Design and Development of Non-Conventional Power Train System

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ABSTRACT

This study is to investigate an alternative approach about hydraulic transmission system in automotive field. A transmission system which consists of hydraulic components will be analyzed by replacing the common mechanical transmission system of a vehicle to observe it's potential to overcome problems that there were in the mechanical transmission system. It is also an alternative approach to reduce the fuel consumption. A near net module is to be designed and to ensure it caters the same performance in the next prototype to be built in the future. Next, critical selection and calculation were done in order for the hydraulic transmission to be working efficiently by identifying parameters involved in this research. The result is based on the selection of parameters values which appropriate to the system. Alternatively, some other approaches were attempt to cater the need.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

LB_f	-	Pound force
PSI	-	Per square inch
ft^2	-	feet square
in^2	-	square inches
HL	-	Head loss
PH	-	Pressure Head
VH	-	Velocity head
EH	-	Elevation head
TH	-	Total Head
NPSH	-	net positive suction head
K_{sys}	-	system operating curve
V_s	-	Velocity head
RPM	-	revolution per minute
MFP	-	main feed pump
MCP	-	main condensate pump
HP		horse power
BFPA		British Fluid Power Association

CHAPTER 1

INTRODUCTION

Hydraulics is a topic of science and engineering dealing with the mechanical properties of liquids. Hydraulics is part of the more general discipline of fluid power. Fluid mechanics provides the theoretical foundation for hydraulics, which focuses on the engineering uses of fluid properties. Hydraulic topics range through most science and engineering disciplines, and cover concepts such as pipe flow, dam design, fluid control circuitry, pumps, turbines, hydropower, computational fluid dynamics, flow measurement, river channel behavior and erosion.

Hydraulic system is defined as force that is applied at one point is transmitted to another point using an incompressible fluid (Marshall Brain, 2000). Hydraulic system uses many liquids such as petroleum oils, synthetic oils and water. The first hydraulic fluid to be used was water because it is readily available. However, water has many deficiencies. It is already freezes, a relatively poor lubricant and tends to rust metal components. Hydraulic oils are far superior and hence are widely used in lieu of water.

In hydraulic system, it is consists of hydraulic pump, hydraulic motor and directional valves. These equipments are essential and provide the muscle to do the desired work. The hydraulic pump exhibit the fluid to be transmitted to the hydraulic motor where the motor will produces a torque resulting in a rotary motion. Hydraulic can provide a huge forces and torque to drive loads with utmost accuracy and precision. The interesting thing in hydraulic systems is the ability to apply force multiplication.

In a transmission system which is used in a car, there is a usage of hydraulic system applied especially in an automatic transmission system. Using a fluid coupling or torque converter and a set of planetary gearsets to provide a range of torque multiplication, it operates the predominant form of the transmission system (Wikipedia, 2006). The multitude of parts, along with the complex design of the valve body, originally made of the automatic hydraulic transmissions much more complicated and expensive to build and repair than manual transmissions. Mass manufacturing and decades of improvements have reduced the cost. The automatic transmission system also needs high in fuel consumption and high in engine maintenance. Furthermore, once the gearbox is damaged, it is needs a high cost for repairing them due to the expensive parts and services.

The purpose of this project is to create a transmission system which only consists of hydraulic system. By removing the mechanical system in the transmission system, we will only use the hydraulic system to provide movement and speed to the car.

The application that will be used to design the hydraulic transmission system will be fulfill the hydraulic system. It is known as hydrostatic transmission that has replaced the mechanical transmission system but the application only can used in heavy vehicles such as track; a type of tractor and the transmission needs a larger engine to be run. With the development of the hydraulic transmission system, maintenance cost can be reduced and a smaller yet compact engine can be developed. Hence it can reduce the cost of making an engine.

The selection of the hydraulic pump and motor will be studied and considered essentially to this project in order to find the suitable horsepower and torque which are equivalent to the automatic transmission system, suitable parameters are to be investigated and calculated. Furthermore, the fluid properties used as a medium to transmit the power to the motor also will be studied and included in this project.

