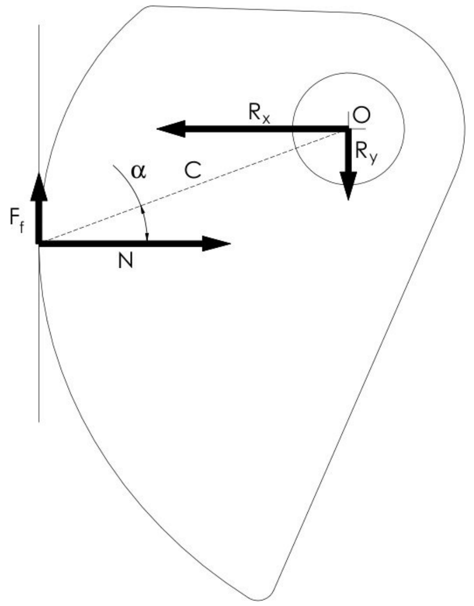
REGULAR CAM ON PARALLEL CRACK



Cam lobe shape is logarithmic spiral, $C = c \cdot e^{\tan(\alpha)\cdot\theta}$

$$\sum M_O = 0$$
$$F_f \cdot C \cdot \cos(\alpha) = N \cdot C \cdot \sin(\alpha)$$
$$F_f = N \cdot \tan(\alpha)$$

To avoid sliding $F_f \leqslant \mu \cdot N$ must be satisfied, then

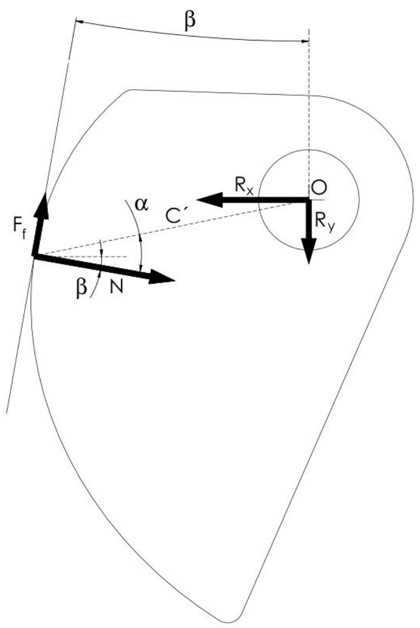
$$N \cdot \tan(\alpha) \leqslant \mu \cdot N$$
$$\boxed{\tan(\alpha) \leqslant \mu}$$

Wall reaction force *R* (or shear on the axle):

The force vector of wall reaction on the cam lobe is the sum of $\vec{F}_f$ and $\vec{N}$ and goes through the axle. If we apply a perfectly aligned *T* load on the cam, from the equilibrium of entire cam we obtain,

$$T = 4 \cdot R \cdot \sin(\alpha)$$
$$\boxed{R = \frac{T}{4 \cdot \sin(\alpha)}}$$

REGULAR CAM ON FLARED CRACK



$$\sum M_O = 0$$
$$F_f \cdot C' \cdot \cos(\alpha) = N \cdot C' \cdot \sin(\alpha)$$
$$F_f = N \cdot \tan(\alpha)$$

and,

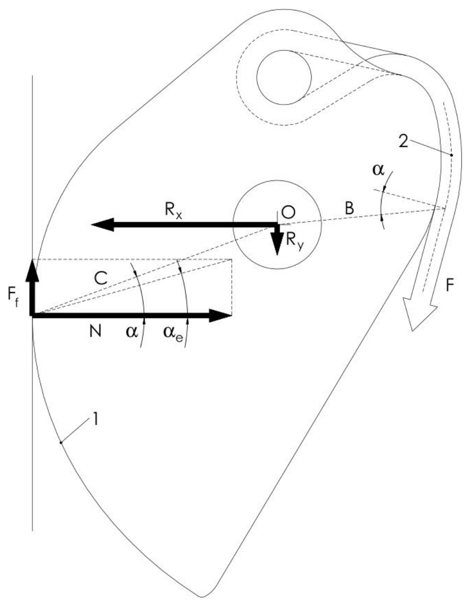
$F_f \leqslant \mu \cdot N$ so, $\boxed{\tan(\alpha) \leqslant \mu}$

From the equilibrium of entire cam with perfectly aligned *T* load,

$$T = 4 \cdot R \cdot \sin(\alpha - \beta)$$
$$\boxed{R = \frac{T}{4 \cdot \sin(\alpha - \beta)}}$$

In the expression above, it can be seen that when β tends to α, *R* is increased toward infinite.

