DIRECT DRIVE SYSTEMS AS APPLIED IN MATERIAL HANDLING AND BELT CONVEYING APPLICATIONS

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INTRODUCTION

Until comparatively recently engineers have in general considered two main methods of providing high torque on drive applications operating below 100 rpm.

The most universally accepted solution is the electro-mechanical drive, which utilises an AC or DC electric motor, a fluid coupling and a reduction gearbox.

When variable speed is called for either thyristor or frequency controllers are called upon to provide the answer.

The traditional alternative to the electro-mechanical solutions is provided by hydraulic drive systems.

These have offered two alternatives, either high or medium speed hydraulic motors again relying on gearboxes for the final speed reduction. Where variable speed is required, variable displacement hydraulic pumps driven by standard AC induction motors provide this.

This paper will consider the alternative to the traditional drive solutions, - the Direct Hydraulic Drive, and compare its characteristics with the better known electro mechanical solutions. We shall consider its form and function and particular attention will be focused on the application of Direct Drives Systems in main conveyor drive and conveyor belt tensioning applications.

BACKGROUND

Hydraulic drive systems have long been accepted as providing a compact, flexible and very powerful source of force and motion in a variety of machines.

Over recent years, much development work has concentrated on the electronic enhancement of control systems, with remote monitoring system, data bus interfaces, and process control, becoming commonplace in many hydraulic systems. However, hydraulic motors in particular have also seen spectacular developments.

It has always been widely accepted that hydraulic drives offer unique performance characteristics. They can develop very high starting torques in excess of 200% of rated torque without time restriction; have an extremely low moment of inertia, offer shock load protection and four quadrant drives over a wide speed range. Moreover, when the physical size of the hydraulic motor is compared to its electric motor equivalent, even before the gearbox is taken into account, the benefits of utilising hydraulic drives are even more apparent. However, many of the inherent advantages of hydraulic drive systems are lost by the need to add a gearbox into the drive train when higher torque requirements are demanded. The motor/gearbox solution becomes a compromise to the simplicity of a hydraulic drive adding inertia, mass and complexity to the system.

The latest generation of High Torque Low Speed motors however has forced a re-assessment of previous design constraints.

Standard hydraulic motors are now offered with displacements up to 250 litres / rev, torque capabilities of 1400 Knm, continuous power capabilities in excess of 1200 Kw and a power to weight ratio some 2 times higher than that of conventional solutions.

These advances in hydraulic motor design have in many applications enabled the complete elimination of gearboxes from the drive train, thus allowing the simplicity of a direct drive to be incorporated in machine designs, and providing designers with a new found freedom in the application of drive systems.

DRIVE SELECTION

Every type of machine has its own unique requirements for the driving equipment, usually expressed as the speed of rotation, torque and/or power output. A distinction can be drawn between high-speed drives in which an electric motor can be connected directly to the driven shaft, and low-speed drives in which some form of speed reduction is required in order to adapt to the performance of the electric motor. Typical high-speed applications include pumps and fans, with speeds in the range from 750-3000 r/min.

Common low-speed applications include belt conveyors, bucket wheels, belt feeders, chain feeders, crushers, mills and mixers. In extreme cases the speeds of rotation may be as low as a few tenths of a revolution per minute whilst high torque levels must be maintained – for example in a live conveyor tensioning application

Fig 1: A Bucket Wheel is a typical low speed drive application

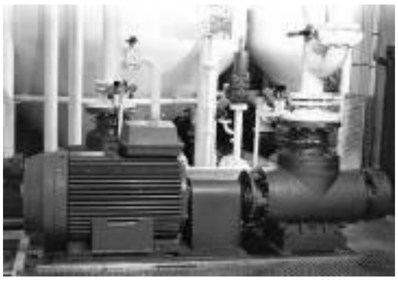


Fig 2: A typical high speed pump drive

It is becoming an increasingly common requirement to adjust the speed of a given machine in order to optimise production, reduce wear or control a process. This can be achieved in principle either by controlling the speed of the electric motor or by varying the gearing between the electric motor and the machine. DC motors, which were the preferred solution in the former case, have to a large degree been superseded by frequency-controlled AC motors. Hydraulic drive systems represent the alternative with variable gearing, although variators and different types of slipping clutches are also encountered and dependant upon torque/power outputs.

HIGH SPEED DRIVES

Conventional electric motors are designed to give their best performance in the 750-3000 r/min speed range. When selecting a size of motor, it is not possible to base one’s choice solely on the rating of the machine, and account must be taken of a number of other factors, all of which can result in the need for over dimensioning. These can include the starting torque, torque-speed characteristic, starting time, moment of inertia of the driven machine, number of starts, stops and/or reversals per hour, not to mention environmental factors such as ambient temperatures. All must be considered.

LOW SPEED DRIVE = GEARED HIGH SPEED DRIVE

A traditional drive system for low rotational speeds consists of a high-speed drive supplemented by a gearbox. There are few suppliers that provide such complete systems. Responsibility for selecting the different components, motors, gearboxes, coupling, inverters etc, so that they function together and also satisfy the requirements of the driven machine usually lies with the machine constructor or the user.

In an appropriately designed drive system the gearbox can account for a major part of the total drive cost dependant upon power output, and machine requirements. It can therefore be appreciated that the specification and design of the gear mechanism is an important procedure, it can quite literally be the deciding factor between high productivity and reliability or unacceptable operating costs.

