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Design of Hydrostatic Power Transmission System of Heavy Duty Vehicle

Sangale Kiran A.[1], Shinde Dhiraj D.[2]

Assistant Professor, Mechanical Engineering, BVCOE, Lavale, India[1, 2]

Abstract: This document gives the information about the design of hydrostatic transmission system used in heavy duty vehicle. In this document we covered the detail process of selection of various component used in hydrostatic transmission system. We also covered the specification of these selected components.

Keywords: HST, PDU, APU, SP.

I. INTRODUCTION

Generally in heavy duty vehicle hydrostatic transmission system is used for power transmission. The primary function of any hydrostatic transmission (HST) is to accept rotary power from a prime mover (usually internal combustion engine) having specific operating characteristics and transmit that energy to a load having its own operating characteristics. In the process, the HST generally must regulate speed, torque, power, or, in some cases, direction of rotation. Depending on its configuration, the HST can drive a load from full speed in one direction to full speed in the opposite direction, with infinite variation of speed between the two maximums - all with the prime mover operating at constant speed. The operating principle of HSTs is simple: a pump, connected to the prime mover, generates flow to drive a hydraulic motor, which is connected to the load. If the displacement of the pump and motor are fixed, the HST simply acts as a gearbox to transmit power from the prime mover to the load. The overwhelming majority of HSTs, however, use a variable-displacement pump, motor, or both - so that speed, torque, or power can be regulated.

Following figure shows the typical layout of hydrostatic transmission system it consist of these components: Diesel engine, power transmission unit, hydraulic pump and hydraulic motor

Auxiliary Propulsion Unit (APU)

APU shall consist of a diesel engine coupled to a hydro-static transmission system which supplies power for self-propulsion. Power generated by APU will be utilized for following

Limited Self propulsion to the heavy duty vehicle when detached from the FAT

Facilitate tandem drive when towed by prime mover to negotiate difficult terrain.

To provide power to operate the various operations of heavy duty vehicle

Hooking / un-hooking of vehicle with tractor/Towing vehicle

It shall consist of following sub-systems:

A) Diesel engine

1. Power output - 95 -110 kW
2. Max. Torque - More than 600 N-m
3. Dimensions (Approx) - 1000 mm L x 500 mm W x 800 mm H

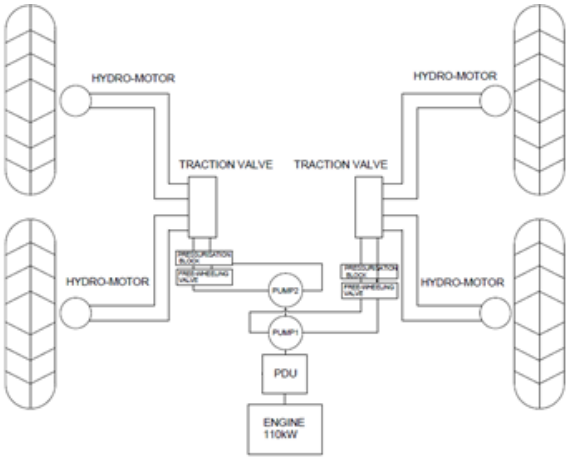

Fig.1. layout of hydrostatic power transmission system

4. Drive for accessories – Should be supplied with (i) Std. Alternator (3kW/ 24V)
5. Should be supplied with suitable capacity Starter motor
6. Flywheel housing should be SAE No.2 type
7. Should be mounted with suitable AV mounts
8. Should have cold start capability

B) Power Distribution unit (PDU)

PDU shall be having input from the engine flywheel/crankshaft and shall have 04 outputs, details of which are given below:

1. Output-1 – Hydrostatic transmission pump drive -To suit pump 1
2. Output-2 – Hydrostatic transmission pump drive - To suit pump 2
3. Output-3 – Alternator drive (for powering Upper carriage) -3000 to 12000 rpm
4. Output-4 – Drive for Accessories Pump

C) Hydrostatic Transmission System

Mode of Operation

The following mode of operation using the Hydraulic transmission System:

Self-Propelled Mode: This includes the transmission of Power from PDU to all wheels in four wheel drive. The provision for braking as well as steering provided.

