Main scientific & technological results/foregrounds

In the following the Scientific & Technological results of the HYECON project will be described going through the different products and items developed during the project within the two different conveyor system concepts: Flat Belt Conveyors and a Closed Belt Conveyor system.

i) Flat Belt Conveyors

Within Flat Belt Conveyors the development have concentrated on developing:

- Energy optimized Drum motors with hygienic design for cleanability and high pressure wash down, and prepared for hygienic integration into the conveyor frame structure
- Hygienic functional conveyor "standard" components, which can be marketed as accessories to OEM's for easy fitting of into conveyor systems as proven hygienic solutions.
- Hygienic water and detergent saving fixed installed CIP-system for belt cleaning
- Best in class Belt material
- Suggestion for hygienic frame structure allowing easy belt replacement.

Drum motor:

Present State-of-Art

AC inductions motors, single and 3-phase, are the predominant motor type presently being used for Belt Conveyor Drive stations within the food industry. Almost all drive stations on the marked are with motors of this type combined with a gear. Motor sizes: typical 0.1 - 1.5 kW; 85% less than 1 kW (Slaughter houses).

Motors with different number of poles are used together with suitable a gear reduction ratio to configure the gear motor for desired belt speed:

- 2 - 4 - 6 and 8 pole for motor speed selection: approx. 2.800 - 1.400 – 950 – 700 RPM
- Gear: Helical/Spur gears and Planetary with Gear ratio range 1:20 to 1:100.

However a few Drum motors with Brushed DC motor have been found running on 24 VDC. They are with small motor power: 60 W. It should be noted that the expected lifetime for the units is relatively short: ~3.000 working hours, whereas 20.000 h is state-of-Art for drum motors with AC induction motors.

For Motorized Rollers, which are used to drive the rollers in a Roller conveyor, Brushless DC motors are widely used. They are typically smaller in diameter: less than ø63 mm and have low motor power in the individual roller, typically less than 100 W. Lifetime is much higher than for the Brushed DC motors: 15.000 – 20.000 h.

Motor control

The majority of motors at run at fixed speed, however the use of speed control is increasing in importance, and for a number of applications some kind of speed control is needed. The most widespread type of speed control used is frequency converters – often called Variable Frequency Drive (VFD), but other terms and brand names are also used (Danfoss: VLT® etc.).

VFD's may be used with Drum Motors for simple adjustment of speed, up and down ramping of speed, specific speed profiles, adjustment of torque, dynamic or DC-braking and positioning.

In the automated pork slaughtering industries frequency converters are used for speed regulation in several applications, such as Automatic primal cutting, Pace lines for manual deboning and trimming, Classification and Sorting Buffer storage conveyors and where synchronisation between belts is needed. Most suppliers recommend using VFD control in connection with many start/stop operations.

Motor overheating protection

Most drum motors are as a standard equipped with a thermal protection, which switch off the power, if the winding temperature is too high. Overheating is known as a problem for Drum motors in certain applications (see below).

Methods of cooling and barriers

The State-of-Art is Drum motors with oil lubrication and cooling. The heat generated in the AC motor windings is transferred by the oil inside the drum shell to the outer shell of the drum motor, and further dissipated through contact with the conveyor belt. The heat generated from AC motor thus has a heating effect on the conveyor belt and may contribute to undesirable bacteria growth on the belt material and have negative impact on the food quality and hygiene.

It is important for the motor that it has adequate cooling, as it may otherwise stop due to overheating and eventually burn the coils. Overheating and burned coils is the most often reason for motor repair or replacement.

Motors running without direct belt contact will be more exposed to overheating, especially if they are running many start/stop operations or used for accumulation, where the transported items are pushed against a mechanical stop. Conveyors running with modular plastic belts, which are driven via sprockets mounted on the drum motor outer shell, do not have direct contact to the drum outer shell. For such applications motors are most often de-rated to a lower max. load, meaning that a larger size motor must be specified.

Drum Motor efficiency

AC-motor efficiency

From the literature it is well known that the efficiency for AC-induction motors is smaller, the smaller the motor. This is a physical law due amongst others the magnetizing loss from induction over the air gap between stator and rotor. The present State-of-Art for drum motors collected from manufacturer motor data sheets and web site catalogue show that the efficiency for 3 phase motors in the relevant size rage working at full load is between 20% and 75%. Single stages motors have lower efficiency than 3 phase. When an AC-Induction motor is run below full load the efficiency is reduced. More the less the load and smaller the motor.

It should be noted that motors often are de-rated in order to avoid overheating, and that they often run at less than 60% of full load. This further reduces the efficiency of the motors, especially for the smaller sizes, where the curve starts dropping down at higher percentage load. This means, that in practice the present motors will run with motor efficiency between <u>20% and 70%.</u> Motors used in the slaughtering industry, which are in the higher end the motor range in question, will typically run with efficiency in the range <u>40% - 70%.</u> This does not include the power loss in the gear.

Gear efficiency

Drum motors generally have planet or helical gears, which are the gear types having the highest efficiency – typically 98% per stage. Drum motor suppliers claim very high “mechanical efficiency” – typical around 94%, which is in good compliance with 2 - 3 stage gears, but as it appears, this is only for the mechanical energy transfer and does not include the motor loss.

Overall Drum motor efficiency

Taking all the contributions into account: motor, gear and possible frequency converters, it adds up to an estimate of the Drum motor system efficiency being in the range 20 – 65%, the loss mainly being transformed to heat generated inside the Drum motor. For a 0.55 kW drum motor running at 75% load this means, that it will use approx. 690 W to produce 400 W mechanical power and that the heat generation is about 290 W.

As the gears typically are oil lubricated helical or planetary gears, with efficiency of approx. 98% per stage, it is not considered possible to improve the system efficiency to any degree of importance by improving the gear design alone.

If improvements shall be obtained (project target is -15%), the only way to obtain this, was to look at:

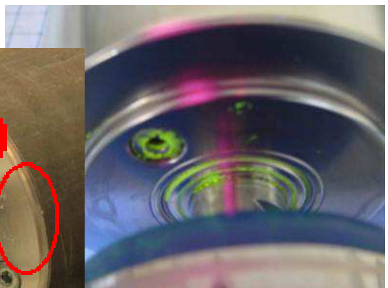
- Motor design (type of motor)
- and/or the way the systems operate:
  - Use optimal motor size and run at optimal conditions
  - Avoid idle run of conveyors (start/stop sensors)
  - Maybe vary speed with need – if possible

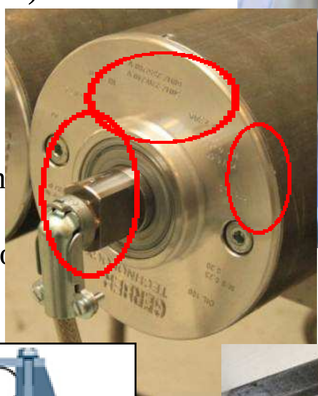
Optimization of the system operation may be done independently of the Drum motor design, and therefore the work should concentrate on trying to find alternative motor designs with higher efficiency than the present State-of-Art AC-induction motors.

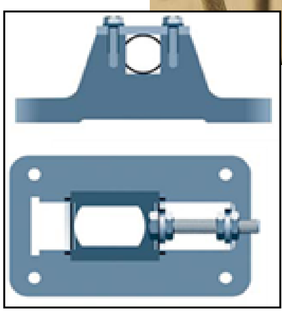
Hygienic design

The hygienic design of the SoA Drum motors is generally relatively good for the motor itself. They have a simple almost cylindrical shape with smooth surfaces, no cavities and generally few difficult to clean areas. However some difficult to clean details should be changed or improved further:

- Oil filling holes (e.g. countersunk screws with inhex)
- Shaft seals (labyrinth seals w. gabs/crevices)
- Cable entry assemblies
- Fastening and tension brackets are generally not optimized (screws and exposed threads, crevices between parts etc.), and generally difficult to clean space between motor and suspension brackets
- Connection box on motor shaft: difficult cleaning area between connection box, brackets and motor.
- Rubber lagging geometry
- Spot-welded fixation of sprockets (modular belts)







Development of new Drum motor

Drive motor

Alternative categories of electric low voltage motors were investigated through literature search, available product information and discussion with selected suppliers. Various types of AC and DC motors were evaluated based on the criteria: high efficiency, durability and life time, flexibility and controllability, technological matureness and availability and price level. As a result, it was found that Permanent Magnet synchronous AC-motors would provide the most promising technology, technically and economically, and it was decided to proceed with the development of a new HYECON Drum motor based on PM motors controlled by a programmable driver in a Control Unit adapted for the purpose.

PM-motors utilize permanent magnets on the rotor (or on the stator), and therefore the loss related to induction of magnetic fields in the rotor coils, as seen in induction motors, does not exist. This further results in a “no-slip” rotation, so that the motor speed is not changing due to load variations. It will always run at the pre-set speed. Today PM-motors have the highest motor efficiency on the market.

Due to the high efficiency the heat generation in the motor is very low resulting in a “cold motor” thus removing the risk of overheating and the need for de-rating of the motors, and further avoiding risk of bacteria growth due to heating of the belt carrying the products.

Other advantages of the PM-motor are the almost constant high torque at various motor speeds, which allows running the motor within a large speed interval without loss in the high motor torque and efficiency, and very few motor-gear combination needed to cover the desired product range. This is a major step forward as opposed to traditional drum motors with AC induction motor, which need many different gears and motors with different number of poles to cover the needed working points.