TOTEM CAM ON PARALLEL CRACK



Both 1 and 2 cam lobe shapes are logarithmic spirals,

1) $C = c \cdot e^{\tan(\alpha)\cdot\theta}$ 2) $B = b \cdot e^{\tan(\alpha)\cdot\theta}$

If we apply a perfectly aligned *T* load on the cam, from the equilibrium of entire cam we obtain,

$$T = 4 \cdot F_f$$

,and the entire T load is equalized into each lobe,

$$T = 4 \cdot F$$

then

$$F = F_f$$

$$\sum M_O = 0$$

$$F_f \cdot C \cdot \cos(\alpha) + F \cdot B \cdot \cos(\alpha) = N \cdot C \cdot \sin(\alpha)$$

$$F_f \cdot \cos(\alpha) \cdot (C + B) = N \cdot C \cdot \sin(\alpha)$$

substituting 1) and 2) expressions,

$$F_f \cdot \cos(\alpha) \cdot e^{\tan(\alpha)\cdot\theta}(c + b) = N \cdot c \cdot e^{\tan(\alpha)\cdot\theta} \cdot \sin(\alpha)$$

$$F_f = \frac{N \cdot \tan(\alpha) \cdot c}{(c+b)} \quad \text{or} \quad F_f = \frac{N \cdot \tan(\alpha)}{(1 + b/c)}$$

To avoid sliding $F_f \leqslant \mu \cdot N$, then

$$\frac{N \cdot \tan(\alpha)}{(1 + b/c)} \leq \mu \cdot N \quad \text{or} \quad \boxed{\frac{\tan(\alpha)}{(1 + b/c)} \leq \mu}$$

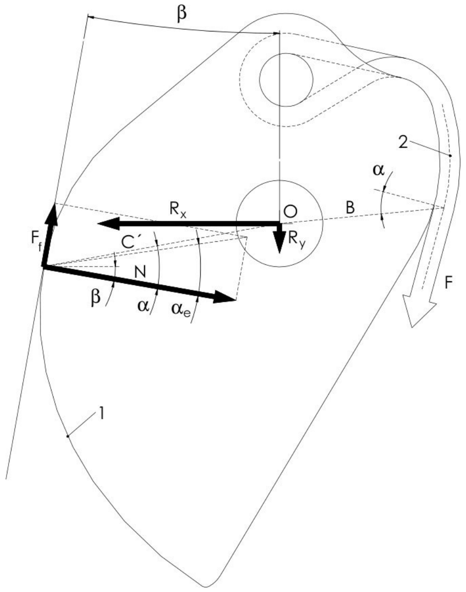
Comparing α with α_e (equivalent cam angle),

$$\tan(\alpha_e) = \frac{F_f}{N} \quad \text{then,} \quad \boxed{\tan(\alpha_e) = \frac{\tan(\alpha)}{(1 + b/c)}}$$

Wall reaction force *R*,

$$\boxed{R = \frac{T}{4 \cdot \sin(\alpha_e)}}$$

TOTEM CAM ON FLARED CRACK



If we apply a perfectly aligned *T* load on the cam, from the equilibrium of entire cam we obtain,

$$T+4\cdot N\cdot\sin(\beta)=4\cdot F_f\cdot\cos(\beta)$$

,and the entire *T* load is equalized into each lobe,

$$T=4\cdot F$$

then

3) $F=F_f\cdot\cos(\beta)-N\cdot\sin(\beta)$

$$\sum M_O=0$$

$$F_f\cdot C'\cdot\cos(\alpha)+F\cdot B\cdot\cos(\alpha)=N\cdot C'\cdot\sin(\alpha)$$

$$F_f\cdot C'+F\cdot B=N\cdot C'\cdot\tan(\alpha)$$

substituting 1), 2), 3) and $C'=C/e^{\tan(\alpha)\cdot\beta}$ expressions,

$$\frac{F_f\cdot c\cdot e^{\tan(\alpha)\cdot\theta}}{e^{\tan(\alpha)\cdot\beta}}+(F_f\cdot\cos(\beta)-N\cdot\sin(\beta))\cdot b\cdot e^{\tan(\alpha)\cdot\theta}=N\frac{c\cdot e^{\tan(\alpha)\cdot\theta}}{e^{\tan(\alpha)\cdot\beta}}\cdot\tan(\alpha)$$

$$F_f\cdot\left(\frac{c}{e^{\tan(\alpha)\cdot\beta}}+b\cdot\cos(\beta)\right)=N\cdot\left(\frac{c\cdot\tan(\alpha)}{e^{\tan(\alpha)\cdot\beta}}+b\cdot\sin(\beta)\right)$$

$$F_f=N\cdot\left(\frac{\left(\frac{c\cdot\tan(\alpha)}{e^{\tan(\alpha)\cdot\beta}}+b\cdot\sin(\beta)\right)}{\left(\frac{c}{e^{\tan(\alpha)\cdot\beta}}+b\cdot\cos(\beta)\right)}\right)\quad\text{or}\quad F_f=N\cdot\left(\frac{\left(\frac{\tan(\alpha)}{e^{\tan(\alpha)\cdot\beta}}+\frac{b}{c}\cdot\sin(\beta)\right)}{\left(\frac{1}{e^{\tan(\alpha)\cdot\beta}}+\frac{b}{c}\cdot\cos(\beta)\right)}\right)$$