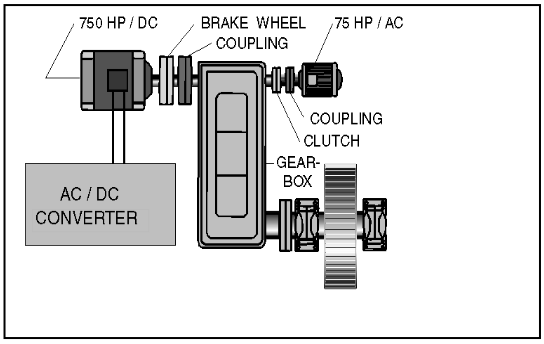


Fig 3: A typical variable speed electro mechanical drive

GEARED DRIVES

Whether the transmission gears concerned are cylindrical gears, planetary gears, worm gears, chain 'gears' or belt 'gears', a number of factors have an effect on operating reliability and service life. For example, torque loads in excess of a gears rated capacity will obviously result in distress to the gears and risk eventual failure.

Many attempts have been made to standardise and consolidate the procedure for the dimensioning and selection of transmissions. AGMA (American Gear Manufacturers' Association) has defined a service factor (SF) which provides a measure of the extent to which a transmission must be over dimensioned in order to meet the set requirements, having regard for external loads, expected service life and operating reliability.

The basic requirement according to the AGMA, for example, is that the bearings in a transmission must be dimensioned for an average service life (B50) of 25000 hours at SF = 1. This is the equivalent of B10 = 5000 hours, at the same SF.

A more realistic requirement for continuous industrial service is for the estimated service life to be equivalent to five years, i.e. B10 = 40 000 hours. The increased service life can be achieved by applying a higher service factor whilst also taking into account any load characteristics of the application.

The drives SF is used to determine the equivalent power rating, which is the result of the motor nameplate power multiplied by the SF. If the application is subject to peak or shock loads further over dimensioning may be necessary.

The thermal capacity, i.e. the power output that is capable of being transmitted continuously at the prevailing ambient temperature, is another factor that may require over dimensioning. The power output capability at 40°C may then be reduced to three quarters of that at 20°C. As an alternative to a larger transmission, separate cooling of the entire transmission or the lubricating oil may be a possible solution.

As the reducer must always be over sized and a significant percentage of the losses remain constant, the efficiency level must therefore drop at normal operating data. If for example the load is reduced from 100% to 50% at fixed speed, approximately 75-80% of the losses remain. This would result in the overall efficiency for a 3-stage planetary gear reducer being reduced when operating at 50% of rated capacity.

Variable speed imposes its own requirements in respect of the satisfactory lubrication of the transmission, including at low speeds of rotation. A normal splash lubrication only function in this case if the oil level is increased, which in turn brings greater losses and heat generation at higher speeds of rotation. (See Fig 4)

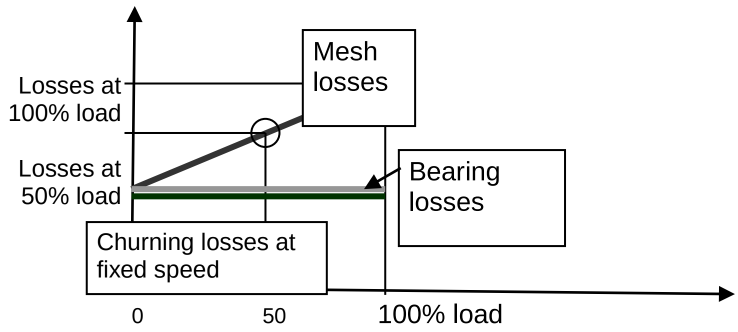


Fig 4: A high proportion of gearbox losses remain constant irrespective of load

When all factors are considered together in accordance with the manufacturer's instructions, this will produce the total service factor, which determines drive sizing.

Unfortunately not all manufacturers apply the same dimensioning standards. More often than not, awareness of the actual loads in a machine is lacking. Experience of similar applications is frequently the only reliable reference base for the designers and users of a machine.

Whilst AGMA's SF which are minimum values are of assistance, it follows of course that if experience is lacking, the resulting choice will be a more or less acceptable compromise between the requirements for reliable function and low cost.

LOW SPEED = DIRECT DRIVE

Today's high torque hydraulic motors offer the possibility to drive some low-speed machines entirely without the need for reduction gears.

Let's therefore consider the alternative to geared Drive Systems. In order to appreciate the potential benefits offered by the Direct Drive System, it is first necessary to understand and appreciate some of the features.

THE DIRECT DRIVE SOLUTION

The direct hydraulic drive comprises of two main components, a Direct Drive High Torque low speed hydraulic motor and a hydraulic power unit.

HYDRAULIC MOTORS

The majority of high torque low speed hydraulic motors fall into the radial piston type either of a multi lobe cam ring design or of the eccentric type. Whilst both have in general terms similar performance capabilities we shall for reasons of expediency focus on the heavier duty and larger displacement cam ring designs which are traditionally applied to the continuous duty industrial market application areas.

These units can, due to their high output torque characteristics be mounted directly to a machines drive shaft via either a spline or friction coupling. A torque arm is utilised to counter the reaction force whilst eliminating undesirable forces on main motor bearings. Bedplates and further coupling arrangements are therefore eliminated, simplifying mounting and alignment issues.

Such motors are multi stroke hydraulically balanced units, incorporating a number of pistons working in radial bores in the cylinder housing. This symmetrical design allows the piston assemblies to work in such a way, that radial forces are opposed to each other, the hydraulic forces being in balance. (Fig 5)

The linear radial piston force creates the useful torque producing tangential force by the reaction of the cam roller against the cam ring. The cam roller is a simple hydrostatic bearing assembly and the reaction force is translated into rolling friction by roller bearings acting along the motor guide plates.

