

Brake Effort Distribution

Ideal Brake Effort Distribution

In addition to determining the weight transfer to find individual wheel loads the longitudinal calculation weight transfer can be used to find the optimum brake effort ratio

Maximum braking will occur when all four wheels produce their maximum retarding force at the same time with neither front nor rear wheels locking prematurely.

To achieve this the brake system must be designed to produce exactly the required brake effort distribution

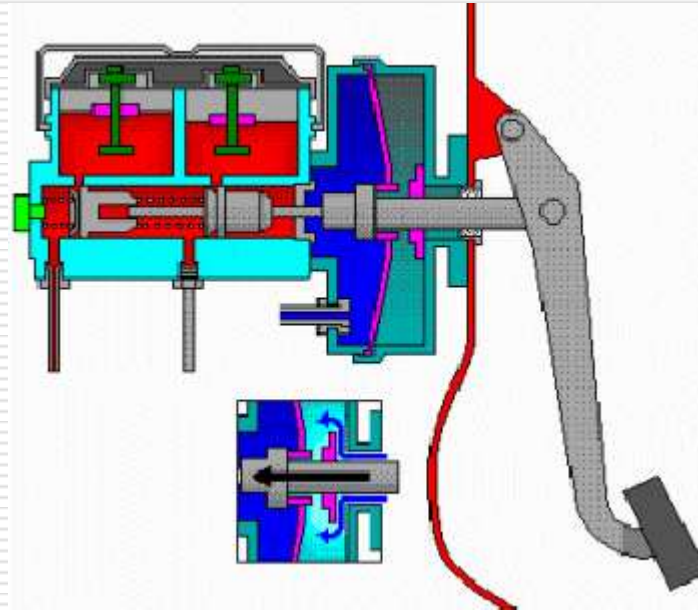
Achieving the required brake effort distribution

Adjustable systems using brake using a balance bar

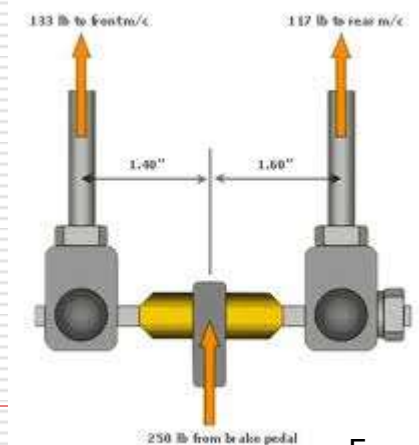
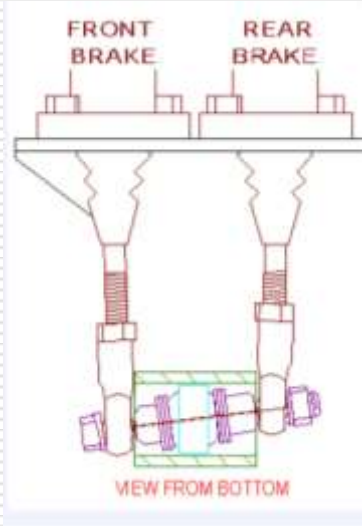
Non-adjustable system using matched components or dual master cylinder to achieve balance required

Dual master cylinder

Different diameter pistons used to achieve different line pressures.



Adjustable brake effort distribution



Maximum deceleration achievable

Looking at the simple case of a single wheel that is slipping sufficiently to give the maximum maximum grip

Brake Force required $F = Ma_x$

Brake Force achievable $F_b = \mu_t R$

$$F_b = F$$

$$\mu_t R = Ma_x$$

$$\mu_t = \frac{Ma_x}{R}$$

but $R = Mg$

So the maximum deceleration $a_x = \mu_t g$

Brake force achievable

In general terms $F = \mu_t R$

Looking at the front wheels

$$F_{fb} = \mu_t W_{fb}$$

Where:

Similarly $F_{rb} = \mu_t W_{rb}$

Example 4:

Data:

