Integrative Ski Building Workshop 2023

ETH zürich

This project is supported by Professor Joël Mesot via the ETH Zürich Foundation.

ENGINEERING DESIGN AND COMPUTING

The Integrative Ski Design and Fabrication Workshop started at EDAC in 2016. Since then, our students have made 92 unique pairs of skis, snowboards and splitboards. With a large amount of imagination, ingenuity, and perseverance, a broad variety of skis and boards were designed and fabricated. Over the years almost every type of ski and board has been built at one point, from stiff carving skis to pure powder skis as well as splitboards and freestyle snowboards. Each ski and board brings its own challenges and hiccups along the way. Therefore, we are immensely pleased that all our students managed to finish their skis and boards. This year, a total of 10 pairs of skis, one snowboard, and one splitboard were built. Each one is unique and the product of many hours of planning and manual work.

First, we would like to wholeheartedly thank the president of ETH Zürich, Professor Joël Mesot for his generous contribution to support this course and his continued interest in its development. A special thank you is also owed to Oxess GmbH, for their valuable support in both the sanding of the cores, as well as the interesting discussions on how to build skis and snowboards. We would also like to thank both ETH and the Engineeering Design and Computing Laboratory for creating the platform that makes this course possible.

After many hours of bending, sawing, cutting, and sanding in our workshop, our students are proud to present this year's results. First, they describe the individual steps of the building process, and then go into detail concerning their personal goals and motivation. Finally, they show their individual designs and final products.

Enjoy the ride!

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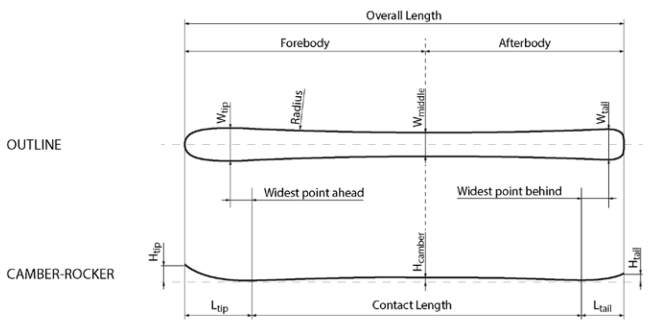
CONCEPTUAL & VISUAL DESIGN

The first question to ask ourselves was what type of ski or snowboard we wanted to build. Everyone has a different understanding of what the perfect ski or snowboard looks like. Some might want to race downhill like Marco Odermatt while others prefer to float through deep powder snow. Based on the different needs the ski/snowboard must meet different requirements – quantitatively (e.g., stiffness, weight) as well as qualitatively (e.g., turning ability, edge grip, carving ability, lift in powder). Therefore, the various types are usually divided into four categories: Piste, Freeride, Touring and All-Mountain. Some of the main features are summarized in the table below, yet there is still a wide scope in the categories themselves. In fact, the categories are not distinct, they overlap in some points and depending on the source considered, different subdivisions are made.

Ski / Snowboard Types				
Property	Piste (Slalom)	Freeride	Touring	All-Mountain
General Traits	High Damping Narrow Width Low Flotation Short Rocker	Medium Damping Wide Width High Flotation Long Rocker	Little Damping Medium Width High Flotation Long Rocker	Medium Damping Medium Width Medium Flotation Medium Rocker
Radius	Ski: 12-15m Snowboard: 9-14m	Ski: 16-22m Snowboard: 5-7m	Ski: 16-22m Snowboard: 6-8m	Ski: 12-18m Snowboard: 7-9m
Bending Stiffness	High	Low to Medium	Low to Medium	Medium
Weight	Heavy	Medium	Very Light	Medium
Focus	Edge Grip Stability	Flotation	Weight	Versatility

After everybody had a rough idea of the snow device they wanted to build, we started the ski building process by setting the different parameters displayed on the picture below (likewise for the snowboard).

We were provided with a MATLAB App to dimension our ski with the help of an integrated data set including different skis and snowboards already fabricated in the workshop as well as the ones we brought as an initial guide. Even though we had the data, it was still quite hard to choose the correct values. For instance, we knew how stiff which skis and snowboards were, but was it really what we wanted or preferred when we are out there hitting the slopes? However, it needs to be said that there is never a one-size-fits-all solution.



"Successful ski design is a compromise of the design variables (geometry, construction modes, elastic properties, dynamic behaviour, economics) to match the skiers' weight, technique and use."