1.1 Problem Statement

Based on the problems occurs in a present hydraulic transmission system and mechanical transmission of an automobile, there are few problems that contribute to implement this project. The problem statements as below:

(a) To create higher speed torque, greater engine capacity is required. For this, new designs are being developed to increase the engine capacity in order to meet the demand.

(b) Bigger engine require more space and critical economic consideration to save fuel consumption.

(c) It incurs higher cost in engine and attachment production.

(d) The mechanical transmission consist many mechanical associates which produces louder noise and power loss.

1.2 Objectives

The objectives for this project are:

(a) Simulate a transmission system circuit which is fully operated by hydraulic system.

(b) Observe and analyze the hydraulic capability in transmitting the power base on the existing system.

(c) To analyze the suitable parameters for the hydraulic transmission system.

(d) Suggestion for development.

1.3 Scope of Research

To design and simulate a new type of transmission system which it will be using in the hydraulic fluid in order to replace the currently available mechanical transmission system for a rear wheel such as at a car.

1.4 Hydraulic History and Principles

Fluid power technology came on its own in the 17th century with the discovery of Pascal's Law and in the 18th century with the discovery of Bernoulli's Principle. These two findings form are the basic principles behind modern hydraulic power.

Pascal's Law - Pressure applied to a confined fluid is transmitted undiminished in all directions. Pascal made this determination when he rammed a cork into a jug completely full of wine and the bottom was broke out. Pascal deduced the pressures were equal at the top and bottom of the jug. However, since the jug had a small area at the top and a large area at the bottom, the bottom experienced a greater total force due to its larger area.

Bernoulli's Principle (see Figure 1.1) - The total energy in a liquid remains relatively undiminished over distance (M. Mitchell, 2003).

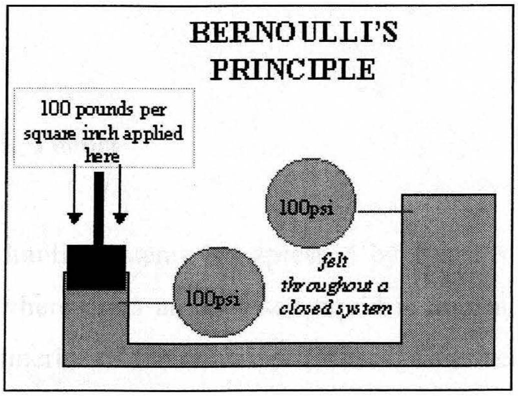

Figure 1.1: Bernoulli's Principle (Courtesy of the Warfighters Encyclopedia)

As Pascal noted, hydraulic force is a function of pressure and area. Generally, hydraulic systems are designed such that relatively low pressures are applied to large areas. This approach avoids the dangers and design requirements associated with applying extremely large pressures to small areas to achieve the same effect (Figure 1.2)

Force = Pressure x Area.

Rearranging the equation:

Pressure = Force / Area

In English units, force is measured in pounds force (LB_f); pressure is measured in pounds per square inch (PSI), and area is measured in square feet (ft^2) or square inches (in^2).

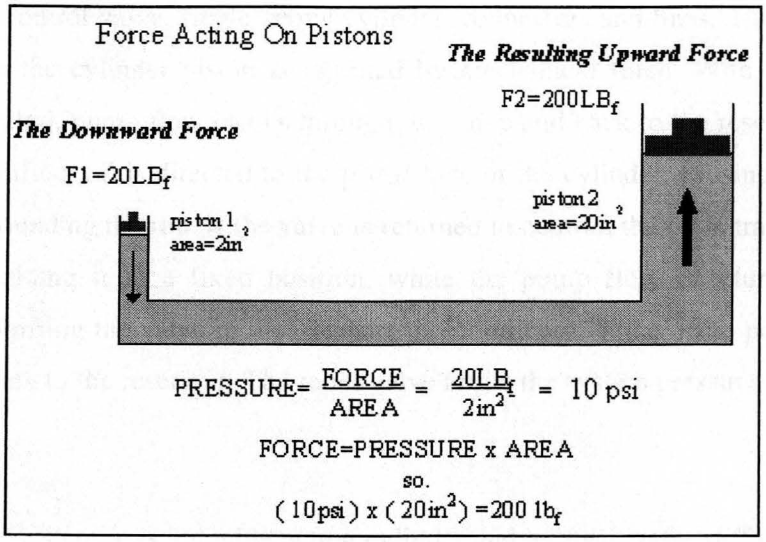

Figure 1.2: Figure example on how to calculate the force acting on pistons. (Courtesy of the Warfighter Encyclopedia)

