Advanced Materials Are a Game Changer in the Winter Olympics

Lynne Robinson

It starts with a push.

Propelled by the strength and collective will of four powerful sprinters gripping its sides, an Olympic bobsled launches from a frozen start ramp, accelerating from a standstill to 40 kilometers an hour in less than five seconds. At about 50 meters into the race, the team hops into the sled one by one, with the pilot already preparing to hit the first of 16 turns built into the ice-encased track of the Whistler Sliding Centre, site of the bobsleigh competitions for the 2010 Vancouver Winter Olympics. Like a fiberglass bullet, the sled shoots down a vertical drop of 152 meters, subjecting its crew to crushing G-force and bruising jolts around the curves, while attaining speeds of nearly 150 kilometers an hour. Victory at the end is measured in hundredths of a second, with almost imperceptible factors deciding the difference between a medal run and a disappointing finish.

For the 2010 Olympics, the Swiss Bobsleigh Federation (SBSV) wanted to make sure that those factors had nearly nothing to do with the construction of the sled. Under the project name CITIUS—which echoes the Olympic motto, “Citius. Altius. Fortius (faster, higher, stronger)—SBSV marshaled the talents and resources of the Swiss Federal Institute of Technology (ETH...
Zurich), a consortium of industrial partners, and current and former bobsleigh athletes to work on “building a better bob” (Figure 1).

THE SCIENCE OF THE SLED

“An initial question we asked ourselves was ‘what slows down a bobsled?’” said Ulrich Suter, professor in ETH Zurich’s Department of Materials and CITIUS project coordinator. “After a careful analysis, we decided to break the problem into a number of simpler tasks. Aerodynamics is clearly important, especially in the very fast track at Whistler. The shape and surface structure of the runners are also very relevant. The hull and chassis materials, as well as the dynamics within the system, play a crucial role in the mechanical dissipation of energy in the bobsled. And, above all, safety is paramount—the sled must survive a crash at full speed and protect the crew. We numerically simulated all key aspects of the sleds and tried to isolate the most important factors, and then experimentally tested our assumptions to optimize the design.”

A particular challenge for CITIUS was developing a state-of-the-art bobsled in accordance with the rules for construction and design enforced by the Fédération Internationale de Bob-sleigh et de Tobogganing (FIBT), the governing organization for competitive bobsledding. The runners, for instance, have to be constructed from a rigidly defined steel procured from a prescribed source, with any type of modifying treatments “forbidden, including those which even cause only a local variation of the physical characteristics and/or of the composition and/or structure of the material.” Steels used elsewhere on the sled are more generally described as “an alloy of iron and carbon with an iron content of more than 50 percent,” while “rubber or rubber-like material” can be incorporated into the sled for the purpose of damping vibrations. Hulls have no prescribed material at all. Suter said he was surprised, actually, at “how many unspecified areas were left in a seemingly very complete—some might say overly complete—book of rules.”

Working within these parameters, a team of more than 20 ETH Zurich scientists and engineers from a wide range of disciplines applied their specific expertise to different aspects of the CITIUS bobsled. A battery of tests revealed the sources and nature of vibrations, which forces were exerted where on the chassis, and the specific stiffness and strength of certain materials. “Our simulations indicated that several apparent inefficiencies of the sleds might be avoided with an appropriate choice of materials,” said Suter. “However, almost all standard elastomeric materials were inadequate to the demands of the sport. And, many tested adhesives proved insufficient under the (dynamic) mechanical and thermal stresses of bobsled racing.”

To address these issues, the research team created elastomeric damping materials specifically for the CITIUS, while also developing a composite hull strengthened with long-fiber reinforcement. Once the components were assembled into prototype sleds, athletes from the SBSV tested the CITIUS in the wind tunnel at the Audi works in Ingolstadt, Germany (Figure 2). The real moment of truth for the project occurred when, bristling with sensors to measure forces, driving dynamics, and aerodynamic properties, the CITIUS hurtled down an ice track for the first time near Innsbruck, Austria. Although highly guarded about revealing details of the CITIUS’ development and performance, the research team was pleased with the results, according to the CITIUS Dossier posted on the ETH Zurich Web site.

A WEIGHTY MATTER

Whether smoothing the performance of a bobsled careening down the Whistler ice track, or giving an aerials skier an extra bounce into the Canadian sky, advanced materials technologies like those used in the CITIUS project will be on prominent display at this year’s Winter Olympics. The quest for a competitive edge through advancements in engineering isn’t limited to these elite athletes, however. Said Travis Down- ing, a materials engineer in research and development at Easton Hockey, California, “Once full composite hockey sticks were introduced onto the market about ten years ago, they immediately became the ‘must have’ stick among professional players. Subsequently, amateur players were quick to jump on that trend, as well. The fact that it is nearly impossible to find a wooden hockey stick anymore speaks volumes to the adoption rate of composite sticks” (Figure 3).

A key advantage of composite hockey sticks over wooden ones, said Downing, is weight. Wooden sticks routinely tip the scales at more than 650 grams, while modern composite sticks can be as low as 400 grams. By being lighter, composite sticks are easier to control and provide for greater swing velocity. Downing said that composite hockey sticks have also been found to be superior to wooden ones in storing and rapidly releasing strain energy, which enables players to boost their shot velocity. From a manufacturing standpoint, composites make it possible to reproduce a hockey stick’s properties exactly each time, while the organic nature of wood tends to introduce inconsistencies from stick to stick (Figure 4).

“For most sports, lowering the weight of the equipment without re-