Paper No. 53

Hydraulics/Fluid Power

Development of Low Speed High Torque Hydraulic Motors and Direct Drive Technology for HMS

Ashok B. Amin Hagglunds Drives Inc.

HEAVY MOVABLE STRUCTURES, INC.

TENTH BIENNIAL SYMPOSIUM

OCTOBER 25 - 28, 2004 The Omni Orlando Resort at ChampionsGate **Abstract;** Describe the history and progress of Low Speed High Torque hydraulic motor, principle of operation of LSHT motor, Features, Improvements & key technical performance of these items applicable to Building and Construction Industries including HMS. Various accessories like Valves, Brakes, Winches, Brackets, Speed sensing devices, etc. Discuss some of these typical applications and concepts. Pros and con's of such devices. Discussion of hydraulic schematic & electronics controls. Reliability and preventive maintenance issues related to LSHT drive.

Introduction; The Building and Construction industry has always placed a high demand on equipment reliability, productivity, efficiency and performance. In today's competitive market place these demands are of even more interest.

Electro - mechanical drives have in the past been the traditional drive in this industry when variable speed has been called for. Today the Hydraulic Direct Drive solution can in many cases be an alternative to the electro-mechanical drives. The hydraulic drives has proved to be a real alternative on applications where Load sharing is essential and in applications where high starting torque is needed and flexible productivity at various capacity needed without sacrificing efficiency using modular flexibility. <u>Hydraulic</u> drives are used in many applications with increased popularity and reduced maintenance. Hydraulic direct drives utilise standard components and are very easy to install on the driven machine shaft without the need of gear reducers or foundation.

Basic concept; A direct drive hydraulic drive system consists of

- a low speed high torque hydraulic motor
- an electric motor
- an oil reservoir
- a pump
- and a control system ,
- In most systems, the equipment except the hydraulic motor, is located in a sound insulated cabinet. The hydraulic motor and the pump are connected to each other by flexible hoses and/or steel pipes. (see fig.1).



Fig. 1. Direct Hydraulic Drive

The **hydraulic motor** (see fig. 1a, 1b & 1c) is a hydraulically balanced radial piston cam curve unit with a mechanical efficiency approaching that of a roller bearing resulting in outstanding torque efficiency. A torque arm is utilised to take out the reaction force whilst eliminating any other undesirable forces on motor bearings. Wide range of motors is available today from 76 cu. in. up to 15338 cu. in. displacement with a torque output of max. 1 000,000 FT-LBf and speeds up to 400 rpm.



Figure 1a, Low Speed High Torque Hydraulic motor, rotating housing type, known as Viking motor.



Figure 1b, Low Speed High Torque Hydraulic motor with large through hole & rotating shaft (1970's)

This motor is known as Hydrex.

Hydrex motors are still produced and available, however they have not been improved with any further research and advancements as a result they are not as economical as newer modern motors like Compact CA & CB, which offers more advantages in size, performance and cost. Hydrex still has largest through hole available for some applications.



Figure 1c,

Low Speed High Torque Hydraulic motor with through hole & rotating shaft (modern 1994). This motor is known as Compact CA for up to 51000 FT-LBf torque & larger sizes up to 204000 FT-LBf torque.



Modular Simple design

- Many sizes available, torque range from 5000 FT-LBf to 1000000 FT-LBf. per motor.
- From 10 HP to 2100 HP
- From 0 to 400 rpm

Figure 1d;

Multiple Cam Rings motor with rotating hollow shaft or female spline & through hole.

(2 cam rings shown, up to 5 cam ring motors available)

Uses same pistons & cam rings, more standard components.



The power of hydraulics

The unique radial piston cam curve design



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Slide 1

L.S.H.T. Hydraulic Motors Development



1960



1978



1983



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Slide 3

2002



Research and Development

One of the largest and most modern hydraulic laboratories in Europe.



- 11 test rooms
- Continuous development of technology and processes
- Skilled personnel

Hägglunds has over the last years invested substantial amounts in development and expansion of the laboratory.

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Slide 4

Extensive research has helped with improved performance and most advanced products available today in a larger volume and standardize modular economical options.

The standard **Power Unit** is designed as a closed loop hydraulic system for continuous high integrity drive applications. The unit consists of a standard AC induction electric motor and a hydraulic pump. The electric motor starts up in an unloaded condition and runs at constant speed, driving the pump. The pump is a variable displacement unit, the displacement of which determines the flow and therefore the final speed of the drive.