1.4.1 Basic Hydraulic Theory

The basis for all hydraulic systems is expressed by Pascal's law which states the pressure exerted anywhere upon an enclosed liquid is transmitted undiminished, in all directions, to the interior of the container (Filters Manufacturers Council, 1996). This principle allows large forces to be generated with relatively little effort. A 5-pound force exerted against a 1-inch square area creates an internal pressure of 5 psi. This pressure, acting against the 10 square inch area develops 50 pounds of force.

In a basic hydraulic circuit, the force exerted by a cylinder is dependent upon the cylinder bore size and the pump pressure. (There is no force generated unless there is resistance to the movement of the piston). With 1000 psi pump pressure exerted against a 12 square inch piston area (approximately 4" dia.), a force of 12,000 pounds is developed by the cylinder. The speed at which the piston will move is dependent upon the flow rate (gpm) from the pump and the cylinder area. Hence, if pump delivery is 1 gallon per minute (231 cu.in./min.) the cylinder piston will move at a rate of 20 in.min. (231 cu.in./12 cu.in./min.).

The simplest hydraulic circuit consists of a reservoir, pump, relief valve, 3-way directional control valve, single acting cylinder, connectors and lines. This system is used where the cylinder piston is returned by mechanical force. With the control valve in neutral, pump flow passes through the valve and back to the reservoir. With the valve shifted, oil is directed to the piston side of the cylinder, causing the piston to move, extending the rod. If the valve is returned to neutral, the oil is trapped in the cylinder, holding it in a fixed position, while the pump flow is returned to the reservoir. Shifting the valve in the opposite direction permits the oil to pass through the valve back to the reservoir. The relief valve limits the system pressure to a pre-set amount.

A hydraulic system uses a double acting cylinder and a 4-way valve differs from the single acting cylinder system in that the cylinder can exert force in both directions. With the control valve in neutral, flow is returned to the reservoir. When shifted in one direction, oil is directed to the piston side of the cylinder, causing the cylinder to extend. Oil from the rod side passes through the valve back to the reservoir. If the valve is shifted to neutral, oil in the cylinder is trapped, holding it in a fixed position. When the valve is shifted in the opposite position, oil is directed to the rod side of the cylinder, causing the cylinder to retract. Oil from the piston side passes through the valve back to the reservoir. Cylinder extend force is a result of the pressure (psi) times the piston area. Retract force is a result of the pressure (psi) times the area difference between the piston minus the rod diameter.

Rotary hydraulic motor circuits are basically the same as cylinder circuits. Systems may be uni-directional or bi-directional. The amount of rotary force (torque) available from the motor is a function of pressure (psi) and motor size. Speed is a function of flow and motor size.

All the systems described above are open center systems due to the oil flowing through the control valve back to tank. Most systems are this type. Closed center systems use control valves with the inlet port blocked and variable displacement pumps. With the control valve in neutral, the pump is "de-stroked" to zero flow.

1.4.2 **The Basic Hydraulic Power System**

All hydraulic power systems are composed of at least the following basic components (Figure 1.3).

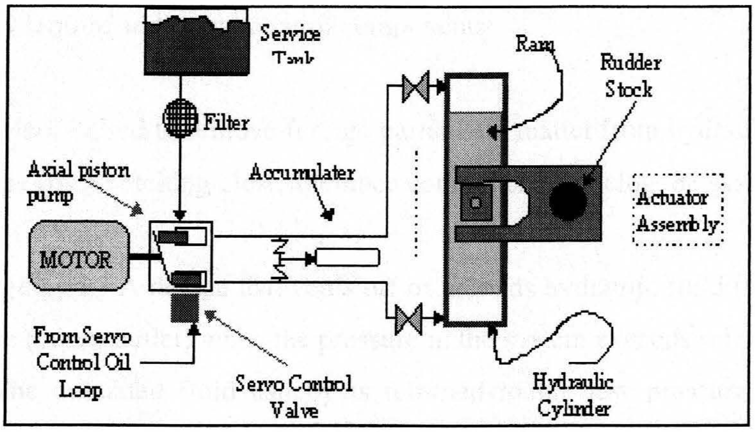

Figure 1.3: Basic Hydraulic Power System (Courtesy of The Warfighter Encyclopedia)