B. Gleane, "Mechanics of Skiing", Handbook of Snow

Visual Design

Choosing how you want your ski/snowboard to look was a very individual process as everyone has different tastes and ideas. Some drew their own designs from scratch, while others found help online with images and patterns they liked. AI was also a helpful tool for finding inspiration or creating whole designs using AI art and image generators.

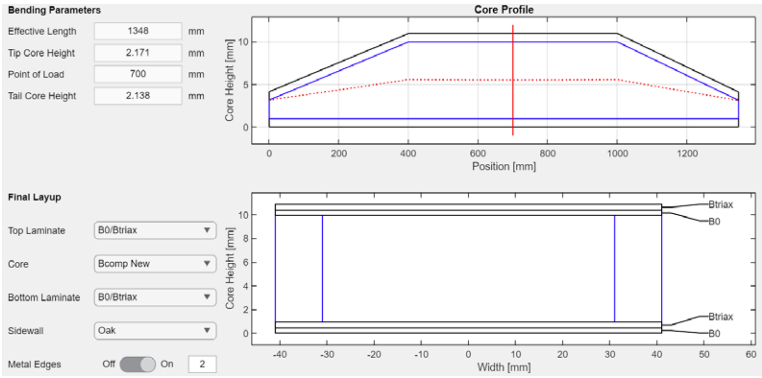
For our design we were able to choose from different types of wood, which are displayed in the picture below.

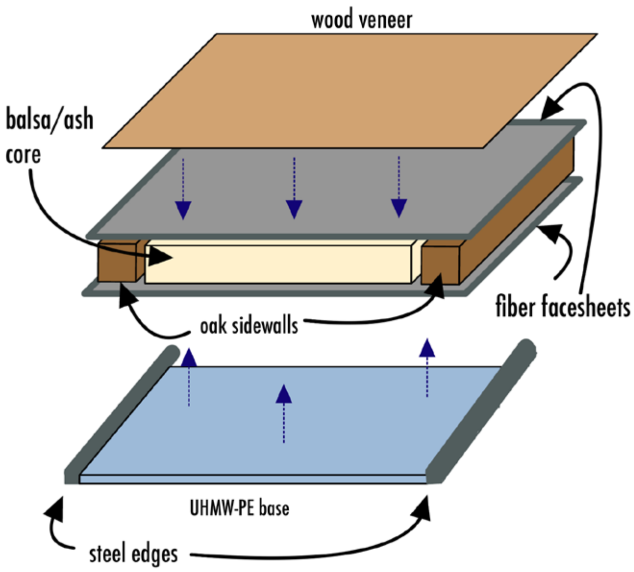
We were able to cut our own designs using a laser cutter for the top sheet. It was also possible to engrave certain things into the wood, such as contours or text, which would be rather difficult to inlay with the wood. Some parts of the top sheet could have been left without any wood which would leave the black fibers visible on the top. Another thing we had to consider in our design was that the cutter was only 1m long, so there would have to be a cut somewhere in the design of the ski/board. Although we were advised to plan enough time for this step, as there are a few things that could go wrong and the cutter was often occupied with no time slots available, most of us still weren't finished until the last week before laminating.

For the base we were able to choose between different bright colors into which we could inlay other colors or choose a transparent base under which we could put different things such as the veneers or even leaves. There was also the option of not putting anything underneath to leave the fibers visible. All in all, everybody could express their creativity which leaves us with 12 individual designs which are impressive to say the least!

ANALYSIS, MATERIALS & LCA

One of the bigger challenges while designing our skis was predicting the mechanical properties they were going to have after manufacturing. The main point of focus was fine-tuning the bending stiffness of the construction to optimize it for the chosen application.





Since we are using a sandwich construction method for the ski, we can influence its properties not only through the choice of dimensions, but also through selection and arrangement of materials in the cross-section. In order to deal with the variable material properties of the ski, we relied on a MATLAB calculation tool provided by the course organizers. For our initial choice of dimensions, this allowed us to easily try out different configurations of fiber layers in the facesheets and see how they affect the spring constant.

