

# THE DIFFERENCE BETWEEN COEFFICIENT-OF-FRICTION AND DRAG FACTOR

Mark George, Am SAE-A  
Director, Accident Investigation Services Pty Ltd, Sydney, Australia.

May 2005

The terms *coefficient-of-friction* ( $\mu$ ) and *drag factor* ( $f$ ) are expressions often used in crash investigation and are commonly associated with various vehicle speed calculations based upon tyre mark geometry. Accordingly, the definitions and application of the respective terms are accepted doctrine by the various international educational institutions associated with crash investigation.

Because the terms are closely related, their definitions and application are often confused by investigators and can result in misinterpretation, errors and confusion associated with vehicle speed calculations. This paper briefly discusses the specific scientific differences and applications between the two terms.

The *coefficient-of-friction*  $\mu$  is defined as the ratio of the tangential force  $F_{(tan)}$  (parallel to the surface) applied to an object sliding across a surface to the normal force  $N$  (perpendicular to the surface) of an object.<sup>1</sup>

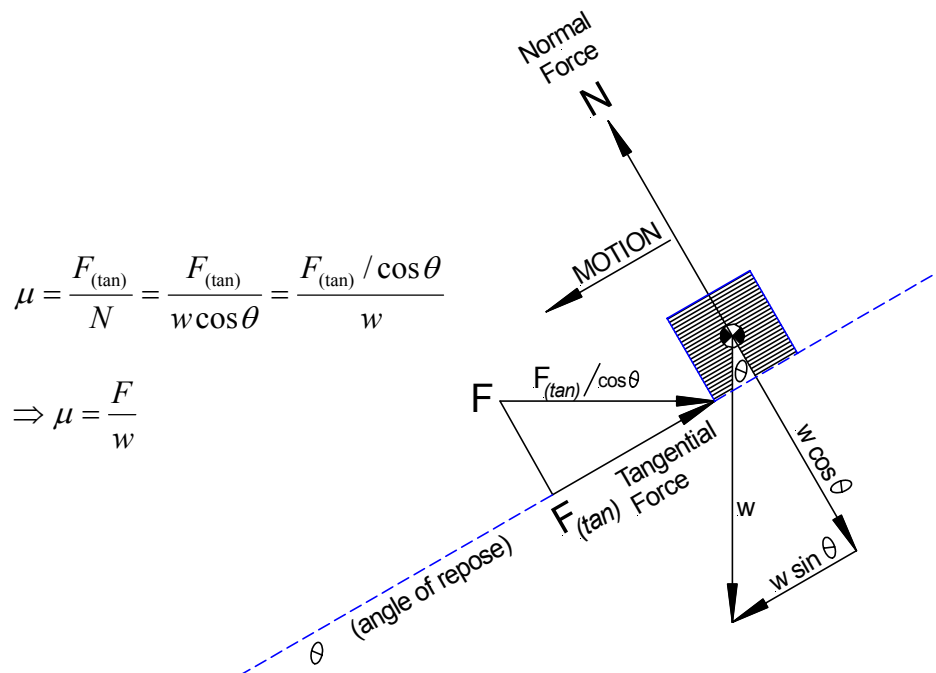


Figure 1. Graphical definition of  $\mu$ .

From the above illustration, it can be seen that the relationship between  $F_{(tan)}$  and  $N$  is proportional to that of the horizontal force  $F$  and weight  $w$ . Thus, a simpler illustration is shown in Figure 2 for a level surface.

<sup>1</sup> FRICKE L.B. (1990), *The Traffic Accident Investigation Manual, Vol 2 – Traffic Accident Reconstruction*, Northwestern University Traffic Institute, 1<sup>st</sup> Edition. Topic 862, Drag Factor and Coefficient of Friction in Traffic Accident Reconstruction.

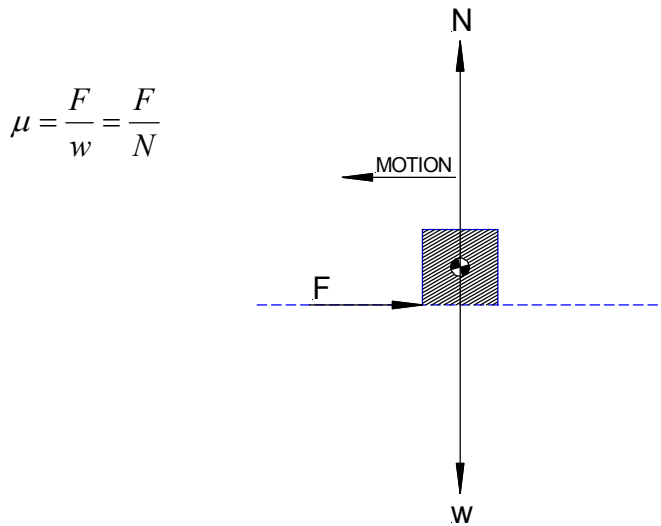


Figure 2. Simplified definition of  $\mu$ .

