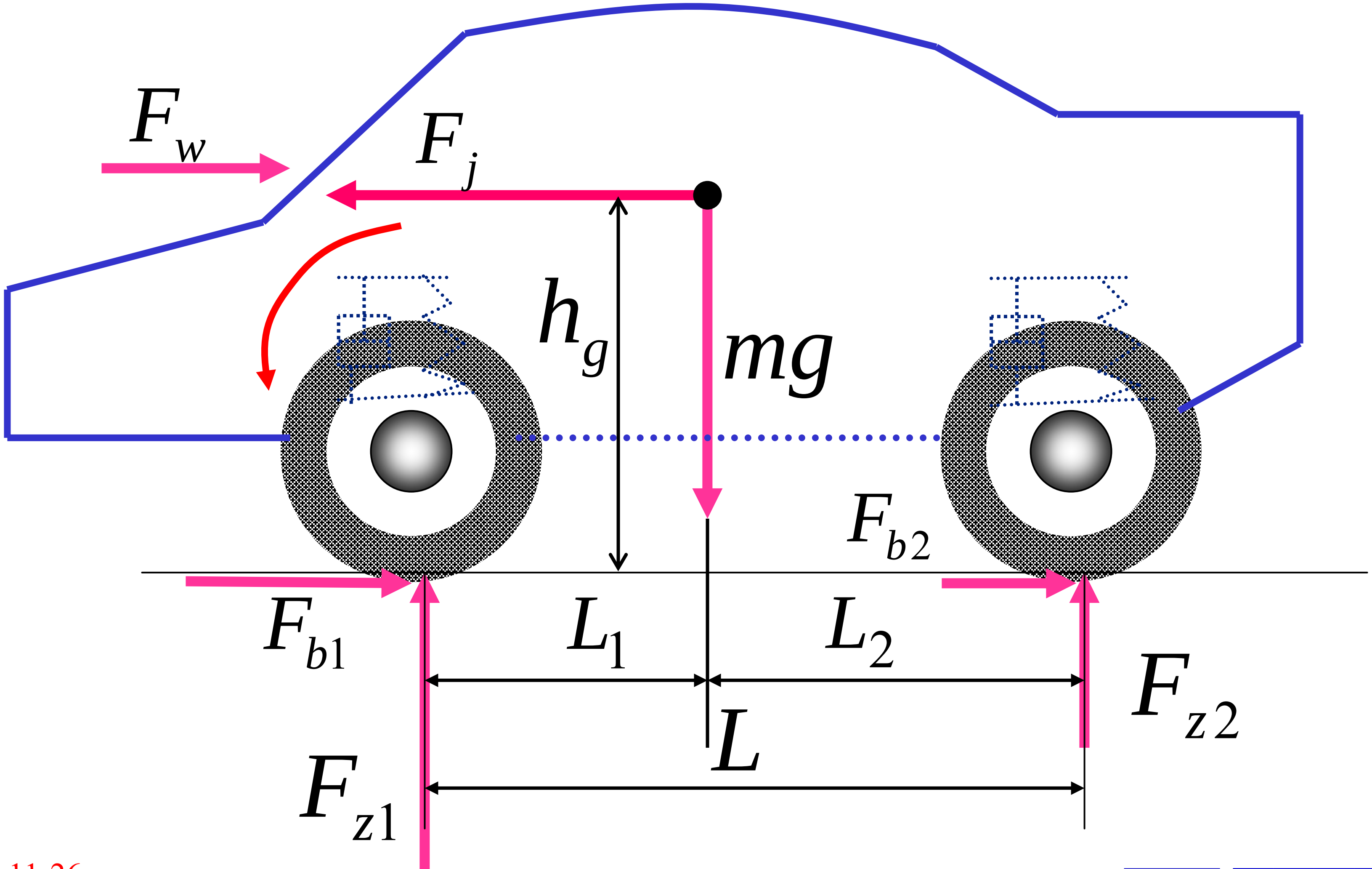
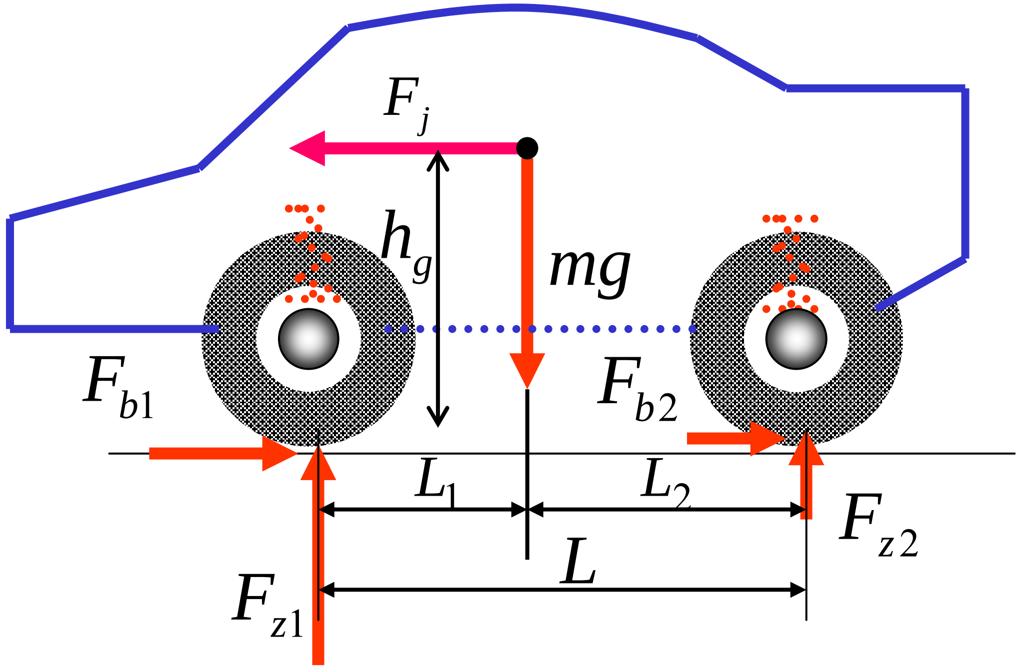
4.5 前后制动器制动力分配