Tank/reservoir/sump - Used to store hydraulic fluid that is not currently in use due to the system's state or configuration.

Pump - Used to force the hydraulic fluid through the system. Acts as the pressure source.

Prime mover - The power source for the pump. In hydraulic systems the prime mover is usually an electric motor.

Valves - Installed to control liquid direction, pressure, and flow rates.

Actuator - Devices that convert the energy of the liquid into mechanical force or torque. Typically, an actuator is either; a single piston and cylinder arrangement that results in *linear motion*. A ship's steering system uses this design. A series of pistons and cylinders arranged in such a way that they produce *rotary motion*. Called a *hydraulic motor*, many of our *gun mounts and missile launchers* use these pumps to train the gun or launcher.

Piping - Used to contain and direct hydraulic fluid from one point to another.

1.4.3 Hydraulic Accessories

In addition to the basic hydraulic power system components discussed, hydraulic systems may require additional control components:

Filters/strainers - Used to remove foreign particulate matter from hydraulic fluid that could damage (by scratching close tolerance components) or clog the system.

Pressure regulator - A device that vents off or unloads hydraulic fluid from the high pressure side (pump outlet) when the pressure in the system exceeds set point (design pressure). The unloaded fluid usually is returned to the low pressure side of the system or the sump. By unloading hydraulic fluid, pressure is reduced. When hydraulic pressure returns to set point, the regulator stops unloading. By constantly loading or unloading, the pressure regulator maintains the pressure at set point.

Accumulator - A device that acts as a hydraulic shock absorber for the system. It is basically consists of a container, divided into two sections by a flexible divider or membrane. One section is open to the hydraulic system's liquid and the other section contains a gas (often nitrogen) under an appropriate pressure. It is used to store a certain volume of hydraulic fluid under pressure. The liquid side experiences the same pressures as the fluid in the hydraulic system. When the hydraulic system experiences a sudden pressure increase, the effect is reduced or dampened by fluid in the accumulator compressing the gas on the other side of the membrane. When the system experiences a sudden pressure decrease, the gas forces fluid out of the accumulator to increase system pressure. The accumulator is designed to handle brief system transients, not system casualties or long term degradations.

Relief valve - A device that protects systems from excess pressure. A relief valve is much the same as a pressure regulator in that it unloads excess pressure. However, a relief valve has a higher set point than the pressure regulator and only operates under abnormal conditions such as a failure in the pressure regulator.

Check valve - A device that permits flow in only one direction.

Sequence valve - A device that controls the sequence of operation of one or more other components.

Servo - A device that measures output or state such as the rotation of a motor or the distance of travel of a piston in a cylinder. The servo's output is compared to a standard or other output signal. The results of the comparison are used to control a system's state or actions.

1.5 Overview on The Hydraulic Equipment

Before the implementation of the project, it is better to understand the equipments that will be needed for the transmission system. The basic hydraulic equipments will be introduced to get a better understanding on its function. These equipments are essential in order to generate the whole hydraulic circuit.

1.5.1 Hydraulic Pump

A pump, which is the heart of a hydraulic system, converts mechanical energy into hydraulic energy. This energy is delivered to the pump via a prime mover such as electric motor. Because of the mechanical action, the pump creates a partial vacuum at its inlet. This permits atmospheric pressure to force the fluid through the inlet line and into the pump. The pump then pushes the fluid into the hydraulic system.

There are two broad classifications of pumps as identified by the fluid power industry:

(a) Dynamic pumps (non-positive displacement).

