Virtual Ski Development

Simulation instead of Field Tests

What a pity, you might think from the perspective of a passionate skier. Thanks to a test bench and newly developed simulation methods from the University of Applied Sciences Eastern Switzerland (OST), a lot of the development of alpine skis will be done at the desk in future instead of with the help of complex practical tests. The finite element method determines data on the comfort, stability and maneuverability of new ski models. However, the system cannot do entirely without humans.

The right mix of flexibility, weight and rigidity is essential for a freeride ski to cope well with difficult terrain. The geometry determines the lift in deep snow. © zai

The development of alpine skis combines engineering skills with the requirements of highly loaded sports equipment. Today, the development process ranges from theoretical conception to material selection and practical testing.

Recently, two main aspects have been at the forefront: finite element simulation (FEM) to optimize geometry and material, and the use of a specially developed test stand to validate and objectify ski properties. These approaches have the potential to revolutionize ski development by eliminating the need for expensive and time-consuming field tests, while still taking into account subjective perceptions when skiing.

Engineering Meets Freerider

The finite element method (FEM) has established itself in engineering science as the standard for simulating mechanical and thermal processes. In ski development, it enables precise analysis of material stresses, deformations and flow properties without the need for physical prototypes. The FEM provides objective values that enable, for example, the dimensioning of cover layers or cores – however, it is difficult to couple these objective values with the subjective skiing impression.

In the project "Holiski", founded by Innosuisse, which pursues a holistic

Fig. 1. Innovative geometry of a freeride ski for zai, developed as part of the "Holiski" project. © OST

development approach for alpine skis, the IWK Institute for Materials Technology and Plastics Processing, together with the ski manufacturer zai, has developed approaches that increasingly rely on the virtual design of new ski models. FEM can be used to simulate factors such as uplift, cornering behavior and smooth running, which are also subjectively perceived by the skier. In this way, the interplay of the various layers of a ski – from the running surface to the damping layer – is analyzed and optimized. Geometry plays a particularly crucial role in freeride skis, which have to generate high lift in powder snow. Iterative simulation cycles provide geometries that theoretically offer maximum lift with minimum resistance, but which would hardly be accessible by purely intuitive means (**Fig. 1**).

Materials Made from Wood, Cork, Recycled Materials and Fibers

A central component of FEM is the definition of precise material models. Skis are made of complex material combinations: wood, glass and/or carbon fiber-reinforced plastic, or even sustainable materials are used. These materials must be described in the simulation in such a way that their properties – such as damping, stiffness and elasticity – are realistically modeled. If an accurate material model is missing, the results of the FEM can deviate significantly from reality. This ultimately has an impact on the skiing experience, which is why determining the material behavior – also in the combination in the ski – is of great importance.

Ultimately, the simulation replaces or reduces costly test cycles, as the ski properties can already be evaluated in the virtual model. It also allows the investigation of scenarios that are difficult to reproduce in reality, such as behavior under extreme loads or with different types of snow. Ultimately, the simulation replaces or reduces costly test cycles, as the ski properties can already be evaluated in the virtual model. It also allows the investigation of scenarios that are difficult to reproduce in reality, such as behavior under extreme loads or with different types of snow.

Finally, variables that are very difficult to measure, such as the flow of air towards the ski during the ride, also become accessible – these can be verified in a wind tunnel, for example, but have hardly been investigated to date. The results from these observations can also lead to very unusual designs, which in turn have to be analyzed with regard to riding behavior (**Fig. 2**).

There Is No Such Thing as "the" Perfect Ski – Every User Feels Differently

Although FEM offers enormous advantages, there are also challenges. The complexity of the interaction between snow, ski and skier is difficult to model. Snow conditions change dynamically and vary depending on temperature, density and moisture. This variability makes it difficult to derive generally valid statements from a simulation. In addition, the subjective perception of skiers plays an important role. Even a ski that is objectively assessed as optimal can provoke different reactions from different skiers – not every test subject assesses a ski in the same way. It will therefore still not be possible to develop skis (or other sports equipment) purely virtually in the future.

