Hydraulic drives market trends and offerings

Keywords: Hydraulic Drives; Motors; Radial Piston Motor; Hydre-MAC™

This paper discusses the current market trends for low speed high torque hydraulic drives, principle of operation and latest offerings in this market

Rotary variable speed drive’s market

a. Market size

The market size for mid power rotary variable speed drives is estimated to be between $700M and $800M, including all forms of power transmission. This includes both direct and indirect drives for hydraulic, electric and mechanical drives.

b. Electric vs Hydraulic

Electric motors are driven by supplying the required electric energy. Torque and speed variations are achieved by using gear boxes or by controlling the electric input power with a Variable Frequency Drive (VFD) controller.

Hydraulic motors are driven by a hydraulic pump. Torque and speed variations are achieved by using a variable displacement pump.

Key reasons original equipment manufacturer prefer hydraulic drive systems include:

• Average load requirements are considered to size the system as compared to maximum load in case of electrical motors
• High power density
• Elimination of gear boxes through the use of high torque low speed hydraulic drives
• Simplified control system design, such as a single pump for multiple actuators
• Smooth operation
• Simplified power accumulation/ retrieving system
• Reliable and safe functions

Technology and market trends

The heavy industry market is looking towards modern and technology driven solutions from hydraulic products and systems for the following reasons:-

• Technology advancements
• Changing in work environments
• Limitations in natural resource & energy
• Stringent norms and regulations
• Industrial automation

Below are a few examples of market trends that are influencing selection of hydraulic components

• Hydraulics – Heavy to compact

Recent developments in plant layouts and implementation of world class manufacturing techniques and space limitations, the need for compact solutions rises to the tier one suppliers for developing compact hydraulic products.

• Hydraulics – Sturdy to smarter

The future of hydraulics includes integration of electronic controls to increase the uptime (productivity). These smart solutions have capability to interface with electronic gadgets (like mobile phones) for monitoring and control.

• Hydraulics – Greasy to clean

With the use of advanced materials and sensing technologies in hydraulic components, it has become more efficient and environment friendly for a cleaner workplace; examples: leak free connections, contamination sensors, etc.

• Hydraulics - Dangerous to safer

As the need arises in terms of government regulations and industry norms, hydraulic products are equipped with self-diagnosis and prognostics controls. It enable users to program the hydraulic system with required safety features.
Hydraulic drive applications

Hydraulic motors provide a primary driving force and are widely used in following applications:

- Oil and gas industry
  - Drill heads
- Bulk material handling Industry
  - Conveyor system
  - Bucket wheel drive
  - Feeders & dumpers
  - Crushers and breakers
- Marine/ Shipyard
  - Winches
  - Loaders & unloaders
- Processing units
  - Mineral
  - Metal recycling
  - Pulp & paper
  - Food & rubber
- Civil applications
  - Dam gate
  - Moveable bridges & cranes

For most of the above listed applications, hydraulic motors play a key role in accomplishing the primary function. For example, in the case of a movable bridge application, motors are used to orient the bridge.

Mostly these applications operate between 0 to 250rpm speed, which is classified as low speed applications. It requires smooth and consistent performance even at higher torque limits.

Introduction and types of hydraulic motors

In hydraulics, radial piston motors are considered for above applications that needs to transfer very high torque at very low speed. Due to its design and construction radial piston motors can deliver consistent performance.

Broadly defined, hydraulic motors are classified as rotary actuation system and have following types of constructions:

- Piston motors
  - Radial
  - Axial
- Vane motors
- Gear motors & orbital motors (Gerotor/ Geroler)

Radial piston motors are categorized as:

- Radial piston motor with external piston support (cam lobe)
- Radial piston motor with internal piston support (crankshaft)

For the interest of this discussion, let us focus on externally supported radial piston motor.

