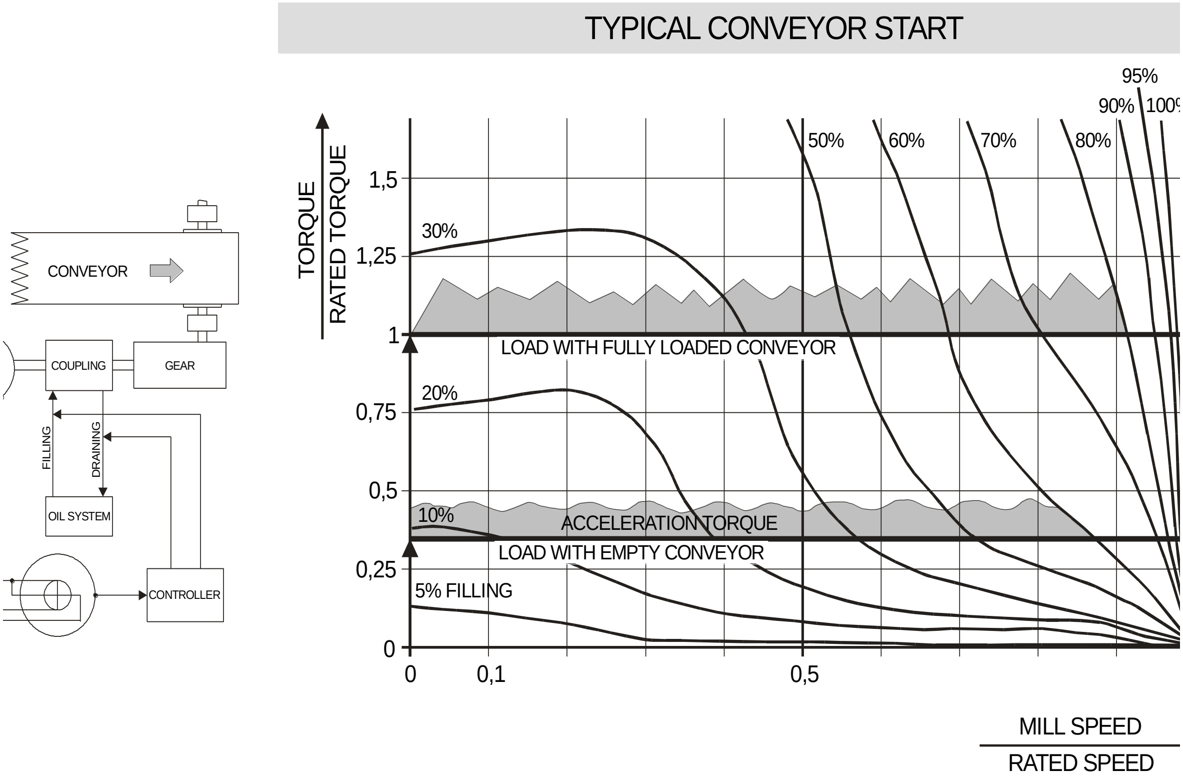
A) **Load-independent torque limitation**
During the total acceleration time, fill and drain valve control, in this case, the torque transmitted to a constant limit value. This corresponds to the maximum permissible belt pull to be initiated into the belt conveyor.

Dependent on the load condition, this results in different run-up times.

The empty conveyor, however, is running considerably faster than the loaded one.

B) **Load-adapted acceleration,** based on the current power demand prior to the last shutdown or trip in each case.

Assuming that the loading and thus the power demand does not change during standstill, the power required for restart is known in order to break away the conveyor. This value is multiplied with the selectable starting factor serving as control limit value for run-up.



The belt pull is the maximum value defined as upper limit for the variable limit value.

C) **Constant run-up time**, independently of the loading

In case of multi motor drives the individual drives are controlled, dependent on the power transmitted in each case, each one equivalent for itself – i.e. no master/slave system. First the limit value is formed as mentioned under B).

Within the progress of acceleration the actual conveyor speed value is, additionally, compared with setpoint deposited in a speed/time ramp. Using the standard PID algorithm the power limit value is then varied accordingly adjusting the actual value to the setpoint.

The torque limitation is superimposing the current acceleration process, in accordance with the maximum permissible belt pull, which is of top priority.

(6) Calculation - Program T-Cycle

To determine the starting characteristic of hydrodynamic coupling more specifically, we developed a calculation program.

This program is not considering the dynamics of conveyor belt, just conveyor start-up.