Wheelbase

$$L = 2.5\text{m}$$

Sprung Mass front two wheels

$$M_{sf} = 295.3 \text{ kg}$$

Sprung mass rear two wheels

$$M_{sr} = 346.7 \text{ kg}$$

Unsprung Mass front two wheels

$$M_{usf} = 76 \text{ kg}$$

Unsprung mass rear two wheels

$$M_{usr} = 82 \text{ kg}$$

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

$$r = 0.275$$

Static front load due to sprung and unsprung masses

$$M_{sf} = 295.32 \text{ kg}$$

$$F_{zsf} = 2897.09\text{N}$$

$$M_{us} = 76 \text{ kg}$$

$$F_{zusf} = 745.56\text{N}$$

$$\text{Total front static load} = 3642.65\text{N}$$

Weight transfer due to sprung mass WT_s

$$WT_s = \frac{M_s \times a_x \times H}{L}$$

$$M_s = 642 \text{ kg}$$

So

$$WT_s = \frac{642 \times 1.4 \times 9.81 \times 0.375}{2.5}$$

$$= 1322.58 \text{ N}$$

$$\frac{M_s \times a_x \times H}{L}$$

Weight transfer due to unsprung mass WT_{us}

$$WT_{us} = \frac{M_{us} \times a_x \times r}{L}$$

$$M_{us} = 158 \text{ kg}$$

So

$$\begin{aligned} WT_{us} &= \frac{158 \times 1.4 \times 9.81 \times 0.275}{2.5} \\ &= 238.69 \text{ N} \end{aligned}$$

Total Front Wheel Load W_{fb}

$$W_{fb} = 745.56 + 2897.09 + 1322.58 + 238.69$$

$$W_{fb} = 5203.93 \text{ N}$$

Similarly:

$$W_{rb} = 804.42 + 3400.93 - 1322.58 - 238.69$$

$$W_{rb} = 2644.08 \text{ N}$$

Maximum brake force achievable

Using this data, calculate the Maximum Brake Force achievable at the front and rear of the vehicle at 0g and at 1.4g decelerations.

$$W_{fb} = 5203.93 \text{ N}$$

$$W_{rb} = 2644.08 \text{ N}$$

Finding F_{fb} and F_{rb}

The maximum deceleration is given as $1.4g$ so, ignoring the fact that front and rear μ_t values will actually be slightly different, assume $\mu_t = 1.4$

$$\begin{aligned} F_{fb} &= \mu_t 5203.93 \\ &= 1.4 \times 5203.93 \\ &= 7285.5N \end{aligned}$$

$$\begin{aligned} F_{rb} &= \mu_t 2644.08 \\ &= 1.4 \times 2644.08 \\ &= 3701.7N \end{aligned}$$

Brake force distribution by total brake force

The brake force distribution or split can be expressed as a proportion of total brake force.

$$\text{Front split} = 7285.5/10987.2 = 0.66 \text{ ie } 66\%$$

$$\text{Rear split} = 3701.7/10987.2 = 0.34 \text{ ie } 34\%$$

Generally, when referring to brake split or brake effort distribution this would be the value used

Braking Force distribution by vehicle weight

The brake force distribution can also be expressed by vehicle weight which expresses the braking force at each axle as a proportion of total vehicle weight.

Braking Force distribution by vehicle weight

F_{fbp} = Maximum Brake Force achievable at the front wheels as a proportion of vehicle weight.

$$F_{fbp} = F_{fb} / W$$

and

F_{rbp} = Maximum Brake Force achievable at the rear wheels as a proportion of vehicle weight

$$F_{rbp} = F_{rb} / W$$

Brake Force Distribution by vehicle weight at 1.4 g when $\mu_t=1.4$

$$F_{fbp} = F_{fb} / W$$

$$F_{fbp} = 7285.5/800g$$

$$F_{fbp} = 0.93 \text{ at } 1.4 \text{ g}$$

$$F_{rbp} = F_{rb} / W$$

$$F_{rbp} = 3701.7/800g$$

$$F_{rbp} = 0.47 \text{ at } 1.4 \text{ g}$$

Brake Force distribution by vehicle weight at 0g when $\mu_t=1.4$

The car is not actually braking but this is the brake force available. (The distribution will be the same as the static weight distribution)