Principle of operation of radial piston motor

The radial piston motor converts the hydraulic pressure force into a mechanical torsional moment/angular velocity and is used for various actuating applications. From a hydraulic pump, the fluid flow is connected to motor’s inlet ports. Dual inlet and outlet ports are provided for higher flow applications.

The fluid flow is directed to the rotor and piston which then pressurizes the piston against the cam ring. In order to reduce the frictional losses between the piston and the cam ring, roller bearings are used between them.

The tangential force generated at the crosshead/cam ring interface, generates rotational torque and speed of the motor shaft. In addition to torque and shaft rotation, there is also a resultant radial force that is acting on the shaft. Motor shaft bearings are incorporated to withstand this radial force transmitted from the rotor to the shaft.

Torque and shaft rotation is generated during the piston extension. During piston retraction, fluid returned to the system through the motor outlet ports. These motor components are designed to allow for very low flow fluctuation between piston extension and retraction.

Critical characteristics of radial piston motor

For a Low Speed High Torque (LSHT) application, the following motor characteristics are important:

- Uniform angular velocity
- Starting torque efficiency

Due to the design and construction of radial piston motors, these characteristics are found better than other types of hydraulic motors.

1. Uniform angular velocity

It is important for a hydraulic motor to have little to no speed fluctuation, especially under load and at low speeds. Speed fluctuation in applications such as loaders, mixers, and feeders will have a direct impact on drive speed variations, which can affect equipment performance and product quality. Speed fluctuation in hydraulic motors can be attributed to the torque loss and leakage during the angular position of the motor shaft.
Hydraulic drives

Refer following schematic for a typical hydraulic motor.

Refer following schematic for a typical hydraulic motor.

The input flow $Q_i$ of motor divides itself into the following three components
1. Theoretical output flow ($Q_o$)
2. Internal volumetric loss ($Q_{\text{int}}$)
3. External volumetric loss ($Q_{\text{ext}}$)

Volumetric losses ($Q_{\text{int}} + Q_{\text{ext}}$) are depend on differential pressure difference ($P_{\text{in}} - P_{\text{out}}$) and speed. With higher motor load, the pressure $P_{\text{in}}$ and the leakage losses $Q_{\text{int}}$ and $Q_{\text{ext}}$ increase. Due to this, speed fluctuation could increase.

Torque losses due to friction are dependent upon the angular position of the motor shaft. This is caused by the dependence of clearances between the parts moving relative to each other at the angular position of the motor shaft. Roller bearing supports are used to support the rotating members as well as reduce torque fluctuation and torque losses.

It is further influenced by the viscosity and therefore by the temperature of the fluid. Leakage increases as the temperature increases and the viscosity decreases. Therefore, higher fluid temperatures could lead to speed fluctuation.

2. Starting torque efficiency

This characteristic of motor behavior occurs during the changeover from standstill till reaching the steady state rotational speed. It is also defined as the minimum torque available on the motor shaft at a given pressure differential.

$M_i$ corresponds to the minimum value of the torque measured over one shaft revolution for a given pressure differential $\Delta p$.

Starting torque efficiency is determined from the below relation with starting torque.

$$n_s = M_i / M = M_i * 2 \pi (\text{rev.}) / V * \Delta p$$

$n_s$ = Starting torque efficiency

$M_i$ = Theoretical torque calculated

$V$ = Displacement volume

$\Delta p$ = Pressure differential

Industry offerings

Being one of the market leaders in hydraulics, Eaton has worked towards fulfilling the above trends through strong customer relationships and distributor base throughout the world. In an effort to meet market and customer needs, Eaton has launched "Hydreme™ - Radial Piston Motor" product line to its existing industrial drives portfolio.

The Hydreme motor’s displacement capacity ranges from 12.78 lit./rev. up to 50.67 lit./rev.

Its power transmitting capacity ranges up to 900kW and capable of operating at pressures up to 350bar (with 420bar peak pressure rating).