For this purpose, the desired starting time is subdivided in 250 steps and the
coupling fill level
coupling torque
output speed
temperature
is determined for each single step.

The necessary data are
- load torque
- mass moment of inertia to be accelerated relative to the coupling
- required start-up factor
- frequency of starts

2 examples are given here:

1 **Application Example:
Constant Fill Annular Chamber Coupling**

- Conveyor data
  - Length = 815m
  - Height = 14m
  - Capacity = 2500t/h
  - Belt speed = 3,2m/s
  - Drive-configuration: 1 drive with 250kW, 1480rpm
- Coupling Type: 562 TVVS
- Load data:
  - max. loading condition: 250kW, 91kgm^2
  - empty conveyor: 100kw, 30kgm^2
  - Inertia I_{red}/drive

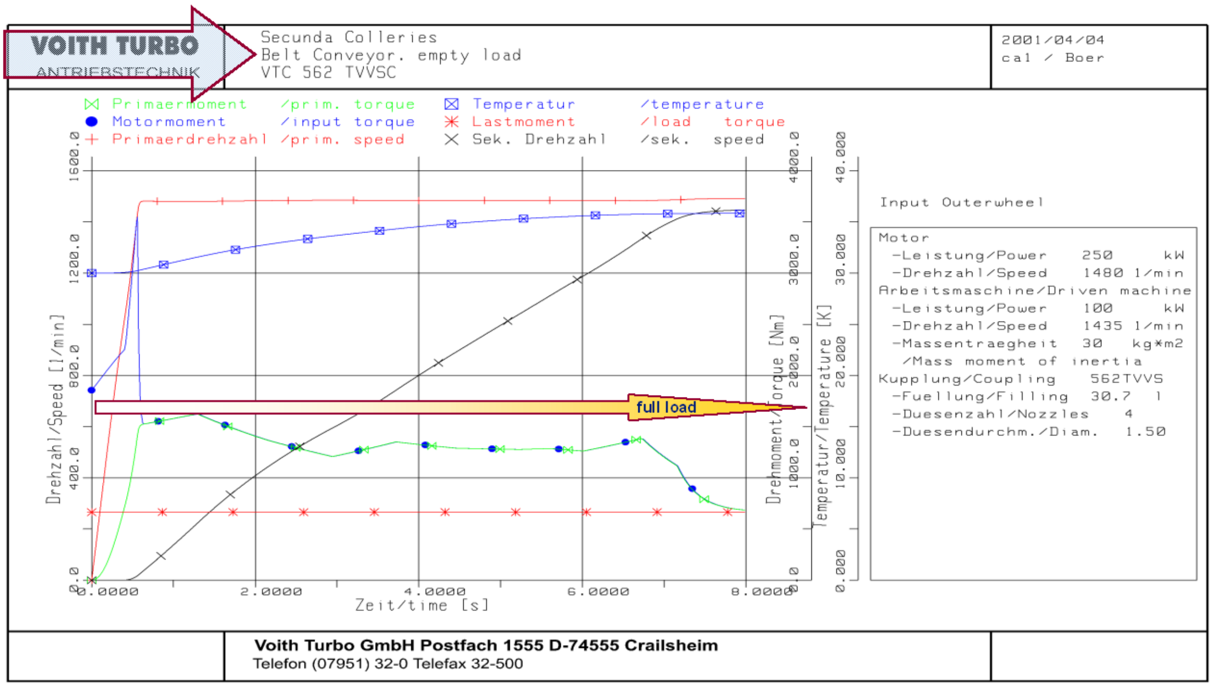
2 **Application Example: Fill-controlled Coupling**

- Conveyor data
  - Length = 2300m
  - Height = 80m
  - Capacity = 1500t/h
  - Belt speed = 3,5m/s
  - Drive-configuration: 3 drives with 132kW, 1480rpm
- Coupling Type: 562 TPKL
- Load data:
  - max. loading condition: 122kW, 40kgm^2
  - empty conveyor: 43kW, 32kgm^2
  - Inertia I_{red}/drive