To avoid sliding $F_f\leqslant\mu\cdot N$, then $\boxed{\frac{\left(\frac{\tan(\alpha)}{e^{\tan(\alpha)\cdot\beta}}+\frac{b}{c}\cdot\sin(\beta)\right)}{\left(\frac{1}{e^{\tan(\alpha)\cdot\beta}}+\frac{b}{c}\cdot\cos(\beta)\right)}\leqslant\mu}$

for $\beta=0$ (parallel crack) we indeed obtain $\boxed{\frac{\tan(\alpha)}{(1+b/c)}\leq\mu}$

and for $\beta=\alpha$, $\boxed{\tan(\alpha)\leq\mu}$

So, as β increases toward α , the minimum friction coefficient required to avoid sliding increases from $\frac{\tan(\alpha)}{(1+b/c)}$ to $\tan(\alpha)$

Wall reaction force *R,*

$\boxed{R=\frac{T}{4\cdot\sin(\alpha_e-\beta)}}$ where, $\alpha_e=atan\left(\frac{\left(\frac{\tan(\alpha)}{e^{\tan(\alpha)\cdot\beta}}+\frac{b}{c}\cdot\sin(\beta)\right)}{\left(\frac{1}{e^{\tan(\alpha)\cdot\beta}}+\frac{b}{c}\cdot\cos(\beta)\right)}\right)$

TOTEM CAM SPECIFIC DATA

Totem Cam *B/C* ratio varies from 0,67 (cam lobes totally closed) to 0,59 (cam lobes totally opened). The drop in *B/C* mainly happens when cam lobes opening is greater than 66%.

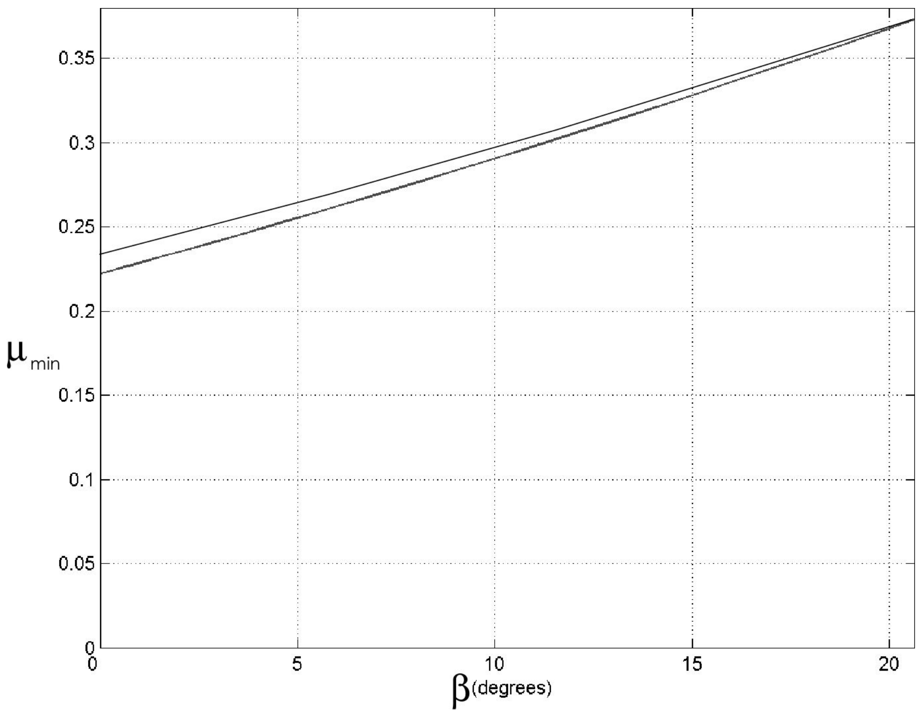
Note that *b/c* is not used but *B/C*. *b* and *c* are cam lobe shape constants and could be used if the loading conditions were constant. On a Totem Cam, even in the case where the applied load to the cam remains perfectly aligned, the loading conditions slightly vary over different openings off cam lobes due to variation in the loading angle of wire ropes.

For lateral loads, the loading angle of wire ropes also changes. To consider *B/C* ratios mentioned above, this phenomena has not been taken into account.

Then, for $\alpha = 20{,}35^o$, aligned loads and parallel cracks, the equivalent cam angle is,

$$12{,}52^o < \alpha_e < 13{,}13^o$$

For flaring cracks, the graph below shows how the required minimum friction coefficient increases with flaring angle. The upper line is for a Totem Cam with lobes totally opened and the other for lobes closed. The flaring angle β is for each wall.



For lateral loads (and parallel cracks), the next graph shows how the required minimum friction coefficient varies with the lateral loading angle. To calculate the equation (not shown in this paper) that leads to the graph below, some simplifications have been introduced, so it's approximate. The upper line is for a Totem Cam with lobes totally opened and the other for lobes closed. Both reach a maximum at about 40 degrees of lateral load.