Together with a major international manufacturer of PM-motors a product program was discussed to cover all relevant drum motor sizes and configurations from relevant suppliers in the marked. Layout of possible product programs (gear-motor combinations) and calculations of performance data were developed in close cooperation with the PM-manufacturer together with a Danish company experienced in developing drivers for controlling such motors. Specifications for the control unit were also discussed in this forum.

The possibility of running the motor completely without a gear and use only the speed regulation of the motor to cover the complete speed range was also investigated. However a much larger diameter motor would be needed to provide necessary torque and the efficiency at very low rotation speed would also be inadequate.

Based on the above findings new drum motors were designed incorporating PM motors in a new HYECON designed drum motor, and prototypes have been build and tested together with prototype control units.

Gear material and lubrication

An investigation has been made to see, if it is possible to run with plastic gear wheels and, if possible, without lubrication, with the aim to develop an oil-free motor.

After intensive work in cooperation with major players on the world market producing technical plastic materials for gears and some of the manufacturers' technical experts, it was concluded, that it would not be possible to make plastic gears with the present state of art materials, that could withstand the complete range of needed loads, and at the same time have a reasonably long life time, not even if lubricated. Plastic gears could be used for some smaller motor sizes, however not for the complete range, and not for the selected sizes most relevant for the slaughtering industry.

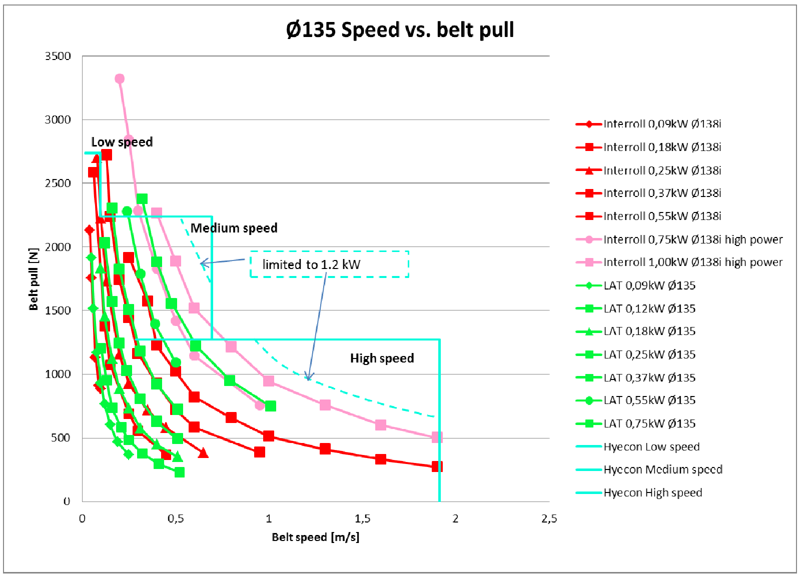
As possible alternatives for an oil-free motor coating of steel gearwheels with a hard, low friction and wear resistant surface was investigated. However after testing of the most promising coating, it was concluded that this would not provide a technical and economical competitive solution.

New Gear motor benefits:

Effective product program with very few variants:

Motor drive flexibility:

The HYECON PM-motors have high efficiency w. motor running within a wide speed range, and thus the motors are adaptable to applications with many different driving needs: With just 3 different variants (gear-motor combinations) a larger working range of Speed and Belt pull can be covered, than typically will need more than 40 different variants with traditional AC Gear-motors:



Advantages:

- For Manufacturer:

  Few variants to be manufactured =>

  - Larger volume production of parts => lower cost price
  - Less number of production orders => lower admin. costs
  - Less capital bound in items on stock
  - More simple sales procedure
  - Easy to set up and change drive parameters in Control unit via PC program

- For OEM's / conveyor system manufactures:

  - Less complicated to configure systems - to select and install correct motors

- Identical motors can be procured in larger quantities
- Motors can be swapped around between different conveyors

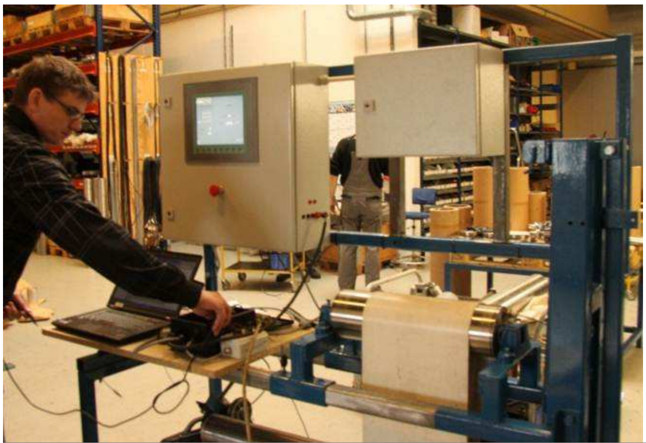
o <u>For End user:</u>

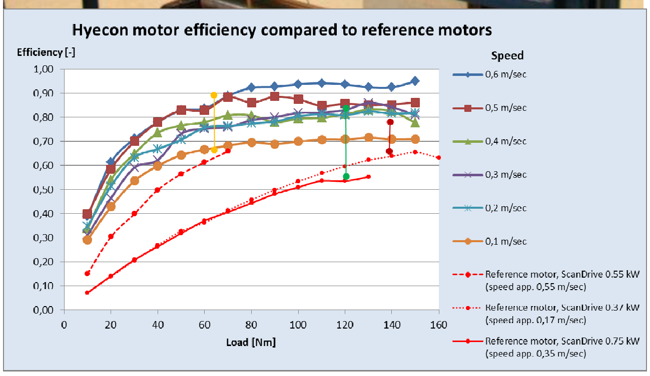
  - Less number of spare motors in different configurations on stock for quick replacement in case of break down => lower capital investment
  - Less space needed for spare motors
  - Motor can be moved to another conveyor and connected to Control unit with different parameter settings
  - Motors drive parameters can be changed by programming the Control unit via PC-program.

Energy savings:

Due to the PM-technology remarkable amounts of energy can be saved. Comparative test have been made in a test stand, comparing the HYECON motor against different traditional Drum motors configured to represent different working points within the working area of the HYECON motor.

The test showed that the efficiency of the HYECON motor was under all conditions considerable higher than the traditional motors. For the traditional motors working at full load efficiency between 55% and 66% was measured whereas the HYECON motor working at the same conditions had efficiency between 78% and 88% including the Control unit loss. For both types of motors the efficiency depends on the speed and load, but much less for the PM-motors.





Measured improvement in efficiency compared to traditional motors running <u>at full load</u> was between <u>23% and 53%</u> and even <u>higher</u> for the traditional motors running at <u>partial load</u>.

As an example the 0.55 kW motor ran at 0.55 m/sec with load 50Nm with efficiency 56%, whereas the PM-motor under the same conditions ran with efficiency 82%.

It can thus be concluded that the target to improve the efficiency by 15% has been more than achieved.

Calculations of energy savings:

Potentially large savings in energy usage and energy costs are achieved both in the primary energy for driving the conveyors but also as secondary energy savings e.g. for cooling the production area to a suitable temperature specified for the food processing area.

Below are some calculated examples:

Calculation basis:
16hours/day; 220 working days/yr.; Energy price: 0,11 EUR/KWh

Primary energy savings per motor:

@ Full load	Present 3 ph. AC motors			Hyecon 107C PM-motor			Savings/year		5 years
AC Motor size	Efficiency	Elect. power	KWh/yr	Efficiency	Consumpt.	KWh/yr	Power	Energy cost	Energy cost
0,37 kW, 4-p, 0.17m/sec	63%	0,59 kW	2.067	82%	0,45 kW	1.588	479 kWh	€ 53	€ 263
0,55 kW, 4-p, 0,55 m/sec	66%	0,83 kW	2.933	88%	0,63 kW	2.200	733 kWh	€ 81	€ 403
0,75 kW, 4-p, 0.35m/sec	55%	1,36 kW	4.800	82%	0,91 kW	3.220	1.580 kWh	€ 174	€ 869
1,5 kW *)	70%	2,14 kW	7.543	93%	1,61 kW	5.677	1.865 kWh	€ 205	€ 1.026

@ 60% load	Present 3 ph. AC motors			Hyecon 107C PM-motor			Savings/year		5 years
AC Motor size	Efficiency	Elect. power	KWh/yr	Efficiency	Consumpt.	KWh/yr	Power	Energy cost	Energy cost
0,37 kW, 4-p, 0.17m/sec	52%	0,43 kW	1.503	82%	0,27 kW	953	550 kWh	€ 60	€ 302
0,55 kW, 4-p, 0,55 m/sec	50%	0,66 kW	2.323	88%	0,38 kW	1.320	1.003 kWh	€ 110	€ 552
0,75 kW, 4-p, 0.35m/sec	50%	0,90 kW	3.168	82%	0,55 kW	1.932	1.236 kWh	€ 136	€ 680
1,5 kW *)	55%	1,64 kW	5.760	93%	0,97 kW	3.406	2.354 kWh	€ 259	€ 1.294

*) estimated values

Example: 2.800 motors running at 60% load

@ 60% load	Present 3 ph. AC motors			Hyecon 107C PM-motor			Savings/year		5 years
AC Motor size	Efficiency	Elect. power	KWh/yr	Efficiency	Consumpt.	KWh/yr	Power	Energy cost	Energy cost
0,75 kW, 4-p, 0.35m/sec	50%	0,90 kW	8.870.400	82%	0,55 kW	5.408.780	**3.461.620 kWh**	**€ 380.778**	**€ 1.903.891**

Secondary energy savings: heat to be removed through cooling:

Example: 2.800 motors running at 60% load

@ 60% load	Present 3 ph. AC motors			Hyecon 107C PM-motor			Reduced heating:	Savings/year	5 years
AC Motor size	Efficiency	Elect. power	Heating	Efficiency	Consumpt.	Heating	Power	Energy cost	Energy cost
0,75 kW, 4-p, 0.35m/sec	50%	0,90 kW	0,45 kW	82%	0,55 kW	0,10 kW	0,35 kW	€ 45	€ 227
total for 2800 motors		2520 kW	1260 kW		1537 kW	277 kW	**983 kW**	**€ 126.926**	**€ 634.630**

In the above example replacing a 0.75 kW AC-motor with a HYECON Drum motor will in primary energy costs annually save EUR 135, and over 5 years: EUR 680. To this could be added the savings in secondary energy for cooling, which typically may be in the magnitude of 1/3 of the savings in primary energy.