1. 地面对前后车轮的法向反作用力 $mg = F_{z1} + F_{z1}$



$$F_{z1}L = mgL_2 + m\frac{\mathrm{d}u}{\mathrm{d}t}h_g$$

$$F_{z2}L = mgL_1 - m\frac{\mathrm{d}u}{\mathrm{d}t}h_g$$



$$F_{z1} = \frac{mg}{L}\left(L_2 + \frac{h_g}{g}\frac{\mathrm{d}u}{\mathrm{d}t}\right) = \frac{mg}{L}(L_2 + h_g\varphi_b) = F_{z10} + \Delta F$$

$$F_{z2} = \frac{mg}{L}\left(L_1 - \frac{h_g}{g}\frac{\mathrm{d}u}{\mathrm{d}t}\right) = \frac{mg}{L}(L_1 - h_g\varphi_b) = F_{z20} - \Delta F$$

$$\left(\frac{\mathrm{d}u}{\mathrm{d}t} = g\varphi_b \Leftrightarrow \varphi_b = \frac{1}{g}\frac{\mathrm{d}u}{\mathrm{d}t}\right)$$

2 理想的前、后制动器制动力分配曲线

制动时前、后车轮同时抱死时，前后制动器制动力分配关系曲线。（自行车模型）前后车轮同时抱死的条件为

$$\begin{cases} F_{\mu 1} + F_{\mu 2} = \varphi mg \\ F_{\mu 1} = \varphi F_{z1} \\ F_{\mu 2} = \varphi F_{z2} \end{cases}$$

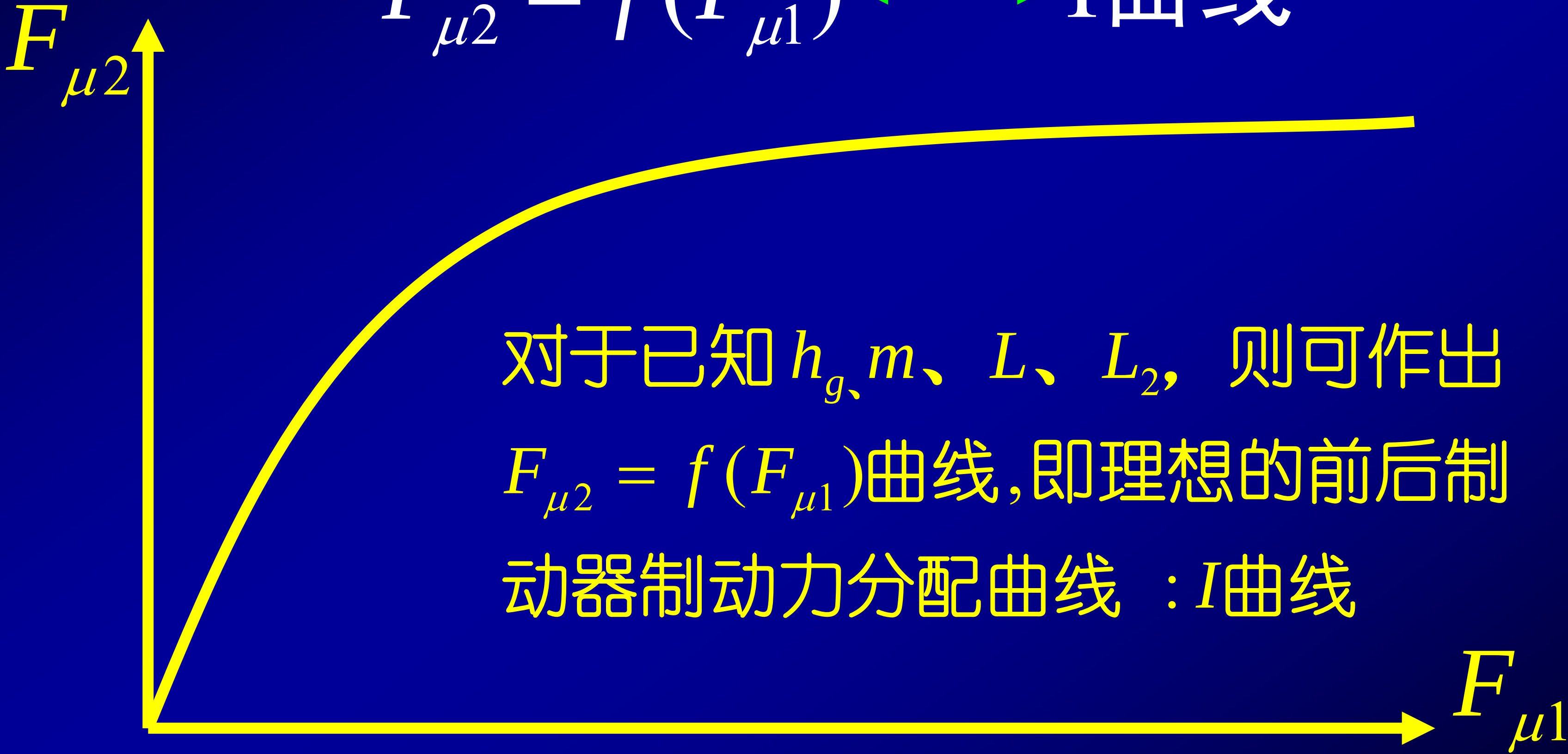
$$\begin{cases} F_{\mu 1} + F_{\mu 2} = \varphi mg \\ \dfrac{F_{\mu 1}}{F_{\mu 2}} = \dfrac{F_{z1}}{F_{z2}} = \dfrac{L_2 + \varphi h_g}{L_1 - \varphi h_g} \end{cases}$$

$$F_{\mu 2} = f(F_{\mu 1})$$

$$F_{\mu 2} = \frac{1}{2}\left[\frac{mg}{h_g}\sqrt{L_2^2 + \frac{4h_g L}{mg}F_{\mu 1}} - \left(\frac{mgL_2}{h_g} + 2F_{\mu 1}\right)\right]$$

