THE ROLE OF TREAD DESIGN IN SKID RESISTANCE UNDER WINTER DRIVING CONDITIONS

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•SO-CALLED winter tires are a relatively recent nomenclature for tires that appear to be more aggressive than winter is slippery. In the past, this emphasis on aggression produced tires that were uniquely noisy, unstable, rough riding, and unsuitable for any mode of motion except excavation. These were designs that bit into the surface in hope of finding dry, hard ground underneath. As tire technology improved, the "mud-and-snow" tire was permitted to remold and grip the surface rather than trench it.

The problem with evolution is that, although progress is certain, it is equally resistant to instant improvement. Hence, the public concept of a good winter tire today still requires that the tire tread be designed to look like a trenching tool. In spite of this constraint, winter tire designs that balance lug-edge pressure for surface penetration with a sufficient contact patch to minimize pressure melt and void ratio with lug shearing area to stabilize rather than displace the snow are measurably more effective in winter driving environments than a ribbed highway design.

However, what the tire tread design will do as compared with what it is supposed to do is best explained by quantifications generated in a two-season winter test program that we conducted recently.

Under winter test conditions that were categorized as virgin snow, soft- and hard-packed snow, and dry and wet ice-covered roads, tires were evaluated for acceleration traction and slip velocity, braking traction and slip velocity, and lateral traction. A tire whose tread design appeared to be classically "winter" rated 84, whereas a tire whose tread design was classically "highway" rated 109 in terms of the performance of a neutral mud-and-snow winter control tire rated at 100.

This particular program, because of its extensive nature, permitted us to draw the following conclusions:

1. There is no justification for the designation of a tire as a mud-and-snow tire solely on the classic appearance of its tread design without regard for its construction or compounding.
2. No single measure of winter tire performance is meaningful. High relative values in one category of winter tire performance are not necessarily associated with high values in another. Tire wear introduces further changes in relative ranking, not necessarily as a function of tread depth but as a function of wear pattern.
3. Because of the very real variability of winter conditions, any attempt to reduce this variability by reducing the quantity of testable environments results in a reduction in the significance of ranking relative winter tire performance based on these tests.
4. Any attempt to influence the interactive tractive potential of paired driving tires on winter surfaces by the use of a locking differential to force paired drive tires to rotate at equal rpm regardless of differences in rolling radii eliminates the possibility of measuring the relative influence of tread design, carcass construction, and tread compounding on tire traction. It is essential in measuring tire traction in a full-scale world on a full-scale vehicle that each driving tire achieve its peak tractive effort at essentially the same time rather than at the same rpm. It is, therefore, necessary that the test surfaces under each driving tire have substantially equal resistance values and that the loads carried by each driving tire be equally consistent. No locking differential can equalize the traction of paired drive tires; it can only reduce the tractive force differential between significantly dissimilar road resistance values by forcing the

Figure 1. Characteristic winter tire acceleration.

