Adhesion: A Description of Ski Drag in Wet Conditions

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While every skier is familiar with sticky slow skis associated with wet conditions, most skiers don't have a good understanding of the mechanisms that cause the wet snow impedance. A good understanding of the mechanisms that slow down the ski will provide a better knowledge of how to minimize the problem.

Too often skiers and technicians refer to the stickiness between the moist track and the ski as "suction". Check a dictionary or encyclopedia and you'll find that "suction" requires a vacuum, or partial vacuum. It is certainly an inappropriate and incorrect description of factors causing wet ski drag. Wet ski drag is not suction.

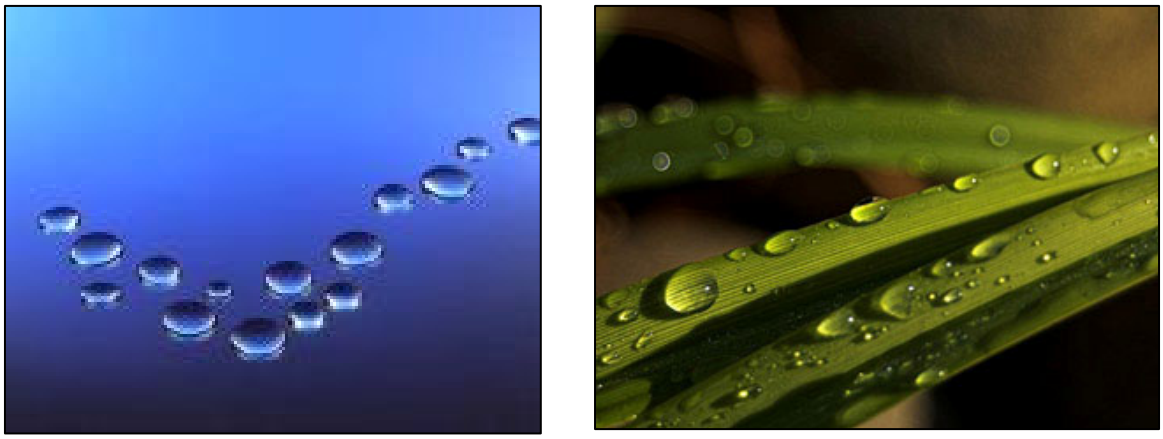
A cross country ski sliding on snow is complex to model analytically. Since the ski-on-snow presents exceptions to the standard assumptions required to simplify friction models for "Physics 101", the ski-on-snow doesn't behave in accordance to simplified dry friction equations.

In wet conditions the sticky drag is largely caused by Van der Waal's Adhesion-Cohesion and compounded by the capillary propagation of the adhesive layer between the ski and the track.

Let's take a look at the Adhesion-Cohesion model of wet ski friction. When we have an understanding of the wet ski friction, we can use the knowledge to prepare skis more effectively.

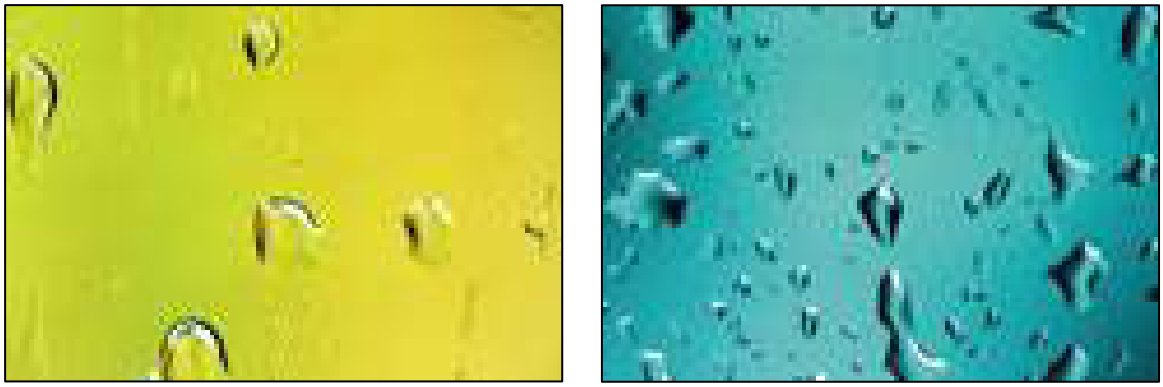
What Is Cohesion? And What Is Adhesion?

Cohesion is the attraction between molecules of the same kind; the tendency of molecules of one type to stick to each other. This is often seen as beading of water or mercury. Cohesion keeps droplets from disintegrating!



Water droplets "bead up" due to cohesion between water molecules.

Adhesion is the attraction between dissimilar molecules. Adhesion occurs when attractive forces between dissimilar molecules are greater than the attractive forces between adjacent molecules. Often a "lowest energy state" is achieved by a combination of cohesion and adhesion.