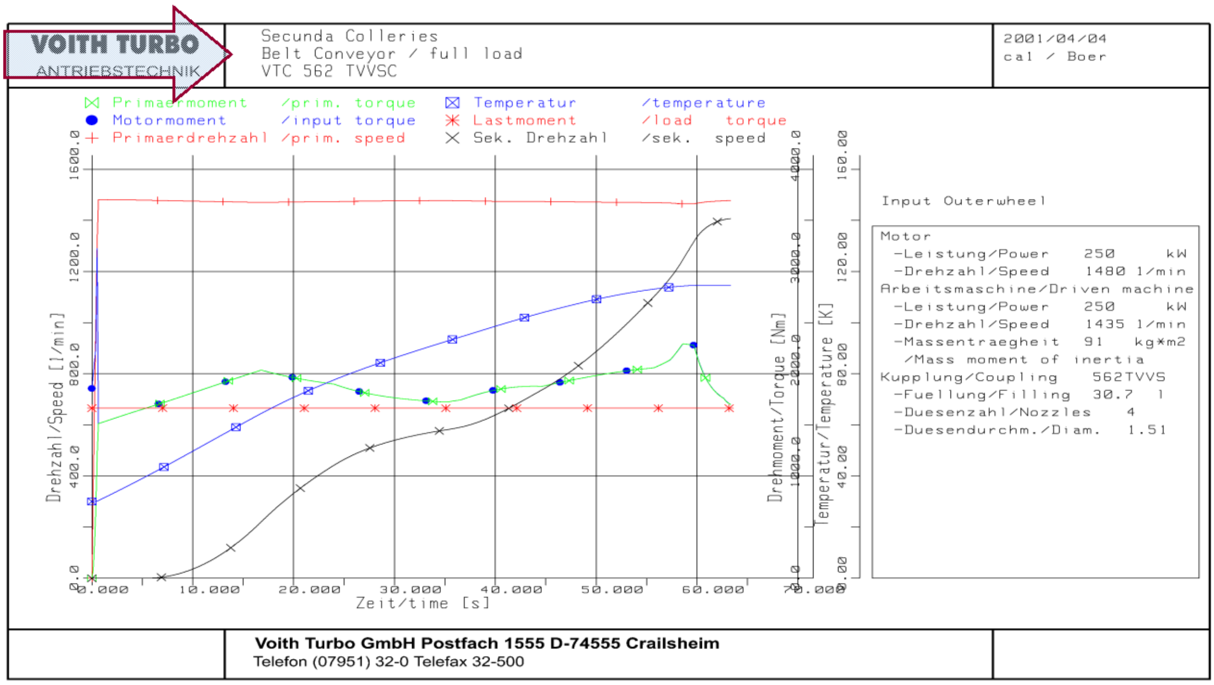
The calculation result shows the starting behavior in form of charts

First the constant filled couplings:

Empty conveyor start:



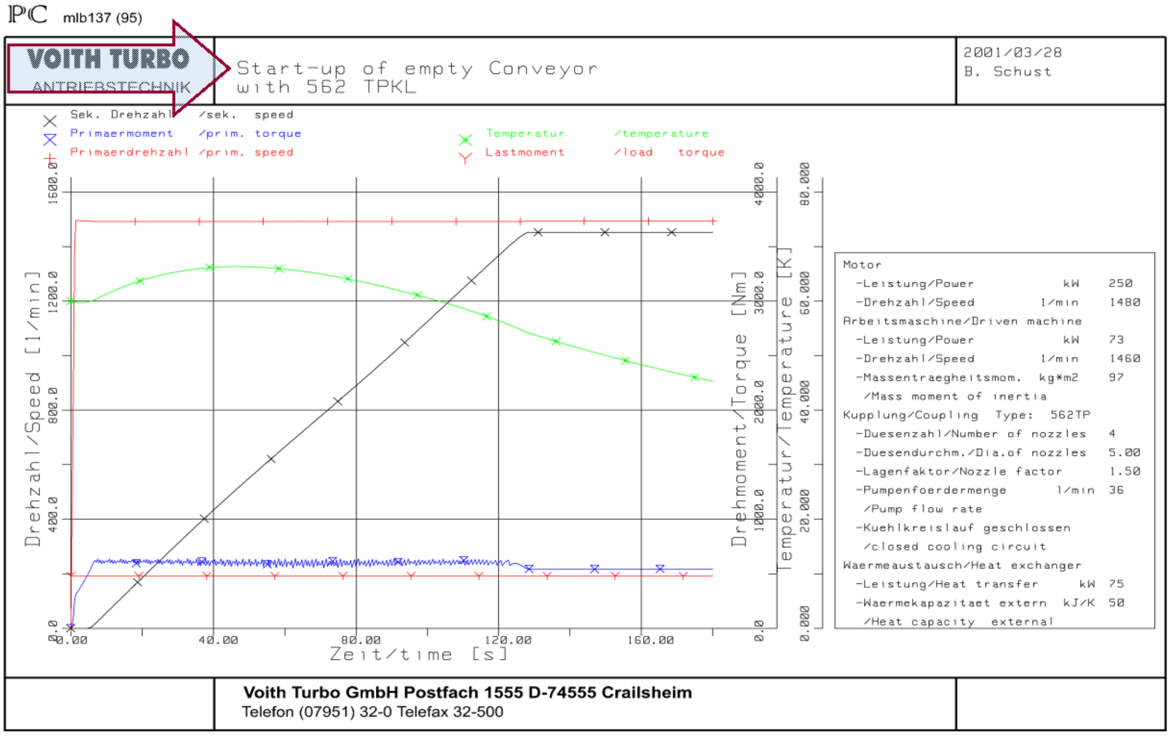
same as above, but fully loaded:



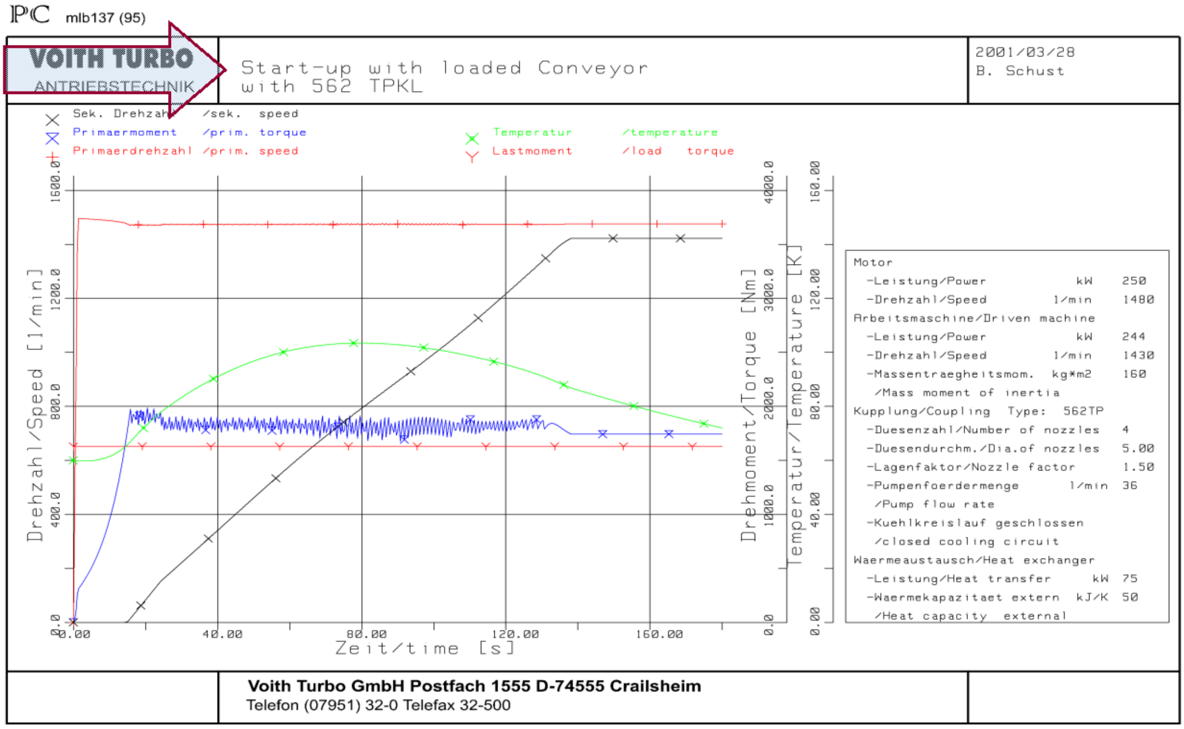
As can be seen from here the coupling automatically adapts to the actual load.

