AI 3401 TRACTORS AND ENGINE SYSTEMS

UNIT IV NOTES

TRACTION

A pneumatic tyre which is flexible has a smaller contact area on cocreate surface than it dose on soft ground. A rule of thumb which can be used for estimation of tire contact area is given below-

$A = bl$

Where:

A = Tire contact area

b = Section width of tire

l = Contact length of tire

Traction Terminology

Traction.

The process by which a tractor develops tractive force and overcomes motion resistance to produce desired motion.

Tractive force

The force developed on the tractor interface by the traction device as a result of applied torque from the power source.

Motion resistance

Any force imposing resistance against desired motion.

Rolling resistance

Motion resistance that arises from deformations in the soil and the traction device

Sinkage

The depth to which the traction device penetrate into the soil measurednormal to the original, undisturbed surface.

Slip

It is an indication of how the speed of the traction device differs from the forward speed of the tractor. It can be defined as as the percentage travel reduction and given as

S = [1 – Va/Vt] 100

Coff

Traction efficiency

The efficiency of the tractive device is converting the axle input power into output power, the term tractive efficiency (TE) has been defined as

TE = Output power/ Input power x100

Basically tractive efficiency is converting the axle torque into net traction .

Traction prediction equation

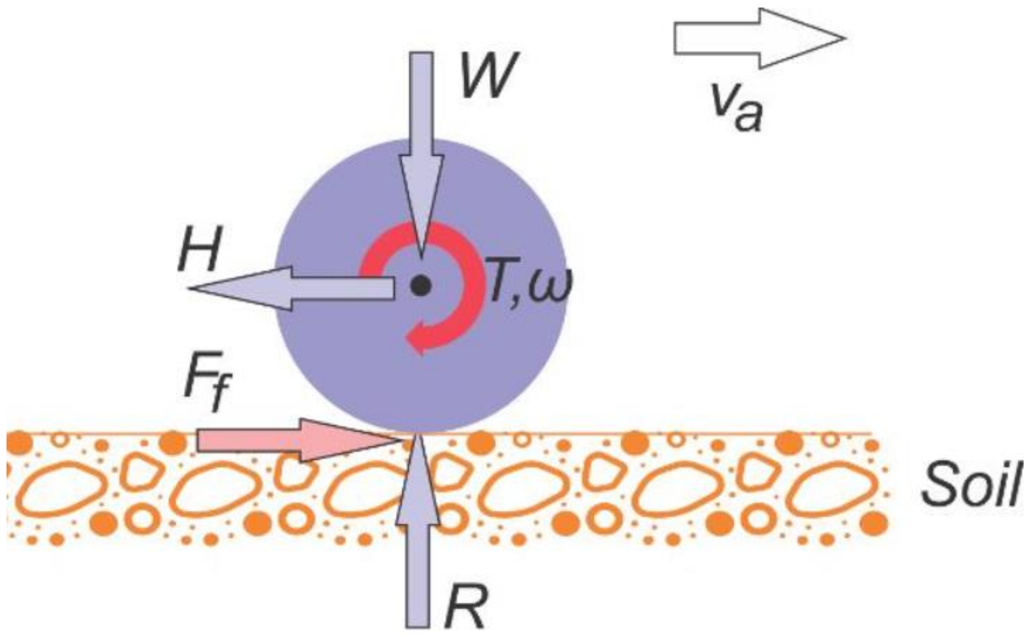
Dimensional analysis is the best technique used to develop the prediction models for traction forces of pneumatic wheel type of tractor in tillage operation. Soil-wheel interaction was considered in developing the prediction models. Based on the Buckingham Pi Theorem, the number of dimensionless and independent quantities required to fully express the relationship between the variables were determined.

Effective factors	Definition	Symbol	Unit	MLT
Soil engineering properties	Cone index	CI	N/m^2	$ML^{-1}T^{-2}$
Tractor parameters	Tyre breadth	B	m	M^0LT^0
	Tyre diameter	D	m	M^0LT^0
	Tyre rolling radius	R	m	M^0LT^0
	Tractor weight	W	N	MLT^{-2}
Operational parameters	Tractive force	F	N	MLT^{-2}
	Towed force	F_T	N	MLT^{-2}
	Pull	F_P	N	MLT^{-2}
	Slip	S	-	

Mechanics of Traction

The simplest way of analyzing the traction produced by a traction device, such as a wheel or track, is to consider friction forces that act at the contact between a traction device and the surface when the system is in equilibrium. For simplification the machine is assumed to be moving at a constant velocity on a non-variable surface (Figure). A traction device (hereafter simplified to the most common implementation as a "wheel") has two main functions: to support the load acting on the wheel axle (*W*) and to produce a net tractive force (*H*). The force *W* is generally called the dynamic load acting on the wheel. The dynamic load depends on how the weight of the tractor at that point in time is distributed to each wheel.