As an example a factory like Danish Crown in Horsens with 2.800 Drum motors would be able annually to reduce primary energy cost with EUR 380.800 and over 5 years: EUR 1.9 mill.

For secondary energy almost 1,000 kW less cooling effect would be needed, and assuming saved cooling costs are 1/3 of primary energy saved, the annual saving would be EUR 127.000. Over 5 years the reduction in secondary energy cost would be: EUR 635,000.

All together the energy savings would annually sum up to EUR 0.5 mill, and over 5 years: EUR 2.5 mill, corresponding to EUR 900 per motor.

Easy controllable motor:

The HYECON motor with the control unit is suited many start/stops and can easily be controlled by input signals from PLC's or sensors and thus it is suited to run in "energy mode" so that conveyors only run, when there are goods to be moved. This will further reduce energy costs – both primary and secondary energy consumption.

Cold motor

Due to the high overall efficiency of the gear motor the power loss and heating of the motor is dramatically reduced. Whereas a traditional Drum motor would typically reach a surface temperature of 65 °C, the temperature of HYECON motor under same conditions would only reach 40 °C. This result in:

- Reduced risk of motor overheating and burned coils
- Smaller size motors may be used (no de-rating)
- Reduced heat transferred to the belt resulting in lower thermal load on the belt material
- Reduced risk of bacteria growth on the belt

Hygienic Design

All during the design of the new HYECON Drum motor the EHEDG Guidelines have been followed in the design of assemblies, components, material selection, specification for manufacture etc. Also the installation of the motor in conveyors has been taken into consideration.

Motor suspension into conveyor

During the work with alternative concepts, it was suggested that the motor should not just be regarded as a traditional stand-alone unit, but that a hygienic integration into the conveyor frame structure could be part of the motor design. Instead of, as intended, one design line, this led to additional development of two different design variants: *A Traditional version* for retrofit and installation in traditional conveyor designs, and an *Integrated HYECON hygienic build-in design*. The development of these two design variants have been made with maximum use of common parts and has resulted in a patent application covering two design details.

The drum motor design have been evaluated and found in compliance with the EHEDG Guidelines by AINIA Centro Tecnológico in Spain. Preliminary report has been issued, and at present we are awaiting the issue of EHEDG-certificate.

Summarizing, the hygienic features are:

- EHEDG certified Drum motor design including hygienic cable entry.
- Drum motor prepared for hygienic integration into conveyor frame structure with optional hygienic Belt tensioner for welding onto Conveyor frame or for fitting together with Quick-Release device.
- Improved cleanablity =>

- o Reduction in water and detergent consumption
- o Reduction in cleaning time => less labour, more time available for production
- o Improved hygienic standards
- o Less risk of product contamination and recalls
- o Improved food safety

A Service friendly motor

In order to fulfil the EHEDG Guidelines smooth surfaces are required. An optimal solution would be to avoid the use of screws on external surfaces. Counter sunk screws with internal hex, cross recessed or slotted are not allowed, and neither is metal to metal contact, so only Hex cap screws with seals between screw head and the tightened component can be used. On the End Caps of a rotating Drum motor this is undesired both for safety and for hygienic reasons. At the same time it was desirable to make a service-friendly motor, which is easy to dismantle for service, e.g. to replace seals and bearings, without the risk of damaging the fine surface finish. In the HYECON Drum motor design this challenge has solved through a new design detail, which is included in a patent application.

Seals

High pressure wash down is widely used to clean equipment in the slaughtering industry, and therefore protection class IP69K was specified for the new motors. New seals have been developed in order to live up to this, both for the seals on the motor shafts, the outer seals between the Drum shell and the End caps and for the cable entry. The complete drum motor in both design versions with new developed seals were tested and certified at independent laboratory DELTA for compliance with IP69K protection class while rotating: Protection class IP69KM acc. to IEC 60529:2001 and DIN 40050 Teil 8-9:1993.

IP protection /Patent pending

The development of the new HYECON Drum motor has resulted in the invention of two design details, for which patent applications have been prepared and filed.

Cost price

After the initial investigations in the earlier stages of the project, the implications were, that the PM-motor parts would cost in the range up to 20% more than the corresponding AC-motor parts, so that change in the motor technology would result in a relatively small cost increases.

During the 2011 world prices on Rare Earth Minerals dramatically increased due to China export quota restrictions resulting in prices on permanent magnet were 10 doubled in the autumn of 2011. On the short term this has had a considerable effect on the drum motor cost price. Lots of initiatives are taken to compensate for the shortages, and USA is bringing a trade case against China aided by Japan and EU at WTO. It is believed that prices will again drop to a lower level.

However at present the cost prices are considerably higher than previously anticipated and in the range of 50% above existing drum motors. In spite of this, the present higher price level could be justifiable by the other benefits achieved for both the motor itself (energy savings, temperature, flexibility, few variants, hygienic integration etc.) and the overall cost reduction by improved cleanability of the HYECON system design.

Conveyor “standard” components

The concept design for hygienic conveying systems and automatic cleaning involved development of various subsystems and components with needed interfaces for interaction and installation in a complete conveyor system.

With focus on fulfilling the main objectives including hygienic design, low energy consumption, cleaner friendliness with good accessibility and low overall cost, the following subsystems have been developed:

- Hygienic installation of Drum motor and control system
- System prepared for both flat belt and belt with traction geometry
- Belt tensioners
- Quick release system
- Belt support rollers
- Levelling Feet
- Simple open frame structure allowing easy belt removal
- Hygienic, fixed installed CIP-system

Regarding installation of Drum motor see motor chapter above, where an *Integrated HYECON hygienic build-in design* was developed for a hygienic suspension in the conveyor. The motor was developed with hygienic cable entry, so only a smooth food grade cable has to be connected to the Control unit, which can be placed on a wall or pillar away from the conveyor. The motor was designed to drive a tensioned smooth flat belt by friction on the smooth drum motor shell, but also to be equipped with rubber lagging for driving belts with traction geometry.

Belt tensioner and Quick-Release system

Belt tensioners are used in Flat belt conveyors to provide a pretension in the belt to ensure sufficient contact pressure against the driving drum to enable transfer the driving torque to the belt via friction. Many different designs are seen, mostly with some kind of open thread connections for tightening the belt. The hygienic aspects are rarely taken sufficiently into consideration: not easy to clean threads, nuts, brackets and sliding guides and metal-to-metal assemblies with dead space and crevices are normal, and excess cleaning effort is needed to clean these areas.

Quick-Release devices have two purposes:

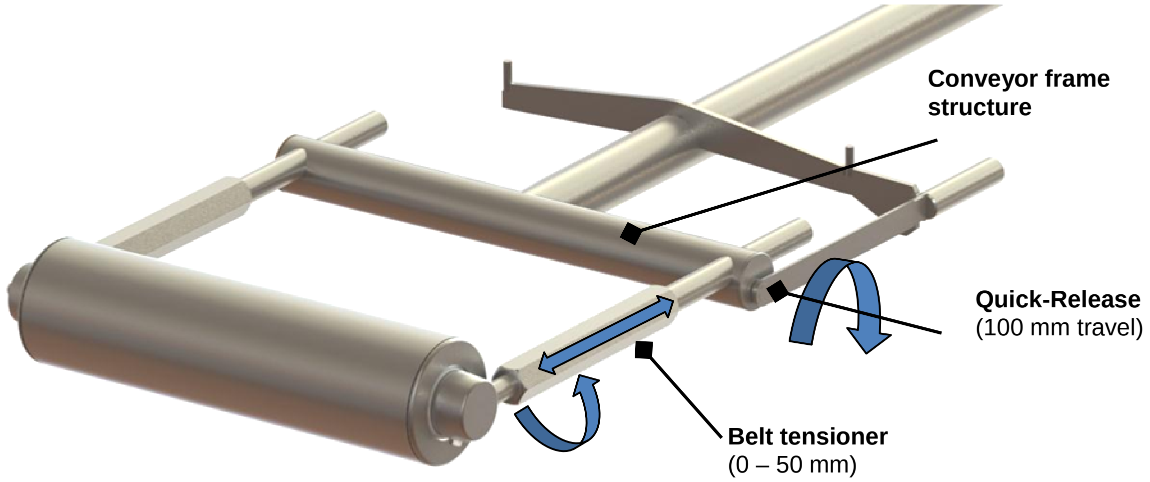
1. Easily release of the belt tension to loosen the belt, so that it can be lifted for better cleaning access to the area inside the belt loop, and to re-tightening the belt to the same tension as before, without needing to go through a tension adjustment procedure.

