VEHICLE DRIVE CALCULATIONS

The following section explains how to calculate the output torque and speed required from a hydraulic drive to propel a vehicle.

Before proceeding to the torque and speed calculations the following variables need to be determined:

Maximum (gross) vehicle mass (GVM)	G	
Maximum vehicle speed	v	
Maximum gradient or incline	$\propto$	
Wheel radius	R	
Axle/gear ratio (if any)	i	
Rolling resistance	r	(refer table below)
Friction coefficient	μ	(0.75 – 0.90)

ROLLING RESISTANCE (Drawbar pull as a fraction of GVM required to keep vehicle moving)	
Surface Type	Resistance Coefficient (r)
Concrete	0.010 - 0.020
Asphalt	0.012 - 0.022
Packed gravel	0.015 - 0.037
Cobbles	0.055 - 0.085
Snow	0.025 - 0.037
Dirt	0.025 - 0.037
Mud	0.037 - 0.150
Sand	0.060 - 0.300

Drawbar pull

The first step is to calculate the drawbar pull required to propel the vehicle. Drawbar pull can be calculated using the following formula:

$$F = G \times (\sin \propto + r)$$

Where

F	=	force in pounds
G	=	maximum vehicle weight in pounds
$\propto$	=	maximum incline angle
r	=	rolling resistance

In metric units

$F = G \times (\sin \propto + r)$

Where

F = force in deca Newtons (daN)
G = maximum vehicle weight in kilograms
$\propto$ = maximum incline angle
r = rolling resistance

Wheel torque

Once the required drawbar pull has been determined, the wheel torque required can be calculated using the following formula:

$T_W = F \times R$

Where

T_W = wheel torque in inch-pounds
F = drawbar pull in pounds
R = wheel radius in inches

In metric units

$T_W = F \times R$

Where

T_W = wheel torque in deca Newton metres (daNm)
F = drawbar pull in deca Newtons (daN)
R = wheel radius in metres

Note that the figure calculated here is total wheel torque. If more than one hydraulic motor is to be used to propel the vehicle, total wheel torque is divided by the number of motors to arrive at the torque required from each motor. If an axle or reduction hub is used, the torque multiplication of the gear ratio must also be considered as follows:

Motor torque

If an axle or reduction hub is to be used, the axle-input torque required from the hydraulic motor will be less than the wheel torque and can be calculated as follows:

$$T_m = \frac{T_w}{i}$$

Where

T_m = motor shaft torque in inch pounds
T_w = wheel torque in inch pounds
i = gear ratio of axle or reduction hub

In metric units

$$T_m = \frac{T_w}{i}$$

Where

T_m = motor shaft torque in deca Newton metres (daNm)
T_w = wheel torque in deca Newton metres (daNm)
i = gear ratio of axle or reduction hub

Motor speed

The shaft speed required from the hydraulic motor to propel the vehicle at the desired velocity can be calculated using the following formula:

$$n_m = \frac{168 \times v \times i}{R}$$

Where

n_m = motor shaft speed in rpm
v = velocity in miles per hour
i = gear ratio of axle or reduction hub
R = wheel radius in inches

In metric units

$$n_m = \frac{v \times i}{R \times 0.377}$$

Where

n_m	=	motor shaft speed in rpm
v	=	velocity in kilometres per hour
i	=	gear ratio of axle or reduction hub
R	=	wheel radius in metres

At this point the torque and shaft speed required from the hydraulic motor(s) to propel the vehicle has been determined. For detailed information on motor and pump sizing and selection, refer to our Technical Library document titled Pumps and Motors.

Other design considerations

Tractive effort

When applying ground drive to a vehicle, it is important to consider the maximum tractive effort that can be transmitted from the wheels to the ground through friction. Tractive effort is influenced by the friction coefficient, which is the ratio of torque and wheel or axle load (mass). In practice this means that a vehicle cannot exert a tractive effort greater than the wheel or axle load. The implication of this for the designer is that if the wheel or axle torque applied to a vehicle is greater than its tractive effort, this excess torque is wasted through wheel spin. Tractive effort can be calculated using the following formula:

$$TE = G \times \mu$$

Where

TE	=	tractive effort in pounds force
G	=	maximum vehicle weight (mass) in pounds
μ	=	friction coefficient (0.75 – 0.90)

In metric units

$$TE = G \times \mu$$

Where

TE	=	tractive effort in deca newtons (daN)
G	=	maximum vehicle weight (mass) in kilograms
μ	=	friction coefficient (0.75 – 0.90)

Note that the figure calculated here is total tractive effort. If more than one hydraulic motor is to be used to propel the vehicle, total tractive effort is divided by the number of motors to arrive at the ideal tractive effort from each motor.

Overspeeding

In mobile applications consideration must be given to possible overspeeding and cavitation of hydraulic motors caused by vehicle-induced load, when travelling downhill. This problem can even occur in closed loop circuits due to the limited braking characteristics of combustion engines. The fitting of load control valves in the propel circuit is recommended to eliminate this possibility.