Because opposing forces are equal in magnitude and opposite in direction (*Newton's 3<sup>rd</sup> law of motion*), the *coefficient-of-friction* between two surfaces can be measured by pulling (or dragging) an object across a surface and resolving the forces. For convenience, figure 3 illustrates an object being pulled (with force  $F$ ) across a level surface.

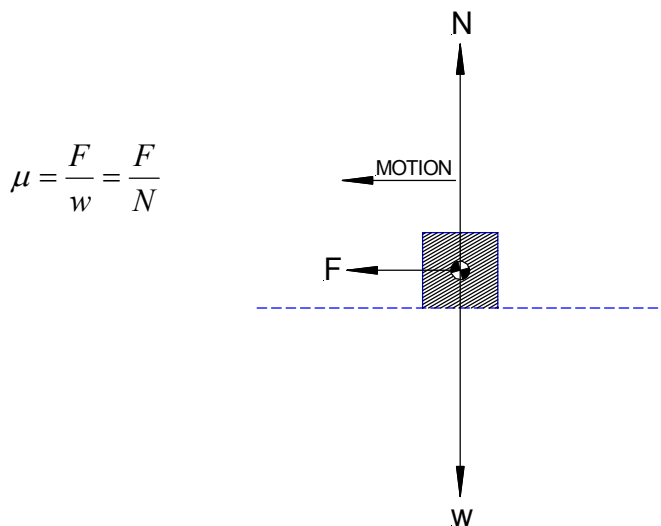


Figure 3. Simple method of measuring  $\mu$

This basic concept is used in crash investigation to measure the *coefficient-of-friction* between vehicle tyres and road pavements and can be achieved in various ways. The most basic form of measurement is with a *drag sled*, where a weighted portion of a vehicle tyre is dragged across the road pavement in a controlled manner whereupon  $\mu$  is obtained by resolving the forces. If the surface is level,  $\mu$  is obtained by dividing the horizontal force  $F$  required to drag the sled, by its weight  $w$ . i.e. if  $w = 10$  kg and  $F = 5$  kg, then  $\mu = 0.50$ . If the surface is not level there will be tangential forces to consider (i.e. less force is required to drag an object downhill and greater force for uphill), however, as illustrated in figures 1 and 2, resolving these forces will produce the same  $\mu$  value as if the surface was level. This effectively means that  $\mu$  between two surfaces does not alter with changes in gradient.

## DRAG FACTOR

**Drag Factor ( $f$ )** is a non-dimensional (no units) number used to represent the acceleration or deceleration of a vehicle. It is defined as the total force  $F_{(tot)}$  required for a vehicle's acceleration (or deceleration) in the direction of acceleration, divided by the vehicle's weight. With reference to figure 4, the equation for  $f$  is expressed:

$$f = \frac{F_{(tot)}}{w}$$

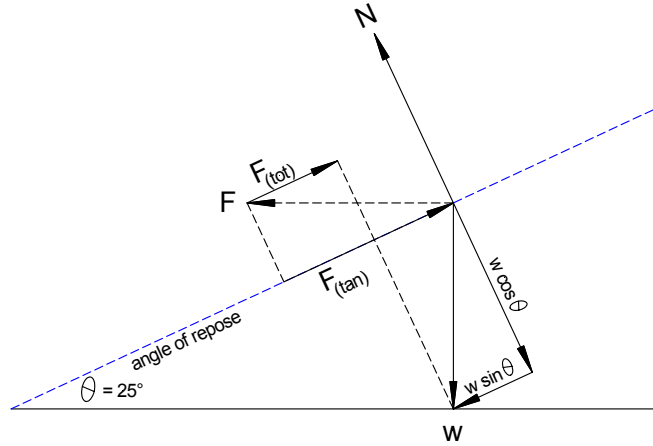
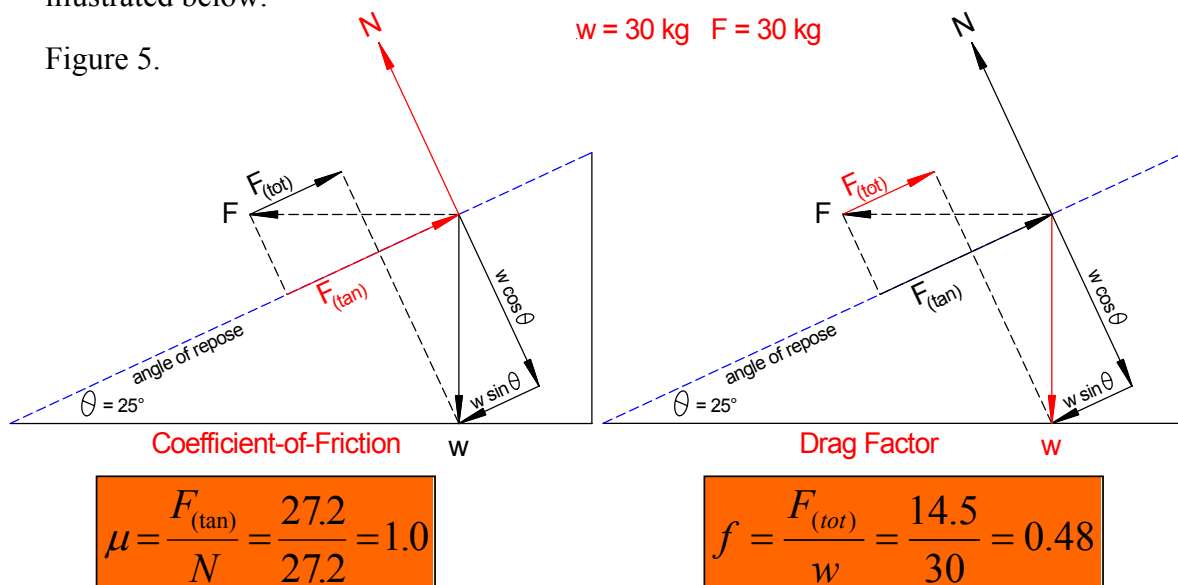