Now the fill controlled coupling (see above mentioned conveyor data):

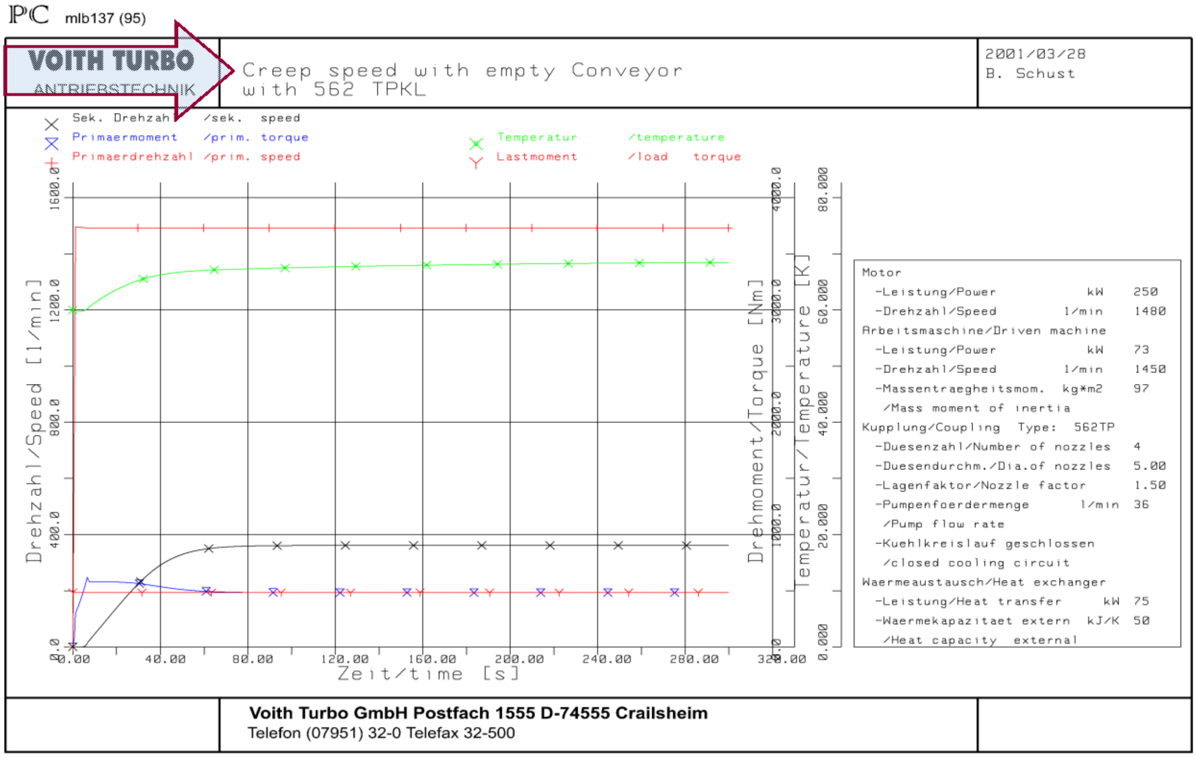
Empty conveyor start:



same as above, but fully loaded:



and additionally creep speed with empty conveyor:



It is possible to incorporate this program in other conveyor calculation programs.

(7) <u>Simulation and Field Measurements</u>

The theoretical bases, however, are forcing to a practical examination.

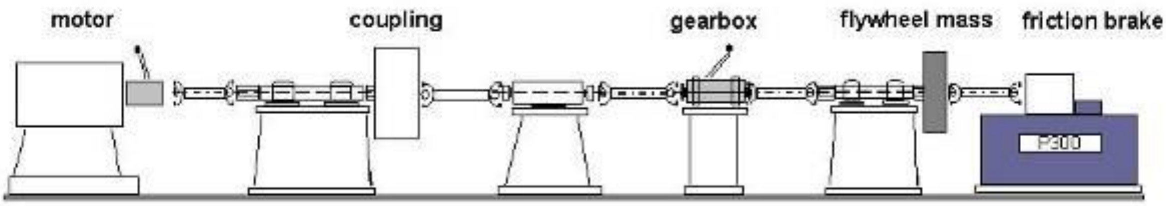
Consequently, a conveyor was simulated in a test field with the aid of a flywheel mass and brakes and later retested in a field test.

Constant-fill Coupling

Motor:			**Motor:**		
Rated power	P_{rated}	= 110 kW	Rated power	P_{rated}	= 110 kW
Asynchronous speed	n	= 1480 rpm	Asynchronous speed	n	= 1480 rpm
Gearbox:			**Gearbox:**		
Ratio	i	= 1:1.5	Ratio	i	= 1:2.45
Conveyor data:			**Conveyor data:**		
Load power	P_{load}	= 110 kW	Load power	P_{load}	= 55 kW
Red. mass moment of inertia	J_{red}	= 32.5 kgm² @ 1480 rpm	Red. mass moment of inertia	J_{red}	= 12.2 kgm² @ 1480 rpm

Startup torque M_A =1.1*M_{load} (optimization by fill degree)