$$F_{fb} = \mu_t W_f$$

$$F_{fbp} = F_{fb} / W$$

$$F_{fbp} = 1.4 \times 3642.65 / 800g$$

$$F_{fbp} = 0.65 \text{ at } 0g$$

$$F_{rb} = \mu_t W_r$$

$$F_{rbp} = \mu_t W_r / W$$

$$F_{rbp} = 1.4 \times 4205.35 / 800g$$

$$F_{rbp} = 0.75 \text{ at } 0g$$

Use of Brake Force as a Proportion of Vehicle Weight

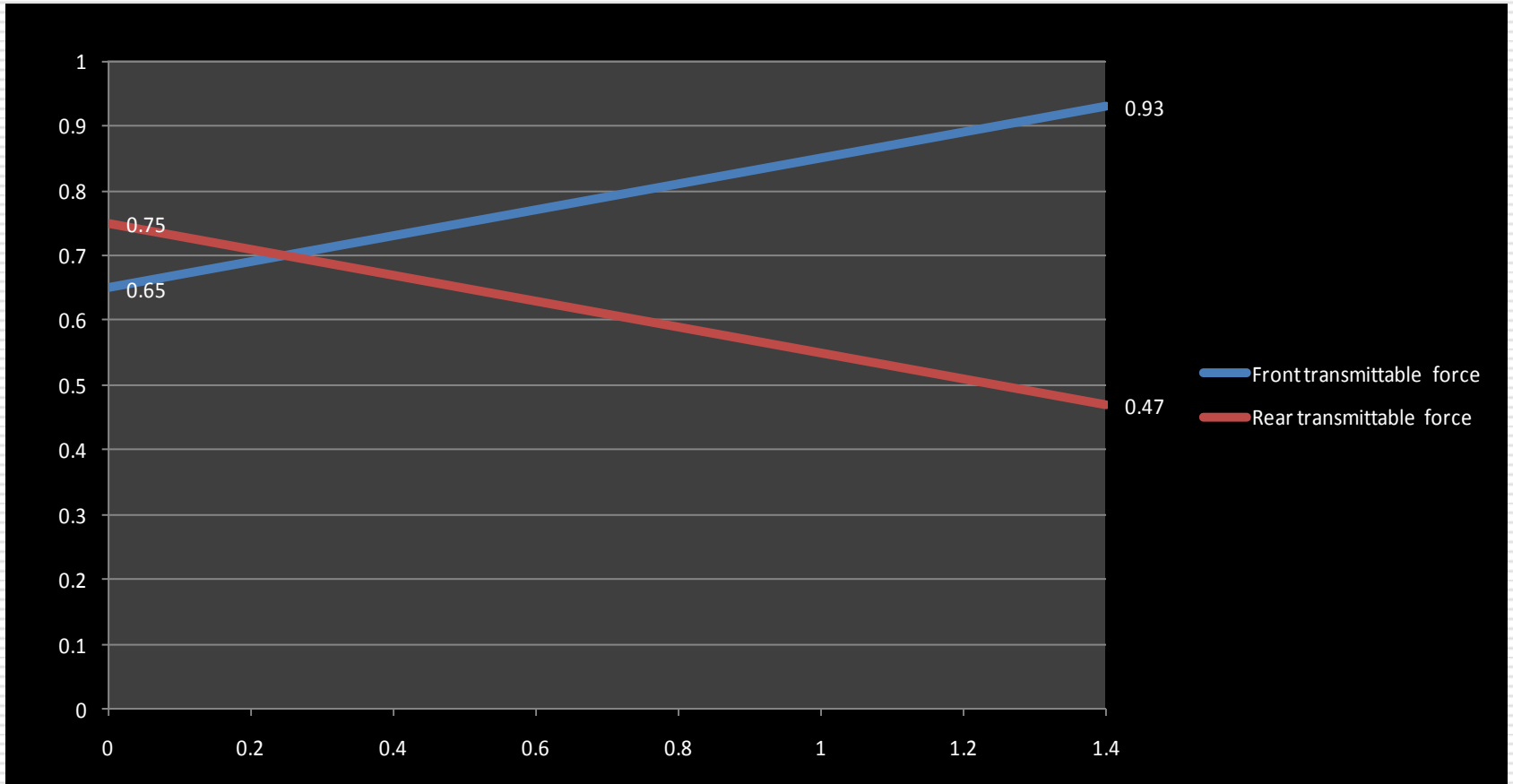
We can use the Brake Force Distribution by vehicle weight description to help understand where brake lockup and limiting deceleration will occur.