This type of pump generally used for low-pressure, high volume flow applications. Because they are not capable with standing high pressures, only a little is use in the fluid power field. Normally their maximum pressure capacity is limited from 250 – 300 psi. This pump is primarily used for transporting fluids from one location to another. There are 2 types of dynamic pumps which are the centrifugal and the axial flow propeller pumps.

(b) Positive Displacement pumps.

This pump universally used for fluid power systems. As the name implies, a positive displacement pump affects a fixed amount of fluid into the hydraulic system per revolution of pump shaft rotation. Such pump is capable of overcoming the pressure resulting from the mechanical loads of the system as well as the resistance to flow due to friction. These are two features that are desired of fluid power pumps. These pumps have the following advantages over non-positive displacement pumps:

i. High-pressure capability (up to 12,00 psi)
ii. Small, compact size
iii. High volumetric efficiency
iv. Small changes in efficiency throughout the design pressure range.
v. Great flexibility of performance.

Table 1.1: Table showing the classification and types of pumps. (Courtesy of The Warfighter Encyclopedia)

CLASS	TYPES	COMMON USERS
Positive Displacement Pumps	Reciprocating (Steam or electric driven) Variable stroke	Emergency feed pumps, Bilge and stripping pumps Steering gear, gun mounts, winches
	Rotary: • Gear • Screw Lobe • Vane	-Attached lube oil on auxiliary equipment - Lube oil and fuel oil service pumps - Air pumps, diesel air blowers -some JP-5 service pump, AC & R equipment.
Non Positive Displacement Pumps	Propeller	High low/flow seawater circulating pumps
	Jets	Self-priming eductors and air ejectors
	Centrifugal	Most water (non-viscous fluids) pumps (condensate, feed, fire main, potable water, etc)

1.5.1.1 Hydraulic Pump Theory

Hydraulic pump used the energy transfer as a method to show how the hydraulic pump works. In order to understand the energy transfer, some fundamental terms need to be explained. They are the head loss, pressure head, velocity head, elevation head, and total head.

(a) Head Loss

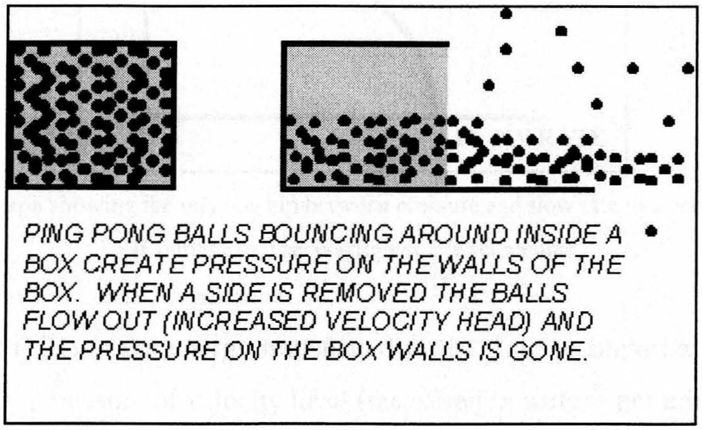

Figure 1.4: The head loss theory based on ping pong balls. Courtesy of The Warfighter Encyclopedia)

A shown in Figure 1.4, head loss (HL) is any force that acts against the system and is considered an energy loss. Friction head is a form of head loss. Some amount of energy must be supplied to overcome the fluid friction created by a fluid traveling through a pipe. Friction head and head loss are dependent on things like the number of bends in the system piping or the relative smoothness or roughness on the inside of the piping system. If there are a great number of bends in the piping or the material is rough, head loss and fluid friction will be greater, making the system less efficient.

(b) Pressure Head.

Pressure head (PH), also known as pump head. It is the pressure that produced at the discharge side of a pump. This pressure head must be great enough to overcome the head losses acting against it if the pump is going to move the fluid. Pressure head is inversely proportional to velocity head.