Ski Test Stand for Determining Material Data and for Validation

A central component of ski development is the test stand developed by the University of Applied Sciences of Eastern Switzerland (OST) and zai. This device was specially designed to test the mechanical properties of skis under standardized conditions. In general, ski testing is not very standardized – this is also a consequence of the rather iterative development process, whereby new models are built and individually »

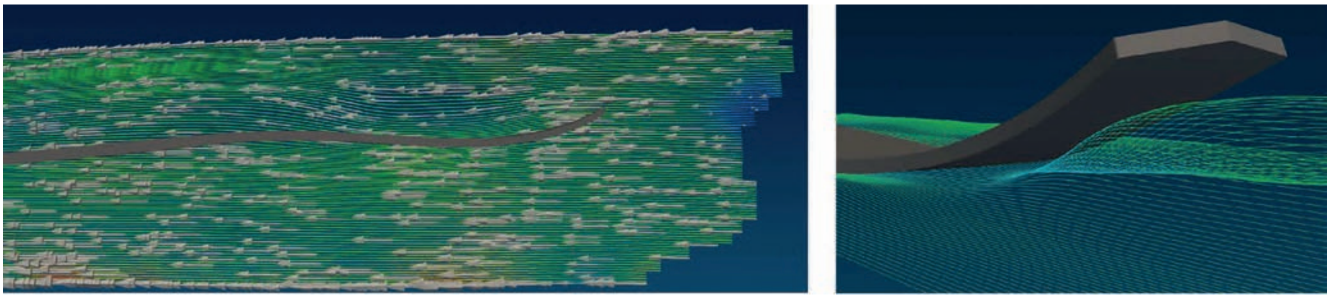

Fig. 2. Flow simulation with a flow velocity of 12 m/s. © OST

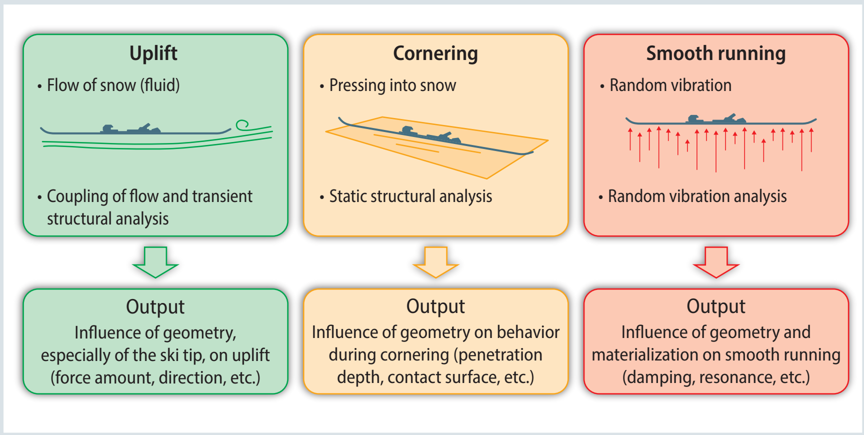

Fig. 3. Simulation and measurement-based effects and their influence on the driving experience.

Source: OST; graphic: © Hanser

Simulate, Build, Test Drive: Ski Course for Students

As part of the so-called interdisciplinary context modules, the course "Ski-Nation Switzerland" is held at the University of Applied Sciences of Eastern Switzerland (OST) every spring semester. The students examine skiing from different perspectives and, as a central element, build a pair of freeride skis that are tested a few weeks later in the Disentis/Sedrun ski area.
In addition to the mechanics and technology of ski design, other aspects are also covered: What are the ecological conditions and consequences of winter sports at that time and in the near future? What health effects does skiing have as a popular sport in society? Which industries in Switzerland and Europe benefit directly or indirectly from snow sports? The students present the results of their research in lectures and in a video documentary. As an interdisciplinary module, the course is open to students in all degree programs at OST.