If the system is in equilibrium, the surface reacts to *W* by applying a vertical reaction force (*R*) to the wheel. In the contact between the surface and the wheel, a friction force (F_f) is generated. To keep equilibrium in the horizontal direction, the magnitude of the net tractive force *H* is equal to the magnitude of the friction force F_f. To produce a net tractive force *H*, the friction force needs to be overcome. This is done by applying a torque (*T*) to the wheel axle. This torque is proportional to the torque produced by the tractor engine according to the drive train, including the current transmission ratio.



: Simplified diagram of the variables related to a wheel developing a net tractive force.

ω = angular velocity of the wheel

F_f = friction force

H = net tractive force

R = vertical reaction force of the wheel

T = torque transferred to the wheel axle

v_a = actual velocity of the wheel

W = dynamic wheel load

When moving, the wheel (Figure below) rotates with a constant angular velocity (ω), and this angular speed is proportional to the engine rotation speed, depending on the gearing ratio in the drive train. The wheel has an actual velocity v_a, which is equal to the angular velocity multiplied by the wheel's rolling radius reduced by the slip (as discussed below). In an equilibrium situation, ω and v_a are constants. The power transferred to the wheel axle (P_w) can be calculated as the product of the torque (T) and the angular velocity (ω), as shown in Equation 1. The tractive power developed by the wheel (P_t) is the product of the net tractive force (H) and the actual velocity (v_a), as shown in Equation 2. The tractive efficiency of the wheel (T_E) can be calculated as the ratio between tractive power and the wheel axle power, as shown in Equation

$$P_W = T\omega$$

$$P_t = H\nu_a$$

$$T_E = \frac{P_t}{P_W}$$

where P_w = power transferred to the wheel axle (W)

T = torque transferred to the wheel axle (N m)

ω = angular velocity of the wheel (rad s^{-1})

P_t = tractive power developed by the wheel (W)

H = net tractive force (N)

v_a = actual velocity of the wheel (m s^{-1})

T_E = tractive efficiency of the wheel (dimensionless)

The friction force (Figure below) is generated by the interaction between the wheel and the surface. The friction force can be calculated by multiplying the reaction force (R) by the equivalent friction coefficient (μ). Table 3.1.1 presents some typical values. Because R is equal to the dynamic load acting on the wheel axle (W) and the net tractive force is equal to the friction force, the tractive force can be calculated as the product of the equivalent coefficient of friction and the dynamic load, as:

Table : Equivalent coefficient of friction for a tractor wheel working on different surfaces.

Surface type	Equivalent coefficient of friction (μ)[a]
Soft soil	0.26–0.31
Medium soil	0.40–0.46
Firm soil	0.43–0.53
Concrete	0.91–0.98

The travel reduction ratio is an important variable for wheel tractive force analysis. The travel reduction ratio of a wheel can vary from 0 to 1 depending on wheel and surface conditions. When the travel reduction ratio is equal to 0, there would be no relative motion between the periphery of the wheel and the surface. The wheel rotation causes a perfect translational motion relative to the surface. However, experience has shown that for a wheel to develop a tractive force, there must be relative motion (slip) between the wheel and the surface. Therefore, a wheel generating tractive force needs to have a travel reduction ratio greater than zero. When a wheel generates more tractive force, the travel reduction ratio increases, and the actual wheel velocity reduces. When the travel reduction ratio is equal to 1, the wheel does not move forward when it rotates. The models used to calculate the tractive force generally use the travel reduction ratio as one of the variables.