The above picture depicts the Hydreme motor with basic features. The addition of Hydreme motor with existing Eaton hydraulic products enables Eaton to provide complete hydraulic system solutions for heavy industry applications. With its simpler and robust construction, Hydreme motors deliver consistent and reliable performance for a longer period of time (motor life) in comparison with other market players.

Eaton’s Hydreme motor contains below attributes by design
- Comparatively lower number of parts makes it reliable and compact
- With addition of other Eaton products like Pump/ Motor Controls, Lifesense® hoses, HFX controllers; it can provide a dynamic machine control ability to the end user
- Considering the tough working conditions, the Hydreme motor is equipped with robust sealing system
- The Hydreme motor has optional brake feature (integral design) to provide safety at stand still condition of the motor (like a parking brake).

The following are some of the key features that differentiate Hydreme motor with other market players in this domain of heavy industry applications

Uniform angular velocity

The design of cam ring impacts the motor characteristics to a great extent. The characteristics includes the displacement volume, torque and speed pulsation, noise, vibration and the life of motor.

Based on the piston velocity requirement for constant surface pressure, each stroke and de-stroke of cam profile can be divided into four zones, as below

- No velocity zone (Initial)
- Acceleration/deceleration zone
- Velocity zone
- No velocity zone (End)

Hydreme motors have an optimized cam profile for constant torque requirements across the entire speed range. It allows the motor to operate smoothly at the start-up and while operating at low speed high torque applications.
Profiles in a cam ring are arranged for optimal timing within the motor to ensure constant speed during operation.

**Higher life**

The following considerations help to provide higher life and uptime in Hydre-MAC motors.

**a. Balanced piston design**

The force due to inlet pressure is transferred equally to both the cam rings through cam follower bearings. The Hydre-MAC motor’s symmetrical cam roller bearing arrangement balances the piston and cam rings in both forward and return strokes. To reduce the chance of piston wear failure, pistons are detached from bearings.

**b. Heat treated Cam tracks**

Both cam tracks are heat treated to ensure long life. It resists wear and limits surface contact failures between cam follower bearings and cam track.

**c. Cam rollers**

Cam follower bearings are selected based on the higher rated life requirements. Also, the prediction of Hydre-MAC motor life is a well-established process by using the duty cycle information. It provides customers a great transparency and flexibility in motor selection process and prepare a well-planned maintenance schedule to improve machine uptime.

**d. Repairable motor parts**

Considering the very high operating cost induced in most of the end applications, the Hydre-MAC motor is designed for rebuild and replacement of following wear items.

1. Shaft seal wear rings
2. Piston seals
3. Bearing plates
4. Cam follower bearings

Wear items replacement can reset the motor life.

**Higher efficiency**

In the Hydre-MAC motor design, internal leakage paths are sealed using piston rings and other necessary sealing elements. Volumetric efficiency of Hydre-MAC motors are very high because of the low internal leakage design.

The use of two roller bearings within a cam follower system helps to reduce the frictional losses. The spring loaded valve plate design helps to provide the required hydraulic oil film at the rotor running surface for heat dissipation and bearing effect. Also, the bearing plates with oil pockets help in reducing the friction to achieve the required mechanical efficiency.

Eaton considers the temperature and viscosity correction factors for proper selection of a Hydre-MAC motor based on the efficiency requirements of the customer.

---

**Conclusion**

By focusing on the radial piston motor, the following key points were discussed in this presentation:

- Applications for radial piston motor
- Market and its size
- Principle of operation
- Critical characteristic of radial piston motor
- Change in hydraulic market needs

The design of Eaton’s Hydre-MAC™ - Radial Piston Motor was then compared with respect to those critical parameters and trends. It is concluded from this presentation that, for the given duty cycle and working parameters the Hydre-MAC motors are best suited for the Low Speed High Torque (LSHT) application market. Comparatively with the higher efficiency and motor life, it can yield better end performance and cost savings.

**References**