Info

Text

Prof. Dr. Gion Andrea Barandun is Head of the Composite Technology / Lightweight Design Department at the IWK Institute for Materials Technology and Plastics Processing at the University of Applied Sciences of Eastern Switzerland OST in Rapperswil, Switzerland.
Benedikt Germanier is CEO of zai.
Dominik Stapf is Head of Testing Technology at the IWK and a lecturer at the OST.
www.ost.ch/en

assessed by test persons, but hardly any measurements are taken. The most important parameters that influence handling and can be reproduced on a test stand are:

- Vibration measurement: determining the damping and natural frequency. A direct influence of geometry and material combination on smooth running/vibration can be determined.
- Bending measurement: determining the stiffness and resulting deflection under load. These parameters, which depend on the materialization and geometry, are responsible for a range of driving characteristics such as the reaction speed of the system and the forgivingness of skiing mistakes.

Testing of Ski Sections

The test bench is used to determine material and geometric properties on the one hand, and to test ski models from the FEM with assembled prototypes or subcomponents on the other. For example, small ski sections are tested, which are much easier to produce than a complete ski. The data obtained allow a direct comparison with the results from the simulation. This allows potential discrepancies to be identified and the models to be further refined (**Fig. 3**).

In addition to the standard tests, the test stand also offers possibilities for examining innovative material combinations. For example, sustainable materials such as cork or recycled plastics are tested to determine their suitability as replacements for oil-based materials or reuse components of the ski. However, these measures must not result in any performance disadvantages.

Additional measurements of an objective nature can also be combined with individual tests. As visualized in Figure 3, the penetration depth into the snow also plays an important role – this can be simulated on the one hand, but also measured (for different angles) on the other (**Fig. 5**).

Recent enhancements to the test bench improve user-friendliness and measurement accuracy. For example, an automated mechanism for recording the bending line has been introduced, replacing previously manual and error-prone processes. The integration of modern sensor technology and data processing enables faster and more precise analysis – another prerequisite for an efficient development process (**Fig. 4**).

Limits of Virtual Development

A key aspect of ski development is the subjective perception of skiers. Aspects such as comfort, stability and maneuverability can only be described to a limited extent by technical parameters. To bridge this gap, objective measurement data is combined with subjective impressions.

For better understanding of the subjective perception, test rides are carried out in which riders document their impressions in detail. These are compared with the objective data from the simulation and the results from the test stand. It often becomes clear that differences in riding style or the expectations of the riders can lead to differing