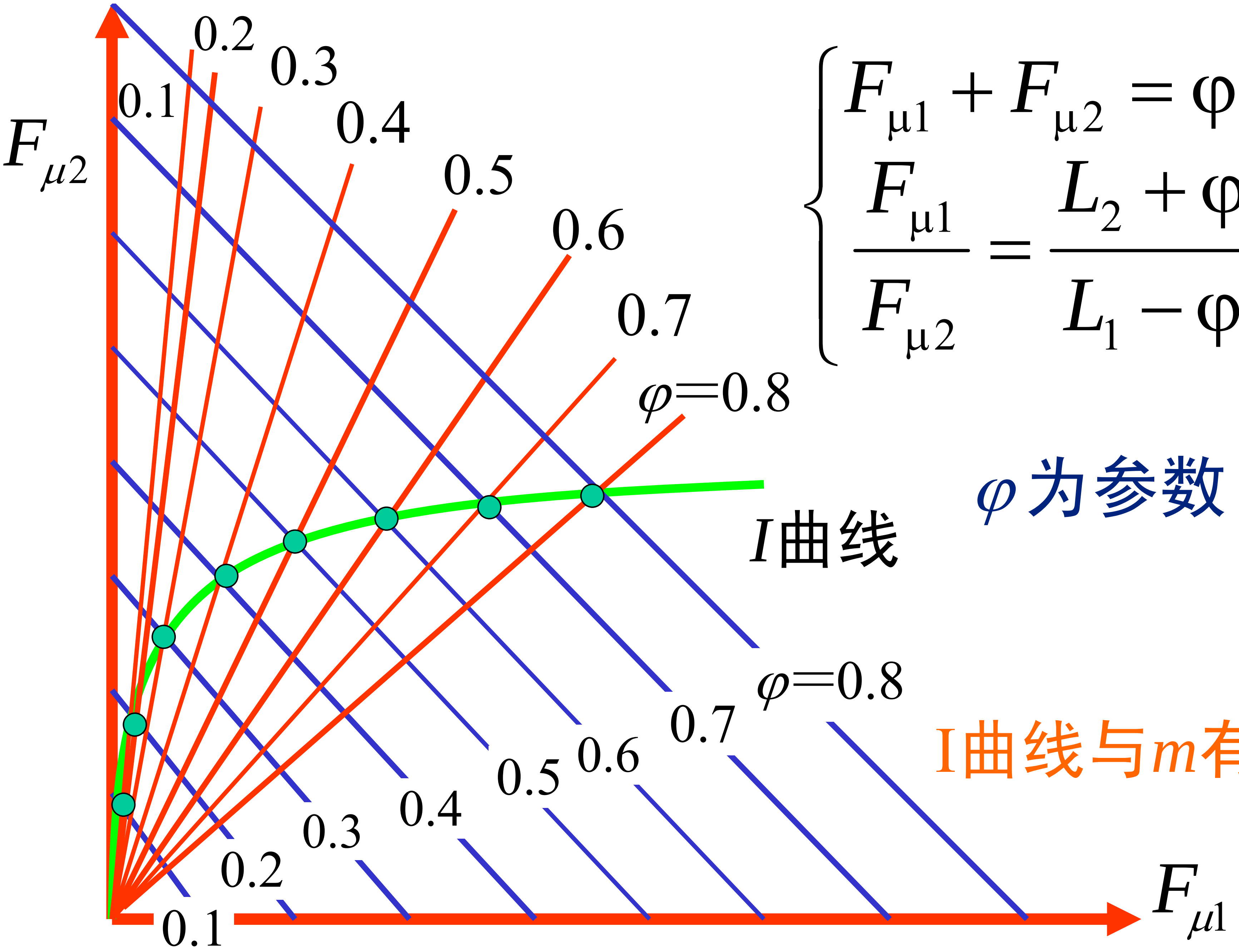
$$F_{\mu 2}=\frac{1}{2}\left[\frac{mg}{h_g}\sqrt{L_2^2+\frac{4h_g L}{mg}F_{\mu 1}}-\left(\frac{mgL_2}{h_g}+2F_{\mu 1}\right)\right]$$