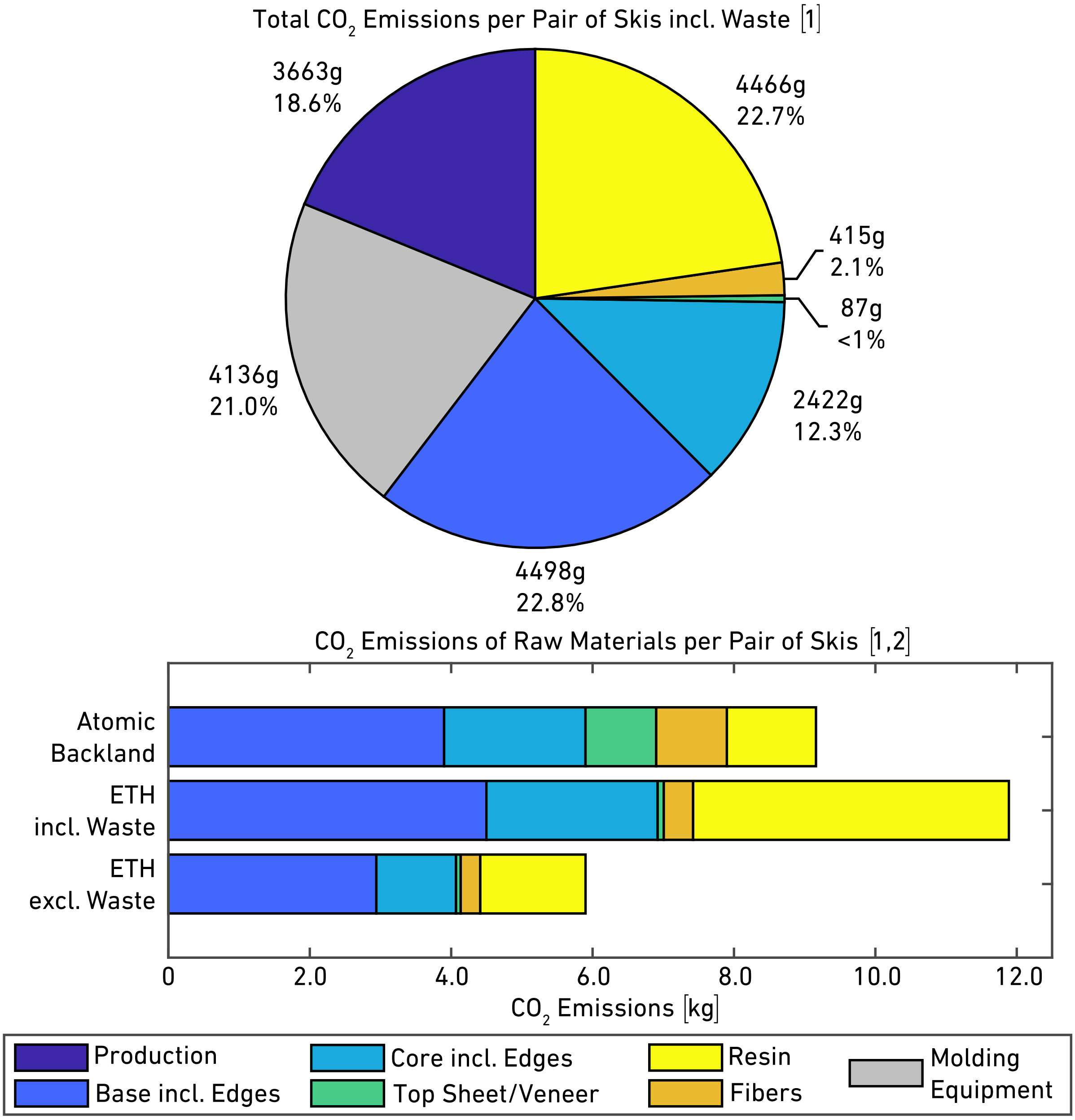
Depending on the stiffness values we wanted to achieve, different fiber materials could be chosen. Several types of fibers can be used during ski manufacturing such as basalt fibers, carbon fibers, glass- or bamboo fibers. Those fibers can be applied in different directions, resulting in varying directional properties. Another way to influence the stiffness of the ski was through the core's dimension and material. In the workshop we could choose to make it from either balsa wood or hardwood. In general, balsa cores are lighter, but hardwood offers more stiffness and damping. Stiffer construction could also be achieved by simply increasing the thickness of the core, thus increasing the distance of the overall neutral axis to the fibers.

In order to further validate the fiber layups, we carried out a series of hand calculations to estimate the torsional stiffness and vibration eigenfrequency of the ski. Together with the MATLAB data, this allowed us to iteratively work through different laminate configurations in order to find the one most suited to our preferences.

As sustainability was an important part of the choice in material a Life Cycle Assessment was conducted to determine the environmental impact of building our skis. In this process the ecological footprint throughout the entire life cycle of the skis is evaluated and quantified. This impact can then be compared with one achieved using different materials, so that the entire process can be improved in terms of sustainability.