Plotting F_{fbp} and F_{rbp} against Decel

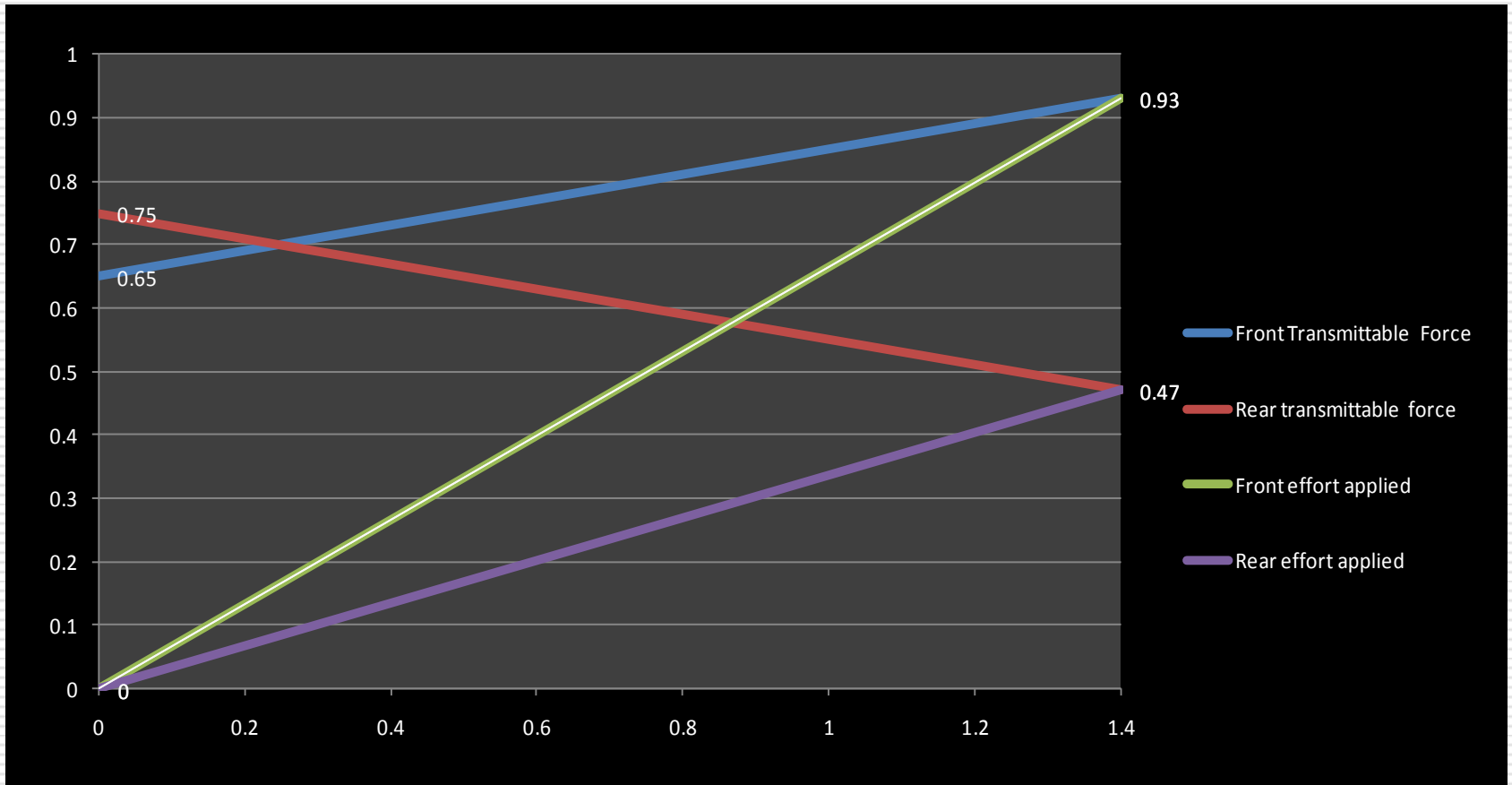
Summary of transmittable brake forces at 0g and 1.4g
ie when $\mu_t = 1.4$