This results in unloading the piston from side forces, the mechanical losses thereby being kept to a minimum and resulting in extremely high torque efficiency, which approaches 97% from, start up from any angular position. It follows this relationship that the differential pressure experienced across the motor will directly relate to the torque produced at the machine drive shaft.

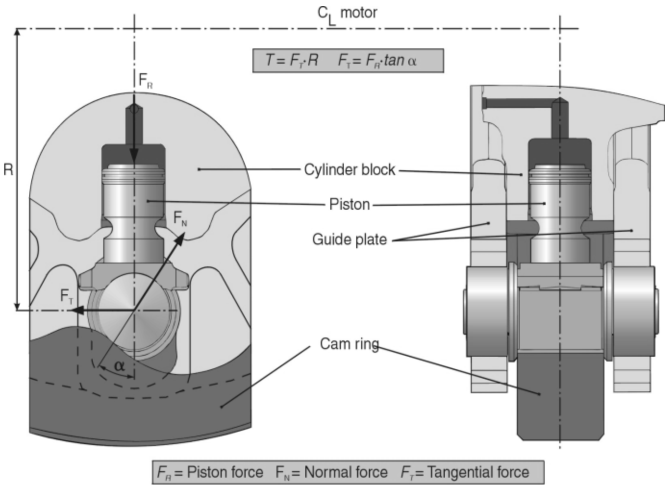


Fig 5: Reaction Forces are eliminated by guide plate bearings

POWER UNIT

The hydraulic power unit supplies fluid to the high torque motor and can be positioned remote from the driven machine.

Power units for such drive applications are predominantly designed as a closed loop hydrostatic system and briefly comprises of a standard AC induction electric motor, a closed circuit hydraulic transmission pump along with an oil tank, filters and the electrical junction box for control interface. The closed loop principle reduces the amount of oil required in the system and reduces tank and component sizing. The diagram below shows the basic design concept of a closed loop system. (Fig. 6, 7)

The pump units predominantly utilised are variable displacement axial piston units which have the benefit of being able to control oil flow output from zero to the maximum system demand. The displacement command will dictate the rate of oil flow from the pump and hence ultimately the speed of the drive motor. The pump flow is controlled by the angle of a swash plate on which the rotating piston group acts.

Fig 6: A power unit supplies fluid to the hydraulic motor

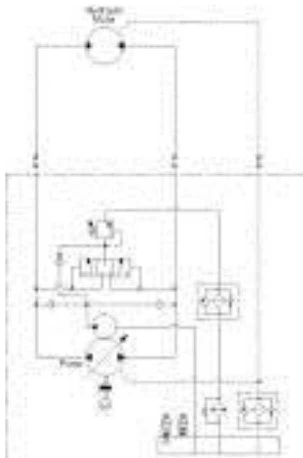


Fig 7: Closed Loop Hydraulic Circuit

To control pump displacement a variety of control modules are available but predominantly an electrical signal is utilised.

The electric motor or motors in multiple drive systems start in an unloaded condition and run at constant speed driving the hydraulic pump.

With oil flow and hence driven shaft speed being controlled by virtue of the pump swash plate angle the prime mover can operate at its rated speed 1470 / 1780 Rpm, (50/60Hz), thus removing the need for electric motor speed control systems and any associated limiting effects. With stopping/starting, reversing, speed control and acceleration / deceleration ramps all catered for by virtue of the pump signal displacement there are no limits to speed control. (Fig 8a, 8b)

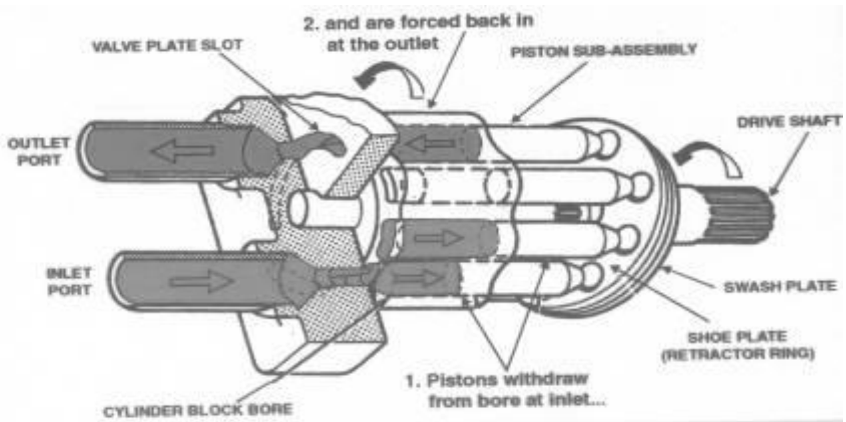
Hydraulic pumps of this design type are usually supplied with a pressure compensator, which operates in such a way that once a pre-determined pressure is experienced, the pump swash plate returns to the zero position thereby producing no flow. In this condition the pump will however maintain pressure thereby allowing full shaft torque to be developed by the hydraulic motor even at stall.

A stall torque condition can be maintained indefinitely without any detriment to the system. As the oil flow has been effectively zeroed (there are some small flows being maintained to maintain pressure) there is no heat generation and therefore power consumption is low. Its worth noting that the absorbed power in a hydraulic system is calculated as follows:

Power (Kw) = Flow l/min x Pressure (Bar) / 600

This important “stall torque”/”torque limiting” feature affords engineers the ability to accurately predetermine the maximum forces a machine will experience. Whilst compensators are adjustable the setting ensures that the actual torque produced at the drive shaft cannot be exceeded affording protection to the driven machine and its components.

