Mastering science of the slide crucial to success of every winter Olympian

By IVAN SEMENIUK

Think about it: Every sport at the Winter Olympics relies on some kind of man-made object sliding over ice or snow. As Ivan Semeniuk writes, winning isn't just about the athletes, but also the scientists – mastering equipment design by understanding the frictional forces at work

Watch a group of children in a schoolyard as they take running leaps onto a bare patch of ice and you know you're witnessing a kind of joy that's been around a long, long time.

Our fascination with ice and its slippery nature may date back to the depths of the Pleistocene, when the first Homo sapiens left Africa and pushed northward into the glacier-bound world beyond. During the course of that epic journey, someone had to have been the first to see the latent fun in a frozen pond or a snow-covered hill.

Fast forward a few hundred thousands years and the 2014 Winter Games are set to begin. Like its summer counterpart, the quadrennial event is humanity's most recognized expression of the athletic ideal. But it's also an acknowledgment that the coolest thing about winter is that we've invented so many ways to play with frozen water.

One way or another, every competition in Sochi will come down to some kind of man-made object sliding over ice or snow – an almost magical phenomenon that makes the winter sports we love possible. And like every love affair, it comes with an element of mystery.

"I see ice as an old friend," says Ed Lozowski, a physicist and professor emeritus at the University of Alberta. "But it's an old friend I still don't understand very well."

Dr. Lozowksi speaks for a long succession of researchers who have pondered and probed the science of slide and its role in winter athletics.

It's a topic he began exploring a decade ago during a sabbatical at the National Research Council in Ottawa. While skating on the Rideau Canal, he started to wonder how it can be that the friction between ice and skates is so incredibly low. He knew there were broad descriptions for what was going

on, but found there was much less known in terms of predicting how different materials interact with ice under different conditions.

"There's been a lot of hand waving but very little in the way of quantitative theory," says Dr. Lozowski, who has been studying the problem ever since.

Ice is unusual as a solid because in the normal range of winter temperatures it's never too far from its melting point. Just a small amount of energy applied to ice in the right way can melt a thin surface layer. This creates a temporary film of liquid water – typically no more than one-thousandth of a millimetre thick – that another solid surface, like the bottom edge of a skate, can slide over with little resistance.

"In a car engine, when we have solid parts in contact with one another, we put in oil for lubrication," says Anne-Marie Kietzig, an assistant professor of chemical engineering at McGill University who studies friction. "Ice is self-lubricating, due to the water film."

Where does the energy to make the water film come from? Scientists once thought pressure was the main source. The pressure from a skater's weight pushing down on the ice raises the ice temperature as much as half a degree, which contributes to melting. But that doesn't explain how a six-ounce hockey puck can seem to slide as easily as a 200-pound hockey player. Instead, the friction created by dragging something over ice is now thought to provide most of the necessary heat.

Even at temperatures well below the freezing point, ice continues to be remarkably slippery. This is in part because as ice get colder, it gets harder. Blades and runners don't sink down into the ice so much, which allows them to ride on top more easily, even if it takes more heat to create the liquid layer. And even in extreme Antarctic cold, a sled can still work because the molecules on the top layer of the ice are only loosely tied to the molecules below, allowing a runner to push across them almost like over miniature ball bearings, which is enough give to get frictional heating started.

But that's just the beginning. The science of slide also depends on whether the frozen surface is smooth or bumpy or packed snow. And it depends on what is doing the sliding.

"It's more about how you can manipulate the materials so that they do what you want them to do," Dr. Kietzig says.

That in essence, is where all Winter Olympics competition leads: to the finely honed triangle of frictional forces, equipment design and athletic performance. The degrees of freedom in that arrangement are what make the Games so engaging. But mastery over them makes victory attainable.

NORDIC SKIING

What's sliding

Polyethylene-base skis on snow

How it works

Skis are sold in pairs but serious competitors have fleets of skis at their disposal, carefully paired with just the right springiness or "camber" to suit specific snow conditions. Snow is a more complicated and variable material than ice, but for sliding purposes the basic principle is still the same: Skis work because when they compress the snow, they also melt it just enough to create a liquid layer that the ski glides over – more like a boat slipping over water than a piece of plastic scraping over something dry.

The key issue for a competitive skier is just how much water is being generated. If the snow is near the melting point to begin with, excess water can hold onto the ski, causing a kind of suction, which slows the skier down. To combat this, competitive skis are stone ground with a fine pattern of scratches on the bottom. The scratches, know as "structure," help channel excess water away when the snow is wet. When the snow is colder and drier, the structure tends to be finer and shallower so that the ski is better optimized for generating and preserving the thin water film.

Ski wax is used to enhance the desired effect. Wax that is rich in fluorine is especially water repellant because of the electrochemical characteristics of fluorine atoms.

What to watch for in Sochi

Weather and snow conditions will have a significant impact on Nordic events in Sochi. As in Vancouver, the concern going in will be what happens if the weather is relatively warm and the snow very wet. Rapid changes in snow conditions are also possible given Sochi's climate, so the best strategy for Nordic teams is to be ready for anything.

Skiers will have many pairs of skis ready to go and dozens may be tested before a race to see which works best. Canada is among the countries that has been sending skiers and coaches to Sochi ahead of time to scout the snow and get a better feel for how it changes with the weather.