2. To loosen the belt so that the belt or the drum motor can easily be demounted for repair, replacement or others.

As for belt tensioners the Quick-Release devices found did not sufficiently complying with hygienic design guidelines.

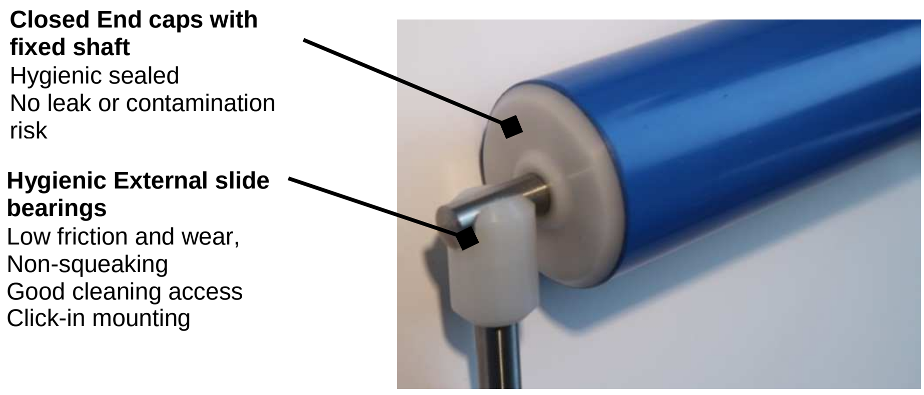
Both Belt Tensioner and Quick-Release system were developed concurrently with the Drum motor suspension solution, such that the drum motor interface is part of the belt tensioning system. The Belt Tensioner is designed to be used alone, together with drum motor or to be a hygienic integrated part of the Quick-Release unit.

Quick-Release systems and Belt Tensioners were modeled as 3D-CAD models in several versions, before a given setup was selected based on design criterions and reviews. Prototypes were manufactured, assembled, tested and further optimized. A final version was manufactured, installed and tested in a test- and demonstration conveyor, build and tested in a production environment at Danish Crown.



A sample of the Quick-Release unit with Belt Tensioner has been sent to AINIA in Spain for hygienic evaluation. At present some details has to be clarified with AINIA, before a possible EHEDG-certification can proceed.

For Belt Support Rollers a new hygienic design was developed including an external, open bearing design, which allows easy access for cleaning the bearing. The Rollers are based on extruded food grade PVC tubes with injection molded End caps comprising a hygienically sealed fixed shaft end. When belts with traction geometry are used, shorter support rollers are used on each side of the traction geometry. Several units were manufactured, assembled and installed into in a test- and demonstration conveyor, build and tested in a production environment at Danish Crown.



Search for commercial available leveling Feet resulted in identifying products already on the marked carrying EHEDG-certificate and at a fair price level. They were therefore selected to be the ones to include in a future HYECON product program.

Frame structure

For the frame structure a simple fully welded open concept build from standard round tubes was chosen, thus avoiding all horizontal surfaces and ensuring good drainability. The Frame consists of a central "Backbone" inside the belt loop with few transversal bracket elements for carrying Rollers and other necessary accessories. The Backbone is fixed to the "under frame" e.g. the legs on one side only, thus allowing an endless belt to be mounted and removed without dismantling any frame elements. There are no screw assemblies in the frame structure and no frame elements shielding the access to the interior belt loop. This combined with the Quick-Release system allows for belt lifting and remarkably good access for cleaning the (few) frame elements and the CIP system placed inside the belt loop.

CIP-system

Regarding cleaning, analysis found that a fixed installed fully automatic cleaning system for cleaning the whole conveyor structure would require either many fixed installed nozzles and pipework to cover all surfaces to be cleaned, thus resulting in high water and chemical consumption or development and installation of cleaning robots, which had to be individually programmed to each conveyor to run through rather sophisticated cleaning paths to cover all cleaning areas. Both solutions would result in high installation costs and installation of extra components and pipework, which itself also had to be cleaned.

Accordingly it was concluded, that a fully automatic cleaning of the whole conveyor structure would neither be economical justifiable nor reduce the water and chemical consumptions as much as a combination of automatic cleaning of the conveying belt, which comprise the product contact surfaces, and manually cleaning of the remaining structure.

Undine Mixing Unit w.

Regarding the CIP system, the unique IWC's Undine nozzle principle, mixing compressed air and water, had proven its value as a very efficient method for cleaning with large savings in water, detergents and time as opposed to as well manual cleaning as to present types of fixed installed CIP systems.

This system has been optimized in two directions: Better "design for manufacturing" and better Exterior cleanability.

During the work with better “design for manufacturing” a new simplified design was suggested for the Mixing chamber. CAD-modeling was used in several stages and shapes. Though this was agreed to be a feasible optimisation regarding manufacturing cost, flexibility and access to the nozzle interior, it was not implemented into the prototype setup for testing, as this would demand more testing and validation work than obtainable within the frames of this project.

ndine Turbo Unit

The exterior design of the CIP system itself was perceived to be too cumbersome to clean, as the existing units are made with many threaded assemblies. This would potentially result in insufficient cleaning and bacteria growth and would require special attention resulting in unneeded additional cleaning effort and water consumption.

praybar w. nozzle

Suggestions were elaborated to avoid almost all threaded assemblies by replacing these with welding as much as possible. Very few threaded connections were still needed for service and cleaning reasons, but they were redesigned such that the threads were sealed from the outside. Square tubes were replaced by round tubes with high surface finish to ensure good draining independent on system orientation, weldings were ground and polished - all following the guidelines from EHEDG to the extent possible.

New Hyecon Mixing chamber w. sealed

Several suggestions were worked out as 3D-CAD models and discussed with the SME covering suggestions for Mixing Units, Manifolds, Turbo Units and Spraybars – all easy adaptable for various conveyors. Besides improving the hygienic exterior design the suggestions for Turbo Units would solve some manufacturing problems with the existing systems.

ew Hyecon Manifold w. welded Mixing chamber, sealed drain

It was decided that for the HYECON project the focus should be on the Manifold with Mixing units and Nozzles, as this is the preferred and most efficient configuration.

The new design resulted in a simple flexible solution for changing the air/water mixture to adapt to different cleaning needs by replacing just one dismountable part in the assembled unit; this at the same time facilitating easy cleaning of the interior of the Mixing unit, typically needed to remove dirt from piping system after first installation run. The nozzle thread connection is hygienically sealed from the outside. The nozzle can be turned and replaced. Detailed fabrication drawings were made and CIP units were manufactured for testing.

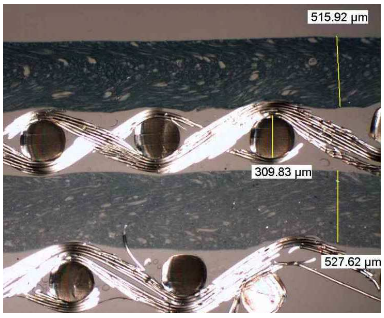
Complete CIP manifolds with Mixing units and nozzles were installed and tested in the Test and Demo conveyor at Danish Crown, Ringsted.

Belt material

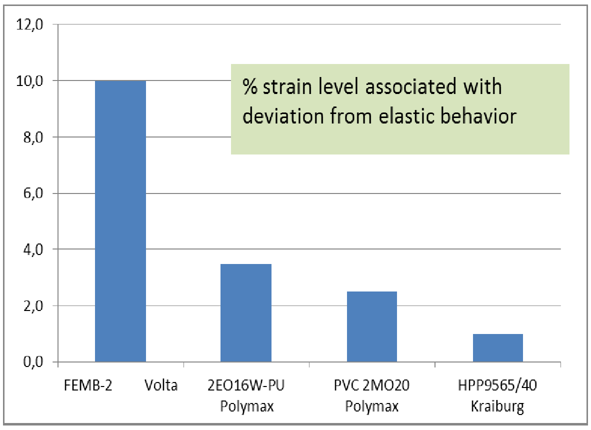
Material qualification of potential flat belt materials has be undertaken with an identification of ‘best-in-class’ approach. For flat belt materials four commercial candidates were selected from an initial gross list defined by DTI.

Chemical analysis conducted with FTIR spectroscopy and optical microscopy revealed the following compositions:

- **Poly(ester urethane)** from Volta Belting Technology (no fiber reinforcement)
- **Poly(ester urethane)** with poly(ethylene terephthalate) fiber reinforcements from Polymax
- **Poly(vinyl chloride)** with poly(ethylene terephthalate) fiber reinforcements from Polymax
- **Nitrile rubber** from Gummiwerk Kraiburg (no fiber reinforcement)



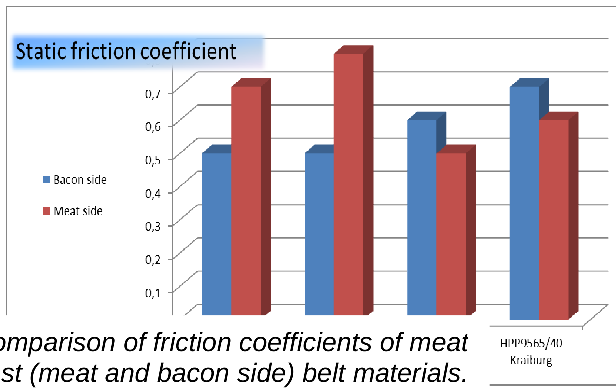
Cross section microscopy of Poly(vinyl chloride) belt material



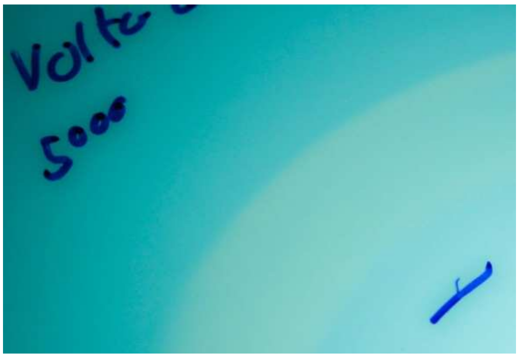
Results from tensile testing of belt materials.

