

Looking at how brake force
distribution limits braking
capability



Using Example 2 Data

Data:

Wheelbase	L	$= 2.5\text{m}$
Unsprung Mass front two wheels	M_{usf}	$= 76 \text{ kg}$
Unsprung mass rear two wheels	M_{usr}	$= 82 \text{ kg}$
CG to front axle	a	$= 1.35 \text{ m}$
CG to rear axle	b	$= 1.15 \text{ m}$
Total mass	M_{tot}	$= 800 \text{ kg}$
Height of CG	H	$= 0.375\text{m}$
Longitudinal acceleration	a_x	$= 1.4g$
Rolling radius of tyre	r	$= 0.275$

Results of weight transfer calculations for $\mu = 1.4$ and 1.0 for Example 2

Mu=1 a= 1	
WTs	941.760
Wtus	170.498
Wfb	4702.718
Wrb	3125.662
Ffb	4702.718
Frb	3125.662
Ffbp	0.601
Frbp	0.399
Sum	1.000

Mu=1.0 a=0	
WTs	0.000
Wtus	0.000
Wfb	3590.460
Wrb	4237.920
Ffb	3590.460
Frb	4237.920
Ffbp	0.459
Frbp	0.541
Sum	1.000

Mu=1.4 a= 1.4	
WTs	1318.464
Wtus	238.697
Wfb	5147.621
Wrb	2680.759
Ffb	7206.669
Frb	3753.063
Ffbp	0.921
Frbp	0.479
Sum	1.400

Mu=1.4 a=0	
WTs	0.000
Wtus	0.000
Wfb	3590.460
Wrb	4237.920
Ffb	5026.644
Frb	5933.088
Ffbp	0.642
Frbp	0.758
Sum	1.400

Non- optimum braking split

In Example 2 the rate of deceleration was defined as 1.4 g and the brake system would have been specified accordingly to give a split of 7206.669.5/3753.06 ie

$$\text{Front split} = 7206.669/10959.73 = 0.658 \text{ ie } 65.8\%$$

$$\text{Rear split} = 3753.06/10959.73 = 0.342 \text{ ie } 34.2\%$$

If this split is used 1.4 g will be possible on a road surface with $\mu_t = 1.4$

Using 60 /40 Split

If, however, the split of 60 /40 were used (which was found to be the optimum distribution for a μ_t of 1) instead, 40% of the total braking force rear would be directed to the rear wheels rather than the optimum of 34.2%.

The deceleration would be limited by premature locking of the rear brakes. The rear tyres would be 'saturated' before 1.4g ie 13.73 m/s^2 were reached

60/40 split by calculation

Brake split = 60% front and 40% rear

To achieve any deceleration total braking force
 $= 800 a_x \text{ N}$

Rear force applied will be
 $0.40 * 800a_x \text{ N}$
 $= 320a_x \text{ N}$

60/40 Split by calculation

Rear brake capability at any deceleration will be:
 μ_t (Static load – WT)

$$(M_r = 1.35 / 2.5 * 800 = 432 \text{ kg})$$

$$1.4 \left((9.81 * 432) - (800 a_x * 0.375 / 2.5) - (158 a_x * 0.275 / 2.5) \right)$$

$$= 1.4 * (4237.92 - 120a_x - 17.938a_x)$$

$$= 5933.088 - 193.113a_x$$

60/40 Split by calculation

The maximum deceleration achievable will be when braking force applied = braking capability