$$F_{\mu 2}=f(F_{\mu 1})\longleftrightarrow \text{I曲线}$$



对于已知h_g、m、L、L_2，则可作出 $F_{\mu 2}=f(F_{\mu 1})$曲线,即理想的前后制动器制动力分配曲线 ：I曲线

Curve of ideal distribution of braking forces

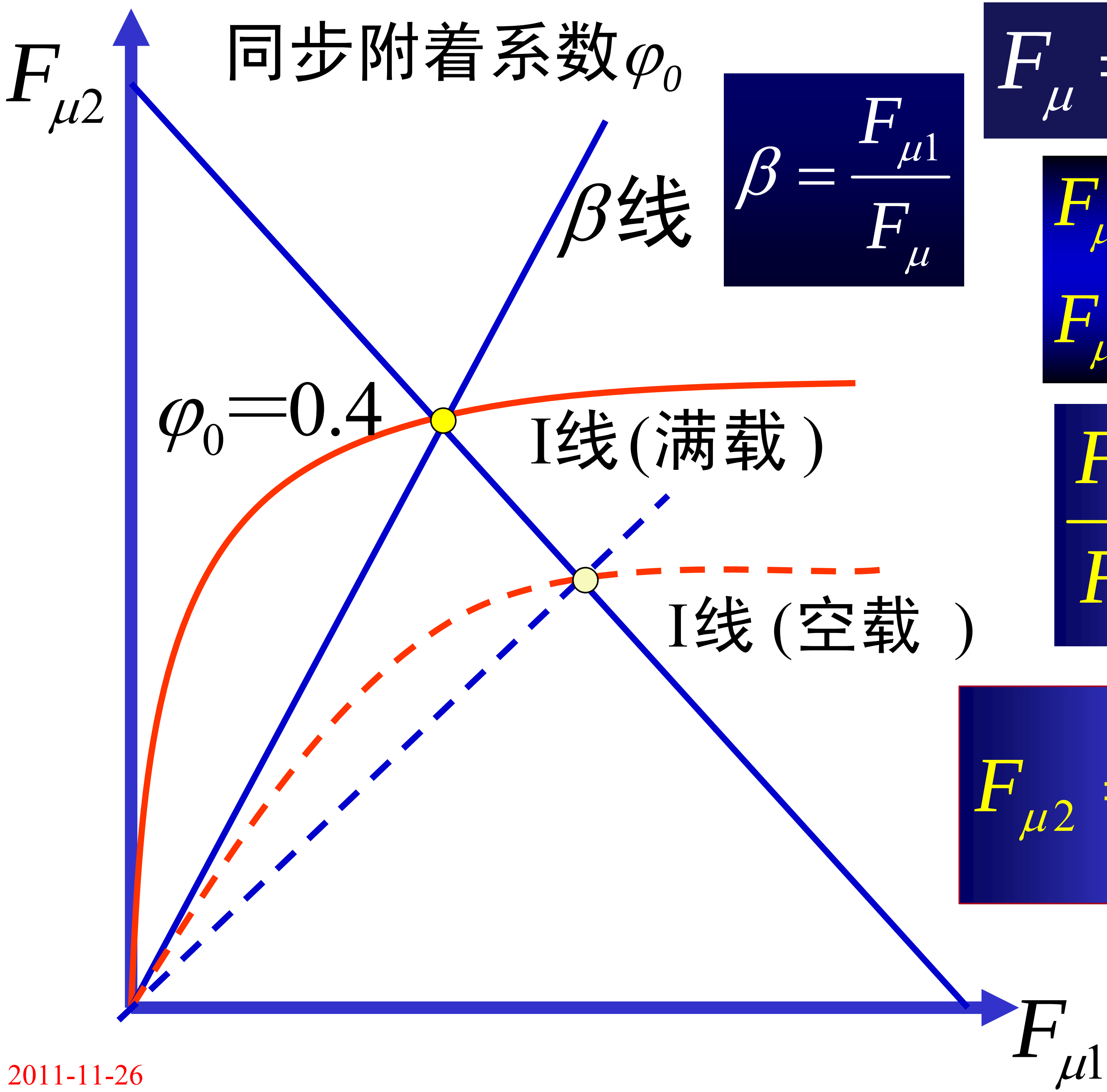


$$\begin{cases} F_{\mu 1} + F_{\mu 2} = \varphi m g \\ \dfrac{F_{\mu 1}}{F_{\mu 2}} = \dfrac{L_2 + \varphi h_g}{L_1 - \varphi h_g} \end{cases}$$

φ为参数

I曲线与m有关

同步附着系数φ_0



$$\beta = \frac{F_{\mu 1}}{F_{\mu}}$$

$$F_{\mu} = F_{\mu 1} + F_{\mu 2}$$

$$F_{\mu 1} = \beta F_{\mu}$$

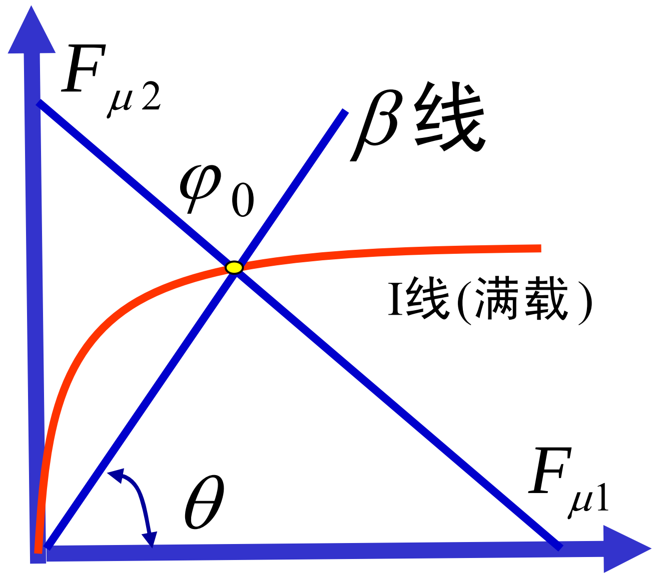
$$F_{\mu 2} = (1-\beta) F_{\mu}$$

$$\frac{F_{\mu 2}}{F_{\mu 1}} = \frac{1-\beta}{\beta}$$

$$F_{\mu 2} = \frac{1-\beta}{\beta} F_{\mu 1}$$

$$F_{\mu 2} = \frac{1-\beta}{\beta} F_{\mu 1} \Rightarrow F_{\mu 2} = f(F_{\mu 1})$$

$$\tan\theta = \frac{1-\beta}{\beta} \Rightarrow \beta\text{线}$$



β线与I线交点处的φ为同步附着系数φ_0。

同步附着系数说明:

前后制动器制动力为固定比值的汽车，只能在一种路面上，即在同步附着系数的路面上才能保证前、后轮同时抱死。

同步附着系数也可用解析方法求出。

用解析方法求同步附着系数

$$\begin{cases} F_{\mu 1} + F_{\mu 2} = \varphi mg \\ \dfrac{F_{\mu 1}}{F_{\mu 2}} = \dfrac{F_{z1}}{F_{z2}} = \dfrac{L_2 + \varphi h_g}{L_1 - \varphi h_g} \end{cases}$$

$$\varphi = \varphi_0$$

$$\frac{F_{\mu 1}}{F_{\mu 2}} = \frac{\beta}{1-\beta}$$

$$\frac{F_{\mu 1}}{F_{\mu 2}} = \frac{L_2 + h_g \varphi}{L_1 - h_g \varphi} = \frac{\beta}{1-\beta}$$