Tensile testing has been conducted on flat belt materials according to ISO 527 (25 mm sample width, 10 mm/min., 23 °C and 50% RH). The relative strain level associated with deviation from elastic behavior has been evaluated as a measure for elastic properties. Measurements indicate values between 1 and 10 % relative strain, with the poly(ester urethane) belt material from Volta Belting Technology showing the highest elasticity and the nitrile rubber from Gummiwerk Kraiburg the lowest.

Examination of friction properties has been conducted on all four flat belt candidates by measurement of static friction coefficients defined by the observed sliding angle on a gradually tilted plane. Testing was conducted on both bacon and meat side against belt materials and revealed static friction coefficient in the range of 0.5-0.9 (dry surface) and 0.2-0.8 (moist surface). This is assessed to be acceptable for practical operation in slaughter houses.



Comparison of friction coefficients of meat against (meat and bacon side) belt materials.



Abrasive wear track on belt material from Taber Abraser test.

Testing of relative abrasion resistance according to ISO 9352 (Taber abraser) has been conducted on flat belt materials by determination of weight loss per 1000 revolutions (wheel type: CS10 and wheel load 500 g).

Test results shown the highest abrasion resistance for poly(ester urethane) belt material from Volta Belting Technology ($\Delta m = -0.8$ mg/1000 rev) and the lowest for poly(vinyl chloride) with poly(ethylene terephthalate) fiber reinforcements supplied by Polymax ($\Delta m = -2.3$ mg/1000 rev).

The output of the qualification process gave the following recommendations for final materials selection:

- **Flat belt material:** Poly(ester urethane) with no fibre reinforcement from Volta Belting Technology (FEMB-2) in light blue colour

The flat belt was selected as a result of the material investigation work. A version was designed, adapted and manufactured to fit the test- and demonstration conveyor build and tested at Danish Crown.

Testing and cleaning results

Liver Belt

In order to make equal comparisons an existing reference conveyor at Danish Crown was chosen, which feeds pork livers to the operator for processing. The operator starts and stops the conveyor by activating a push button. A HYECON version Test- and demo conveyor was designed and manufactured with the same dimensions and with the same user interface.

At the end of the production hours the tray on top of the conveyor was removed and the conveyor was cleaned.

The existing conveyor was manually cleaned by the normal cleaning operators and video recorded. The cleaning procedure, the cleaning time and the usage of water was recorded.

The existing conveyor was then replaced by the HYECON version, and after running a normal production and being soiled, it was cleaned according to a revised procedure making use of the Quick-Release and a combination of manually cleaning of the frame structure and automatic inside and outside CIP of the belt. This was also video recorded and the cleaning data were recorded.

For cleaning the existing liver belt manually, a professional contract cleaner used for the complete cleaning approx. 18 minutes in time to clean the small belt from in and outside. He used approx. 22 bars in pressure, 56 degrees temperature and a usage with a zero degree nozzle from approx. 45 liters per minute.

For the HYECON conveyor the combination of manual and automatic cleaning appeared to be great regarding the needed labour for cleaning the belt effectively. Frame, rolls, and drum motor cleaning took approx. 6.5 minutes in total, while in approx. 6 revolutions the complete belt was cleaned from both in and outside.

It was noted that it was easy to get contact from spray with the internal frame work in the HYECON Liver belt and the smooth surface from the belt, and that the improved hygienic open design of the frame and the hygienic design of Drum motor, Rollers and Belt Tensioners, and the Quick Release provide good access to clean the space inside the belt loop.

In spite of the belt being very short and not being regarded so obvious a candidate for automatic cleaning, in fact this also proved very efficient in saving water and labour.

yecon Liver conveyor at Danish Crown


utomatic CIP of belt (both sides)

Savings

As it appears in the table below, large savings were measured on all parameters: approx. 45% in total cleaning time, 64% in labour, 60% in water usage:

DC Ref system - Liver conveyor						Hyecon test-& Demo convceyor					
Cleaning procedure steps:		P, Bar	Q, l/min	t, min	Water consumpt., liters	Cleaning procedure steps:		P, Bar	Q, l/min	t, min	Water consumpt., liters
1	rinse all	22	45	7	315	1	frame cleaning manual	22	45	3,5	157,5
2	foam	22	15	1	15	2	automatic in/out	22	21,5	1,1	23,65
3	main cleaning	22	45	7	315	3	foam	22	15	1	15
4	disinfection	22	15	1	15	4	automatic in/out	22	21,5	1,1	23,65
5	rinse	22	45	2	90	5	disinfection	22	15	1	15
6						6	automatic in/out	22	21,5	1,1	23,65
7						7	frame cleaning manual	22	45	1	45
	Total				750		Total			3,3	automatic 70,95
				18	all manual					6,5	manual 232,5

Cleaning data:			DC Ref.	Hyecon	Savings:	
Total duration of cleaning, min.:			18 min	10 min	8 min	45,6%
Labour (man hours) spend, min.:			18 min	7 min	12 min	63,9%
Water consumption, liters:			750 Liters	303 Liters	447 Liters	59,5%
Chemical A, liters:			0 Liters	0 Liters	0 Liters	0,0%
Chemical B, liters:			0 Liters	0 Liters	0 Liters	0,0%
Other:			0 Liters	0 Liters	0 Liters	0,0%
Direct cost of cleaning:						
Cost of Labour	21	euro p/h	€ 6,30	€ 2,28	€ 4,03	63,9%
Cost of Water	5	euro p/1000l	€ 3,75	€ 1,52	€ 2,23	59,5%
Cost of Chemicals			€ 1,00	€ 1,00	€ 0,00	0,0%
Total direct cost of cleaning			**€ 11,05**	**€ 4,79**	**€ 6,26**	**56,6%**
Annual saving @ 220 working days per year:					**€ 1.376,71**	

The figures for this short HYECON liver belt, indicate a daily saving of € 6,26 + saving on chemicals, adding up to at least € 1.375 /year + detergents @ 220 days per year. This in spite of the short belt is not regarded to be an obvious candidate for automatic cleaning.

<u>Detergents</u>

On this small belt savings on chemicals were not measured. Never the less, chemicals are easily to measure on larger conveyor belts. Normally approx 5% from the complete cleaning time is used for foaming and approx. 3% is used for disinfection.

Adding foam to belts always has to be done very effectively. It seems to be easier to add foam to the very open construction of the complete HYECON Liver belt.

Long open plastic modular belt

In order to get data from other types of flat belts than the above rather short liver belt, it was chosen also to make comparative tests for a 24 m long open plastic modular belt at Danish Crown, which had already a fixed installed CIP system.

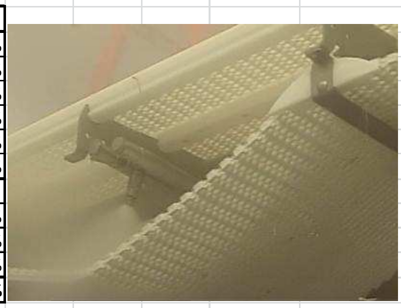
The existing open plastic modular belt is difficult to clean. The professional contract cleaner started cleaning on the frame work after finishing to 100% visual clean he started the automatic cleaning. The revolution time on the belt was approx. 1 minute and 15 seconds. The number of revolutions was 2 for both in and outside. The water pressure was approx. 40 bar.

The contract cleaner was not satisfied because many small pieces of meat were still in the open shackles in the belt. After the automatic cleaning the open modular belt still needed approx. 6 minutes manual cleaning with a 45 liter using zero degree nozzle.

On day 2 we started with the Undine manifold, using 22 bars (less than the original spray bars, which were only acting on 40 bar).

DC Ref system - Plastic modular belt with existing CIP system						DC - Plastic modular belt with Undine/Hyecon CIP system					
Cleaning procedure steps:		P, Bar	Q, l/min	t, min	Water consumpt., liters	Cleaning procedure steps:		P, Bar	Q, l/min	t, min	Water consumpt., liters
1	automatic cleaning original	40	55	7,5	413						0
2	rinse all	22	45	12	540	1	frame cleaning manual	22	45	5,5	247,5
3	foam	22	15	2	30	2	automatic in/out	22	21,5	3,75	80,625
4	main cleaning	22	45	8	360	3	foam	22	15	2	30
5	disinfection	22	15	2	30	4	automatic in/out	22	21,5	1,2	25,8
6	rinse	22	45	8	360	5	disinfection	22	15	2	30
7						6	automatic in/out	22	21,5	1,2	25,8
8						7	frame cleaning manual	22	45	2	90
	Total				1320		Total			6,15	automatic 132
				39,5	all manual					11,5	manual 398

Cleaning data:				DC Ref.	Hyecon	Savings:	
Total duration of cleaning, min.:				40 min	18 min	22 min	55,3%
Labour (man hours) spend, min.:				32 min	12 min	21 min	64,1%
Water consumption, liters:				1320 Liters	530 Liters	790 Liters	59,9%
Chemical A, liters:				0 Liters	0 Liters	0 Liters	0,0%
Chemical B, liters:				0 Liters	0 Liters	0 Liters	0,0%
Other:				0 Liters	0 Liters	0 Liters	0,0%
Direct cost of cleaning:							
Cost of Labour	21	euro	p/h	€ 11,20	€ 4,03	€ 7,18	64,1%
Cost of Water	5	euro	p/1000l	€ 6,60	€ 2,65	€ 3,95	59,9%
Cost of Chemicals				€ 1,00	€ 1,00	€ 0,00	0,0%
Total direct cost of cleaning:				**€ 18,80**	**€ 7,67**	**€ 11,13**	**59,2%**
Annual saving @ 220 working days per year:						**€ 2.447,80**	



The Undine CIP-units removed all pieces of meat, prepared all perfectly for foaming and was also used for removing the foam and the disinfectant. This was not done with the existing spray bar at all.

