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The Adarraga Story

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Abstract

This story is about speedskiing. It starts in 2016 and stretches to the spring of 2021. Five years of research comprising tribology, boot-fitting, ski design, aerodynamics and psychology. Five years of friendship and vivid exchange of ideas and concepts, but also five years of networking with international partners.

How everything started

At the beginning of 2016, I received a call from a Spaniard with a Heidelberg phone number. It was about speed skiing and the caller was none other than the reigning Spanish champion Ricardo Adarraga, which due to the many rolling R in his beautiful name sounded like RRRRRRRicarrrrdo Adarrrraga from Andorrrra, olé!!!!

Figure 1: The first visit to Karlsruhe.

But why, I asked, the German number? To which Ricardo replied: he is the son of a Spaniard and a Swiss, studied industrial engineering at the Karlsruhe Institute of Technology and lives with his family in Heidelberg.

The horror trip

Ricardo contacted me about my article in *SkiMagazin*, which I had written in 2015 on new findings about the ski base. Ricardo had literally inhaled the article and confronted me, as a

full-blown friction specialist, with questions that I had to reach deep into my scientific treasure chest to answer. It was about new types of ski bases, fast grinds, questions of ski tension, edge grinding and of course about wax and at the end of the phone call about how he could get even faster, because 240.642 km/h was not enough to embarrass the world record holder Simone Origone!!!! After this brilliant end to the conversation, a short horror video spontaneously ran in my mind's eye: Latest findings on ski optimization - cut - ski preparation - cut - race on steep slope - cut - crash at 250 km/h - cut - Ricardo dead as a doornail and me small and gray in the background. When asked if my Team Snowstorm would accompany Ricardo for the upcoming season, I hesitated at first and then answered yes, but. First, the team wants to get to know him properly to get a full picture. Then the team will decide if we can contribute something in this extreme area. Team Snowstorm is a network of companies and research institutions supporting winter sports. The aim is to provide athletes with technical assistance on equipment and competition preparation, and to offer Snowstorm partners cooperation opportunities as well as advertising platforms. Team snowstorm currently has more than 50 partners and is active in cross country and alpine skiing as well as in luge and bobsleighing. The team is located in Karlsruhe.

Figure 2: Body posture during race. Photo provided by Eugenio Cabaleiro.

Fast train to Karlsruhe

Then everything went fast, as you should expect for Speedski. Fourteen days after the phone call, Ricardo came to Karlsruhe for a meeting of the network. Expecting the young hottie I had seen in my short horror movie, I was stunned to find myself looking at a well-trained, very agile and calm athlete who had celebrated his fiftieth birthday in 2015. How is it possible that someone who is only 0.93 times younger than me goes about 3.5 times faster? Ricardo presented the answer with a lecture that was very exciting due to a combination of Spanish fire, Swiss precision and the analytical thinking of an engineer. As a result, a group of 4 companies formed for the pre-season work on ski development, ski and boot adaptation and friction reduction. In addition, the Fraunhofer IWM MikroTribologie Centrum contributed its knowledge from the in-house ice and snow friction laboratory.

What is speed skiing?

To achieve the highest speeds, the slope must be steep, the athlete must be very well trained and streamlined, and the ski must be fast. The steep-

ness of the record slopes is breathtaking and is more than 45°, which corresponds to a gradient of more than 100%. For comparison. The inrun of the Planica ski jump has a slope of 35.1° and allows jumps of over 250 m! The demands on the athlete's training condition can be guessed from Fig. 2. A deep squat combined with a relatively wide ski run results in the smallest possible attack surface for the air. Speed skiers glide faster than a skydiver falls in a balanced position, with arms and legs perpendicular to the direction of fall. Perfect aerodynamics are achieved by giving the boots spoilers and the helmet resting flush on the shoulders. The athlete's body is also encased in a skintight suit that becomes a lubricant in the event of a crash. Resistance when skiing results from the sum of air drag and friction between the ski and the snow. Basically, both components are fluid-driven forces, because on snow, gliding occurs in contact with a nanometer-thin film of water.

Figure 3: Pressure distribution measurements performed by Dr. Jens Hollenbacher using a molibso hi-res plate.

How do you get a superfast ski that ensures a safe ride?

In the first stage of the project, the initial situation regarding the ski and the athlete was first analyzed. For this purpose, Ricardo was placed on a highly sensitive pressure plate with a length of 4 m, see Fig. 3 again. The size of the plate was necessary because Ricardo's skis are 2.40 m long. On the plate, the position on the ski was first analyzed in terms of body posture during the race. Since edging the skis has a destabilizing effect, the optimal distance between the two skis was determined. Then it was measured how weight shifts to the front and to the rear affect the pressure distribution. Due to the very high sensitivity of the plate, even the slightest effects of ski pretension and manufacturing deviations from the ideal shape were revealed. Furthermore, it became clear how strongly the ski boot interferes with the pressure distribution if, for example, the buckles are tightened differently.

In the boot camp

With the detailed knowledge of pressure distribution, Ricardo was sent to Davos to Hans-Martin Heierling to further improve the boots and the associated posture on the skis. Heierling has been manufacturing and optimizing ski boots since 1883. In 2005, Heier-

ling signed a licensing agreement with Atomic and worked with Atomic to develop the Hawx with I-Flex Technology. After Didier Cuche and Bode Miller, Ricardo Adarraga was now also in Davos and came back optimized. With the professional help of the Heierling company, the position on the ski was significantly improved.

Figure 4: Boot-fitter Hans-Martin Heierling in Davos.

How can skis be made faster?

