Drag Factors in Spins and on Hills

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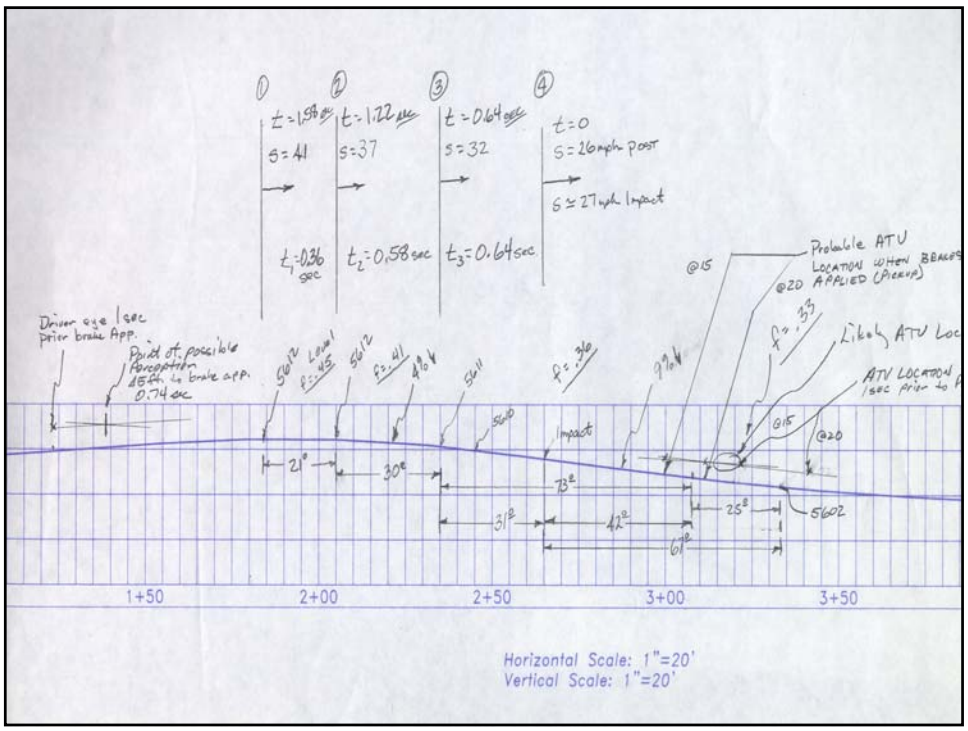
Drag Factor Adjustment

- Adjusting the drag factor for road alignments or conditions is a normal crash reconstruction procedure.
- The basic drag factor equation:
  - **$f = \mu n \cos\theta + \sin\theta$** (general)
  - **$f = \mu n + m$** (10% or less slope)

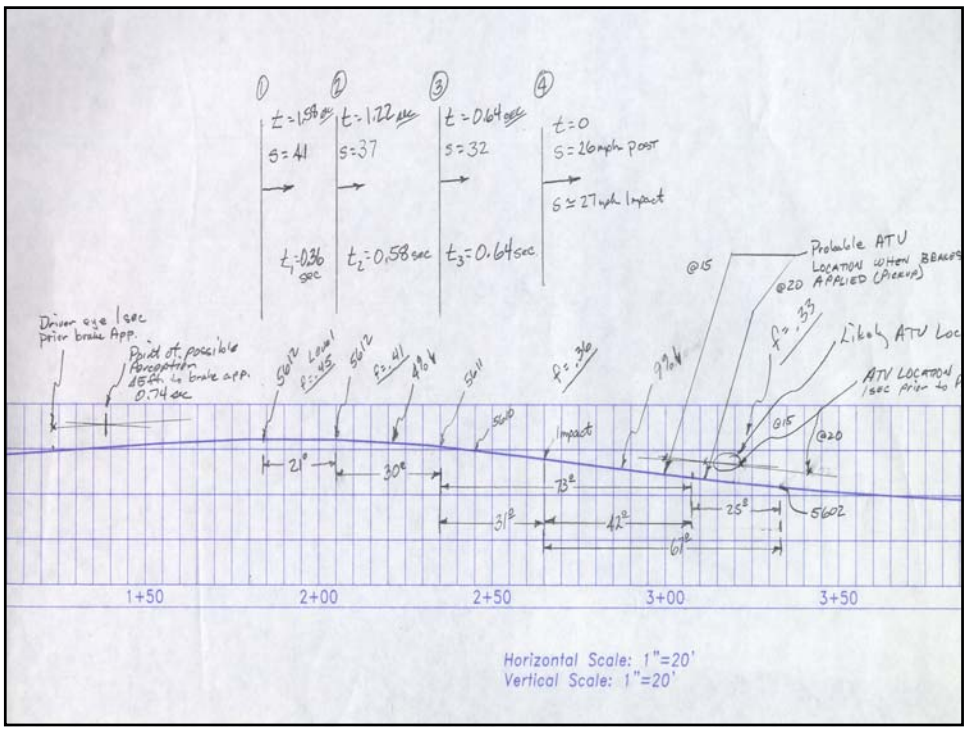
Drag Factor Adjustment, cont'd.