For cleaning of the long Plastic modular belt, the indication is - just by switching from existing type automatic cleaning to Undine, that there is a daily saving of € 11,13+ saving on chemicals, adding up to at least € 2.445 /year + chemicals @ 220 days per year.

Over all conclusions:

The hygienic design of the HYECON components, the open conveyor frame structure with very few internal elements and the further improved access due to the Quick-Release device together with a cleaning procedure combining manual cleaning of the Frame structure with an automatic CIP of both sides of the belt has proved, that very large savings are possible in cleaning costs, labour and in environmental load due to less water and detergent usage. Also the total cleaning time can be considerably reduced, thus freeing extra capacity for production time.

The measured the savings were:

Water:	approx. 60%
Duration of total cleaning time:	45 – 55 %
Labour (man hours):	64%
Total direct cleaning costs:	56 - 60%

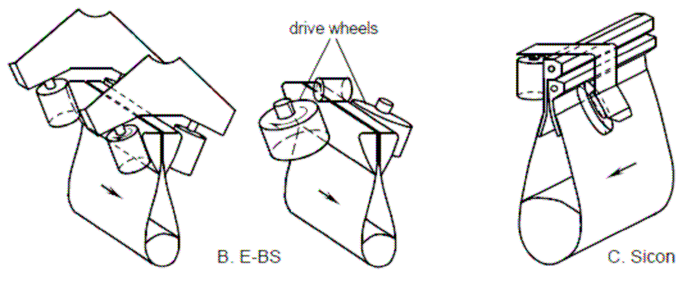
The automatic cleaning of the belt with a the fixed installed HYECON/Undine CIP system removes the human factor from the critical part of the cleaning: the product contact surfaces, and thus it will ensure more consistent cleaning results with the possibility to validate the cleaning procedure. This will be an important tool for maintaining a product shelf life, preventing hygienic problems and possible products recalls.

ii) Closed Belt Conveyor system

Closed Belt systems for large scale transportation bulk solid materials have been used for more than 20 years, mainly for dusty materials such as raw and waste materials for various industries such as Construction, Power, Cellulose, Steel/metal, Mining Processing industries. For the foodstuff industry some use have also been seen for e.g. residual products, raw materials, fish meal, fish feed, grain and pellets. However for smaller scale indoor use for human food products no systems have been seen so far.

In the HYECON project a novel concept has been developed for transporting food products from A to B in a "closed compartment" protected against contamination from the outside environment in the production area and at the same time preventing any product parts to drop, drip or in any other way pollute the environment or contaminate any other food products in the area below the conveyor.

The HYECON conveyor system is based on the pouch type of closed belt conveyors, however optimized for food contact and hygiene, for fitting inside production rooms, e.g. hanging above other production equipment, being able to turn around small radii to fit into existing building constructions and be very flexible regarding the layout of transportation path to adapt to already existing layouts.



The project had to develop new solutions within different areas:

- Mechanical design of suitable size functional modules to configure complete conveyor systems, these designed according to guidelines for hygiene and cleaning.
- Belt materials suited for direct food contact.
- Belt materials and hygienic belt design, which have flexibility for belts being turned around small radii, and the same time have the needed strength and stability for carrying the products and for the needed tension to move the belts, as well as being opened and closed for loading and unloading. This also includes developing suitable manufacturing methods to make belts in various sizes.

Closed Belt system elements

A Product Design Specification (PDS) for the complete system was worked out and modules were defined for the various needed functional elements to build a complete Closed Belt conveyor. The system with modules was sketched in a 3D-CAD model. The PDS and the modules were discussed with the SME as well as with DTI, who was responsible for the material development, and a number of iterations were made.

Based on knowledge from parallel technic, but refined to suit the size and food environment, alternative concepts for various elements and interfaces were at first sketched in a combination of pencil sketches, 3D-CAD models, and for Rollers and Suspension elements also product data sheets and procured samples found in a marked scan. Calculations were made for dimensioning of the "Frame" Backbone structure, which was intended to be self-supportive and take up the needed belt tensioning forces all through the system as "internal forces" without the need to use external building structures otherwise than for supporting/suspension of the backbone structure.

The various concepts were presented and discussed with representatives from the Ellegaard, Danish Crown and hygienic experts from DTI. After selection of concepts all modules were modelled as 3D-CAD models.

For preliminary testing a small functional model /test equipment was designed by TPU and manufactured by Ellegaard per TPU instructions. The test equipment consists of a simple setup with one motor drive unit and a turning wheel at the other end. The overall length of the belt is around 3,5 meters and the width of the opened "drop shape" cross section is approximately 0,6 m. Different diameter turning wheels could be installed, and the length could be adjusted accordingly. Further the pretension could be adjusted, as well as the spacing between carrying roller sets.

The intent of the system was to get "real life" experience and data covering critical mechanical elements, material properties and their interaction:

Critical mechanical elements:

- Carrying and guiding Roller system
- Spacing between Roller sets,
- Belt pretension,
- Minimum turning radius etc.

Properties of belt material for evaluation during:

- Durability of belt material
- Durability of belt to rim attachment
- Initial kinking assessments
- Load effects
- Noise effect

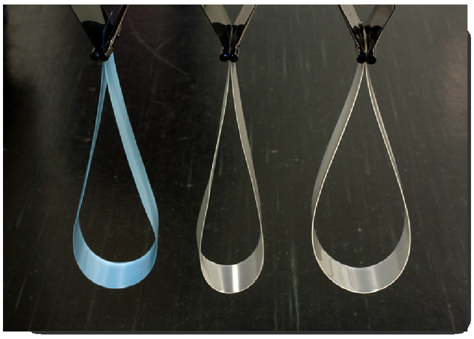
The tests performed at PE and DTI yielded specific input to belt material thickness and durability and to durability of rim attachment to belt material. The second iteration of the belt seems to fulfil the demands and was selected to be suitable for a "full scale" function model. For further details see material chapter below.

As a consequence of the experience gained during the tests a design solution has been developed for a self-adjusting tension equalising unit, which has been included in at patent application.

Belt material and belt design

For the closed belt material completely new materials concepts have been needed as the closed belt conveyor system is regarded as new to the food industry and no similar solutions exist. It was concluded that the development strategy for the closed belt should be aimed at harmless kinking (instead of avoiding kinking) in order to meet the requirements for relatively low turning diameters.

As a consequence, new candidate materials were based on thin foils in the range of 250-1400 µm. The innovative concept of the closed belt system brings along requirements for special features such as design for kinking resistance of the closed structure when transported at turning diameters down to 300 mm. The kinking challenges have been examined through studies of kinking mechanisms and their relation to tube geometry, material properties and turning radius.



The closed belt concept based on thin polymer foils.

Selection of closed belt materials designed for harmless kinking has aimed the materials mapping in the direction of relatively thin foils with thicknesses ranging from 200-1000 µm. The approach identified two commercial candidates for the closed belt material. For the closed belt materials chemical analysis (FTIR spectroscopy) and optical microscopy revealed the following compositions:

- Poly(ether urethane) foil from Epurex Films (no fiber reinforcement)
- EPDM rubber sheet laminated with 'strong bond' layer from Tec Joint (no fiber reinforcement)

All laboratory scale characterisation activities have been conducted on translucent (natural coloured) poly(ether urethane) foils from Epurex Films. Designing the closed belt system has been given special attention to kinking properties due to the drop shaped geometric design proposed. Mechanical testing in terms of cyclic tensile testing has been conducted (25 mm sample width, load/unload 1000 mm/min., 23 °C and 50% RH, amplitude 40% strain, number of cycles = 1000).

Delaminated top layer of EPDM rubber from cyclic loading in tension

Marginally, yet acceptable, softening of the poly(ether urethane) foil from Epurex Films was observed (possibly due to orientation of molecules or heat up mechanisms). For the EPDM rubber sheet the 'strong bond' laminate was observed to delaminate partially from the EPDM base material during cyclic loading, which was assessed to disqualify the material as closed belt candidate.

Examination of friction properties and abrasion resistance has been conducted on closed belt materials using the same approach as for flat belt materials. Testing of friction properties revealed static friction coefficients in the range of 0.7-0.8 (dry surface) and 0.6-0.8 (moist surface), which is evaluated to be acceptable for slaughter house applications.

Test results showed a very high abrasion resistance for the poly(ether urethane) foil from Epurex films (Δm < -0.1 mg/1000 rev, same methodology ISO 9352).

The mechanical testing procedures for closed belt material were concluded with perforation testing in order to evaluate perforation strength of foils in different thicknesses simulating rough handling and assembly routines. Testing was conducted according to FTMS 101C drawing the foil through a puncturing tool at 305 mm/min.