Figure 4. Vector diagram of forces associated with drag factor and coefficient of friction.

It can be seen from figure 4 that the equation for  $f$  is similar to the simplified equation for  $\mu$ , and hence the two definitions are often confused. However there is a distinct difference between the two. When measuring  $f$  and  $\mu$  on a level surface,  $F_{(tot)} = F$  and  $w = N$ , which produces identical values for  $f$  and  $\mu$ . As applicable to a vehicle speed from skid analysis, this means that  $f = \mu$  only when a vehicle is skidding *with all wheels locked on a level surface*.

It is common knowledge that it is easier to pull something down hill than uphill, and that downgrades make vehicle stopping distances longer than upgrades. Hence, for a skidding vehicle,  $f$  will reduce with a downgrade and increase for an upgrade, but  $\mu$  remains constant regardless of the grade. Consequently, investigating  $f$  and  $\mu$  for a sloped surface will produce different values. It is important that investigators do not confuse these values and understand the differences. A comparative investigation is illustrated below.



It is sometimes necessary to refer to published charts for estimating a range of  $\mu$  for a given surface, i.e. dry/wet concrete, asphalt, gravel, snow, ice etc. If this information is to be applied to a sloped roadway, then a range for  $f$  needs to be investigated. If the case in question involves a speed from skid analysis, then  $f$  can be provisionally solved if the grade is known, but will only be relevant if the vehicle is skidding with *all wheels locked*. If not all wheels are locked, further investigations are necessary to solve for the vehicle's resultant drag factor  $f_R$ .

### RESULTANT DRAG FACTOR - $f_R$

During harsh braking, a car experiences forward load shift, increasing the load on its front axle and reducing the load proportionally on its rear axle. If all wheels are locked during the skid, as discussed earlier the vehicle's deceleration will equal  $\mu$  and  $f$  if the surface is level, or just  $f$  if on a sloped surface. If not all wheels lock during the skid, particularly on an axle group, it cannot be assumed that the vehicle has decelerated with a drag factor equal to locked wheel conditions.

Where a vehicle has unequal axle drag factors, the vehicle's resultant drag factor  $f_R$  is expressed:

$$f_R = \frac{f_f - x_f(f_f - f_r)}{1 - z(f_f - f_r)}$$

where:

$f_R$	=	resultant vehicle drag factor
$f_f$	=	drag factor on front axle
$f_r$	=	drag factor on rear axle
$x_f$	=	horizontal distance of the centre of mass from the front axle as a decimal fraction of wheelbase
$z$	=	height of the centre of mass as a decimal fraction of the wheelbase.

Analysis of unequal axle drag factors on a vehicle therefore requires a more detailed investigation of the subject vehicle's mass and careful consideration of the variables in question.

### CONCLUSION

The *coefficient-of-friction*  $\mu$  between two surfaces does not alter with changes in gradient.

*Drag Factor*  $f$  changes proportionally to the gradient.

As applicable to crash investigation,  $f = \mu$  only when a vehicle *is skidding with all wheels locked on a level surface*.

## REFERENCES

1. FRICKE L.B. (1990), *The Traffic Accident Investigation Manual, Vol 2 – Traffic Accident Reconstruction*, Northwestern University Traffic Institute, 1<sup>st</sup> Edition.
2. Britannica Macropaedia Vol. 23, Edition 15, 1992 – Mechanics.

## ACKNOWLEDGEMENTS

George Bonnett JD, Reconstruction Technology, Rockledge, FL USA for peer review of the article.

## AUTHOR

Mark H. George *Am SAE-A*  
*Director/Principal Investigator*  
Accident Investigation Services Pty Ltd  
P.O. Box 695, Kingswood NSW Australia  
Tel: +61 2 47364736  
[www.accidentinvestigation.com.au](http://www.accidentinvestigation.com.au)  
[mail@accidentinvestigation.com.au](mailto:mail@accidentinvestigation.com.au)