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Design and Analysis of Hydrostatic Transmission System Required for Mobility of Railway Wagon for Limited Movement

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Abstract : *The purpose of this study is to look into different factors that are used in transporting heavy loads. This study develops ahydraulic circuit to drive a conveying system dealing with heavy loads.Effective power transmission is an important parameter in transportation of heavy and delicate loads.Various safety circuits have been added in order to ensure stable working at high pressure and precise controlling. Also the circuit design and calculations of various components used are depicted along with the system simulation. The calculations are done and taken into account for designing the circuit. The results show that the system is stable and efficient enough to transmit heavy loads.*
Keywords:*Hydrostatic System,Hydraulic Pumps,Hydraulic Motor.*

I. Introduction

Hydraulic systems are driven by the pressurized hydraulic fluid to transmit power from source to sink. Here, the source of power of the circuit is diesel engine whereas the sink is the hydraulic Motor. Hydraulics plays an important role in case of power transmission as the power is delivered to the exact point where it is needed. hydrostatic system uses a hydraulic pump and hydraulic motor which gives us fixed speed as well as fixed displacement. It has very high power density ratio as compared to mechanical system. The advantage of Hydrostatic Transmission System (HST) is that it remains stalled and undamaged under full load condition and comparatively less maintenance required to keep system operative. If they are not used continuously, they can be smoothly operated even after a long time.Present work is carried out for a railway wagon to carry a cylindrical load of 170 tonne with the use of hydraulics system. The best way to deliver required power with the help of hydrostatic circuit to exact point where it is required with very good efficiency.The whole transmission system weighs about 2.5 tonnes which is quite less as compared to traditional engine. The circuit simulations show that the circuit is working well to deliver the required power with great efficiency.

II. Problem Statememt

Cost of diesel locomotive starts from Rs.13 Cr, which is too expensive. Due to tunnel network, diesel engine produces large exhaust gases which are hazardous and remain in tunnel for long period of time. The present study shows an example of how hydraulic system can be an effective way for the transportation of heavy load. As the load is very high, it is required to carry this load at very slow speed and smoothly. In such cases it will be inefficient to call a railway locomotive to perform such small movements.

III. Methodology

Select the most suitable and efficient Hydrostatic Transmission System.Select engine to drive the hydraulic pump. The engine selection should be done on the basis of load to be carried. Once the engine is finalized, pump and motor are selected for the required displacement and speed(rpm). Design the gearbox of suitable reduction ratio to achieve desired torque and speed output. Side by side design the required hydraulic circuit using either MATLAB or AUTOMATION STUDIO. Do the simulations and analysis of gearbox and hydraulic circuit. Analyze the results and finalize the design of each component.

IV. Design of Power Transmission System

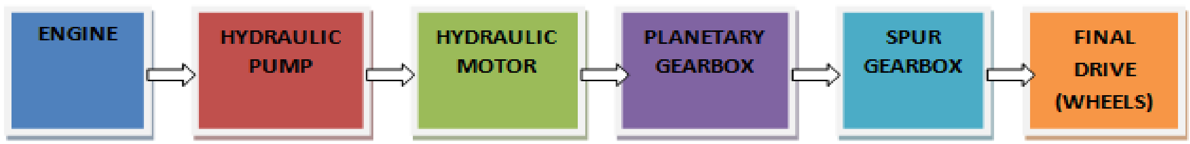

Fig.1 Power flow of Transmission System

The power flow diagram is as shown in above fig1. This system is powered by a diesel engine which drives hydraulic motor that delivers power to axel through gearbox. Here the speed assumption for required system is less i.e.5 Km/hr. Hydraulic Motor is giving the output as it is powered by Hydraulic Pump. The Final drive is the gearbox which is attached in between Hydraulic Motor and the Load i.e. Axel and wheel.The capacity of reservoir in a closed loop circuit is less since the oil flow is only between motor and pump. The closed loop reservoir is used only to compensate the pressure drop in circuit in case of any leakages. The capacity of reservoir is more in case of an open loop circuit since the pressurized oil flows from pump to motor and from motor to reservoir. For a closed circuit to maintain the constant discharge and pressure, two hydraulic pumps are employed. Main line pump is variable displacement pump while the secondary line is connected to fixed displacement pump. The variable displacement pump is having larger displacement while the fixed displacement pump is having smaller displacement.