Power units in the mine environment are usually of the industrial design, totally enclosed and suitable for mounting in the working environment.



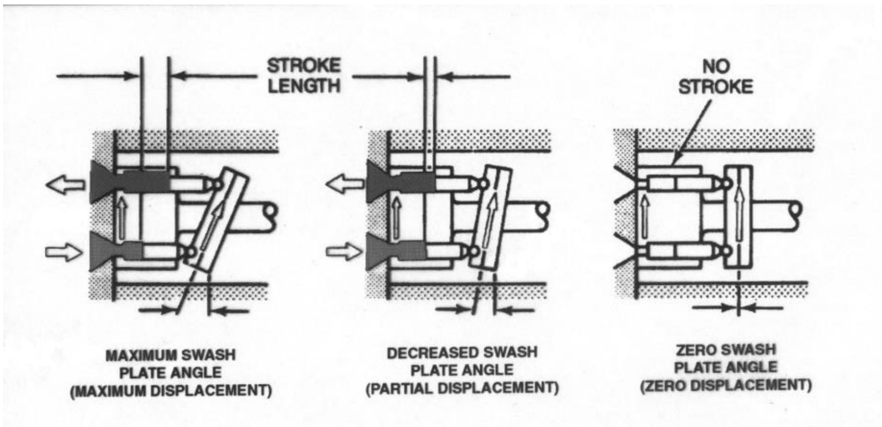


Fig 8a 8b: The pump swash plate angle determines oil flow and hence speed of the drive

COMPARISON OF VARIABLE SPEED DRIVES

The different types of variable speed drives that exist on the market have different output characteristics of torque and speed. It is important to know the differences when selecting the drive especially if final speeds or accelerations are undecided, when the torque levels can vary or when a high breakaway torque is needed. Below is a short comparison between the variable speed drives that are commonly used today, variable frequency AC electro mechanical, Hydro/Mechanical and Direct Hydraulic Drives.

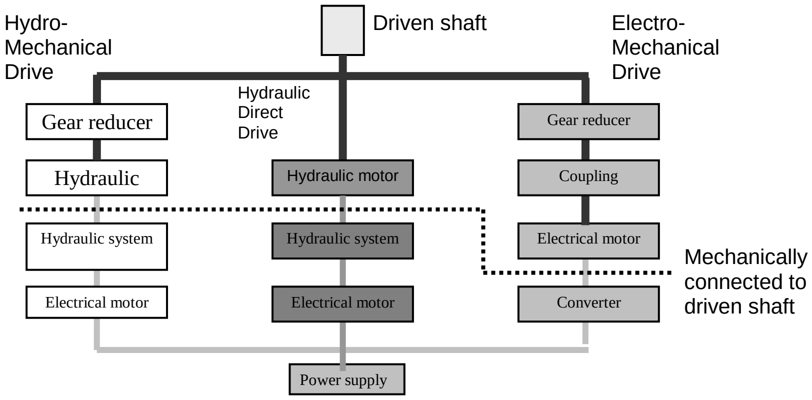


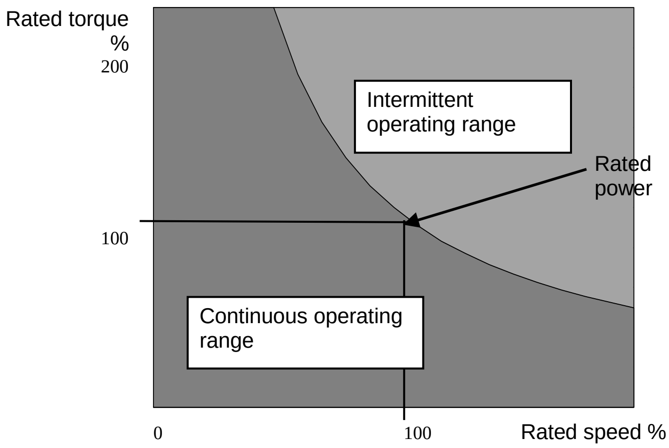
Fig 9: Drive Alternatives

DIRECT HYDRAULIC DRIVES

A Direct Hydraulic drive can operate continuously throughout the entire speed range up to 200 % of the normal operating torque from zero to full speed. The speed range is determined by the displacement of the selected pump and the installed electrical power, see fig.10

The drive can operate above the installed power rating with the same limitation as any fixed speed electric motor with equivalent service factor.

Fig 10: Direct Hydraulic Drives



Performance Characteristic

The drive solution has an advantage during ramped acceleration cycles, high torque low speed conditions high frequency of loaded stops and starts or during prolonged overload conditions. Loads that exceed the maximum designed torque requirement are effectively avoided by a pre-set pressure limiting function, which de-strokes the pump. This, coupled to the low moment of inertia of the drive, serves to limit overload forces within a machine.

The standard drive can operate in both driving and braking mode, forward and reverse (4-quadrant drive) without any special accessories or considerations.

HYDRO/MECHANICAL DRIVES

This drive consists of a medium or high-speed hydraulic motor in combination with a gear reducer, normally a planetary gear reducer. The drive has basically the same torque and speed characteristic as a direct drive.

The main difference between these two types of drives is that when introducing a gear reducer, the mechanical losses will increase which reduce the output torque. How much depends of type of gear reducer, number of gear stages and how much the gear reducer is over sized. The gearbox in some applications must also be over dimensioned for shock loads.