	0g	1.4g
F_{fbp}	0.65	0.93
F_{rbp}	0.75	0.47

Plot of F_{fbp} and F_{rbp} against deceleration for $\mu_t = 1.4$



Ideal brake effort lines added for $\mu_t = 1.4$



Ideal distribution for $\mu_t = 1.0$

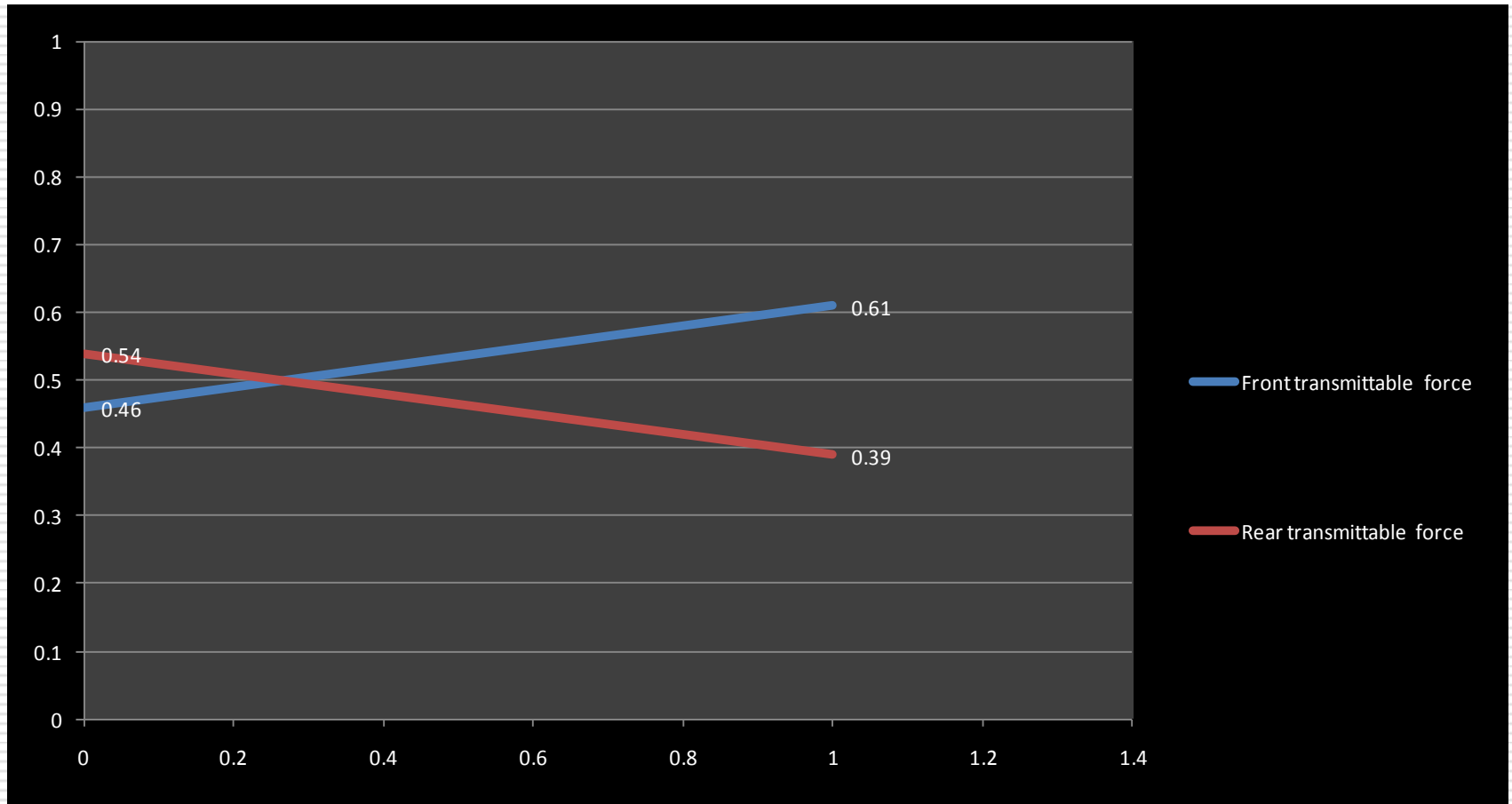
Now repeat the exercise for Example 4 but with $\mu_t = 1.0$

