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Atheneaum Paper on Hydraulic Motors

By Hol White

Introduction

Good evening to you all. Mr. President, Mr. Secretary, and fellow members of the Athenaeum society, thank you for the opportunity and privilege of presenting this paper tonight. I will keep my paper to an appropriate amount of time knowing the appreciation the society holds for brevity. I would also ask that since I struggle with the projection of my voice that those in the back of the room please touch your hand to your ear if I begin to fade in volume.

I am here tonight to try to shed light on one of the essential mysteries of life. Because of my education, vocation and family history I am uniquely qualified to address the subject at hand, that is, where are hydraulic motors used and how do hydraulic motors work. At the conclusion of tonight's paper you will revel in your newfound knowledge of "hydraulic motors the hidden giant"

The hydraulic motor is a small but powerful device. In engineering terms it has a high power density ratio. Its' applications range from Dixie Chopper lawn mowers that Lawntamers use ^{to cut} across the green yards of Hopkinsville ^{the} to scissors lifts at the super Wal-Mart used to stock shelves. ^{Other uses include the} It includes Vermeer wood chippers used by the city street department to dispose of fallen limbs ^{and} to the stinger on the back of grain truck coming from one of the elevators in the industrial park. Every where you look in Hopkinsville, a motor can be found.

Let me begin with some family history about my association with the hydraulic motor. When I was a kid our family would make the Christmas pilgrimage from Northwest Indiana to southwest Iowa. I developed a keen sense of spotting a hydraulic motor attached to a piece of agricultural equipment. Where most kids were playing license plate bingo, the White kids were doing marketing research on applications for the motor. Every year we piled in back of an '64 American Motors Rambler and made the 550-mile trip across Americas breadbasket eyeballing machinery as we motored on.

^{farm equipment}

My dad and his brother, Uncle Harvey were receiving a royalty payment for each motor sold. They had earlier moved from Northwest Missouri to Northwest Indiana to make and sell motors for Ross Gear. Ross Gear paid a royalty of about a quarter a motor. ^{More and more} ~~The~~ more motors being used in applications eventually ^{which} resulted in rambler being sold and we ^{the family} ~~started~~ ^{began} riding to Grandmas in Oldsmobiles. We were quickly learning to tell whether the motor was one of ours or one of the competitors. A side note, the Ross in Ross Gear is the same Ross in Ross-Ade stadium where the Purdue Boilermakers play.

Motors have moved from the farm only to almost
~~Today the motors are~~ everywhere, from playing a lead role in the movie "Fargo" as the key element used in a wood chipper to dispose of a body and in real life for the same purpose. In the real case that occurred up north, the authorities ^{could only} identified the wife's remains from the bone fragments that were not cleaned out when the chipper was returned to the rental yard.

I have seen the motors on scissors lifts at the Super Bowl and at the Olympics that are used to lift cameras into a better viewing position. . I have seen them at O'Hare airport and on the IMAX screen in Knoxville. They can be seen helping to tow your car to pulling up the salmon you have for dinner out of the Pacific Ocean. These hidden giants are found all over the world.

What does a hydraulic motor do?

There are 3 things a motor must do.
It commutates oil flow, ^yand converts pressure to force and transmits shaft rotation and torque.

What is flow and pressure?

Flow is what happens when you fill a glass with water from a water pitcher. Flow is the movement of a volume liquid from one location to another in a matter of time. Flow to that right glass at the right time is commutation.

Pressure is force over area. It is what you feel when you try toss stop water coming out the end of a garden hose with your hand. The pressure in automobile tires applied over the footprint of your tire is what supports your car's ⁶weight.

What is rotation and torque?

Rotation is turning. It is the motion of a wheel on a bicycle.

It is your foot on the

Torque is a force applied on lever at right angle. ~~A wrench with the force applied by your hand at a distance~~
~~away is torque.~~ It is what Moe is doing to Curlys' nose when he grabs it, ~~he is applying torque.~~

pedal of a bicycle,

Why is a hydraulic motor useful over other methods?