$$\tan\theta = \frac{1-\beta}{\beta}$$

$$(L_2 + h_g\varphi)(1-\beta) = \beta(L_1 - h_g\varphi)$$

$$L_2 + h_g\varphi - L_2\beta - h_g\varphi\beta = L_1\beta - h_g\varphi\beta$$

$$L_2 + h_g\varphi - L_2\beta = L_1\beta \qquad L\beta = L_1\beta + L_2\beta$$

$$L_2 + h_g\varphi - L\beta = 0$$

$$\varphi_0 = \frac{L\beta - L_2}{h_g}$$

4 固定 β, 在不同路面上的制动过程分析

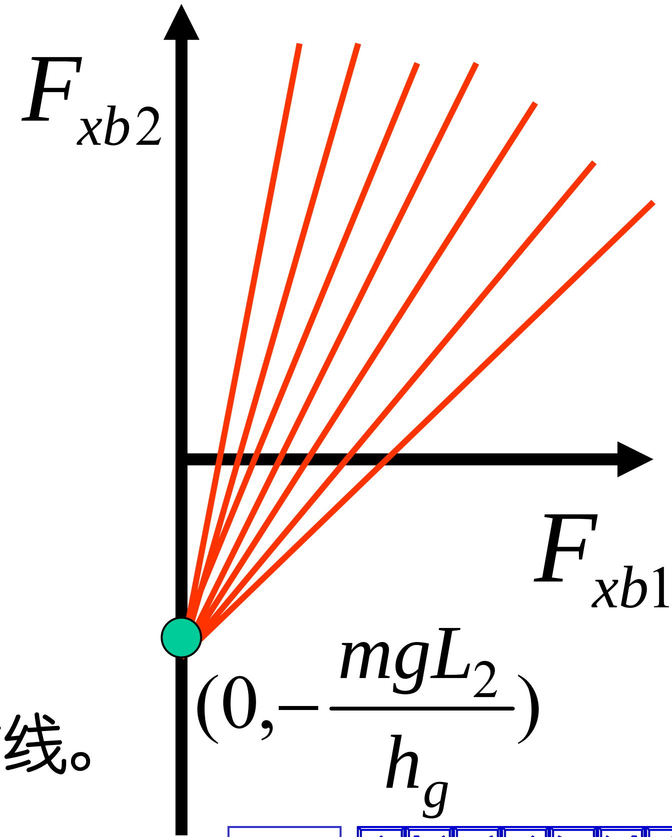
求f线组： $F_{xb} = mg\varphi$

$$F_{xb1} = \varphi F_{z1} = \varphi \frac{mg}{L}\left(L_2 + \varphi h_g\right) = \varphi\left(\frac{mgL_2}{L} + \frac{F_{xb}h_g}{L}\right)$$

$$F_{xb} = F_{xb1} + F_{xb2}$$

$$F_{xb1} = \varphi\left(\frac{mgL_2}{L} + \frac{(F_{xb1} + F_{xb2})h_g}{L}\right)$$

$$F_{xb2} = \frac{L - \varphi h_g}{\varphi h_g} F_{xb1} - \frac{mgL_2}{h_g}$$



$F_{xb2} = 0$,固定φ，求得F_{xb1},过两点得一条射线。

$$F_{xb2}=\frac{L-\varphi h_g}{\varphi h_g}F_{xb1}-\frac{mgL_2}{h_g}$$

如果后轮无制动力(因堵塞或者间隙过大)，前轮有足够的制动力

若$F_{xb2}=0$，则$\frac{L-\varphi h_g}{\varphi h_g}F_{xb1}=\frac{mgL_2}{h_g}$

$$\frac{L-\varphi h_g}{\varphi}F_{xb1}=\frac{mgL_2}{h_g}$$

$$F_{xb1}=\frac{\varphi mgL_2}{L-\varphi h_g}>\frac{\varphi mgL_2}{L}$$

前轮动态制动力比静态的大！

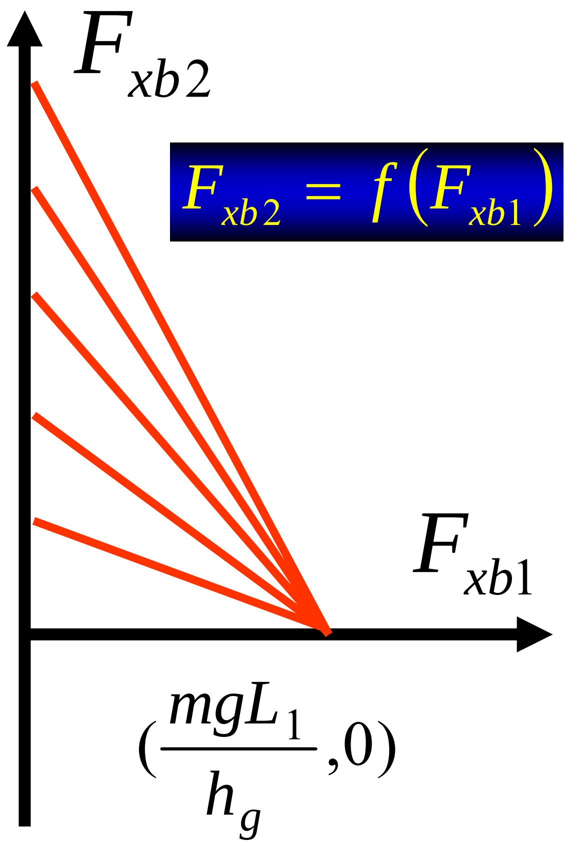
求r线组：$F_{xb} = mg\varphi$

$$F_{xb2} = \varphi F_{z2} = \varphi \frac{mg}{L}\left(L_1 - \varphi h_g\right) = \varphi\left(\frac{mgL_1}{L} - \frac{F_{xb}h_g}{L}\right)$$

$$F_{xb} = F_{xb1} + F_{xb2}$$

$$F_{xb2} = \varphi\left(\frac{mgL_1}{L} - \frac{(F_{xb1} + F_{xb2})h_g}{L}\right)$$

$$F_{xb2} = \frac{\varphi mgL_1}{L + \varphi h_g} - \frac{\varphi h_g}{L + \varphi h_g} F_{xb1}$$



$$F_{xb2}=\frac{\varphi\, mgL_1}{L+\varphi\, h_g}-\frac{\varphi\, h_g}{L+\varphi\, h_g}F_{xb1}$$