The loads at rupture were noted as a measure of the perforation strength. Perforation strengths ranged from 190-730 N for foil thicknesses of 250, 500 and 1000 µm (for comparison the requirement for Danish land fill barrier foils is 300 N).

Perforation testing of foil according to FTMS 101C

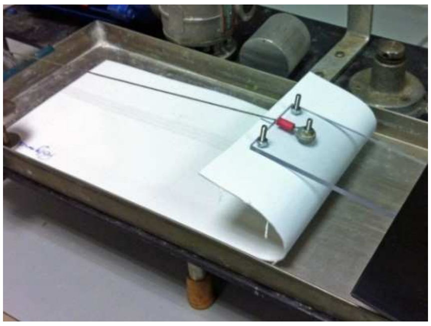
The closed belt system is designed with a thin foil attached to a v-profile, which has the function of transferring mechanical energy during operation. A market scan has been conducted and the following three main types of v-profiles have been investigated:

- Homogeneous thermoplastic material without reinforcement
- Homogeneous thermoplastic material with polymer fibre reinforcement
- Homogeneous thermoplastic material with steel wire reinforcement

The output of the study was selection of a commercial polyurethane v-profile from Volta Belting Technology with polyester fibre reinforcement. The main advantage of the selected v-profile is ease of assembly (overlap joints can be made with simple handheld tool), lower sagging risk, reduction of creep and good cohesion with poly(ether urethane) foil.

An effort has been put into developing and optimizing (hot air) welding parameters for both assembly of v-profile ends and bonding of foil materials to v-profiles. For assembly of v-profile ends both the process for overlap and butt welding have been evaluated with overlap welding showing the highest strength.

The hot air welding process for bonding of v-profile and foil has been optimized using production scale equipment at P. Ellegaard. By variation of heating time, applied power and nozzle positioning strong bonding was obtained without wrinkling issues and length differences in parallel assemblies. The developed welding process was used for manufacturing of the prototype closed belt (24 m in length).



Experimental setup for accelerated chemical exposure of

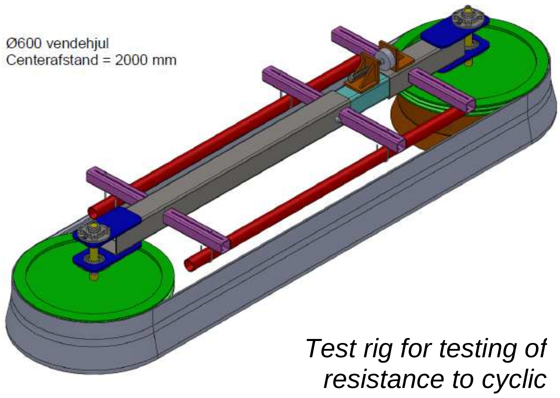
In order to document the reliability of the proposed closed belt concept, experiments to reduce the project risk have been designed and completed. The framework used for stability testing has been twofold addressing both longer term chemical resistance of foil material to repeated cleaning procedures and mechanical stability to cyclic kinking exposure. For stability testing on pilot scale testing rig and the final closed belt prototype white-coloured foils have been qualified (by structural and mechanical comparison with natural coloured foils) and used.

Compared to a selected commercial poly(ester urethane) belt material (reference material), the poly(ether urethane) foil showed slightly faster (surface) degradation when exposed to hypochloride- based disinfection agent and alkaline cleaning foam for four cycles of 23 hours each. The observed (accelerated) degradation rate was assessed to be acceptable for real-life service conditions based on industry experience with similar observations.

The expected main source of mechanical degradation was envisioned to be cyclic kinking exposures. Hence, it was decided to conduct accelerated stability testing on a small test rig with a 3 m testing belt and turning wheels with radius of 300 mm. A foil of 1000 µm in thickness was tested and seen to fail after a duration of 96 hours (0.3 m/s, load = 5 kg/m) corresponding to 35.000 turns at 180° due to destructive kinking.

Similar testing was conducted with a foil of 500 µm in thickness. In this case no, failure could be observed in the testing period of 770 hours (limited by the end date of the project) corresponding to 280.000 turns at 180 °. Due to the stability results the 500 µm foil was used for the 24 m closed belt prototype.

The output of the qualification process gave the following recommendations for final materials selection:



Test rig for testing of resistance to cyclic

- **Closed belt material:** Poly(ether urethane) foil from Epurex Films (Platilon 4251 Y) in white colour, 500 µm in thickness and no fibre reinforcement
- **V-profile material:** Poly(ester urethane) profile with polyester fibre reinforcement from Volta Belting Technology (Volta VMW)

The Closed Belt function model

The aim of the present activities was to develop a "full scale" functional model, which should be used to test, if the concept with the new developed belt solution with food grade material and welded rims and the mechanical solutions would provide a realistic and reliable closed belt conveying system for the food industry. The functional model should be made to test operation with all functional units, and also a linear inclination system for testing different inclination angles should be developed.

Although the system design should take into consideration suspension in the ceiling or on walls/pillars, it was decided to make a transportable stand-alone demo unit, which could be transported and tested at various food industries.

The frame and the layout for the full scale Closed Belt function model was modelled in a 3D-CAD model including all subsystems in more versions at TPU, and via design reviews with the RTD's and the SME's a given setup was agreed upon. Amongst others, it was decided develop a combined Drive- and tensioning module with a drum motor to drive the system instead of a traditional gearmotor. CIP-units, similar to those made for the flat belt system, were installed right after the unload module to simultaneously clean both sides of the belt material, while it is in flat open position.

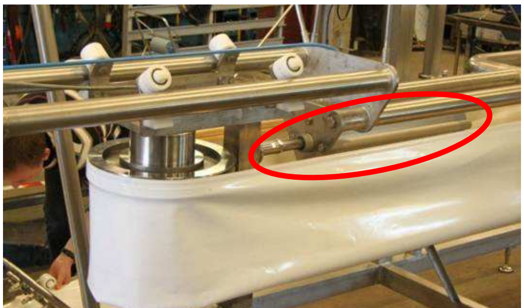
The final function model was designed in a complete 3D-CAD model. With regards to the frame, the model was further detailed, and according to agreement this was build up by Ellegaard in Ringsted to include all the above mentioned subsystems via sketches and supervision from TPU.

Fabrication drawings were made of all individual components for the subsystems. The parts were manufactured by subsuppliers and mounted into the system at Ellegaard's, and the complete system was assembled with the new belt developed.

The system consists of an approximately in total 24 meter long conveyer system with a closed belt profile based on the knowledge developed in the testing equipment. Unfolded the belt is 540 mm

wide and the system consists of several subsystems for real life testing, including:

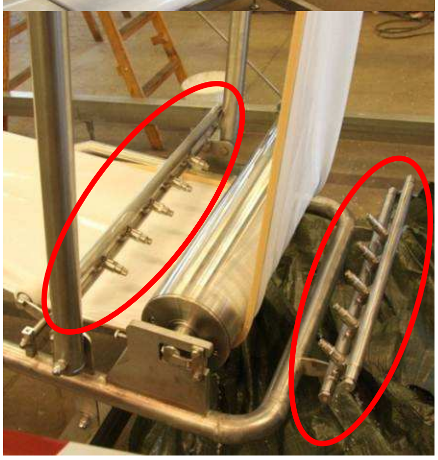
- Frame and system to fit a confined demonstration trailer installation.
- Load system (partly opening of the closed belt profile to get access to the inside of the closed belt profile for product insertion).
- Drive system (based on the HYECON drum motor design with support skirt for the closed belt profile).
- Automatic self-adjusting Belt tensioning system to ensure continued traction and tension in system.
- Linear transportation section.
- 4 x 90 degree turn systems, ø300 mm, with support skirts for support of closed belt profile.
- Linear inclination system.
- Unload system (opening of the closed profile, and turning the "inside out" via two vertical axis rolls).
- Closing and flipping section.
- CIP system.



Belt drive and tensioning

The intent of the system was to get "real life" experience and data covering headlines as follows:

- Function of belt in longer installation with more turns
- Function while transporting various types of materials in the system
- Assess possibilities for including incline sections in the system
- Function of system with small radius turns without kinking
- CIP cleaning installation

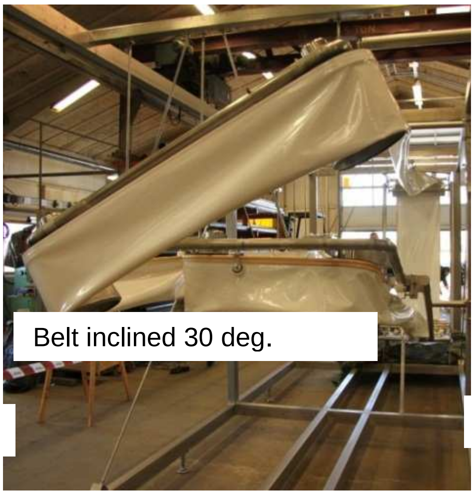


The system was initially tested after assembly at Ellegaard's and modifications were made.

The test results showed that the system after relatively small adjustments did function as intended with regards to the desired test points as describe above and the system successfully transported plastic granulate and plastic parts in the expected closed and easy routing way, transporting it through all the sections from loading to unloading.

CIP system for cleaning each side of

Granules filled into belt in



Belt inclined 30 deg.

Plastic granules unloaded from

Although it was possible to make all the functional elements work more or less as intended, and the overall evaluation looks promising, there is a need for further testing and optimisation, before the system is ready for testing in a real production environment.

Further, the system must be safety protected with wire cage or/and optical sensors before setting it up in external demonstration or testing installations.