SKELETON SLED

What's sliding

Steel runners on sloped ice

How it works

If going head first down an ice-covered concrete chute seems like a challenge to self-preservation, it's also a study in how a race can be won with the smallest of adjustments in pressure and timing. All three sledding sports - bobsled, luge and skeleton - depend on gravity to pull a sled down an ice track. Gravity provides the power, and the key to winning is to minimize energy loss through friction on the way down.

But not all the possible ways of reducing friction are allowed. Runners can't be heated to to make them slide more easily by speeding up their ability to melt the ice beneath them and form a water. And because mass can help overcome friction on a slope, there is a weight limit - without it, the heaviest sledder might waddle away with the gold.

In the case of skeleton sleds, the rod-shaped runners are all made from the same officially approved brand of steel that is marked for identification. This ensures that the race does not become one of differently engineered materials with slightly different heat capacities and behaviour on ice. One place where sled designers have some latitude is in the shaping of a skeleton runner's "spine". This is formed at the back of each runner by machining out two grooves. The precise profile of the spine affects friction, particularly on the turns when g-forces are pressing the runners into the ice. A sledder can then make slight body movements to vary the pressure on the runners and steer the sled. Competitors choose which set of runners offer the best balance of speed and control based on ice conditions on the day of an event.

What to watch for in Sochi

Unlike Whistler's notoriously fast track, where a Georgian luger was killed at the 2010 Games, the sledding track at Sochi has uphill sections built in. These are the places where it's predicted that races will be lost, as sledders make split-second decisions to try to conserve momentum on those upward sloping areas. The track is refrigerated so sledding sports will not be as affected by weather as skiing could be but air temperature and sunlight will still have an impact on the sliding surface and, for skeleton sleds, influence the choice of runners.

CURLING

What's sliding

Granite on pebbled ice

How it works

Unlike a hockey or skate rink, a curling "sheet" has a bumpy texture, rather like the skin of an orange. The texture is created by first scraping the ice flat and then sprinkling it with water. The sprinkler head determines the shape and distribution of the water drops, which form tiny hills as they land and freeze on contact with the ice.

For the Olympics, the curling stones, which weigh about 20 kilograms, are traditionally made from a particularly water-resistant granite found on Alisa Craig, an island in the Firth of Clyde off Scotland. The bottom surface of the stones are made with a slight indentation, so each stone only glides on a thin ring, about one centimetre wide. Since the ring can only sit on a few rounded bumps of pebbled ice at one time, the contact with the ice surface is minimal and the stone can travel a long distance across the ice even at a relatively low speed.

When a stone is thrown, it is given a bit of rotation, which makes its journey more predictable. However it also causes the path of the stone to bend – the curl. The reason for the curl has to do with the slightly greater amount of frictional heating the ice experiences on the side of the stone that is spinning into the direction of motion. This increases the slipperiness of the ice, which means the stone is pulled a bit more by the ice on the opposite side and the stone's path bends. In order to place the stone precisely, sweepers brush the ice immediately in front of the stone. This raises ice temperature, which makes it easier for the stone to glide and tends to both lengthen and straighten a shot.

What to watch for in Sochi

Canadian curling teams are likely going into Sochi enjoying a relatively high comfort level with the curling facility there, in part because Canadian know-how has contributed to its design. As soon as teams arrive, they will begin by testing the stones, which are provided by the venue, to get a sense of whether there are slight differences in the weight and density that could slightly affect a throw, and therefore the order in which the stones will be thrown in during competition.

SPEED SKATING

What's sliding

Steel blades on smooth ice

How it works

Speed-skate blades are longer and thinner than hockey-skate or figure-skate blades. The extra length keeps the skate in contact with the ice longer during each push-off and gives the skater more power per stroke. The thinness – about 1 mm – means the blade can slice through the ice more easily and doesn't have to work as hard to push ice aside, like a tiny snow plow.

There's also less of a rocker – the rocking chair-like curve at the bottom of the blade that in other skates makes it easy to quickly pivot and change. Since this isn't required for speed skating, the rocker is shallower. The skate doesn't dig as deep into the ice and so glides better. That also makes it harder to turn, but since speed skaters only have to turn in one direction, the skate blades are given a bit of a warp, or bend, to make them naturally want to turn that way.

Finally, speed-skate blades are flat ground on the bottom surface, rather than hollow ground. This minimizes the contact area with the ice and the friction still further, but it means that speed skaters have to keep their edges sharp otherwise they'll lose their grip on the turns and take a spill.

What to watch for in Sochi

Speed skating is a fast as human can go without motorized or mechanical aid, reaching speed in excess of 50 kilometres per hour. More speed means more frictional heating and more melting of the ice under the blade. If the ice track is too warm to begin with, a faster skater will sink into the ice a bit more. If it's too cold, the skates won't slide as well because they're not able to melt enough ice with friction. That's why the ice temperature in modern indoor racing ovals is optimized for racing speed and kept at around -7°C, as it will be in Sochi.

With the ice already tailored for speed, the deciding factor in racing time will be air resistance, or drag. Like Vancouver, Sochi is at sea level, with a greater average barometric pressure than high altitude tracks like Calgary. High pressure means more air resistance, so while the competition is likely to be fierce at Sochi, it's unlikely that world records will be broken there.

Source: The Globe and Mail

Url: http://www.theglobeandmail.com/sports/olympics/mastering-science-of-the-slide-crucial-to-success-of-every-winter-olympian/article16512030/?page=all

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