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A backup transmission to drive all four wheels through a single hydraulic pump.

Towed Mode: This includes the freewheeling of all wheels during the towing mode and braking from towed vehicle using pneumatic line.

Tandem Drive: Starting of the engine and driving from towing vehicle's driver cabin in synchronisation

II. OBJECTIVE

Design of Hydro-static transmission system includes selection of following component

1. Selection of Hydraulic Motor
2. Selection of Hydraulic Pump
3. Selection of Diesel Engine
4. Selection of Fuel tank
5. Selection of Auxiliary component.

III.REQUIREMENT

For the design of hydrostatic transmission system the following requirement must be fulfilled.

1. Each wheel shall be driven separately by individual hydraulic motors.
2. Each LH side motors & RH side motors shall be powered by separate pumps.
3. Motors shall be able to be driven in 4 x 4 or 4x 2 configuration depending upon the terrain conditions.
4. As a redundancy if one pump fails other pump shall be able to drive all four motors.
5. Hydraulic motor drive should be designed for GVW 16000 kg.
6. Speed on normal roads – 20 kmph
7. Speed on cross country – 10 kmph
8. Pump & Motors shall be of Rexroth/Eaton/Parker/Sai make
9. Driving controls shall be located at Drivers Station.
10. Tandem drive control unit, capable of operating the APU from Towing vehicle drivers cabin, shall be provided.
11. Hydraulic wheel motors shall be able to be disengaged and freewheeling drive facility during towing shall be available.
12. Necessary safety interlocks shall be provided so that set speed in SP mode does not exceed specified values.
13. Each wheel will be controlled individually in the self-propelled mode by levers at the layer's station as well as at driver's control panel. This dual control need to be properly synchronized and arrangement shall be made like that only one control panel will be active at a time. The selection switch of dual control may be provided on driver's panel.
14. All sub circuits are to be controlled electrically. However, the majority of electro- control valves of hydraulic system shall be able to operate manually if electrical system is not in operation.
15. One Hydraulic tank of suitable capacity made of stainless steel sheet shall be installed at the rear in engine compartment

IV. METHODOLOGY

For designing of hydrostatic transmission system following methodology is used.

1. Find out total resistance offered to motion of vehicle
2. Find out torque required to run vehicle
3. Find out required rpm of hydraulic motor
4. Find out power required to run vehicle.
5. Select the motor on basis of required rpm and torque.
6. Find out torque motor-pressure
7. Find out required flow rate to operate motor.
8. Find out pump displacement.
9. Based on displacement of pump, select the pump size.
10. Do all steps for various cases.
11. Then find out engine size from above calculation.

V.CALCULATION

Various cases for calculation as follows

1. Max speed 20 kmph on flat road.
2. climbing on flyover on flat road at 10kmph
3. Max gradability of 20 deg.
4. Restart gradability at 20 deg.
5. Max speed 10 kmph on cross country road.

Engine Selection:

Power Requirement: When a vehicle is traveling at constant speed, its resistance to motion, termed the tractive resistance, it consists of:

Rolling resistance (R_r): This depends mainly upon the nature of the ground, the tires used, the weight of the vehicle, and to a lesser extent, the speed.

$$R_r = \mu * M_v * g$$

$\mu$is the rolling coefficient.

$M_v$is the mass of vehicle.

Air resistance (R_a): Air resistance depends upon the size and shape of the vehicle and increases approximately as the square of the speed of vehicle.

$$R_a = \frac{1}{2} * \rho * A * V^2$$

V is the velocity of vehicle.

A is the area exposed to air drag.

Gradient Resistance R_g : This is determined by the steepness of the hill and the weight of the vehicle, which must, in effect, be lifted from the bottom to top.

$$R_g = W_v * \sin\theta$$

$W_v$is the weight of the vehicle.

Acceleration force:

$$R_{acc} = \frac{M_v * V}{2 * t}$$

t is the time required to accelerate.