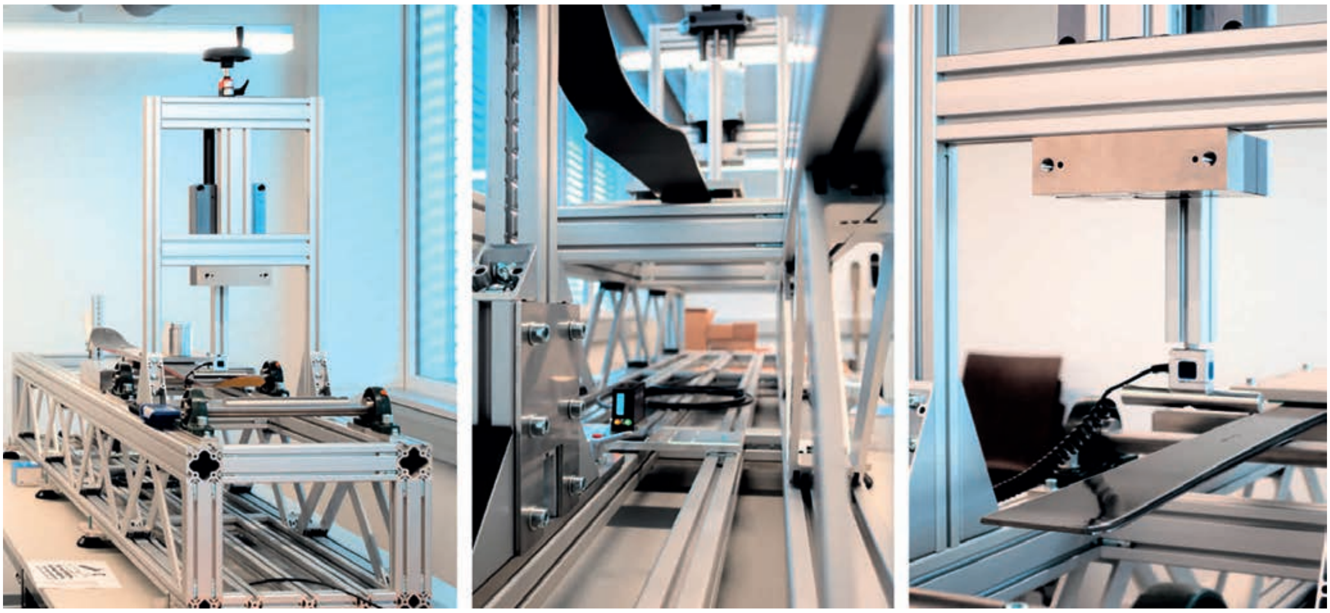

Fig. 4. Ski test stand developed at the IWK for the objective measurement of typical parameters. © OST

assessments – an effect that cannot be avoided.

The concept of the "digital twin" offers at least one solution here: by linking simulation results, test bench measurements and subjective test results, complex simulation models are created that can map both the physical properties and the perceived performance of a ski. These models can be used to predict the effect of certain changes on the skiing experience as early as the development phase, thus saving development cycles.

The Future: a Combination of FEM, Practice and New Materials

The combination of FEM and test bench has taken ski development to a new level. While the simulation provides early insights and reduces test cycles, the test bench ensures that the results stand up to real-life use. The biggest challenge, however, remains the consideration of individual rider experience.

Another trend in ski development is the integration of sustainable materials and manufacturing methods. Companies such as zai and Stöckli are working on using new materials or material combinations in their products. The challenge lies in achieving the same performance as with traditional materials. In this context, not only the materials but also the design can be questioned: completely new concepts in terms of design also allow for completely different materials. However, there is only very limited experience in this area and a rather high risk of negatively influencing driving behavior. A slow approach to new designs, e.g. through simulation and parallel testing of typical functional models, represents the first step towards a new type of construction.

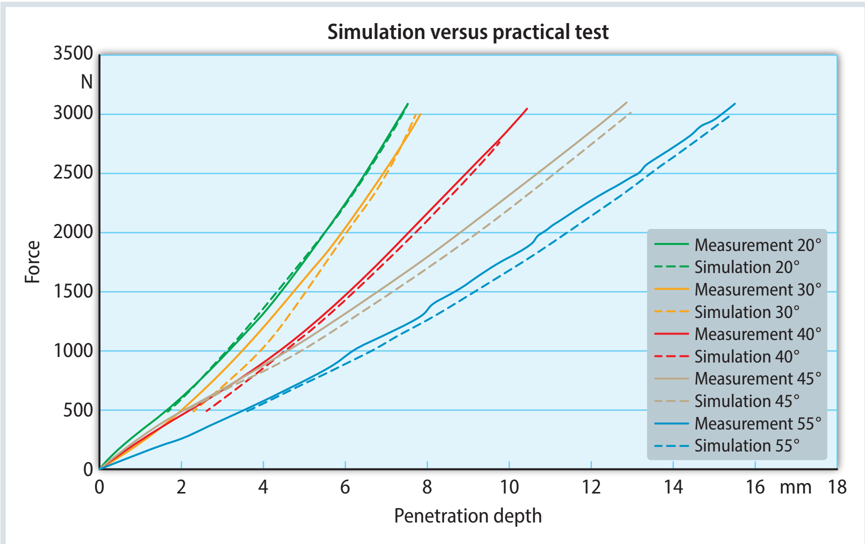

Fig. 5. Comparison of simulation and experiment with regard to penetration depth in snow, as a function of the angle of attack. Source: OST; graphic: © Hanser

Future developments will focus on integrating digital technologies even more closely into the development process. For example, machine learning and AI can be used to recognize patterns from the data of past projects and make predictions for new designs – including the individual driving impressions of different test subjects. This can further shorten development times and reduce costs.

Conclusion

The combination of simulation, test bench and subjective perception enables a holistic view of ski development. With these approaches, there is a good chance that the next generation of alpine skis will be even more efficient, sustainable and user-oriented. At the same time, technical innovations and the individual experience of skiers remain inextricably linked. The future belongs to hybrid models that combine science and skiing culture. ■