Design consideration data is as follows:

1. Total Weight : 162.4 Tonne
2. Wheel Radius : 0.445 m
3. No. of Wheels : 16 (8 in front Bogie and 8 in rear Bogie)
4. Drive given for : 2 Wheels out of 8 wheels of front Bogie
5. Efficiency of Motor : 0.85
6. Efficiency of Pump : 0.85
7. Efficiency of Pump Mount : 0.98
8. Speed of Wagon : 5km/hr
9. Coefficient of Friction : 0.272
10. Motor Volumetric Efficiency : 0.85
11. Pump Volumetric Efficiency : 0.85
12. Efficiency of Final Drive : 0.98

According to NPTEL Transportation Engineering – II,

Rolling resistance : This occurs due to rail-wheel interaction on account of the movement of the steel wheels on a steel rail. The total frictional resistance is given by the empirical formula [1].

$$\mu = 0.0016W$$

Where, W is the weight of the train in Tonne.

According to friction, consider weight of the wagon is 170 Tonne and coefficient of friction is 0.272.

According to Indian Railway (RDSO) Technical Circular No. 27 dated on 31st July 1998, Following calculations are done [2].

1. Tractive Efforts (TE) required for hauling a load 'T' tonne on one in 'G' Grade and 'S' degree of Curve is given by:

TE = T1 + T2 + T3 + T4

Where,

T1 = Wagon Rolling Resistance in kg/t

T2 = Grade Resistance for Wagon in kg/t

T3 = Curvature Resistance For Wagon in kg/t

T4 = Locomotive Resistance in kg/t

For BOX N type of Wagon.

Load : 162.4 Tonne

Grade : 1/200 (uncompensated)

Speed : 5 km/hr

Curvature : 2 Degree

Case I :

Tractive Efforts required to start the Wagon

T1 $= 162.4\, t \times 4$ kg/t

$= 649.5$ kg

T2 $= \frac{1\times 1000 \times 162.4}{200}$ kg

$= 812$ kg

T3 $= 0.4 \times 2 \times 162.4$

$= 129.9$ kg

$= 130$ kg

T4 = 0 kg as Locomotive is absent.

Total Tractive Efforts = T1 + T2 + T3 + T4
= 649.5 + 812 +130 + 0
= 1591.5 kg
= **15,597 N**

Tractive Efforts (TE) is nothing but the Total Force required to move the wagon.

Case II :
Wagon is Moving at 5 km/hr.

For BOX N type wagon moving at some speed, R in T1 is given as
R $=0.6438797 + (0.01047218 \times V) + (0.00007323 \times V \times V)$
For V= 5 KMPH,
R = 0.69941045 kg/t
T1 = $162.4\ t \times 0.6994$ kg/t
= 113.5842 kg
T2 and T3 remains Same as speed doesn't effect on them.
Therefore, Total Tractive Efforts
TE = T1 + T2 + T3
= 113.5842 + 812 + 130
= 1055.58 kg
= **10,355.2815 N**

As TE of Case I is greater, consider it for further calculations.

From Fluid Power Circuits and Control: Fundamentals and Applications [3], required wheel torque at each driving wheel is where required wheel torque is the torque that must be supplied to the wheel to move the vehicle.

$$\text{Tw} = \frac{\text{TE} \times \text{r}}{\text{n}}$$

Where, n = no of driving Wheels
r = radius of wheel

Tw $= \frac{15{,}597 \times 0.445}{2}$
= **3,470.3325 N-m**

The ability of a vehicle to develop traction is a function of the weight on the drive wheels and the coefficient of friction between the wheel and surface.

Torque at wheel slip is given by
Ts $= \text{Weight on wheel drive} \times \mu \times r$
$= 10 \times 1000 \times 9.81 \times 0.272 \times 0.445$
= **11,874.024 N-m**

Since Ts is greater than Tw, vehicle can meet functional objective.