(c) Velocity Head

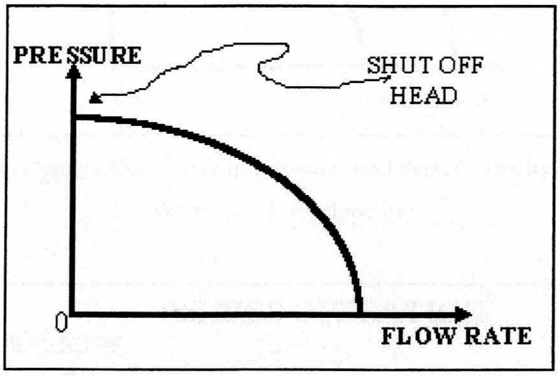

Figure 1.5: Graph showing the relationship between pressure and flow rate in a centrifugal pump. (Courtesy of The Warfighter Encyclopedia)

Velocity head (VH) is the energy transferred to the fluid to impart a velocity upon it. Flow rate is a measure of velocity head (measured in gallons per minute or GPM). As stated above, velocity head and pressure head are inversely proportional to each other, meaning that as velocity head (flow rate) increases, pressure head (discharge pressure) decreases. Figure 1.5 shows this relationship for a typical centrifugal pump. Notice that when there is no flow through a pump, its pressure head is at its maximum value. This is the shut off head discussed earlier.

(d) Elevation Head

Elevation head (EH) is the head acting against the pump caused by the weight of the fluid in the piping above the discharge of the pump. The greater the elevation head, the harder the pump must work to deliver the fluid to its destination at the proper velocity and/or pressure.

Total head (TH) is the sum of all these values:

$$TH = PH + EH + VH$$

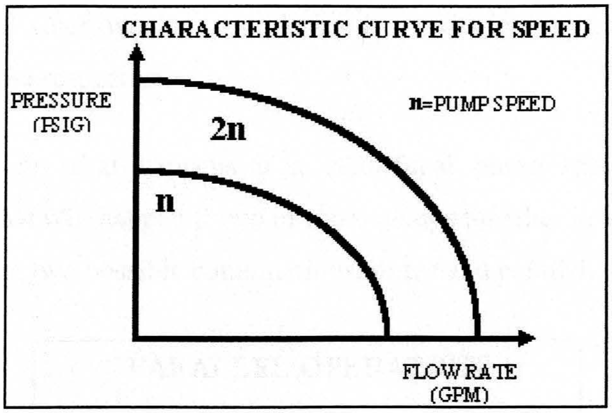

Figure 1.6: Basic pump characteristic curve of pressure head versus velocity head. (Courtesy of The Warfighter Encyclopedia)

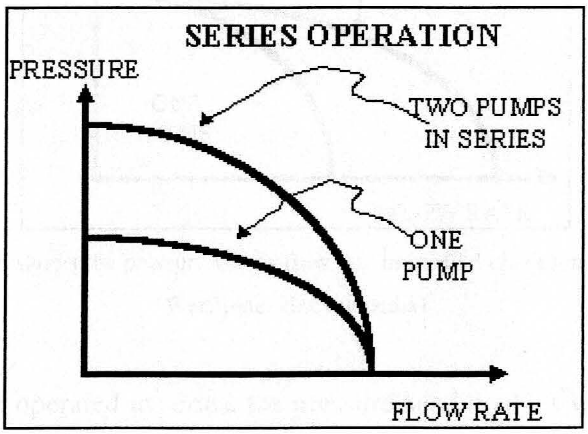

Figure 1.7: Graph shows the characteristic of a pump when speed is increased(Courtesy of The Warfighter Encyclopedia)

The best way to describe the relationships between TH, VH, and PH are with centrifugal pump characteristic curves. Figure 1.6 shows a basic pump characteristic curve of pressure head versus velocity head, PH and VH respectively. As velocity head (VH) decreases, discharge pressure (PH) will be increase. If the speed of the pump is increased, a greater amount of energy will be transferred into the water so both the pressure head and velocity head will increase. In other words, the pump will operate on a higher characteristic curve as depicted in Figure 1.7. If the speed of the pump is twice as it is, the velocity head also doubles. However, look at what happens to pressure head; it will increase as a square of the pump speed. The power required to make that pump turn twice as fast increases as a cube of the pump speed.

The net positive suction head (NPSH) of a centrifugal pump is similar to elevation head except that it is a positive value because it acts on the suction side to the pump.