Maximum deceleration will now be 1.0g

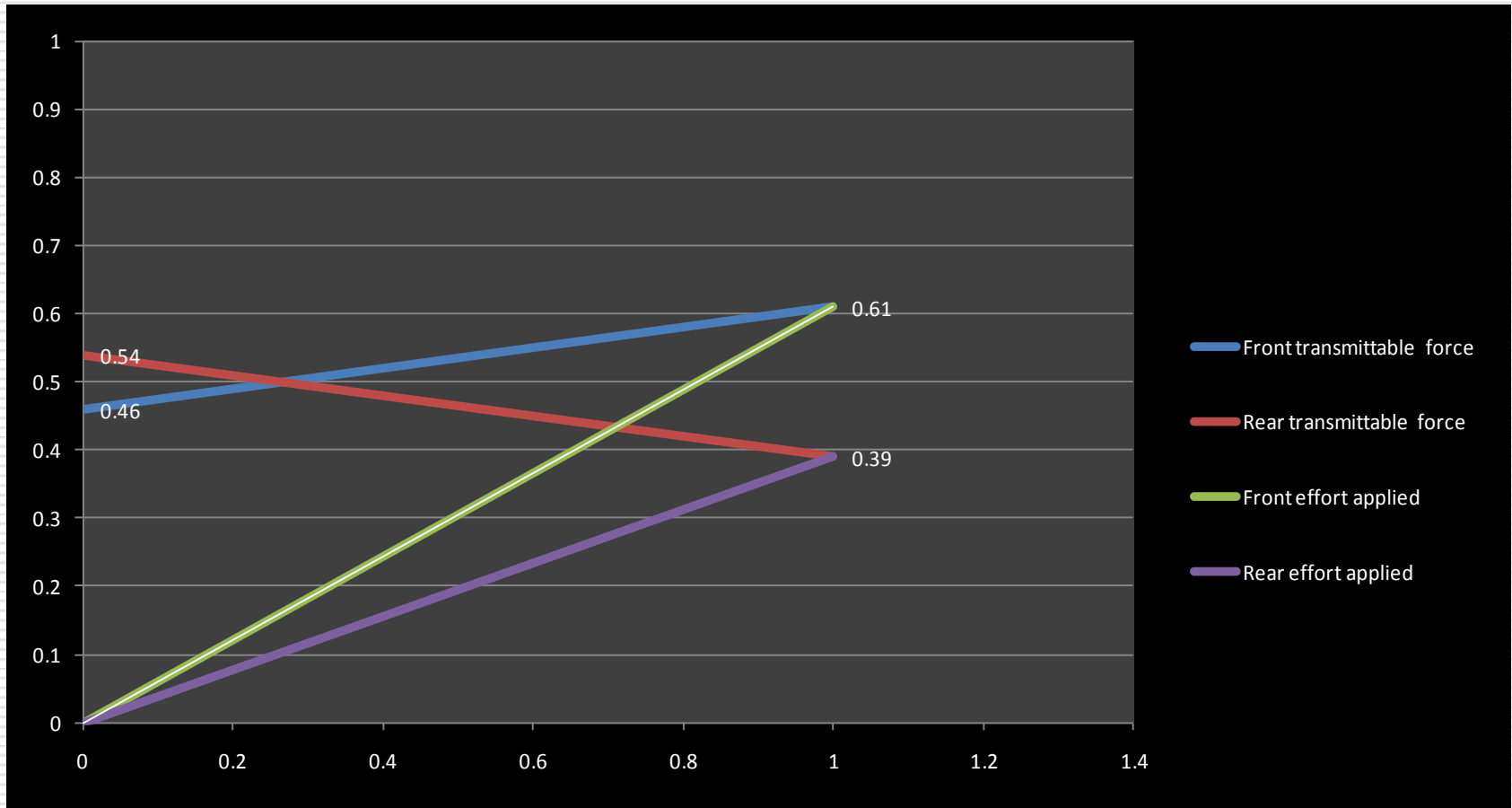
Summary of transmittable brake forces at 0g and 1g