Total ResistanceR_t: Total resistance is summation of all these resistances is given by

$R_t = R_r + R_a + R_g + R_{acc}$

Total tractive effort required to propel the vehicle is given by

$$F_t = (R_r + R_a + R_g + R_{acc}) * RF$$

RF is resistance factor which is equal to 1.15 to 1.2

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Total torque required to propel the vehicle is given by

$$T_t = F_t * R$$

Where R is the radius of wheel.
Speed of vehicle in RPM is given by

$$N = \frac{V}{2 * \pi * R}$$

Total power required to run the vehicle is given by

$$P = 2 * \pi * N * T_t$$

Hydraulic Motor selection:
Motor selection is done on basis of required speed of vehicle in RPM and torque required on one wheel to run the vehicle. Required torque for one wheel is given by

$$T_w = \frac{T_t}{4}$$

Speed of vehicle in RPM is given by

$$N = \frac{V}{2 * \pi * R}$$

HydraulicPump selection: pump selection is done on the basis of required power displacement to run the hydraulic motor. Pump displacement is given by

$$Q = \frac{n_m * cc_m * N}{\eta_m}$$

n_m is number of motors. cc_m is displacement of selected motor. η_m is efficiency of motor

$$D_{pump} = \frac{Q}{N_e * n_p}$$

Q is flow rate required to run motor. N_e is engine RPM
n_p is number of pump used. Hydraulic tank size selection: there are two charge pump is used for these two pump so that hydraulic tank size is selected as

$$T_{size} = cc_{cp} * N_{pump}$$

Fuel tank selection
The fuel tank is mounted inside the engine housing near the engine. The fuel tank is provided with fuel level indicator. It is provided with lock arrangement. Engine fuel tank is mounted in the engine housing and near to the engine location. The fuel tank capacity of 100 litres is decided based on calculation.
Hydraulic Oil
The hydraulic oil selected as per the operating temperature range i.e. -20°C to + 70°C.

VI. RESULTS

Engine selection: From the calculation of engine selection power required to drive the vehicle as follows

TABLE 1 POWER REQUIREMENT

Sr. No.	Cases	Force at wheelkN	Power required kW
1	Case 1	11.11	55.57
2	Case 2	13.66	34.15
3	Case 3	51.626	43.02
4	Case 4	51.615	43.13
5	Case 5	14.5	40.269

Hydraulic motor selection: From the calculation of motor selection torque required and required RPM to drive the vehicle as follows

TABLE 2 TOURQUE REQUIREMENTS

Sr. No.	Cases	Torque at wheelkN-m	Required RPM
1	Case 1	6.457	83
2	Case 2	7.936	41
3	Case 3	29.99	15
4	Case 4	29.99	15
5	Case 5	8.408	45

Pump selection: From the calculation of pump selection required pump displacement to drive motor as follow

TABLE 3 PUMP DISPLACEMENT REQUIREMENTS

Sr. No.	Cases	Pump displacement CC/rev
1	Case 1	52.288
2	Case 2	24.837
3	Case 3	18.922
4	Case 4	18.922
5	Case 5	27.614

VII.CONCLUSION

From the result table we select the required component size as follow by considering some factor of safety and efficiencies.
Engine size: 120 kW engine is required to run the vehicle in required condition
Hydraulic motor size: 1815 cc/rev radial piston motor is selected to run the vehicle at required speed.
Hydraulic pump: 60 cc/rev size axial piston pump is selected to drive the hydraulic motor
Oil tank: oil tank of size 130 lit is selected.
Fuel tank: fuel tank of 100 lit is selected.
Hydraulic oil: The hydraulic oil selected ShellTellus S2 V 68 as per the operating temperature range.

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REFERENCES

[1] V. B. Bhandari, Design of Machine Elements, 3rd Edition, McGraw Hill Publication
[2] R S Khurmi, J K Gupta, A Textbook of Machine Design, S. Chand Publication
[3] PSG Design Data, PSG Coimbatore
[4] R S Khurmi, J K Gupta, Theory of Machines, S. Chand Publication
[5] Richard G Budynas, J Keith Nisbett, Shigley's Mechanical Engineering Design, 9th Edition, McGraw Hill Publication
[6] Anthony Esposito, Fluid Power with Applications, 6th Edition, Pearson Publication