For example, in order to reduce the enviromental impact of fibers, we opted to use mostly basalt and flax instead of carbon or glass. Overall, the use of wood and other natural materials is beneficial for sustainability, which can be seen when we compare our skis to mass-produced ones. This translates to much lower CO_2 footprints of veneer and fibers in comparison to commercially available equipment.

Some components such as the base sheet made from UHMW-PE, edges made from steel, resin and all the other supplies used for lamination had a significant impact in the LCA but couldn't be replaced without impacting important ski properties. It's also worth noting that a significant part of the carbon footprint could also be attributed to waste generated during manufacturing, which is to some degree unavoidable with small scale production.



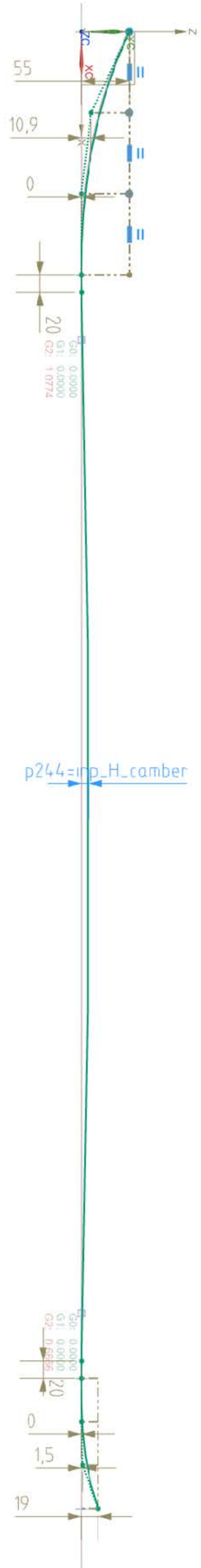
1. N. Czopek-Rowinska, "Life Cycle Assessment and Sutainability of Skis Built at ETH Zürich", ETH Zürich, 2023.
2. Atomic, "Atomic Impact Report," Atomic Ski, Tech. Rep., 2023.

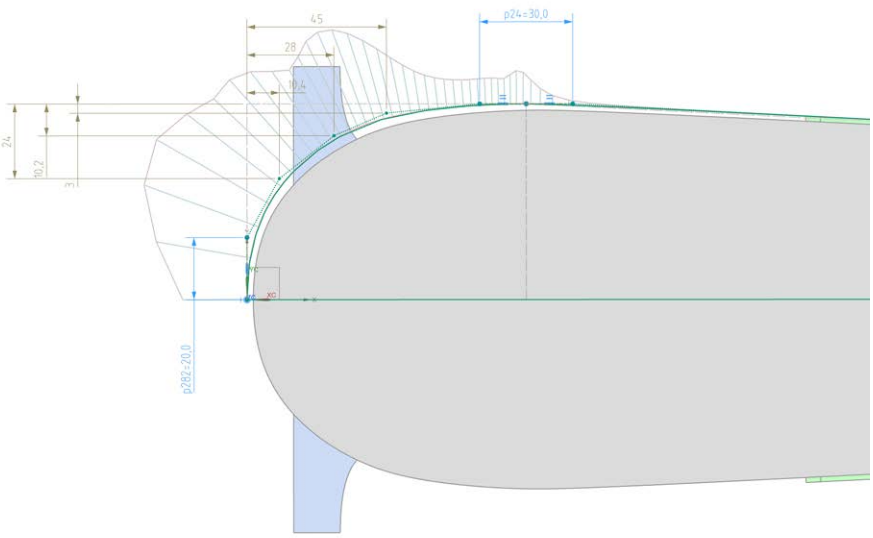
COMPUTER AIDED DESIGN

Now we come to how we digitally design our skis and snowboards. This step is important for creating a detailed plan for building the skis in the workshop. In addition, some parts of the design were made using CNC machines based on the 3D models we had made in Siemens NX1988. Using the aforementioned NX1988 CAD software and two MATLAB apps, we determined the dimensions of our skis and boards. We started by entering our preferred dimensions into the MATLAB apps and checking the calculated values such as stiffness and turning radius of the skis. We kept refining our design until we were happy with the results.

Once we were satisfied, we imported these values into NX. The provided models were then customized, and our skis were displayed as 3D models. But our skis were not finished yet, as we still had to fine-tune the exact shape of the tip and tail to our liking. There were a few things we had to keep in mind; it was important to make sure that the curvature between the tip and the midsection, respectively between the midsection and the tail, was not negative. We ensured that the widest part of the ski stayed where we wanted it to be to prevent changes to the turning radius. There were also some restrictions regarding the swallow tail, but more on that later.