- In these equations:
  - μ = surface friction coefficient
  - θ = road slope in degrees
  - n = percentage of braking
  - m = slope of road in percent (decimal)
- Either of these equations work for a constant road slope.
- What if the slope of the road varies as the skid progresses?



Drag Factor Adjustment, cont'd.

- This scale profile drawing illustrates the skidding path of a vehicle on a county road.
- The skid starts on the level surface and then progresses to different downhill slopes.
- We must account for the changing slope if we are to compute the correct speed.

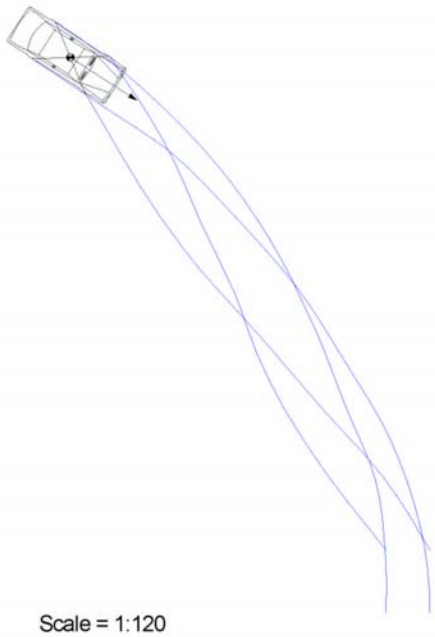


Drag Factor Adjustment, cont'd.

- In this case, the initial investigators considered only the steepest part of the slope. In addition, the skid mark was measured short by the vehicle wheelbase.
- The speed computed was 34 mph.
- The proper way to handle the problem is to compute drag factors for each section of constant slope.
- This information is then put into the combined speed equation.
- When this is done, the computed speed rises to 41 mph.

Adjustments for Spin

- Vehicles may spin out after a collision or may rotate into a spin after entering a critical speed yaw.
- Sometimes only one or two of the wheels have any effective braking, perhaps due to damage.
- Sometimes, there is no driver applied braking.
- The drag on the free-rolling tires will be a function of the angle the tires make with respect to the vehicle motion.
- The minimum level drag factor for a free-rolling wheel is about 0.01.
- To examine this situation, we will consider the following analysis…



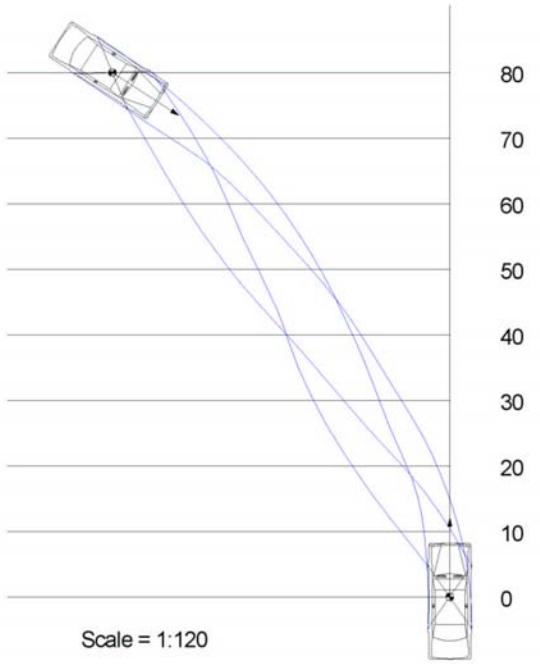
This vehicle has come to rest after impact, leaving the tire marks shown.

If we confuse these tire marks with critical speed yaw marks, we will calculate an erroneous speed.

The speed we calculate will likely be too high.

The following procedure will help us determine a more accurate speed.

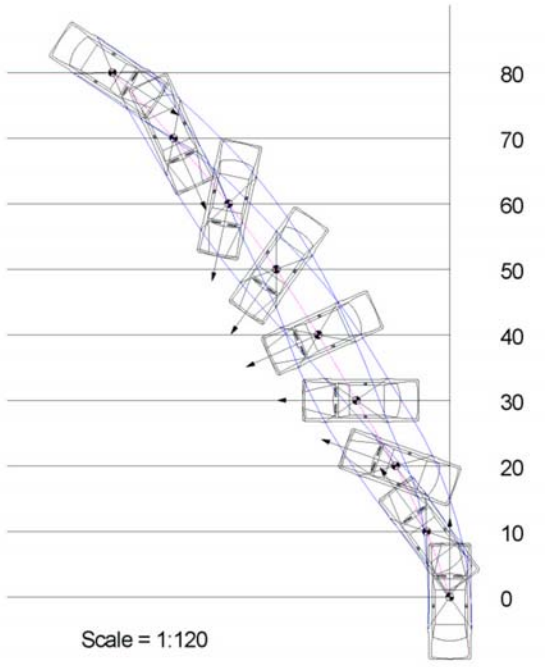
We will calculate drag factors for small distance increments and will use the combined speed equation.