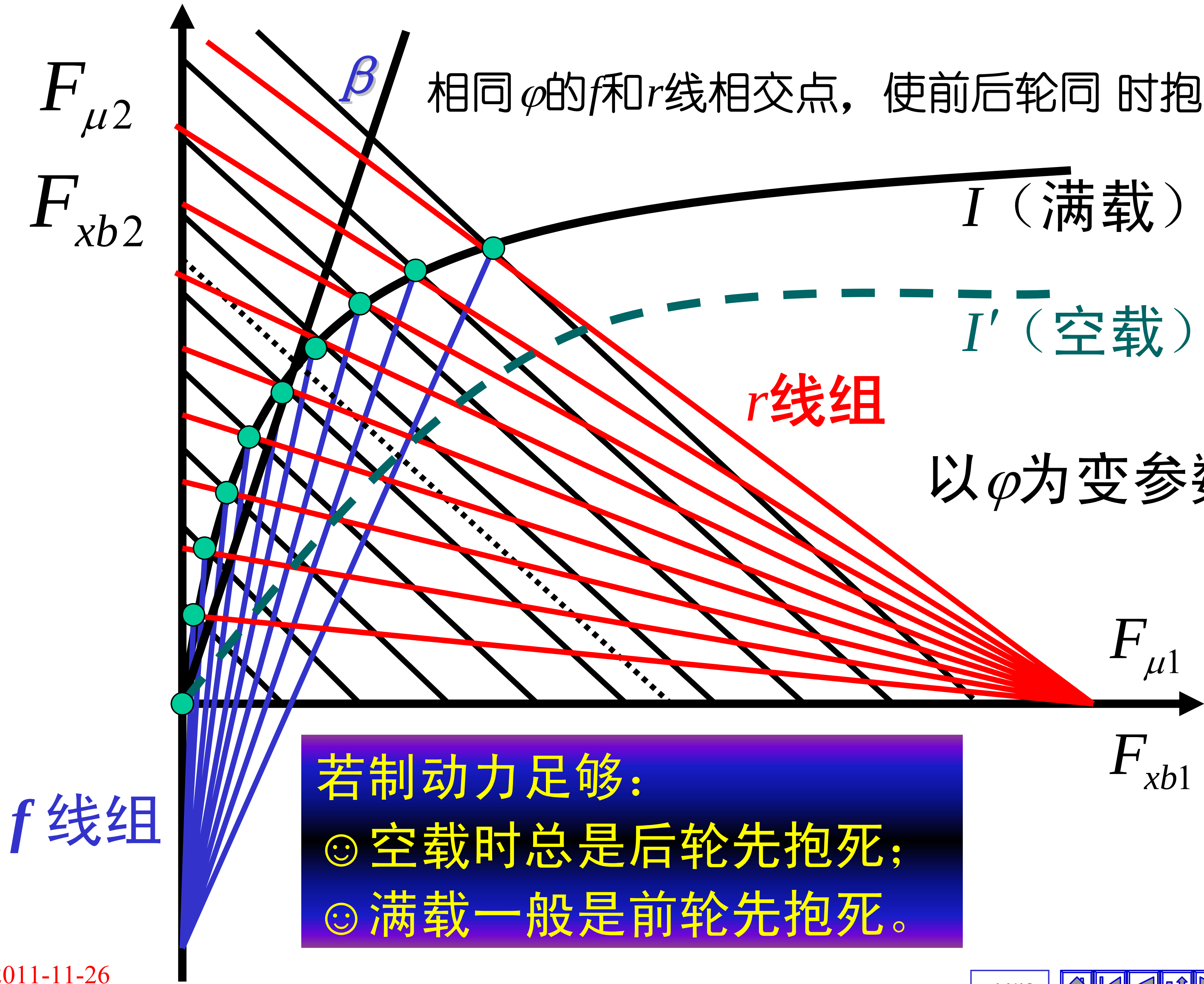
如果前轮无制动力(因堵塞或者间隙过大),后轮有足够的制动力

即$F_{xb1}=0$,则

$$F_{xb2}=\frac{\varphi\, mgL_1}{L+\varphi\, h_g}<\frac{\varphi\, mgL_1}{L}$$

后轮动态制动力比静态的小！

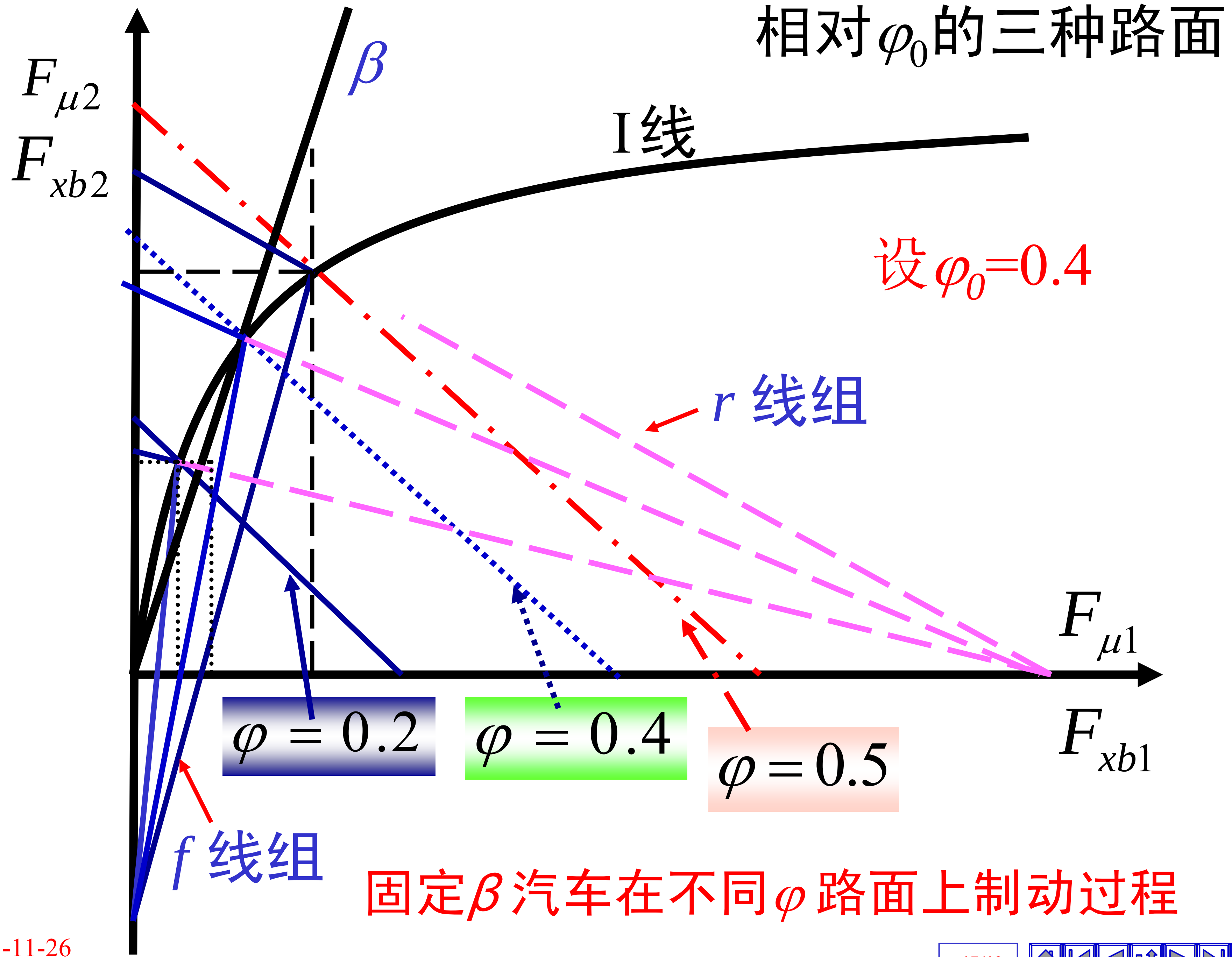
相同φ的f和r线相交点，使前后轮同 时抱死。



若制动力足够：

☺空载时总是后轮先抱死；

☺满载一般是前轮先抱死。



相对φ_0的三种路面
$F_{\mu 2}$
F_{xb2}
β
I线
设φ_0=0.4
r 线组
$F_{\mu 1}$
F_{xb1}
$\varphi = 0.2$
$\varphi = 0.4$
$\varphi = 0.5$
f 线组
固定β汽车在不同φ路面上制动过程

利用附着系数和附着效率

$\frac{\mathrm{d}u}{\mathrm{d}t} = zg \Rightarrow z$制动强度， $z = \varphi_b$。前轮和后轮均不抱死时$z < \varphi_0$。只有$z = \varphi_0$，附着条件才能得到充分的利用。汽车以一定减速度制动时，除了$z = \varphi_0$以外，不发生车轮抱死的地面附着系数总是大于制动强度z。这个要求的路面附着系数为汽车在该制动强度时的利用附着系数。