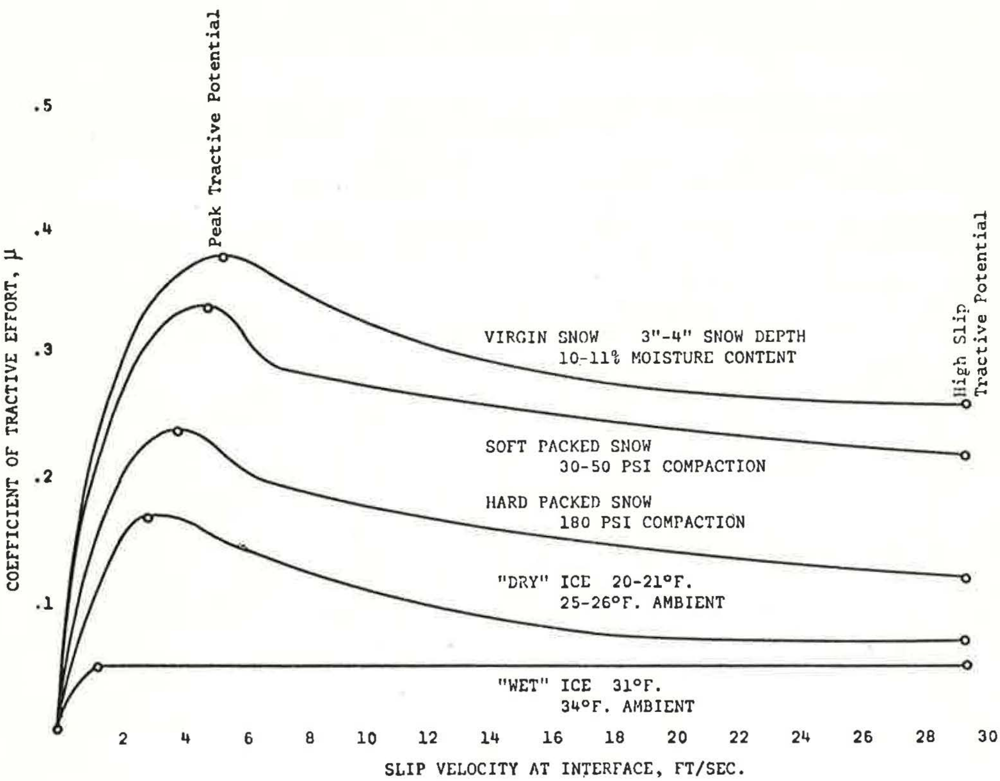
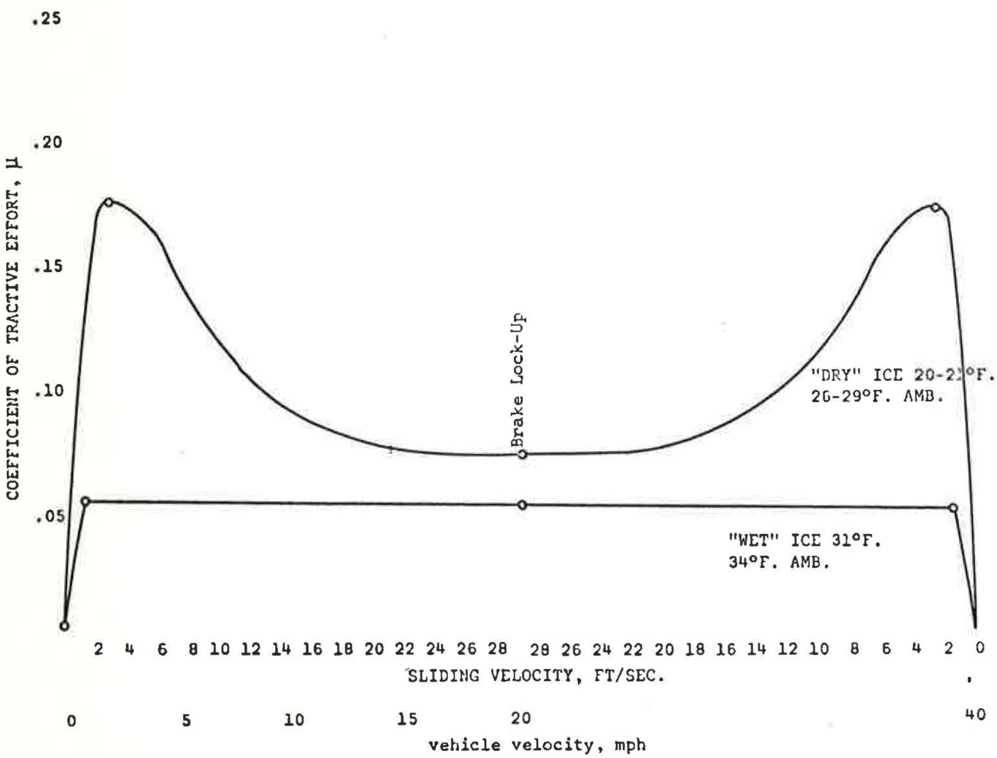


Figure 2. Characteristic winter tire braking.



tire on the surface with the highest tractive resistance to drag the other tire along. These reactions can be clearly identified if individual torque meters are applied to each driving wheel.

5. With proper measurement techniques any practical separation among tire designs that have acceptable winter performance from those that do not will probably take the form of weighted numbers that express winter performance as some multiple of the weighted performance numbers earned by a standard control tire.

In summary, the role of tread design in skid resistance under winter driving conditions is considerable, providing the tire is not operated at differential interface velocities that exceed the peak tractive effort of the tire balance by the maximum tractive resistance of the material on which the tire is driven. In simple terms, the tire must continue to turn if the tread design is to be meaningful in skid resistance. Figure 1 shows the relative tractive performance of the same paired drive tires over a range of specific winter environments. Note that on wet ice no change in tractive effort occurs as a result of increased wheel slip velocity. These measured values are pure sliding friction values of a wet tire on wet ice without the additive coupling of elastic deformation of the contact interface between the tire and the ice because of the thin film of water that separates them. Figure 2 shows that tire traction on dry ice is dependent on sliding velocity rather than on vehicle speed. It clearly identifies the critical loss of tractive effort because sliding velocity increases after peak tractive effort has been achieved. On wet ice, this tire's traction is again independent of sliding velocity. It shows that the characteristic traction-sliding velocity relation is independent of driving mode, whether the tire is accelerating or decelerating.

If we cannot control tire lock-up in winter driving, elements must be added to the tire that spike the road surface and lock the tire to the ground by mechanical means rather than the more efficient method of harnessing the peak traction values available through elastic and plastic deformation of the contact patch interface.