There are other methods we can use to generate torque and rotation. We could use the internal combustion engine, the electric motors, and the pneumatic gun? So why not use an electric motor or a gasoline powered engine?

The Hydraulic motor is useful over these devices in specific applications for the following reasons:

It can generate high torque at low speed. Atypical electric motor wants to run at 1750 rpm. It is more
When we try to operate at a different speed bad things start
efficient at that speed. For example while drilling through a 4x4 piece of lumber for my daughters' swing *to happen*

set my Black and Decker electric drill began to bog down and stop and heat up. The drill stops because it
between the bit and wood the drill
does not have enough torque to overcome the friction that it is encountering at low speeds. ~~It~~ worked fine
when I started and not much of the bit was engaged in the wood. The drill was able to run at its design
speed, but as the bit ~~sank~~ *drilled* deeper into the wood the load increased and its speed dropped, as did its ability to
supply torque.

Conversely a hydraulic motor prefers to run at the lower speed. A hydraulic motor has the ability to move
large equipment at low speeds. It ideal for use in scissors lift applications where it is require to move the
that is necessary for
heavy vehicle weight ~~required as a~~ counter balance and the batteries. It also give it the ability to shred tree
trunks, and limbs and not bog down.

The Its low speed ability and being impervious to the environment makes it ideal for use in the car wash.

Jerry Orten's Texaco car wash here in Hopkinsville has several White motors right now doing what they do
best, slowly rotating brushes against dirty cars impervious to the environment around it. Lets see an electric
motor do that without a fair amount of protection.

The hydraulic motor does not work alone there are other component that form a drive system for most
vehicles.

What is a Drive System?

A top-level description of the drive system for a scissors lift is the conversion of energy that takes place.

We have in a scissors lift the conversion of electrical, to mechanical to hydraulic to mechanical. Although this seems a little circuitous to get a vehicle to move, it is designed to utilize the benefits of each subsystem to convert electricity to motion. A drive system for a scissor lift consist of batteries, these batteries are used to drive an electric motor. The electric motor is used to drive a hydraulic pump. The pump is used to provide oil pressure and flow to a motor and the motor torque and rotation to a wheel. A tank for a reservoir for return oil, a filter is provided to remove any contaminants. Control devices are used to control speed and direction. A relief valve is used to protect the entire system.

Now

In this system how does the motor accomplish its responsibilities or torque and rotation?

Through these 3 basic functions of:

1. The commutation of flow
2. The conversion of Pressure to torque
3. The transmission of torque and rotation

How are these functions accomplished?

Let me first go through the basic building blocks of a hydraulic motor.

①

With these four basic components of a motor

2. The Housing

The Shaft

The Drive link, AKA Dog Bone for it's distinct shapes

And the Rotor Set consisting of Stator, rotor, and rolls

2 The Housing is made of cast iron and is ported to allow connection to a pump and is valved to facilitate commutation. The housing valving is accomplished a high and low-pressure groove for the shaft and by a series of equally spaced six holes for the rotor set.

that feeds

that feed

3 The shaft is made of a forging. It has internal splines to accept the drive-link and it is also valved for commutation. The shaft valving utilizes a series of six long slots and 6 short slots. It is heat treated to give strength and durability

4 The dogbone is used to connect the rotor to the shaft. It is splined at both ends and is made of barstock

5 The rotor set is the heart of the motor. The rotor set is an assembly made up of the following components

The stator is made of ductile Iron broached with pockets to accept rolls

The rolls are made of bearing barstock. They are cylindrical with flat tops that help the rotor slide relative to the stator and reduce leakage. They also provide a bearing surface for the rotor to handle the loads generated by the pressure inside the motor. While developing the process to hack rolls here in Hopkinsville the shop floor employees were surprised to come in at 4 AM and see the owner in his pajamas and slippers hard at work developing the process required.

The rotor is a highly precise external form with internal splines to engage the drive link.

These four components form the basis of a hydraulic motor. That is the

Housing, Shaft, Drive link, and rotor-set.