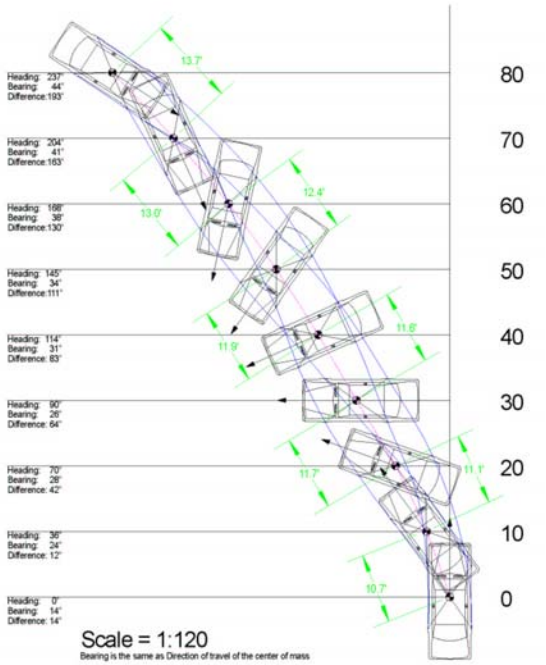
Plot the vehicle back at its skid initiation point.

Draw a station line parallel to the initial velocity vector of the vehicle.

Draw offset lines perpendicular to the station line every 10 or 20 feet.



Plot the vehicle heading by placing the vehicle back on its tire marks, locating the center of mass on the appropriate offset line.



Determine velocity vector bearing tangent to the vehicle path at each CM location.

The angle the vehicle makes with respect to its velocity will be the difference between bearing and heading.

Use the CAD program to determine the center of mass distance moved between each offset line.

Once we know this information, we can calculate the drag factor for this vehicle for each distance increment.

We may then calculate speed using a combined speed equation.

For this example, we will use

μ= 0.75

Distance	θ	Sin θ	f = μnsinθ+m	$f_n d_n$
10.7	12°	.207	.155	1.65
11.1	42°	.669	.501	5.56
11.7	64°	.898	.673	7.87
11.6	83°	.992	.744	8.63
11.9	111°	.933	.699	8.31
12.4	130°	.766	.574	7.11
13.0	163°	.292	.219	2.84
13.7	193°	.224	.168	2.30
Total 96.1 ft				Total 44.27

Post Impact Movement

- Use Combined Speed Equation:

$$S = \sqrt{30(f_1 d_1 + f_2 d_2 + f_3 d_3 + ... + f_n d_n)}$$

S = 36.44 mph

Effective Drag Factor: 0.46

Percentage of Braking: 0.61

Drag Factor Equation by Wheel

$$f = \left[\mu_{LF} n_{LF} \sin\theta + \mu_{RF} n_{RF} \sin\theta + \mu_{LR} n_{LR} \sin\theta + \mu_{RR} n_{RR} \sin\theta\right] \pm m$$

f = overall drag factor

μ= tire – road friction by wheel

n = percentage of braking (weight distribution) for each individual wheel

θ= angular difference between the vehicle heading and the velocity vector (direction of travel for the center of mass).

Drag Factor Equation by Wheel

- EXAMPLE:
  - A crash vehicle has the following braking percentages per wheel
    - LF = 32%
    - RF = 32%
    - LR = 18%
    - RR = 18%
  - The left front wheel is locked due to damage.
  - The remaining wheels are free rolling.

Drag Factor Equation by Wheel

- The general wheel by wheel equation reduces to this:

$$f = \left[\mu_{LF} n_{LF} + \mu_{\mathrm{Re}st} n_{\mathrm{Re}st} \sin\theta\right] \pm m$$

or

$$f = \left[0.32\mu + 0.68\mu \sin\theta\right] \pm m$$

Spin Adjustments

- The method allows us to compute a drag factor for each distance increment.
- This allows us to account for variations in braking between the wheels and accounting for the spin angle.
- If one or two wheels are locked, we may handle the problem in a straightforward manner by expanding the drag factor equation.
- We account for road slope for each distance increment.

Summary

- Drag factor adjustments for constant slopes are straightforward.
- Sometimes the slope is NOT constant, especially on city streets and county roads.
- The changing slope will result in a changing drag factor, which must be accounted for.
- Post-impact spins are not difficult to handle even if there is no braking.
- Plot the path, compute the angle, and account for the grade.
- The minimum level drag factor for any given wheel will be on the order of 0.01.