Simulation on comparison of pressure medium in hydraulic hybrid system

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ABSTRACT – Natural concerns of fire and safety in hydraulic system promote the uses of water-based hydraulic hybrid system. The main focus of this paper is to simulate the potential of using water hydraulic technology in hydraulic hybrid systems. The research will include an extensive study on the mathematical modeling and simulation by using Matlab/Simulink to determine the feasibility of water compared to oil SAE-30.

1.   INTRODUCTION

Typical hydraulic hybrid vehicles depend on petroleum based hydraulic fluid. Typical concerns of fire and safety in hydraulic systems promote the uses of water-based hydraulic system. Mineral oil used in oil hydraulic equipment poses a fire hazard in the event of a spillage or leakage. This is especially critical in vehicle accident scenarios where the oil spillage might trigger fire mishaps as explained in the previous study [1]. Through the usage of water hydraulics, problems related to safety and contamination of oil hydraulics in typical hydraulic hybrid technology can be avoided.

1.1   Hydraulic hybrid system

Hydraulic hybrid system or hydraulic regenerative braking system is a mechanism that store a portion of the kinetic energy that was a momentum as potential energy in the form of pressure. It is stored by a short term storage system, this is done by using a displacement pump to pump hydraulic fluid into an accumulator. That energy is kept until needed by the vehicle, by which the pressure is released from the accumulator as the vehicle accelerates. This pressure will spin the drive shaft while the engine remains idle. As the vehicle achieves the desired speed or the accumulator is emptied, the engine will take over to continue the process that is beyond the capability of accumulator as stated in the previous study [2-3] .

1.2   Hydraulic fluid properties

The implementation of water instead of oils is offers advantages, but certain factors need to be studied in depth in order to match or surpass the current outcome of the oil hydraulics. The specific characteristics of water in term of corrosion, flow erosion, friction, internal and external leakage, lubrication, cavitation, freezing and micro organism are essential prospects that could affect the efficiency of water compared to oil as in previous study [1,4-5].

This project concerns on the effect of novel water-based hydraulic hybrid system. Therefore, the objective of the project is to understand the fundamental knowledge on how to utilize water hydraulics technology. Futhermore, the feasibility of using water as a pressure medium instead of hydraulic oil is analyse.

2.   METHODOLOGY

The hydraulic hybrid system is operating in 2 mode which is charge mode and discharge mode. Charge mode occurs while the brake pedal (V1) is pressed that generate the fixed displacement pump which will channel pressurized fluid from low pressure accumulator (AccL) to occupied high pressure accumulator (AccH). Meanwhile, in discharge mode, as the throttle (V2) is pressed, the pressurized fluid stored in the high pressure accumulator (AccH) is release that eventually will operate the fixed displacement motor which will drive the wheel. Besides that, 2 set of 2/2 way directional control valve (V1, V2) are used to control the water flow during charge and discharge mode. Pressure relief valve (PRV) is used to limit pressure in the system. Figure 1 shown fluid circulation as the system in charge mode (red arrow) and discharge mode (green arrow).
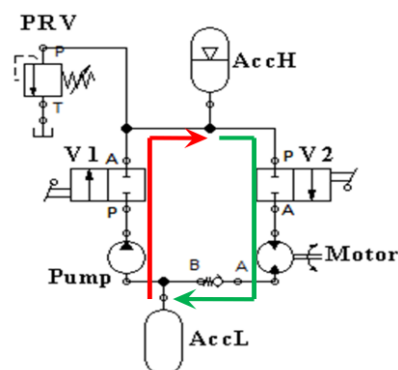

Figure 1 hydraulic hybrid circuit.

The circuit model of water hydraulic is simulate using simulink corresponded to simscape toolbox. Simulation was done by implement water and oil SAE-30 as the pressure medium. Whereas, the output value of torque,T_m and rotational speed,n at motor output shaft are calculated. Torque,T_m and rotational speed,n is given

by the following equation (1,2):

$$n = \frac{q_m \eta_v}{V_g} \quad (1)$$

$$T_m = V_g p \eta_{mech} \quad (2)$$

Where, q_m and p are input flow rate and pressure for hydraulic motor. V_g is volume displacement, η_{mech} is mechanical efficiency and η_v is volumetric efficiency. The following Table 1 and 2 shows the component specification and hydraulic fluid properties that used as the parameter in the simulation.

Table 1 Component specification.