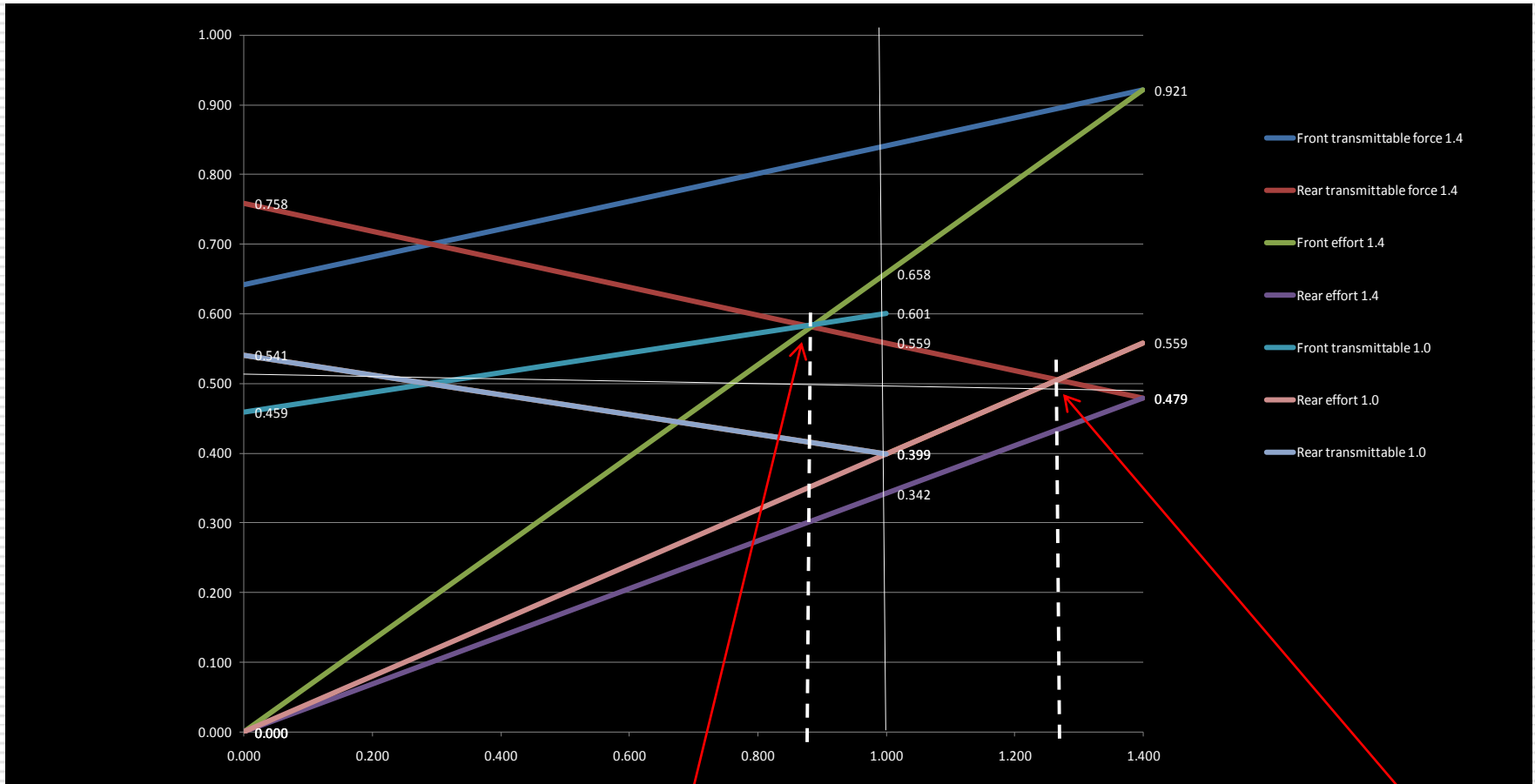
$$\begin{aligned}\text{ie} \quad 320a_x &= 5933.088 - 193.113a_x \\ a_x &= 11.56 \text{ m/s}^2 \\ &= 1.2 \text{ g}\end{aligned}$$

So maximum deceleration = 1.2g before the rear wheels lock and directional stability will be compromised, compared with 1.4g with the optimum braking split (when both front and rear axles will lock simultaneously)

Finding the effect graphically

The use of a graph plotting braking force as a proportion of vehicle weight is another method of showing the same effect

Premature wheel lockup using setup for 'wrong' μ_t



Early front lockup due to μ_t 1.4 setup on μ_t 1.0 😊

Early rear lockup due to μ_t 1.0 setup on μ_t 1.4 ☹️