Friction microscopically is the sum of all resistances between the ski base and the snow grains. Since the snow in the race is predetermined, the sliding resistance must be reduced by the ski preparation (waxing, brushing, etc.). The smaller the contact area between the ski base and the snow, the faster the ski. In addition, an optimal ski grind gives not only wings but guidance, which prevents splitting on steep slopes, especially at the highest speeds. Therefore, the grinds of all the skis in Ricardo's possession were analyzed three-dimensionally, correlated with the results of the pressure plate and evaluated by his subjective impressions during the completed races. From this mishmash, ideas for the optimal grind were formed. Figure 5 shows an images of the grinding structure. Particularly important are the number of grinding grooves and their width in relation to the snow grain size.

The interplay of friction and grinding structure can be computed. The model introduced in 2017 by Böttcher *et al.* [1] utilizes a microscopic approach originating from the pioneering studies of Bowden in 1939 [2]. Friction, in this approach, is mainly determined by the shear resistance and the contact area between ski sole and snow. Shear depends on the amount of water present on the micrometer-sized grains snow is composed of. Even without any contact between ski and snow, the grains carry a water films with a thickness of some nanometers (1 nm = 10^{-9} m). This type of water has to be considered liquid-like and physicists call the effect of water generation pre-melting [3–5], meaning that the near-surface crystalline structures of the ice grain gradually becomes disordered, i.e., liquid-like. To achieve lowest coefficients of friction, the water film thickness must be in the nanometer range. However, due to frictional heat the water film growths. At a certain thickness

the friction-reducing effect vanishes, since viscous drag arising from turbulences inside the water film confined between ski sole and snow grain slows down the ski. This last statement is crucial since it emphasizes the impact of the environmental conditions during competition. It is obvious that only appropriate conditions allow top speeds.

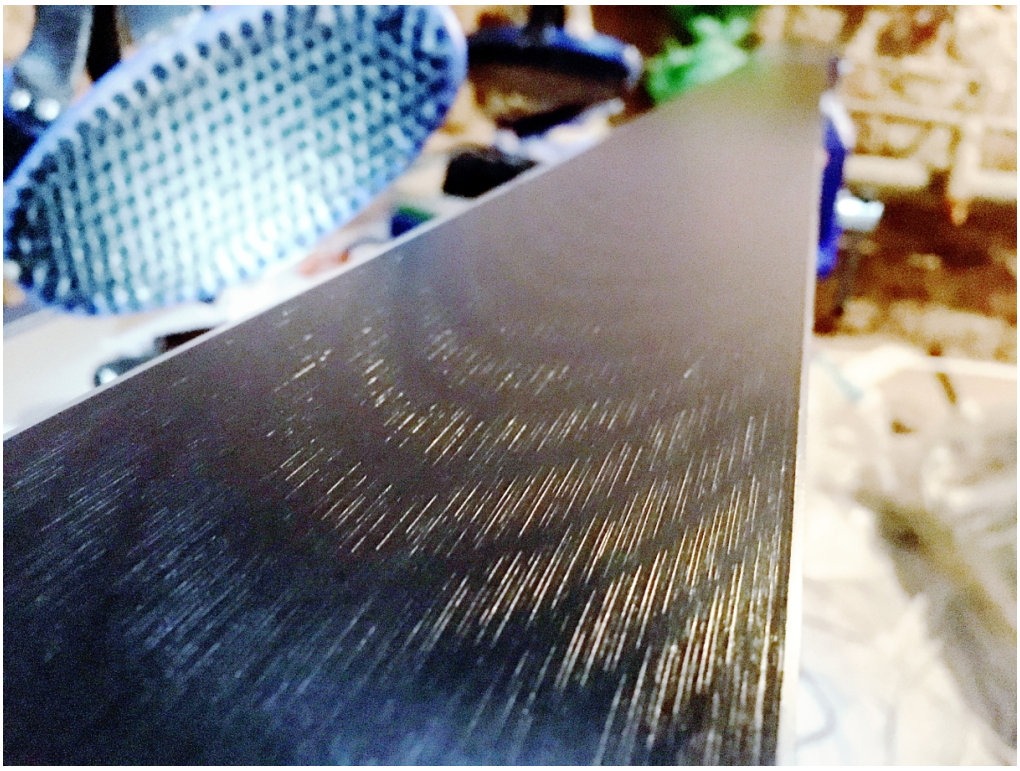

Figure 5: Grinding structure. Photo provided by Ricardo Adarraga.

The battle against air resistance

While friction dominates in the first third of the run, the cw-value becomes increasingly important in the further part of the chase [6]. Ricardo therefore completed several tests in a wind tunnel at the Technical University in Geneva. The concepts for helmet and spoiler shape grew out of these tests. Furthermore, the body posture could be optimized and related to the results on the pressure distribution between ski and ground.

Figure 6: Aerodynamic tests in Geneva. Photo provided by Flavio Noca.

The power of networking

By using bundled know-how, it was possible to put together a technical package specifically tailored to the athlete Ricardo Adarraga. In January 2017, the trials began at Atomic's test center. Thanks to the support of Team Snowstorm, Ricardo received 5 pairs of skis for this season instead of the usual 2 pairs. The skis are equipped with a Hi-Tec base from our Snowstorm partner Perlatech. We have been researching this base for 8 years and improve it every year. In February 2019 Ricardo went to Vars, France, the Mecca of speed ski riders, where the fabulous world record of 254.958 km/h was set in 2016. At the this race and many times in later years Ricardo proved to be one of the 10 fastest men on snow.

Figure 7: Ricardo during tests in Tignes, 2017. Photo provided by Mr. Snow.

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