2. Maximum Power Calculation (Preliminary Power)

The tractive effort at wheel slip for two-wheel drive is
TE $= \frac{\text{Ts} \times \text{n}}{\text{r}}$
$= \frac{11{,}874.024 \times 2}{0.445}$
= **53,366.4 N**

Power $= \text{TE} \times \text{V}$
= 73.645 Kw
= **98.7595 hp**

The final drives are 98% efficient, so hydraulic motors have to deliver power of
$\frac{73.645}{0.98}$ = **75.1479 Kw**

The hydraulic motor is 85% efficient, therefore the motor input must be of
$\frac{75.1479}{0.85}$ = **88.4093 Kw**

The hydraulic pump is 85% efficient, therefore the pump must has input of
$\frac{88.4093}{0.85}$ = **104.0110 Kw**

The Pump mount is 98% efficient so, the engine has to deliver power of
$\frac{104.0110}{0.98}$ = 106.1337 Kw
= **142.3276 hp.**

3. Hydraulic Motor Selection

Design Pressure = 250 bar = 250,00,000 N/m²

At wheel slip, Ts = Tw = 11,874.024 N-m

Motor Capacity $Vm = \frac{(2\times\pi\times Tm)}{P}$

Where, Tm is torque required from Motor = 11,874.024 N-m and P is design pressur

$Vm = \frac{(2\times 3.142\times 11{,}874.024)}{250{,}00{,}000}$

= 2984.6 cc / rev

= **2.98 lit / rev**

Vehicle travels at a speed of 5 km/hr, the wheel speed should be

$Nw = \frac{V\times 60\times 3.142\times r}{2}$ rev / min

$= \frac{(1.38\times 60\times 3.142\times 0.445)}{2}$

= **30 rpm**

Required flow to Motor is

$Qm = \frac{Nw\times Vm}{0.85}$

$= \frac{30\times 2.98}{0.85}$

= **105.1764 lpm**

4. Pump Selection (Initial Selection)

If the Volumetric efficiency of pump is 85%, then the total flow for Motor is

$Qp = \frac{Qm}{0.85}$

$= \frac{105.1764}{0.85}$

= 123.7370 lpm

= 0.123737 m^3/min

If the pump speed is 1800 rpm then the required displacement is

$Vp = \frac{Qp}{Np}$

$= \frac{123737}{1800}$

= 68.7427 cc /rev

Maximum Hydraulic Power

$P = \text{pressure} \times \text{flow}$

$= \frac{(25000000\ N/m^2 * 0.1237370\ m^3/min)}{60}$

= 51.557 Kw

5. Final drive calculations

The final drive with gear reduction ratio (Gr) of 31.6 is selected with the efficiency of 98%.

Therefore, the torque must be delivered is

$Tm = \frac{Ts}{Gr\times efficiency}$

= 383.4288 N-m

The required Motor displacement to supply this torque at 250 bar

Pressure drop is

$Vm = \frac{2\times 3.142\times T(N-m)}{P(N/m^2)}$

$= \frac{2\times 3.142\times 383.4288}{25000000}$

= 96.37 cc/rev

Required wheel speed for 5 km/hr road speed is Nw = 30 rpm

Maximum required motor speed occurs for highest gear ratio of 31.6

$Nm = 30 \times 31.6$

= 948 rpm

Maximum flow required to achieve the speed of 948 rpm is

$Qm = \frac{Nm\times Vm}{evm}$

$= \frac{948\ rpm\times 109\ cc/rev}{0.98}$

= 105.5 lpm

From Catalogue of Parker Fixed Displacement High Torque Radial Piston Motor of MR Type naming MR 110 B is selected having displacement of 109 cc/rev which is greater than our required displacement of 96.37 cc/rev.

Required pump displacement at 1800rpm is

$$Vp = \frac{Qm}{(Np \times evp)}$$

$$= \frac{0.1055\ m^3/min}{(948 \times 0.9)}$$

= 123.6 cc/rev

Hence select the pump which has displacement more than 123.6 cc/rev.

From Catalogue, we selected the variable displacement pump as P1-PD series naming P1 100 with variable displacement of 100 cc/rev and fixed displacement pump of Parker PGP/PDM 500 series naming 0270 with displacement of 27 cc/rev.