	0g	1g
F_{fbp}	0.46	0.61
F_{rbp}	0.54	0.39

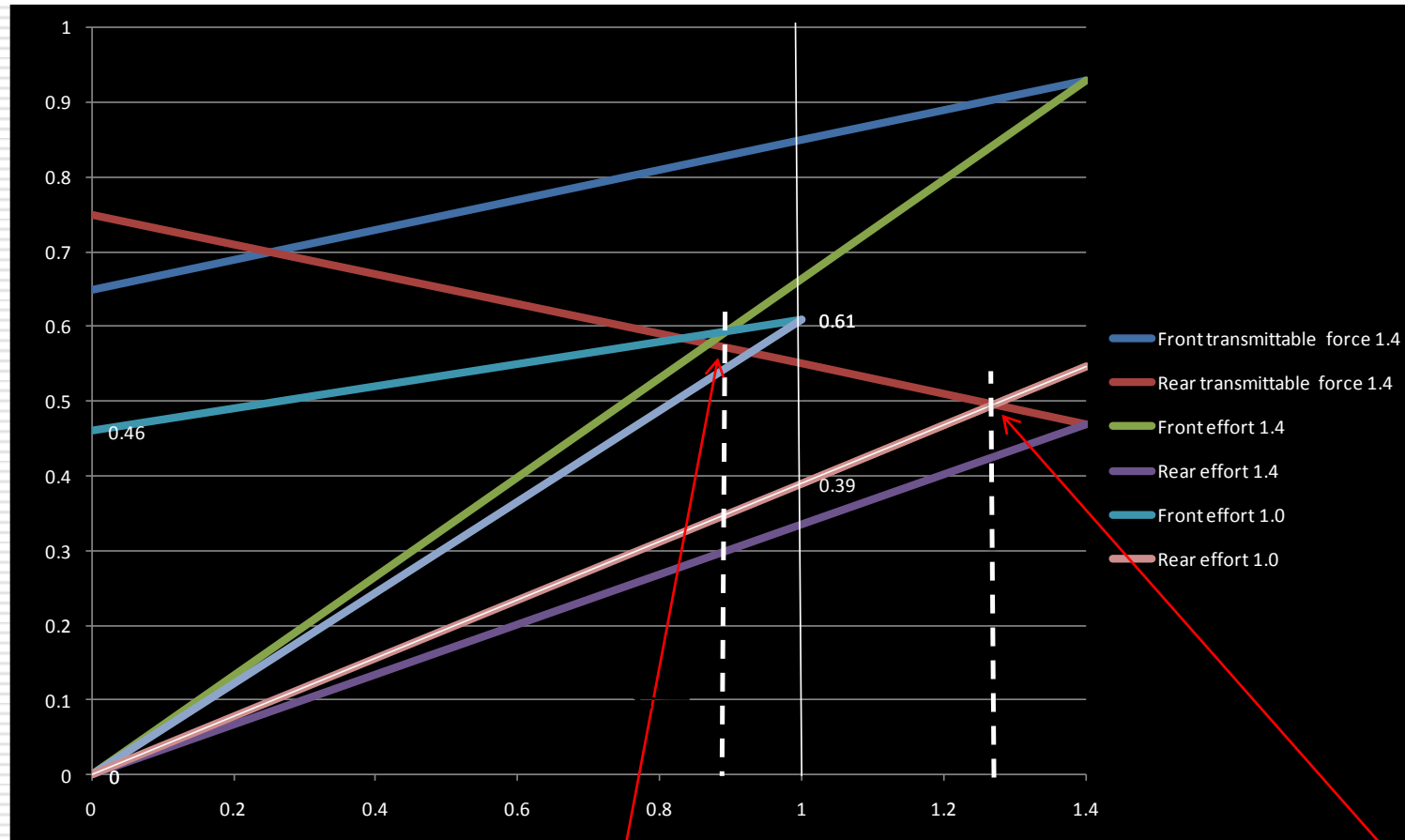
Plot of F_{fbp} and F_{rbp} against decel for $\mu_t = 1.0$



Ideal brake effort lines added for $\mu_t = 1.0$



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 ☹️