利用附着系数 E的解析计算

$$\frac{\mathrm{d}u}{\mathrm{d}t}=zg \Longleftrightarrow \frac{1}{g}\frac{\mathrm{d}u}{\mathrm{d}t}=z$$

$$F_{\mu 1}=F_{b1}=\beta m\frac{\mathrm{d}u}{\mathrm{d}t}=\underline{\beta mzg}$$

$$\underline{F_{z1}=\frac{mg}{L}(L_2+zh_g)}\Rightarrow \varphi_f=\frac{F_{b1}}{F_{z1}}=\frac{\beta z}{\frac{1}{L}(L_2+zh_g)}$$

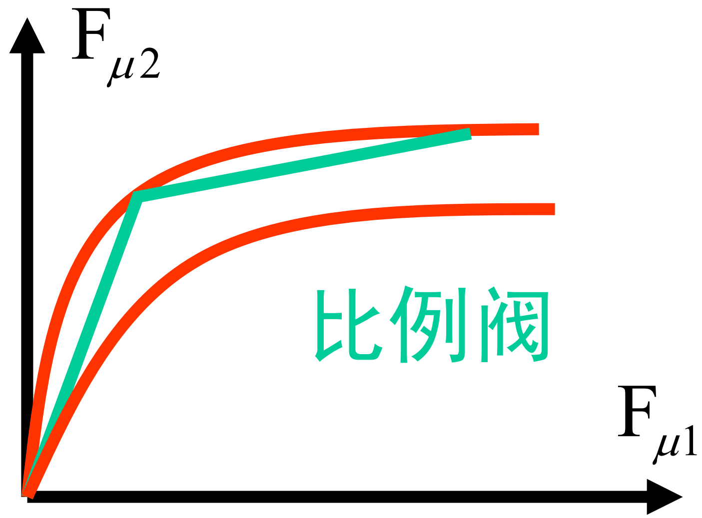
$$F_{\mu 2}=F_{b2}=(1-\beta)m\frac{du}{dt}=\underline{(1-\beta)mgz}$$

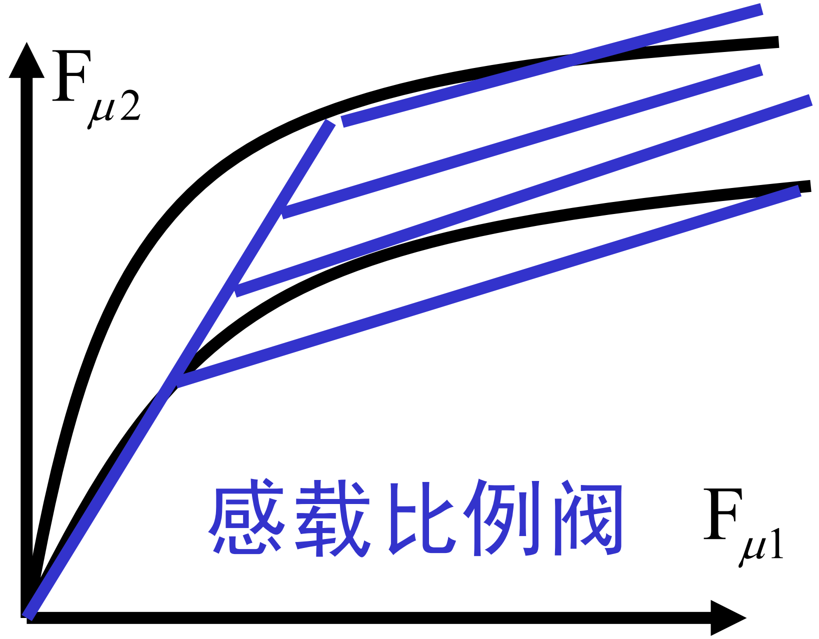
$$\underline{F_{z2}=\frac{mg}{L}(L_1-zh_g)}\Rightarrow \varphi_r=\frac{F_{b2}}{F_{z2}}=\frac{(1-\beta)z}{\frac{1}{L}(L_1-zh_g)}$$