DC as a representative for a customer in the toughest segment liked the perspective in the system and would - if possible in the future - test the system in a slaughter house environment, like it was done with the flat belt system.

For further demonstration of the various project components please refer to the following videos:

Hyecon Motor	http://youtu.be/JIONjIF7mAI
Hyecon Dropbelt	http://youtu.be/3-DD6q5Cfws
Hyecon CIP System	http://youtu.be/6qaoO1DK04k
Hyecon Quick Release	http://youtu.be/BI6Xwan0Ero
Hyecon Belt Tension	http://youtu.be/rfOWL5ILkNw

Main dissemination activities and exploitation of results

The SME´s chose jointly to disseminate all findings, in face to face meeting or presentations. Neither of the SME´s wanted to market products and ideas before IPR was secured. IPR was finalized in month of February and March 2012, thus the time for dissemination has been somewhat limited. As Illustrated below we intend to show all findings in a direct way towards the potential customers and partners, but certainly also towards end-users and policy makers. In part of our findings, training or educating users will be essential, namely the new Dropbelt development has to be explained and shown in order to grasp the basic idea of the "corner turning conveying concept".

We have at this point in time established a severe interest on findings, however despite all calculations and theoretical advantages, we need to implement drum motors, CIP systems and dropbelts in the correct and harsh industry environment i.e. slaughterhouses. In this we will be supported by the end-user in the project Danish Crown headed by Mr. Jesper Frørup, Søren Tinggaard and Technical Manager Niels Konradsen. These gentlemen will be introducing the HYECON concept within the DC organization.

As shown below the SME´s intend to participate in various exhibitions focused on food safety.
Further a number of product meetings will take place in Denmark as well as Germany and Holland.

Who/What	*When*	*CIP*	*Drum Motor*	*Belts*	*Dropbelt*	*Accessories*
Exhibition Food Pharma, Herning	13-15 nov. 2012 www.foodtech.dk	X	X	X		X
Danish Crown	Automn 2012 Tour DK	X	X	X	X	X
Tullip, DK	Demo, autumn 2012	X	X	X	X	X
Vion Foodgroup	Demo	X	X			
Marel Food Company	www.marel.com Demo for engineers	X	X	X		X
SFK	Demo on site SFK	X	X	X		X
KJ Engineering	Demo on site KJ	X	X	X		X
Ellegaard Customer days	Demo at Ellegaard production site Viborg DK	X	X	X	X	X
Dissemination web	You tube and other	X	X	X	X	

http://www.expocentral.com/directory/Business/Food_and_Related_Products/Meat_and_Seafood/Tools_and_Equipment/more4

The strategy for exploitation of the result achieved in the HYECON project relies heavily on demonstration and proof of concept. The demonstration activities will be taken care of by mainly 4 sales persons including IWC-International CIP cleaning experts. We realized that face to face discussions with customers in the slaughtering Industry is necessary for us, since new technologies is adopted fairly slowly in this sector. The IWC-International road to success has been to build in installations and afterwards measure the amount of water/detergent and power used, compared with results.

For the drum motor a new set of USP´s (unique selling points) will be developed, since an IP69K motor has not been on the market before and especially a PM motor with low heat dissemination and a constant torque curve. The advantages beside the IP69K has to be calculated with the customer in his environment and this includes: savings on cooling, saving on power, saving on spare parts, realizing that one PM motor can cover the range of nowadays 5-8 motors implying savings on stock and spare parts. Concerning the IP69K implies that high pressure spraying directly on the drum motor will not harm the sealing and thereby let in water which at the end of the day is the main reason for drum motor damages. Further testing will involve the test of vacuuming talcum into the drum motor, during a period of 8 hours with a certain under pressure inside the motor.

Use and dissemination of foreground

The HYECON SME’s have all contributed jointly to the development of the project results. And the results are significant and will be introduced to the marketplace over the coming years. The project progression was somewhat delayed due to the number of iterations we had to go through in order to innovate new components to the industry. The effect was that the project dissemination was limited to seminars and end-user meetings discussing the direction of the innovations going on, hence we did not write up any academic articles mostly due to the fact that emphasis was focused on bringing new components from drawings to real (prototype) products. The SMEs were reluctant to share to the public any information on new elements of conveying and/or cleaning, since this could inhibit the possibilities of patents at the final stage of this project. Therefore any presentation or discussion has been held on a general level identifying the challenges of the industry and indicating new ways of solving conveying and energy consumption issues.

During the project period we have been in close contact with Danish Crown, our end-user. They have delivered a constructive and useful feedback concerning background measurement on water/detergent/energy consumption as well as a valuable insight in processes in slaughterhouses.

Project result no. 1:
The development of the PM drum motor was indeed a big leap in this HYECON project. Included were the IP 69 K approval and some test result on performance underlining LAT/Ellegaard believes in the future market place for hygienic and energy optimized conveyor solutions. We have had very good feedback from the end-user indicating that the number of variants of drum motors could be reduced dramatically due to the fact that a PM motor have a significant wider operating range. Another end-user stressed the idea of coupling the drum motor (PM) and the Quick Release system into one unit. The reflection being that the amount of engineering power being employed to make both conveyor ends could be used more efficiently. Further meetings on this background will take place.

Both LAT and Ellegaard are aware that further efforts are waiting ahead in order to develop the right product range for the food industry. Amongst these are the control box which will have to be designed smaller and smarter. LAT and Ellegaard will be working together on gear optimizations and testing systems for drum motor production.

Overall the development of the PM motor has sparked a new Food product line, which the partners will name HYECON. This line will be addressed not only towards the slaughterhouses but also in a broader food industry context as well as to customers with special request such an extremely slow conveyor belt speed.

Major project findings relating drum motor development:

- Significant energy savings for end-user
- Fewer components in PM drum motor manufacturing
- “Cold” motor does not heat up surroundings
- Fewer motors can solve a much wider range of use
- Reduced spare part stock
- Easy adjustment of motor parameters in PC program
- IP 69 K approval and EHEDG approval obtained.

Project result no. 2:
In close cooperation between IWC-International and RTDs, we have succeeded in the development of an improved CIP (clean in place) system, specifically taken into account the harsh environment in the slaughterhouses. The development of a new designed nozzle brought forward results on cleaning efficiency and water and detergent savings. The CIP system was tested in live situation at Danish Crown, Ringsted, Denmark. Technical Manager Mr Conradsen stressed that automating the cleaning process in slaughterhouses is of great importance in the struggle to keep jobs and production in high salary countries like Denmark. When cleaning manually one tend to overdo the cleaning, applying too much water, too much detergent and too many minutes.

Tests showed significant savings on water and time spend during cleaning using the Undine Nozzle system. Tests were conducted both on own developed Liver belt conveyor but also on plastic modular belts in the production hall of Danish Crown. The overall conclusions were impressive

- Water reduction of 60%
- Cleaning time reduction of 45% to 55%
- Labour reduction 64%

Project result no. 3:
Noticing the vast array of different type conveyor belts running at a conventional slaughterhouse and taking into account the SME knowledge level on chemicals, it was decided to investigate and identify best in class belt for slaughterhouses. Different food applicable belts were engaged in a vigorous testing scheme, testing for friction properties and for abrasion resistance using spectroscopy and optical microscopy.

The Polyester Urethane with no fibre reinforcement turned out to be the recommended choice for the specific harsh slaughterhouse environment. This belt type was also mounted on the test Liver conveyor, which have both quick release and CIP spray bar mounted for cleaning tests.

Project result no. 4:
The aim in this HYECON project has been not to go only for the low hanging fruits but to stretch out and take a chance developing something that would have the potential to alter the industry. In the very beginning no-one believed in the idea of turning corners with a conveyor belt. Even the SME were reluctant to pursue the RTD’s constructive provocations. The kinking problem seemed to be the stopping point of this part of the project. Until the RTDs insisted that instead of avoiding the problem with kinking we should identify the material that could actually handle the kinking. A foil was chosen and a very strong and durable one too. Everyone in the HYECON team was engaged in this wild idea of conveying material inside a “plastic bag”. After intense dialogue and challenging the old conveyor school of thinking the drop belt took form developing a conveyor to transport material in a closed environment that could turn corners and at the same time protect the goods being transported.

A large number of drawings and a substantial number of different material samples lead the way towards a muck-up model just for testing the effect of continuous kinking of the thin foil. Next challenge was to fit a proper profile to this “plastic bag” material. Meanwhile RTDs and SMEs blue collars worked together to build the frame in stainless steel, developing new components for loading and unloading of the Closed belt.
The team managed to finalize a 6 m x 3 x 2.5 meter demonstration unit that actually works. During March demonstrations we gained the knowledge that not only is the Dropbelt a new invention, but it is also attracting quite some interest. Danish Crown representatives could foresee totally new slaughterhouse processes, reducing the dangerous and intensive fork lift driving on the shop floor dramatically. From an economic point of view they also saw clear productivity gains with the Dropbelt being installed, hanging from the ceiling, in already running slaughterhouse facilities.

Dropbelt innovation:

- The kinking challenge is solved untraditionally by introducing a very strong foil as “carrier”
- We proved it possible to turn 90 – 180 degrees
- Material in the Dropbelt can be conveyed upwards up to 30 degrees
- Ceiling hanging system will save square metres and increase productivity
- Multiple loading and unloading stations will be possible
- Strong interest not only from the food sector but also from general industry. Real requests for live on-site demonstrations.
- CIP system can be installed were Dropbelt opens.
- A game changer within material handling has been innovated!
- IPR is secured.