Max. startup torque M_a =1.4*M_{load} (optimization by nozzle diameter)



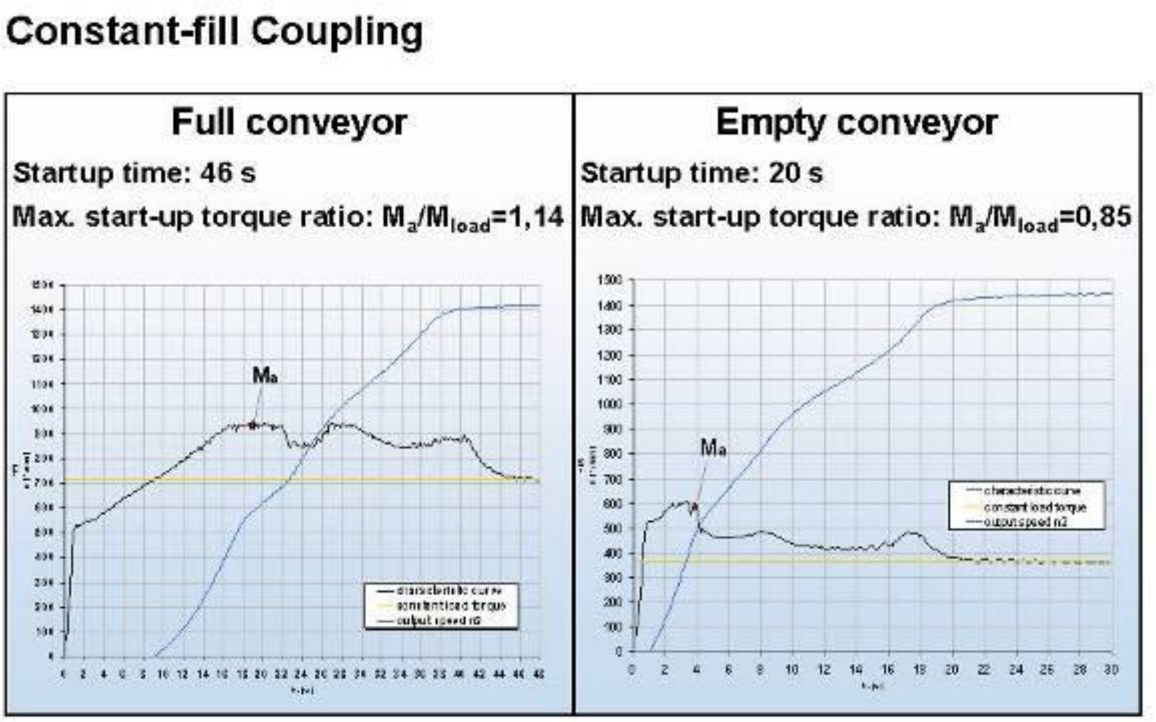
Constant fill coupling:

The coupling type selected in this case was a type 562 TVVS, constant fill coupling.

The following basic measurements were performed.

- start at full load
- start at no load

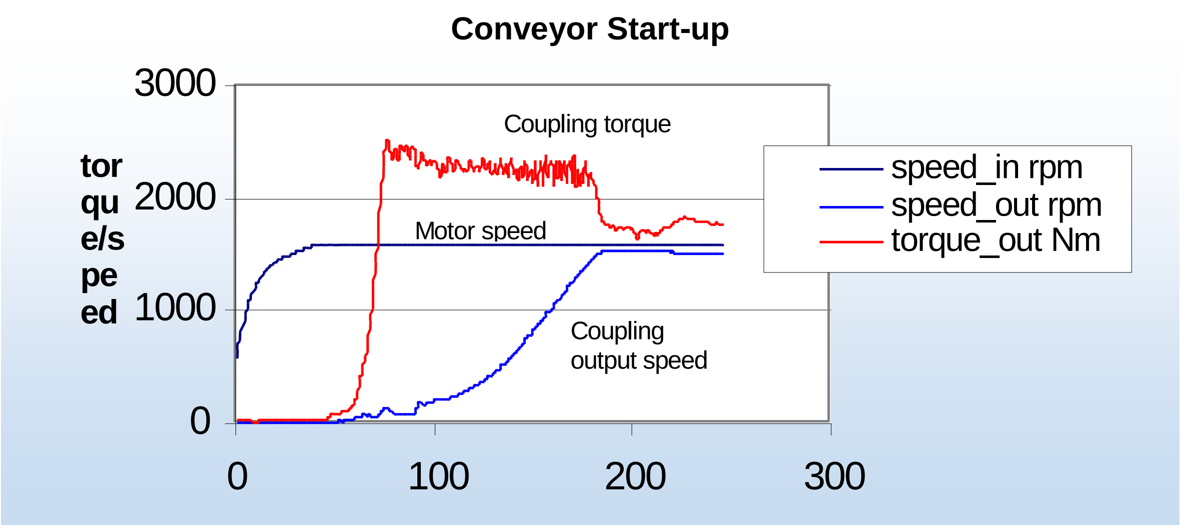
Mineral oil was used as operating fluid with the same volume in the coupling.