So final selection is

Sr. No.	Entity	Make	Size
1	**Hydraulic Motor**	**Parker Fixed Displacement High Torque Radial Piston Motor of MR 110 B**	**109 cc/rev**
2	**Hydraulic Pump**	**Parker P1-PD series naming P1 100 Parker PGP/PDM 500 series 0270**	**100 cc/rev 27 cc/rev**
3	**IC Engine**	**Cummins Engine ISB5.9G 150**	**150hp**

V. Design of Hydraulic Circuit And Its Simulation

The above Fig.2 shows that the simulation of proposed hydraulic circuit. This hydraulic circuit contains a **1. Hydraulic motor, 2. Hydraulic pumps, 3. Pressure relief valves, 4. One directional control valves, 5. Proportional Flow control Valve, 6. Switches , 7. Knob and 8.Reservoir.** It is a closed loop closed circuit having flow from motor to pump and pump to motor. Its space requirement is less, resulting in less capacity of reservoir tank. The main line starts from variable displacement bi-directional pump to fixed displacement bi-directional motor. Fixed displacement pump is used to make up for the pressure drop due to leakages. This makes circuit to provide constant torque. The addition of flow control valve can make possible to vary speed up to its maximum limit of speed. This torque can be increased up to its requirement by using the combination of two different gearboxes.

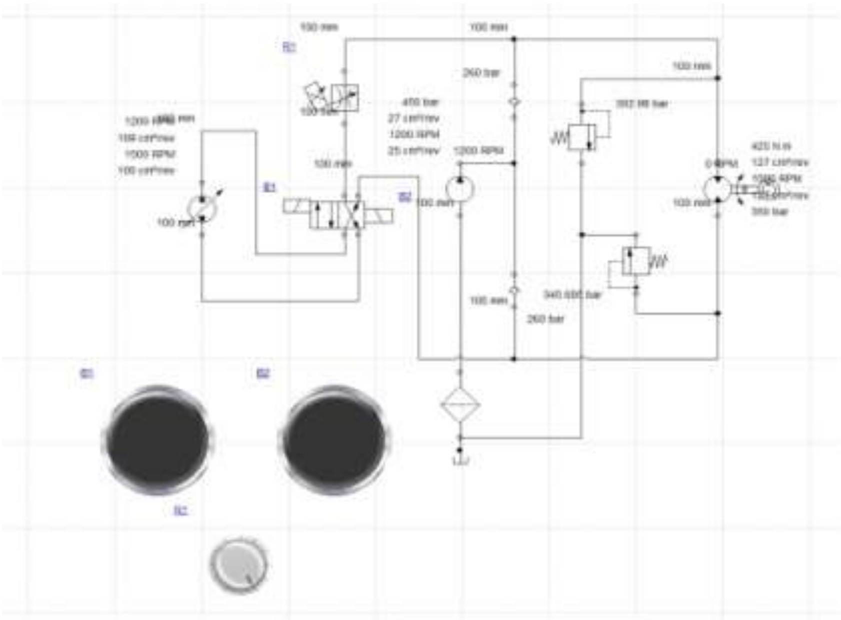

Fig.2 Design of hydraulic circuit using automation studio

VI. Conclusion

The use of hydraulic system can be a better way to transmit the power direct from source to sink with high efficiency due to absence of mechanical linkages. The improved system can be utilized in the railway wagon to make small movements possible in absence of railway locomotive. Also by using hydraulic system, almost 80 percent less power is used as compared to the actual locomotive.With the proposed design, one can create hydraulic circuit that will solve the problem of heavy load's movement. The cost of proposed system is much less compared to that of a diesel locomotive. It can be an effective transmission system for low speed and less usage.

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Conflict of interest The authors declare that there is no conflict of interests regarding the publication of this paper.

References

[1]. Tom V. Mathew et al,' Introduction to Transportation Engineering.
[2]. Ministry of Railways et al,' Research Design and Standard Organization, Technical Circular No.27, No. EL/3.1.39 / 1, Lucknow, 1998.
[3]. J.S. Cundiff et al,'*Fluid power circuits and Control: Fundamentals and Applications (*New York, CRC Press, 2001).
[4]. Mistry, K. A. et al,'*Design and Analysis of Hydrostatic Transmission system* ', IOP Conf. Series: Materials Science and Engineering,2018, Issue 10, 2010, ISSN (online):1757-899X, PP 1-10.
[5]. Shrishrimal, A. et al, 'Design of two stage Planetary Gear Train for high reduction ratio, 'IJAERD - International Journal for Advance Engineering and Research Development, Vol. 5, Issue 1, 2018, ISSN (online): 2348-4470, PP- 400-408.