The 3 functions that these parts accomplished when assembled are again:

1. The Commutation of oil
2. The Conversion of pressure to torque
3. The Transmission of torque and rotation

What is commutation? Commutation is the flow of oil to the right place at the right time. The water going to the right glass at the right time. Commutation is provided by the housing and shaft combination. These two parts are nested together with less than one thousandth diametric clearance. We want the housing and shaft combination to direct the oil the correct chamber of the rotor set.

Oil is provided by a hydraulic pump through hoses to the housing inlet port of and is returned to tank via the outlet port of the motor. The oil at inlet has high pressure the oil at the outlet is low pressure.

The design consideration is how to direct the high-pressure oil to the correct chamber of the rotor set and vent the appropriate chamber of the rotor set to low pressure

6 In one direction the long shaft slots are exposed to the high pressure oil groove and the short slots to the low-pressure grooves of the housing. The shaft slots are then exposed to slots in the housing providing an entrance for high-pressure oil or an exit for low-pressure oil from the chambers in the rotor set. The chambers are filled and then emptied as the rotor orbits and turns the drive link which turns the shaft which brings a new combination of slots of both high and low pressure between the housing and shaft.

Extremely tight tolerances are required to keep leakage at a minimum and ^{have} ~~results in~~ ^{for} effective commutation.

But too tight of tolerance can lock up the motor. The parts are so close that even a temperature rise can lock them up. In automobiles a check engine light is provided when temperatures threaten to lock up the engine.

While a motor has no check engine light the principle is the same.

Some of you may or may not be able to relate to that fact.

The second function is the generation of torque.

8 In order to create torque a force must be applied at right angles to the arm used to apply the torque. Torque is created within the rotor-set. In the case of the hydraulic motor the force is ^{provide} ~~generated~~ by oil pressure in the chambers applied across a section of the rotor times it's length. This creates a force. Remember pressure times area equals force. We are using the pressure provided by the pump commutated by the housing and shaft to the correct chambers in the rotor set.

We are now able to use this force to obtain a mechanical advantage and speed reduction and direction reversal.

Just like a set of gears
The rotor acts as an arm and it is offset from the shaft by an eccentric. This force applied against the arm generates torque; the torque is magnified by ratio of the eccentric to the arm. The direction that the shaft and drive-link rotate is reversed from that of the drive-link shaft combination.

The final function is the transmission of torque and of rotation. The shaft, drive-link and rotor set are used to accomplish this.

9 *or orbits*
The ~~orbiting~~ of the rotor processes inside the stator. The rotors' ~~with its~~ internal splines drive one end of the drive-link. The other end of the drive-link drives the output shaft.

The primary design consideration here is how to transmit torque at an angle that is caused by the eccentric encountered ^e in the rotor set. In most gear set the gears run parallel. In the case of a motor the drive-link must

run at an angle while the rotor and shaft run parallel. It might also be described as trying to run a car down the road tilted up on two wheels. Different ratios of spline to gap are employed until the optimum is found and also a crown used to accommodate that running angle. These are the same reasons those clockwise ^{have} circling mountain goats shorter right legs.

To summarize a motor takes the inputs of both pressure and flow from a pump it converts these inputs through the process of commutation to generate torque using the rotor set. The torque and rotation are then outputted from the rotor set through the drive link to an output shaft and to a wheel on a scissors lift. This provides vehicle movement.

We take the current design for granted. But it required a lot of inspiration; perspiration and full-time commitment of those involved creating the design. The manufacture of the product is a story I will reserve for future papers. Will my kids be trying to spot motors on their vacations ^{? Perhaps} ~~I do not know~~. On some occasions I will wear the blue uniform of a shop floor employee. Having seen this my son has informed his mother that he will become a gas station attendant just like his dad. I have stopped wearing the uniforms.

Today new applications for the motor continue to be discovered. From use on applications that are helping provide the infrastructure to the Internet to stirring the tanks at a sewage treatment facility, motors fulfill their role. This hidden giant provides hydraulic powered High torque and low speed to the world.

Will they
become
involved
in the
business