The addition of a gearbox also increases the moment of inertia of the drive.

ELECTRO-MECHANICAL VARIABLE FREQUENCY DRIVES

A variable frequency alternating current (VFAC) or variable voltage variable frequency (VVVF) drive consists of a frequency converter, an electric AC induction motor and a high-speed coupling. For a low speed, high torque application, a gear reducer with a low speed coupling has to be added.

The speed of the induction motor is controlled by regulating the frequency of the supply voltage. The controlled frequency range for the heavy-duty drives is considered to be from 0 to 100 Hz. When running at the rated frequency 50/60 Hz, the VFAC drive can operate continuously at 100% of the electrical motor rated torque. At lower frequency/speed the allowed continuous torque is reduced, see figure 13. At close to zero speed the continuous torque is limited to approximately 70% of rated torque for a self-ventilated induction motor. The VFAC drive can intermittently operate above 100% of rated torque, i.e. up to 150% during 1 minute every 10 minutes. The starting torque can intermittently, for a few seconds only, be in the 180-200% range. A VFAC drive selection must be based on its continuous torque capacity over the required speed range. This is an important consideration if the drive is to experience high torque of low speed or prolonged acceleration times that may require some over dimensioning.

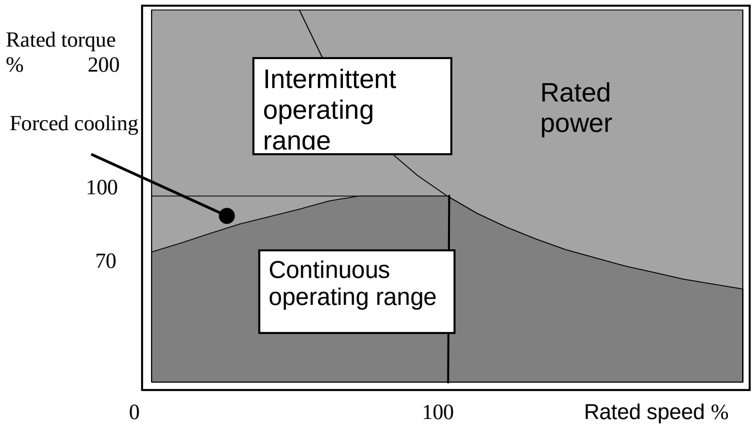


Fig 11: AC Variable Frequency Drives Characteristics

APPLICATIONS OF DIRECT DRIVE IN CONVEYING APPLICATIONS

Hydraulic drives have successfully been used in the Mining and Materials Handling industry for many years, the advantage of the high power to weight ratio having been long recognised in many applications. Today, hydraulic drives are used in a wide variety of applications such as apron and belt feeders, bucket wheels, belt tensioning systems, chain conveyors, however in recent years we have seen the applications growing in conveyor applications.

PURPOSE OF BELT TENSIONING DEVICE

The operation of belt conveyors under varying load conditions demands that the conveyor tension requirements are carefully evaluated.

Whilst tensioning is considered critical by conveyor designers for reliable trouble free conveyor operations the effects of inadequate poorly maintained or inappropriate application of tension devices by some end users or contractors often proves costly.

Whilst there are many methods employed to tension the belt the main functions required by the device will include:

1. To ensure adequate slack side tension (T2) is applied at the drive drum to prevent "belt slip" during start up.
2. To accommodate for changes in the length of belt due to the elastic behaviour, during the starting/stopping acceleration and various load conditions.
3. To maintain a minimum constant tension in the belt at all times avoiding belt sag.
4. To avoid over tensioning and stressing of the belt and the conveyor components during start/stopping.
5. Provide belt storage for advancing/retreating conveyor systems.

When these requirements are reviewed, one is forced to consider if how the features of a direct hydraulic drive might well benefit a conveyor when applied to a live tensioning device such as a winch.

DIRECT HYDRAULIC DRIVES FOR TAKE UP SYSTEMS
The hydraulic motor provides a high torque rapidly acting drive, which can be directly mounted to a winch drum, which in turn is connected to the take up trolley by a rope.
The hydraulic motor torque output is controlled by pressure within the motor which is directly proportional to torque output due to the previously stated high mechanical efficiency.

As the motors mechanical efficiency remains constant, irrespective of direction of rotation, starting position or speed then the torque applied to the winch rope and hence the conveyor take up trolleys will also remain constant.

Since the motor can develop the necessary torque, without the assistance of gearing the resulting winch is a compact fast responding unit with the added advantage of low inertia. (Fig 12/ 13 below show winch unit and position on loop take up)

Fig 12: The winch unit incorporates a fail to safe spring applied hydraulic release brake.

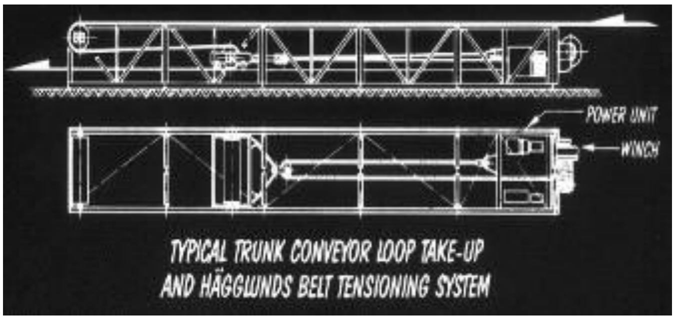


Fig 13: A typical 6 lap Loop take up configuration

HYDRAULIC POWER UNIT
The hydraulic power unit runs continuously, automatically maintaining belt tension by sensing pressure – hence load within the system.