Hydraulic fixed displacement pump	
Max torque (Nm)	500
Max displacement (cm^3/rev)	32
Nominal pressure (bar)	400
Hydraulic fixed displacement motor	
Max displacement (cm3/rev)	107
Nominal pressure (bar)	500
Low pressure accumulator, AccL	
Total accumulator volume (l)	100
Min gas volume (l)	30
Precharge pressure (bar)	5
Initial Fluid Volume (l)	70
High pressure accumulator, AccH	
Total accumulator volume (l)	100
Min gas volume (l)	36.4
Precharge pressure (bar)	100
Initial Fluid Volume (l)	2
Pressure Relief Valve, PRV	
Valve pressure setting (bar)	400

Table 2 Hydraulic fluid properties.

	SAE-30	Water
Parameters		
Relative amount of trapped air	0.005	0.005
System temperature (c)	40	40
Viscosity operating factor	1	1
Fluid Properties		
Nom kinematic viscosity (cSt)	93.9899	0.6572
Nom fluid density (kg/m^3)	878.4	992.6
Bulk modulus (Pa) *	1.68E+9	2.3E+9

* Bulk modulus at atm. Pressure and no gas

3. RESULT AND DISCUSSION

In order to investigate the performance of the system in both medium, a model is implemented in Simulink using corresponded Simscape toolbox as shown in Figure 2.

Simulation results for the comparison of output power produced by the hydraulic motor based on the application of water and oil SAE-30 is showed in Figure 3. The graph indicates that the output power produce by the usage of oil SAE-30 are higher than water which shows 41.3kW are produced at 370.5rpm, meanwhile water produce 34.23kW at 336.2rpm. In other hand, the result shows that water achieve the maximum power at a lower speed compare to SAE-30 due to the occurrence of internal leakage are higher at water, that causes

pressure loss in the system as stated in previous study [1,4]. The condition of internal leakage can be explained by the value of total efficiency in hydraulic motor. The efficiencies of hydraulic components are defined as ratios between its hydraulic power at outlet port and that ones at inlet port. Efficiency of water calculated at the maximum power is 78.7%, whereas SAE-30 is 92.5%.
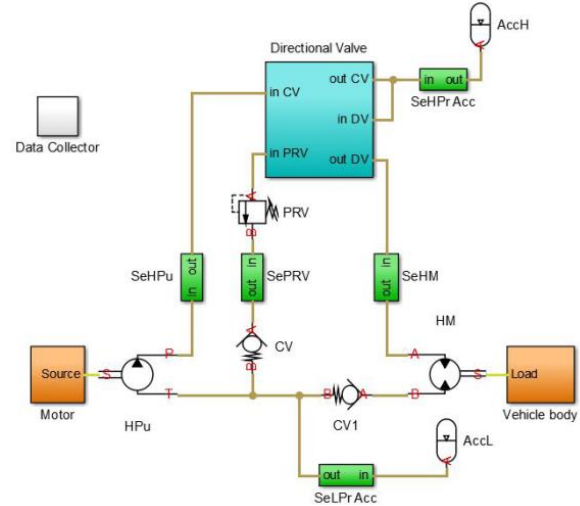

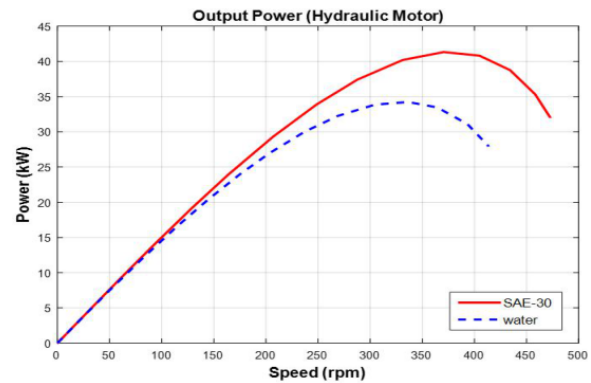Figure 2 hydraulic hybrid simulation (simscape).

Figure 3 Output power at hydraulic motor.

4. CONCLUSIONS

In this paper, the relationship between oil SAE-30 and water involved in hydraulic hybrid system has been analyzed. Simulation results indicated that oil SAE-30 is more compatible compare to water as the properties which are kinematic viscosity, density and bulk modulus influences the resulted output power and efficiency. In other hand, a small differences of the result should be able to overcome by adjust the diameter of hydraulic hose use in water hydraulic system that eventually will increase the input pressure which will increase the output torque and power.

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