Adhesion and Cohesion: Water sticking to a surface and also partially beading up.

Adhesion, Cohesion, and Capillary Action

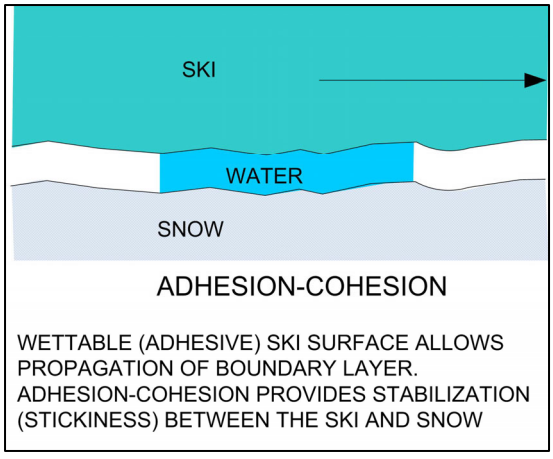
If the adhesivity of a surface is stronger than the cohesivity of the adjacent fluid, then the fluid will adhere to the molecules of a surface. In the case of the skier, the fluid is water, and the surface that we're worried about is the ski base. Water is sticking to the ski (adhesion), and also sticking to itself (cohesion), and sticking to the track.

Molecular adhesivity will cause water to adhere to a ski base, and to further complicate the situation, capillary action will draw the fluid into adhesive contact with even more of the surface. The capillary action will spread the area of adhesion, increasing the stickiness.

Adhesion-Cohesion

Adhesion-Cohesion is a mechanism by which two wet surfaces are held together by the strength of the molecular attraction of the fluid to itself, and the attraction of the fluid to the two surfaces. The strength of the bond is dependent on the fluid and the surface materials.

Adhesion-Cohesion describes the stickiness between the ski and a wet track.

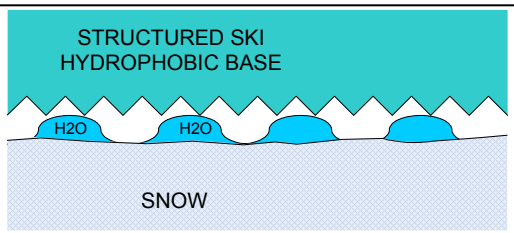


In a Nutshell

If the mechanism were to be described in two sentences, it would be as follows: ***Adhesion-Cohesion is the stickiness caused when a wet layer adheres to the ski and the track. Capillary action can spread the adhesion to a large area.***

Strategies for Minimizing Adhesion for the XC-Skier

In moist or high humidity and warm conditions, Adhesion-Cohesion can be the primary mechanism of ski impedance. A strategy for minimizing the stickiness can be broken down into three parts:



SURFACE DISCONTINUITIES AND HYDROPHOBIC TREATMENT REDUCE ADHESION AND INHIBIT CAPILLARY PROPAGATION

ADHESION-COHESION IS REDUCED

Reduce the adhesivity of the surface. Highly hydrophobic base material and base treatments will resist adhesion and will resist sheeting of water. High-fluoro waxes, pure fluoros in blocks, powders or liquids will greatly improve the resistance to adhesion. If the water can't stick to the ski, it won't slow you down.

Structure the ski base to resist propagation. A deep, closely spaced structure will inhibit the spread of adhesive areas. A structured surface has a greater path length to inhibit expansion of the adhesive layer, and the sharp edges provide surface discontinuities which resist capillary propagation, especially when used in conjunction with fluoro treatments on the ski base. Broken structure patterns often resist capillary spread better than uninterrupted linear rills.

Consider the track conditions. When selecting the ski and structure, it's important to consider the conditions. On a wet hard track, a ski that has a small pressure distribution area will limit the intimate contact. This will further minimize the area available for adhesion. However, in very soft conditions, a stiff ski with a small contact area may displace snow (plow) and feel slow. Be aware that fine, sharp-featured snow crystals will have significant drag in deep, aggressive structure. Transformed icy conditions, and firm corn snow allow almost unlimited structure to combat adhesion.

Certainly there are limits to how much structure should be used. Too much structure has to be considered as a friction mechanism as well, since surface roughness can be a big source of sliding friction. Grind selections, and structuring, are topics that can fill a very long article on their own.

Summary

A good strategy for maximizing glide starts with a good understanding of the all the mechanisms that slow down the ski. In wet conditions, a basic understanding of adhesion provides a basis for making better-informed ski, structure, and wax choices to minimize net total sliding friction.

Postscript

This discussion has been limited to the description of wet Adhesion-Cohesion. There are several other sources of sliding friction – Displacement and Deformation, Surface Roughness and Mechanical Interlock, and Dry Adhesion are other primary mechanisms that should be considered. These other mechanisms will be discussed in another article.

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