Fill-controlled coupling:

We performed an intensive prototype test with this coupling which was subjected to its load limit on our 1000 kW test stand. The paper shows some exemplary test results:

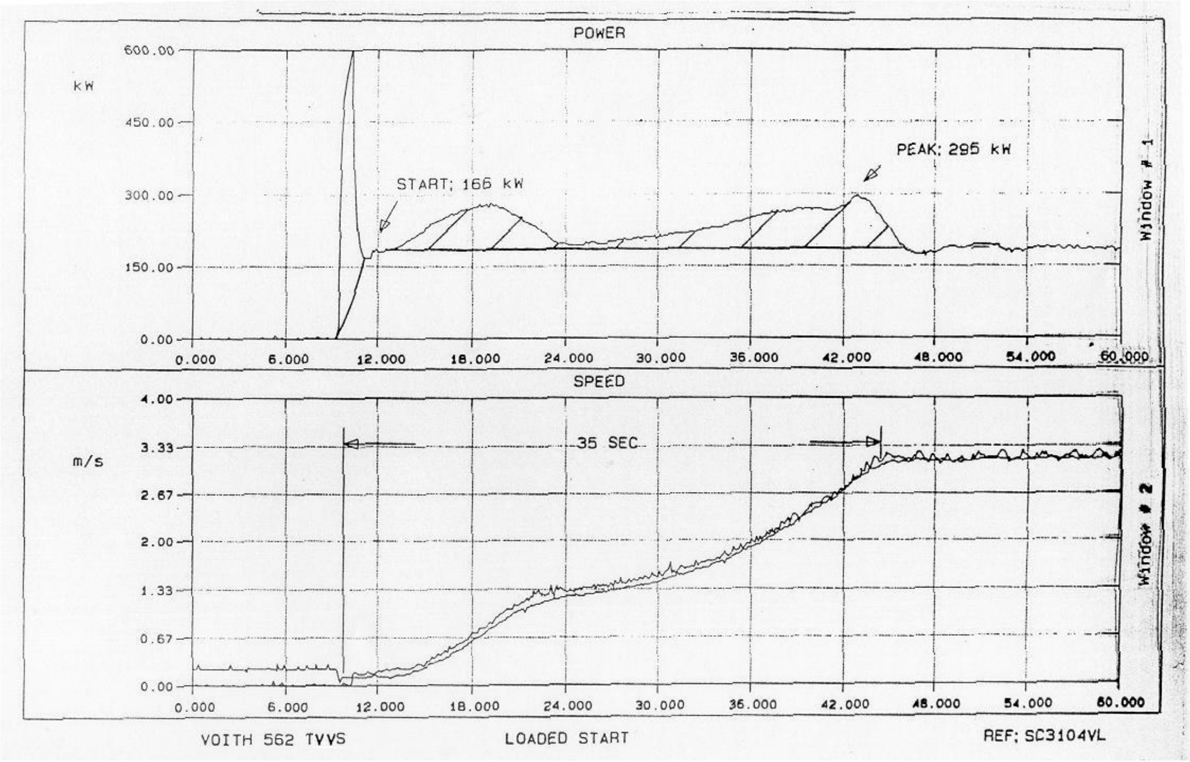
- The paper shows a start vs. constant load at an acceleration time of more than 2 minutes.