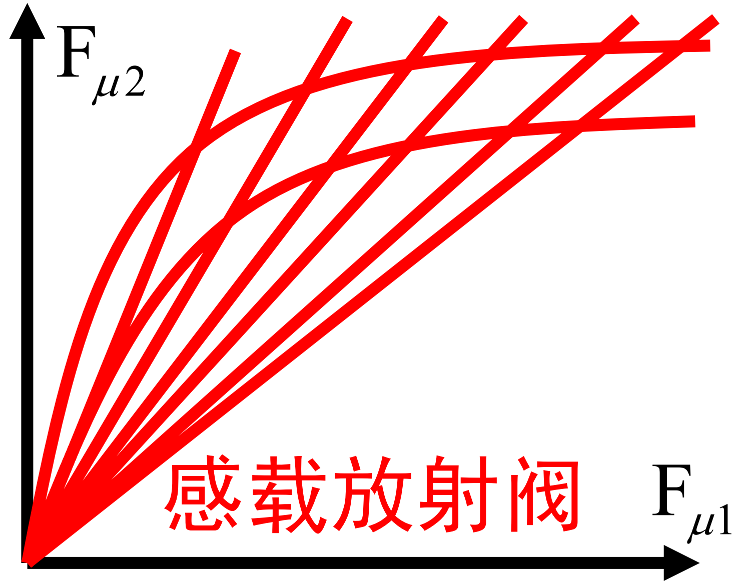
附着效率：制动强度与利用附着系数之比。

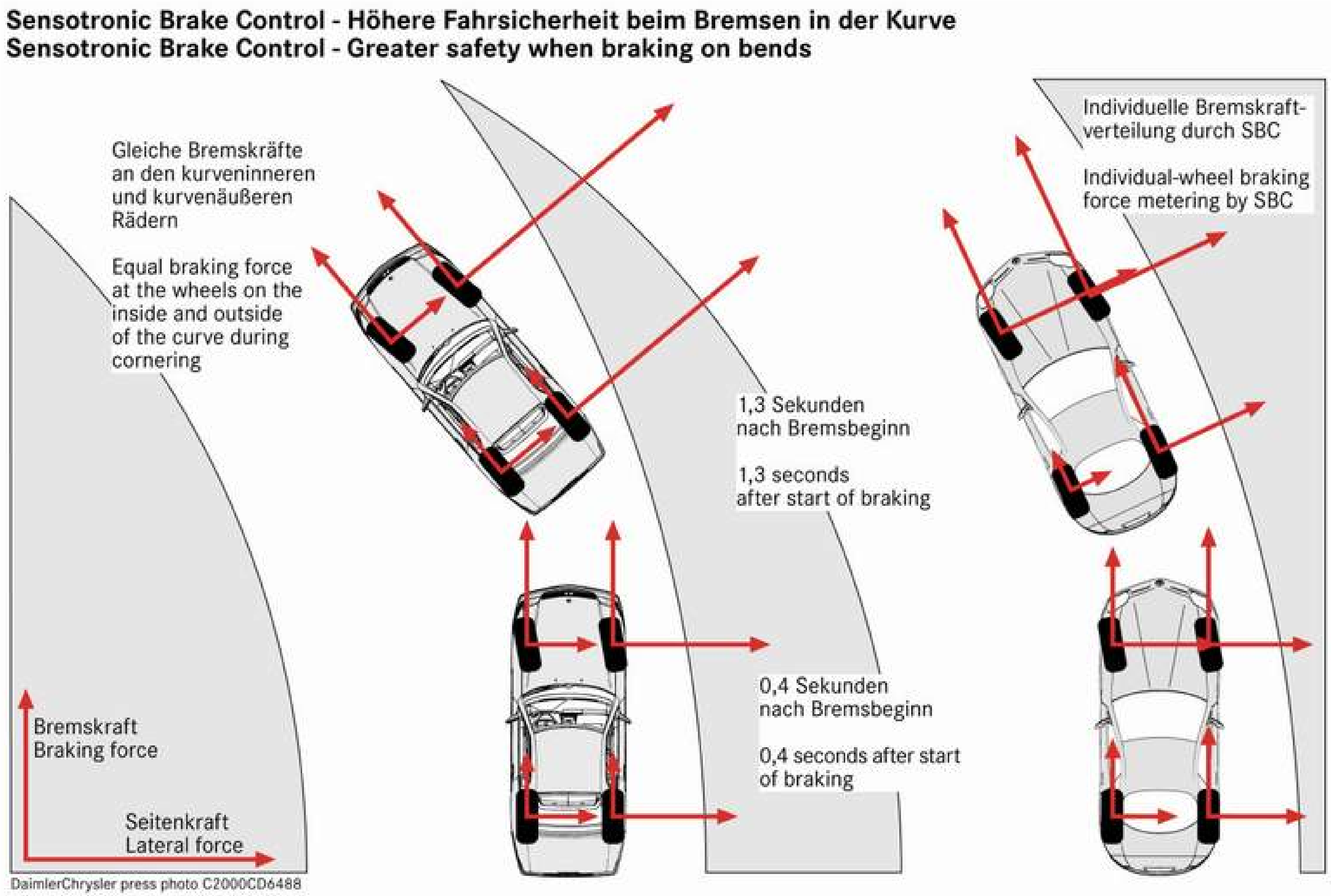
$$E_f = \frac{z}{\varphi_f} = \frac{L_2}{\beta L - \varphi_f h_g}$$

$$E_r = \frac{z}{\varphi_r} = \frac{L_2}{(1-\beta)L - \varphi_r h_g}$$









SBC根据车轮负荷Fz确定制动力