There is no need for load cells, as outlined previously pressure is a direct measurement of torque developed, however they are sometimes installed purely to cross reference data and allow calibration.
The system facilitates operation in both automatic and manual mode.

With selection of the automatic mode, (Auto constant tension) mode a mooring function is engaged by which any line pull greater than the “preset” tension will cause the winch to “payout” whilst any pull less than the preset tension will cause the winch to “Haul in”, automatically self tensioning and maintaining a constant belt tension for all operating conditions.

The manual mode allows for local operator intervention facilitating “Haul in” and “payout”, for maintenance belt maintenance, etc.

Constant tensioning feature of the system is provided automatically within the pump package, and the system offers the added facility to set and select different tensions for different operational requirements, starts, stops and running. On some conveyors the difference between start / stop and running tensions being in the order of 50%

It follows that as a compact and mobile self contained system a unit originally applied to a dual tension fixed length conveyor may in time be transferred to a variable tension extending conveyor.

APPLICATION HISTORY

Hydraulic tension units have now been commonly applied on numerous underground mine and tunnelling projects in addition to surface conveyor applications, in many countries around the world including the UK, China, Australia, and USA.

TUNNELLING CONVEYORS

Tunnelling projects require their supporting dirt and spoil removal systems to be almost constantly available and for that reason conveyors systems are often selected in preference to the intermittent nature of train/car systems.

To assist in the continuity of tunnelling operations large belt storage systems are demanded, thereby facilitating constant extension of the belt line, increasing Tunnel Boring Machine utilisation. These spoil removal systems on conveyors, some of which exceed 15 kilometres in length, with multiple horizontal bends demand sophisticated conveyor designs.

Fig 14: Belt tension unit on CTRL 6.5 Km tunnel with 660 m 12 lap loop storage unit

Fig 15: Tunnel bend- Heathrow Extension Train tunnel

Belt tensioning systems are of vital importance, typically located at the portal of the tunnel, they must provide vital functions:-

(a) Ensure adequate tension to prevent belt slippage and ensure belt sag does not become excessive causing belt tracking or other associated problems.

(b) Provide the necessary belt storage facility for belt extension during Tunnel Boring Machine operations, as the tunnel then extends. Storage according to Continental Conveyor Ltd, recognised experts in this field, is typically 400-660 metres of belting. This providing 200-300 m of tunnel extension without interruption of operations.

The tensioning winch allows belt to be extracted from the storage system whilst maintaining constant tension on the belt system. The system must have the ability to offer different tensions for starting, running and stopping the system, whilst the ability to vary tensions depending upon belt length deployed in the tunnel is also a requirement

Conveyors having used or presently utilising such systems during construction include the Channel Tunnel Rail Link, Barcelona Metro, UTE Guadarama and Karahnjukar Dam (Impregilo) Iceland.

UNDERGOUND COAL MINING

Deep coalmines place their own specific requirements on equipment, not least being that all equipment must conform to the latest relevant ATEX legislation. The same conveyor belt tension systems have been successfully deployed in UK Coal and other underground mines for many years.

Daw Mill Colliery is situated in the UK a 3.7 m tonne / year coal mining operation. Today the mines coal clearance system utilises Continental Conveyors Tension Master Loop take up systems which utilise direct drive hydraulic motors

With ten years operational experience of the units Daw Mill has also decided to utilise the same units on their latest trunk belt installations.

Daw Mill Loop Take Up Units

Year	Qty	Name	Carriage Tension-Start	Carriage Tension-Run	Carriage Speed M/S	Rope Ø	No. of Layers	No. of Reeves
1997	1	SID3	235.3kN	225.6kN	.16	20	2	2
1997	1	300'S	141.3kN	136.4kN	.13	20	2	4
2001	1	301'S	235.4kN	-	.16	20	2	4
2004	2	31'S (Face)	480.0kN	360.0kN	.13	22	3	6
2004	1	302'S (Tail Gate)	235.4kN	-	.13	20	3	4
2004	1	302'S (Main Gate)	450.0kN	300.0kN	.16	22	3	6

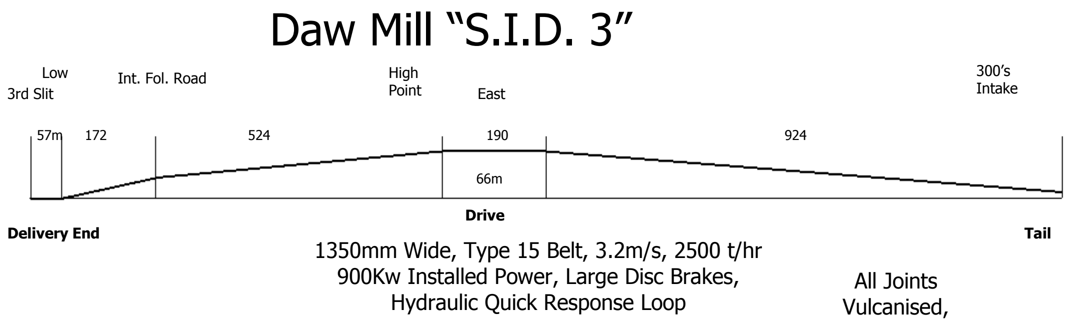


Fig 16: SID 3 – is a 2500 tph, 1350 mm wide, type 15 belt with an installed power of 880 Kw. The belt speed being 3.2 m/s it is also undulating with the possible loads going from 440 Kw driving to 600Kw regenerative. Loading and discharge at similar levels.