Application Example: Constant-fill Coupling

- Conveyor data "Secunda Collieries"
  - Length = 815 m
  - Height = 14 m
  - Capacity = 2000 t/h
  - Belt speed = 3,2 m/s
  - Drive-configuration: 1 drive with 250 kW, 1480 rpm
- Coupling Type: 562 TVVS

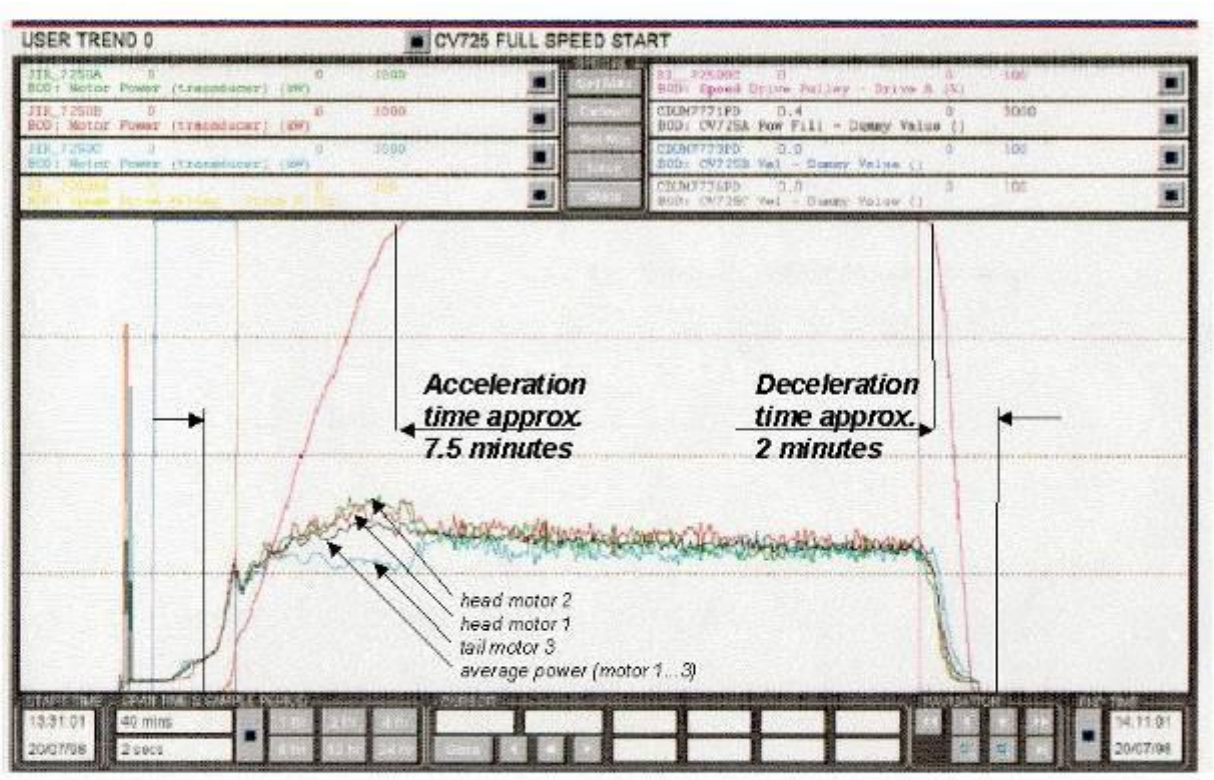
The following graphs were taken at site:



Application Example: Fill-controlled Coupling

- Conveyor data "BHP, Nelson Point, WA"
  - Length = 7500m
  - Height = 0m
  - Capacity = 4500t/h (Top Flight) & 1800t/h (Return Flight)
  - Belt speed = 6m/s
  - Drive-configuration: 3 drives with 900kW, 1480rpm, 2 x head, 1 x tail
- Coupling Type: 650 DTPK

The field measurements shows start-up and rating (load sharing) followed by a conveyor stop while draining the couplings.



(8) <u>Conclusion</u>

The subject is hydrodynamic couplings for conveyor drives.

This paper is to show how the increased requirements of a conveyor drive can be solved with the aid of the hydrodynamic coupling.

Due to its development the coupling has adapted to more exacting requirements. The calculation program allows to calculate the coupling powers and thus to make an general prediction. The hydrodynamic coupling itself is a high-quality and cost-saving drive solution and is, for many applications, far superior to the electrical solution in power and costs. As far as the conveyor drive situation is concerned we need today guaranteed results and not just competent selections.

References

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CV of the authors

- Bernhard Schust, Dipl.-Ing. of the University Aalen/Germany
  is employed since 1979 at Voith Turbo GmbH & Co. KG and at present
  Head of Fill Controlled Couplings
- Klaus Maier, Dipl.-Ing. of the University Heilbronn/Germany
  is employed since 1983 at Voith Turbo GmbH & Co. KG and at present
  Head of Constant Fill Couplings