Figure 1c. Direct Hydraulic Drive (power unit, Single pump, Double pump unit)

Alternatives of variable speed - high torque 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 a wide speed range is called for, when the torque levels can vary or when a high breakaway torque is needed. Below is a short comparison between the **DC**, variable frequency **AC** and hydraulic direct drives. See fig. 3 & 4



Variable Speed Drives Alternatives



Fig. 3



Slide 19

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Figure 4. Hydraulic drives characteristics

Electro-mechanical variable frequency drives;

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

The VFAC drive can operate continuously at lower speeds up to 40 % of rated torque for standard drives and up to 70 % of rated torque for drives with forced cooling. At synchronous speed the continuous operating torque is approx. 90 % of rated torque and available within +/- 10 % of the nominal frequency, see fig. 5.

The drive can intermittently operate up to 150 % of the rated torque for a few minutes and at starting operate at 180 % of rated torque for a few seconds.

A VFAC selection must be based on its continuous torque capacity over the entire speed range. This is a most important consideration due to limitations, especially at lower speeds.





VSAC Drives performance

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Slide 20



Comparison of Direct Hydraulic Drives - VSAC

Fig-5a

Using Features of Direct Hydraulic Drives and Maintenance practices Applications like Heavy Movable Structures, Bridges a longtern reliable solution can be achieved. Various features are explained below;

1-Frequent starts & stops.

The hydraulic drive has the ability to provide full shaft torque without time restriction. The power unit's prime mover is a standard AC induction motor, which runs at synchronous speed driving the hydraulic pump. The hydraulic motor mounted on the driven shaft turns only when the pump receives the demand signal and flow is generated. Therefore there are no requirements to start/stop the electric motor, only to zero the signal to the pump. This important feature means that the high current and the associated effects when starting electric motors are negated and infinite number of starts/stops and even reversals are available.



Fig 6a Starts/stops & reversals without limitations



Fig 6b Starts/stops & reversals without limitations

2-Shock Load protection;

A significant feature is the shock load protection afforded by the direct drive solution. A hydraulic direct drive has approximately 1/500th of the inertia of an equivalent high-speed drive with gear reducer. This feature is significant when considering the amount of down time experienced on feeders due to chain related problems.

By effectively disconnecting the high-speed elements such as electric motors, gear reducers and couplings from the drive, the direct hydraulic drive is able to control the overload forces. These forces must normally be absorbed in the machine when sudden stops or stall conditions occur. This offers substantial benefits by reducing downtime and maintenance cost due to damage caused by shock loads.

The operating pressure of the hydraulic motor is directly proportional to the loads to be overcome, i.e. material to be crushed.

By limiting the pump compensator to a certain pressure the actual torque transmitted is limited to any given setting, i.e. crushing force required. This ability to limited forces in the machine along with the low moment of inertia of the drive means any shock loading, i.e. stalling the crusher rolls, are absorbed by the hydraulic system and not by the machine components. This also means a reduction of wear of the machine components.



3-High Starting torque capacity;

The hydraulic drive has the ability to provide full shaft torque without time restriction. This is an important feature in applications, i.e. when the feeder is required to start from a full hopper condition. The ability of the hydraulic drive to continuous overload torque without limitation means undesirable stalls of the feeder are avoided.



Fig 7a Torque & Speed characteristics

4-Load sharing capacity;

The feature of the hydraulic drive ensures that the drives always experience a common load. As the hydraulic motors are part of a common system the load is always equally shared within the system. This load sharing eliminates any problem with oscillations sometimes experienced when trying to balance Electro - mechanical drives.

The hydraulic drives remain balanced irrespective of load or speed requirements.



Fig 8a-100 % Load sharing, which is natural for hydraulics.



Fig 8b-100 % Load sharing, 20 motors(each 45000 FT-LBf torque) turning wheels to move LC-40 launching unit with rocket and payload between home and site for Titan IV program at Cape Canaveral location. This project was designed by Bechtel, Fabricated by XKT Engineering and Construction by Martin Marrietta. This has been in operation since 1989

5-Easy to mount;



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6-Constant Torque Capacity Throughout the speed range;

In some applications it is important to maintain the torque when changing the speed. A Direct hydraulic drive allows practically constant torque throughout the entire speed range. It can provide full torque at standstill without time restriction and thereby eliminate overheating of the electrical motor as in conventional Electro-mechanical drives.