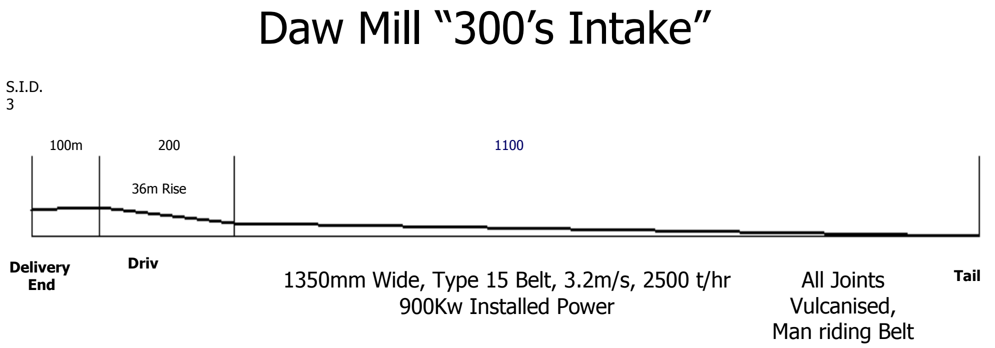


Fig 17: 300s is 2500 tph , 1350 wide , type 15 with installed power of 880 Kw belt speed 3.2 m/s the belt is uphill –with a 80 m lift over its length.

Fig 18: Direct Drive loop take up on Daw Mill SID 2

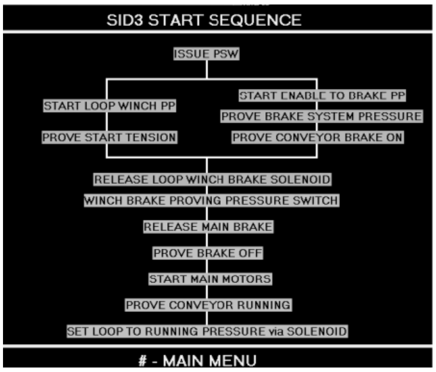


Fig 19: The Start Sequence from Mine Control

The applications of these units in both underground and surface installations have proved to be beneficial providing:

- Fast response to tension changes
- Multiple tension facility (Start, Running and Stopping)
- Can allow tensions to equalize after conveyor stopping
- Dynamic advance of tail loading sections on gate belts
- Lower maximum loads on loop structure
- Retro fit to existing loop units

BELT CONVEYOR DRIVES

Conveyor engineers have always recognised the need to avoid high tensions in belts and to control belt acceleration and deceleration dynamics. To this end the traditional electro mechanical drives with a variety of fluid couplings have endeavoured to achieve the compromise between developing adequate torque for the various belt starting conditions whilst simultaneously controlling the prime movers inertia, to reduce the dynamic loadings experienced during the various stopping and starting conditions.

This has proved at times to be a difficult task and proves more difficult as more sophisticated higher capacity higher-powered longer belts are contemplated. Multiple drives add to the complexity, as load sharing must be taken into consideration.

However in recent years Direct Drive systems have been applied as main drives on conveyors of varying size and capacity.

If we consider some of the inherent features of the direct drive it can be seen that when applied to a conveyor, features such as, controlled torque application and unrestricted speed and acceleration control can offer substantial benefits for some conveyors.

LKAB ORE SHIPMENT TERMINAL – LULEA, SWEDEN

LKAB is a modern process industry and one of the worlds leading producers of refined iron ore pellets, which are shipped to the worlds steel mills.

Situated in the north of Sweden the sophisticated loading and discharge systems permit year round operation despite the plants remote location 110 km south of the Artic Circle.

The facility has a design capacity of 8550 Tph with an operating capacity of 8000 TPH. Train unloading with 52 cars (4000 tonne capacity) takes thirty minutes and is a rolling discharge.

All the conveyors on the plant were designed by Roxon and the Hagglunds contribution was the supply of the main conveyor drives.

A 240 m long 2 m wide 8550 Tph rated conveyor carries and elevates the ore 40 metres where it is discharged into three silos. The drive is provided a single hydraulic motor type MB 1150, which is mounted directly to the conveyor drive drum. The power unit contains 5 x 315

Kw electric motors all of which can be run independently depending on required running parameters, giving a total installed power of 1575 Kw

Fig 20: 1575 Kw drive on the 8500 Tph inclined conveyor

Fig 21: LKAB LULEA Shipment Terminal

It was essential that the drive rpm could stop and start fully loaded and operate at low speed depending on discharge requirements. The hydraulic drive system's speed can be varied from 0 to 45 rpm whilst maintaining full torque.

Discharge from the silos is via chutes to a 183 m long 1.6 m wide conveyor which carries ore to the ship loader. The loading capacity is 3500 Tph and the drive is provided by a single CA 140 with speed range of 0 - 73 rpm and an installed power of 315 Kw.

Fig 22: LKAB's 3500 Tph conveyor showing the Hydraulic direct drive directly mounted to the drive drum.

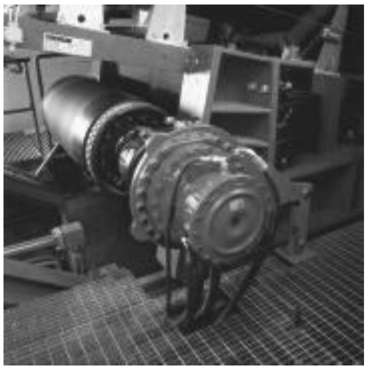


Fig 23: The motor includes a rear mounted brake Total installed power 315kW

Being able to "crawl "the conveyor during loading and unloading is a major advantage. The pellets are round and pretty well uniform without smooth stops and starts there is a risk of product rolling back down the conveyor, which is at a 12 degree incline.