ω = angular velocity of the wheel

F = gross tractive force

H = net tractive force

R = vertical reaction force of the wheel

r = rolling radius

T = torque transferred to the wheel

F_r = motion resistance force

v_a = actual velocity of the wheel

W = dynamic wheel load

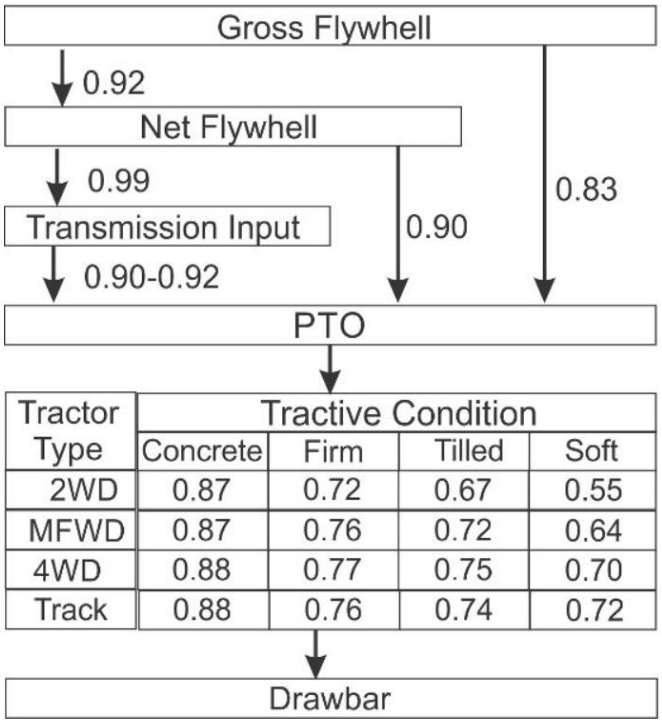
Engine Power Needed to Produce a Tractive Force

ASABE Standards (2015) presented a diagram (Figure)of the approximate typical power relationship for agricultural tractors. Tractors can be specified by their engine gross flywheel rated power (P_e). One of the standards used to define the engine gross flywheel rated power is SAE J1995 (SAE, 1995). The rated power defined by this standard is the mechanical power produced by the engine without some of its accessories (such as the alternator, the radiator fan, and the water pump). Therefore, the engine gross flywheel rated power is greater than the net power produced by the engine. The approximate engine net flywheel power can be estimated by multiplying the gross flywheel power by 0.92. The power at the tractor PTO is about equal to the engine gross flywheel power multiplied by 0.83 or the engine net flywheel power multiplied by 0.90.

The power that the tractor can generate to pull implements, often termed drawbar power because many implements are attached to the tractor's drawbar, depends on the tractor type, i.e., 2-wheel drive (2WD), mechanical front wheel drive (MFWD), 4-wheel drive (4WD), or tracked. The surface condition where the tractor is used has an even greater effect. Using these two pieces of information, coefficients that show estimates of the relationship between the drawbar power and the PTO power is given in Figure below.

Applications

The concepts of traction and tractor power are necessary for properly matching the tractor to an implement. Agricultural operations cannot be performed if the tractor cannot develop enough power or traction to pull the implement. As implements have increased in size over the years, it is necessary that the tractors have enough power and enough traction for the tasks they have to perform. Choosing a tractor that is too large will negatively impact agricultural profitability because larger tractors cost more than smaller tractors. An oversize tractor may also increase fuel consumption and exhaust emissions. This is significant because even the most efficient tractors get less than 4 kWh of work per liter of diesel fuel.



agram of the approximate power relationships in agricultural tractors (types are defined in the main text) and soil conditions (ASABE, 2015).

Problem:

Calculate the tractive force produced by a tractor wheel that works on a firm soil with a dynamic load of 5 kN. The wheel velocity is 2 m s^{-1}. If the tractive efficiency is 0.73, what is the power that needs to be transferred to the wheel axle?

problem

Assume an equivalent coefficient of friction of 0.48, the mean value for firm soil given . Calculate the tractive force using required Equation

$$H=\mu W=0.48\times 5=2.4\ \text{kN}H=\mu W=0.48\times 5=2.4\ \text{kN}$$

Now, calculate the tractive power for the tractor wheel using Equation 3.1.2:

$$Pt=Hva=2.4\times 2=4.8\ \text{kW}Pt=Hva=2.4\times 2=4.8\ \text{kW}$$

Calculate the power that needs to be transferred to the wheel axle for using Equation 3.1.3 with the given tractive efficiency of 0.73:

$$PW=PtTE=4.80.73=6.58\ \text{kW}PW=PtTE=4.80.73=6.58\ \text{kW}$$

This value of needed power can be used to design the various power transmission components. The power consumption can also be used to calculate the power demanded of the ultimate power source, probably an engine, to calculate fuel consumption and, thereby, costs of a particular field operation.