The hydraulic motor is mounted directly onto the feeder drive shaft. There is no need for bedplates, couplings or gear reducers between the motor and the driven shaft. As there are no high-speed elements which need reducing in speed the hydraulic motor can develop its exceptionally high torque from zero speed. This allows exceptional controllability of the feeder speed in all materials conditions



Fig 10a. Hydraulic drive Torque characteristic



Lock Gate drive using a winch with a LSHT motor and a band brake. Fig. 10b



Fig 11a-Hydraulic drive for Jack up Rigs, 45 different rigs in operation. Using 15 to 45 Motors per rig. Each motor capable of providing 100000 FT-LBf torque to pinion, which travels over Rack at each leg by load sharing, all motors provide smooth operation up and down, very efficient and ease of operation.

7- Four Quadrant Drive;

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The variable displacement pump delivers fluid to the drive motor on receipt of a command signal.





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Slide 54

RO RO RAMP WINCHES Location: Port of Calais, France



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Fig. 12, RO RO Ramp using winches with a LSHT Hydraulic motor

8-Well Engineered System;

Using well designed systems for the applications gives most reliable and smooth performance for a long term operation without any unscheduled maintenance down time. It is very important to have proper system and documentation, training, maintenance schedule.



Fig. 12a- Bad Engineered system example of a HPU



Fig. 12b- Well Engineered system example of a HPU

Car Handling Systems

- Train Positioners
- Capacity 25 Wagon Trains (85 T)
- □ Haul Speed = 0.66 m/sec
- □ Reverse Speed = 1.77 m/sec
- Handling rate 1500 Tph (30 cars per hour)
- Drive Solution
- 4 Drive pinions with Hagglund CA 100 Direct Mounted
- 2 Motors fitted with brakes
- 3 motor s Re-circulate and one drives (97 rpm) for return





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Slide 52

Fig-13, Car handling system to unload coal from rail cars using LSHT motors

There several more factors help improve reliability of the drive using **Direct Hydraulic Drive system listed below;**

Maintenance; Direct Hydraulic drives are getting more and more user friendly and more and more applications are utilizing the features and benefits of DHD in increasing the growing demand of productivity. The experience from many of these applications have allowed DHD professionals to optimize new and improved ways to provide long-term reliability and reduced maintenance. DHD does require some skills and training, which is well within the capacity of a typical process plants.

There are many monitoring devices available to record and review key parameters like Oil Temperature, Pressure of the system, Oil condition, Oil level monitoring, Logging these data and reviewing with good preventive maintenance schedule and training improves reliability of these drives.

Erection and Commissioning; DHD offers some unique features during commissioning. The hydraulic motors do not require any foundation. Also the power unit can be placed at a convenient flexible location. You can also use DHD for rotating Feeder or Kiln during assembly and welding etc.

Size of Equipments; DHD uses modular multiple Electric motors / Pumps and Hydraulic motors, these items are standardized readily available produced in reasonable volume compared to a large electric motor and Gear reducer used for VFAC drives. Even

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larger Hydraulic motors are made from many common parts from several different motor sizes.

Energy Savings; Energy savings varies depending on operating parameters and application situation. When operating over wider range of production capacity DHD offers significant savings due to modular concept, which allows varying number of pump/ motor combination operated at a given time. Also in case of future expansion to increase production capacity, DHD allows an economical upgrade by changing some components compared to replacing large Gear reducer or Electric motor for VFAC drive.

Environmental Aspects; DHD does require handling Hydraulic fluid, which is an environmental hazard. The design of DHD is such that it is a sealed system and uses mostly o-ring type fittings and connections, which are made for industrial quality and for the process industrial. Mostly routine commonsense type maintenance practice is needed. Also oil companies are coming up with environmentally friendly high performance synthetic oils.

Conclusion;

Using the knowledge and experience available to utilize these features of direct hydraulic drive can help solve many puzzling failure problems from traditional Electro-Mechanical drive.

The number of hydraulic drives in the Building and Construction industry is increasing steadily. In applications where variable speed is needed, high starting torque is required, power sharing is essential or where shock loads occur frequently, hydraulic direct drives should seriously be considered. The close loop hydraulic system has also proven to be insensitive for harsh environments which means a low maintenance cost for the drive.

Direct Hydraulic drives have made Technological advancements and are getting more user friendly with increasing training efforts by industries.

These types of drives have been used for long time in the process industries like Mining & Materials Handling, Pulp and Paper, Chemical, Rubber and Plastics, Recycling and Steel. All these industries want to have the highest possible reliability and a low life cycle cost. These demands can be fulfilled by using a Hydraulic Gearless Drive (DHD).