The installation at Lulea's is an example of how a direct drive can offer operational benefits to an end-user.

FOSTER YEOMAN – GLENSANDA, SCOTLAND

Working in a remote area without any history of major quarrying was an enormous challenge. However, Foster Yeoman team at Glensanda has created a world class quarry operated by a very efficient and motivated team.

The quarry located 520 metres above sea level is being developed in a series of 20 metre benches with high capacity primary crushing. The material is then transferred by the 'Glory Hole' method - a vertical shaft 300 metres deep into the mountain connected to a 1.8 kilometre long tunnel conveyor, which transfers the aggregate to the Processing Plant on the foreshore. This produces a wide range of dry and washed aggregate stored in large capacity stock piles ready for ship loading. Glensanda Harbour can receive vessels of over 100,000 tonnes loading at 6000 tonnes per hour. Ultimately the quarry will reach 15 million tonnes per annum through phased development

Fig 24: Foster Yeoman - Glensanda operation has used
Direct hydraulic drives on its 1850 meter long main conveyor

When considering the requirements of the main 1.8 km conveyor Foster Yeomans project team viewed the long term development of the quarry. The initial capacity required would only be 2000 Tph building in stages to 6000 Tph. The conveyor would also be critical to the entire operation of the quarry, due to terrain there is no alternative method of transporting material from the "Glory Hole" to the process plant

It was essential that the conveyor drive must be able to achieve start up in a fully loaded condition but without straining the belt. For this a high torque drive would be required that could develop its torque at low speed and over extended acceleration cycles. It was also considered that as the quarry was going to develop over a period of time there was little to be gained in running the belts at speeds relative to 6000 Tph for lower tonnages, the idea of using a variable speed would therefore be advantageous.

Foster Yeoman decided to install hydraulic drives on their conveyor. The system comprised of 2 Hagglund MB 400 motors one mounted either side of the drive drum. A power unit would utilise three electric motor / hydraulic pumps and sharing a common oil reservoir. The three electric motor / pump sets provided Yeomans with a facility to operate on just one electric motor pump set for their lower tonnage requirements whilst using further motor / pump sets as greater speed was required for increased tonnage, resulting in reduced running costs over the first years of operation.

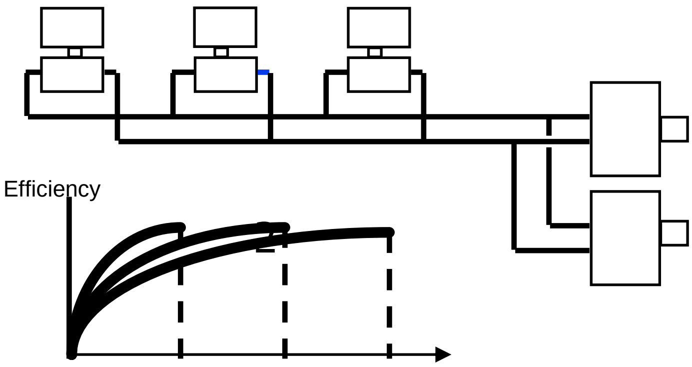


Fig 25: Three motor pump sets can be used simultaneously or independently
depending upon operational requirements.

It also provided an added security , if an elecric motor or pump failure occurred a standby unit could be used.

The conveyors acceleration rate is presently approximately 35 seconds from 0 –full speed of 3.5 m/s, however the start time is easily altered by adjusting the ramps for the pump stroke.

The conveyor does on most occasion's have to start in a fully loaded condition and it is these situations when the smooth torque transmission of the drive is critical. The drive develops its torque from standstill and gradually accelerates the belt to speed. It is a very smooth power transmission, which is always under control and is sympathetic to the belt. There are none of the dynamics normally associated with starting a belt of this size.

One of the benefits realised has been during maintenance operations, and belt inspections. The belt is 2 metre wide ST 1250 with 9mm and 5mm covers and there is 3200m of belt through the tunnel. There is a maintenance station at the mouth of the tunnel.

Foster Yeoman's have utilised the low speed capability to creep the conveyor stopping as and when required, thus making inspections, maintaining and replacing belt much easier and reducing down time. It also helps in maintaining the rip detection loops, which are placed every 50 metres in the bottom cover of the belt, and the 16 joints at approximately 250 m intervals.

The unique application requirements of Foster Yeoman where satisfied using the versatility offered by the direct drive concept.

CONCLUSION

Direct hydraulic drives have proved themselves to be highly robust and versatile in many tough Mining and Material Handling applications from apron feeders to bucket wheels reclaimers and crushers

The concept as outlined above has also offered substantial benefits in some conveying applications.

Whilst it has not been specifically promoted or identified, there are today numerous conveying applications around the world successfully applying this technology.

Conveyor applications utilising direct drives range from installed powers of 37 to 2.5 MW and belt lengths from 30 to in excess of 3000m with tonnages from 400 – 8000 Tph on a variety of materials, on both conventional and tube conveyors.

The conveyor tensioning systems utilising a hydraulic winch system offers a fast responding variable live tensioning device that has been successfully deployed on numerous mine and tunnelling projects around the world

Understandably the features a direct drive offers are not always required on all conveying applications however on some applications this technology offers substantive benefits and has proved itself to be worthy of serious consideration.

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