Finally, in another sketch in NX, we adjusted the height of the tip and tail. The program then automatically calculated the exact curvature, completing our CAD model, which was now ready for export.

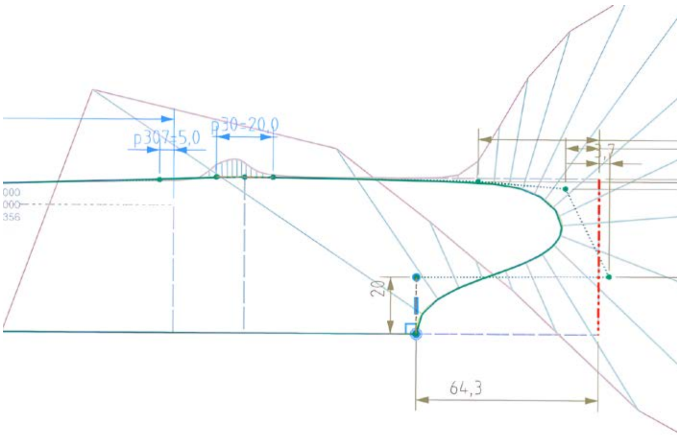




The core was then milled into the desired shape using the CAD model. This year, the base-sheet was cut on the milling machine using a special cutting tool, a drag knife, based on the model. The outline of the ski, was also exported from the CAD model and used for the visual design of the top sheet.

There were some problems with the design process when importing the parameter file (.exp). If the NX template was not imported correctly at the beginning (load from folder, fully load), there were problems with the subsequent editing of the model. These problems were quickly solved by reimporting the CAD template correctly.

During fine-tuning, the spline points in the sketch could be adjusted to suit the outer contour. Two participants wanted to make a swallowtail on their skis. As the sketch was intended more for fine-tuning the front shovel, there were not enough spline points on the rear edge to design a swallow tail. Joël then edited the CAD model to include more points that could be moved. This meant that the desired shape could also be created on the trailing edge. The only thing to do was to make sure that the contour did not go beyond the rear limit of the ski's length. Otherwise, the ski would have been longer than planned.



Designing in NX was fun because you get a feel for how the ski will look like in the end. It was also an opportunity to spend some time in NX for the first time in a long time and deepen our knowledge. The MATLAB apps made it very easy to import the parameters and quickly compare multiple versions. Every step was well described in the instructions, so there was no room for error.

After designing the ski and snowboard in NX, we started with the production of the individual ski and snowboard components. The data from the CAD model also served as a reference for the LCA, the construction of the mold for lamination, and the mechanical testing. An accurate and complete CAD model was of great importance due to the great number of future steps that depend on it.

COMPONENT MANUFACTURING

Structure

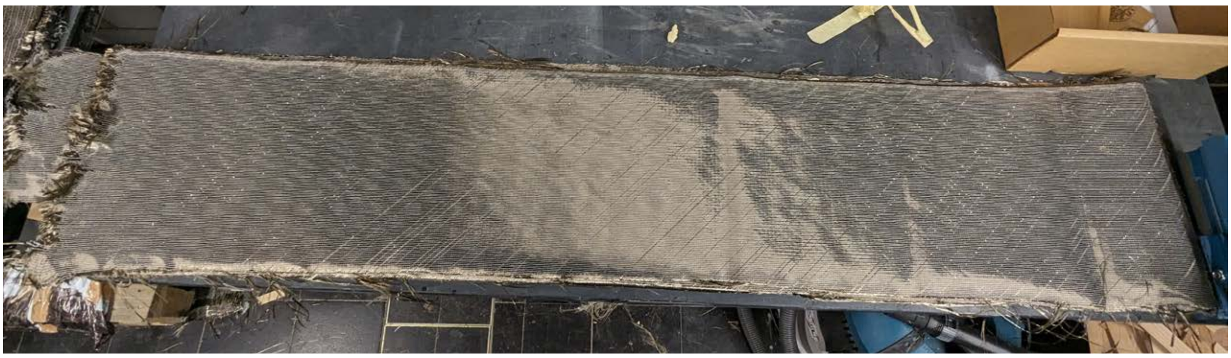
1. Veneer Top Sheet
2. Fiber Layer
3. Wood Core and Sidewalls
4. Fiber Layer
5. Base Sheet and Steel Edges

Veneer Top Sheet

For the design of our top sheet we had a variety of different materials to choose from. All of us chose wood as our top layer, as it gave the skis a unique custom built look. Furthermore, we could choose from different wood types and combine them. To bring our design to life, we cut and engraved the veneer sheets with a laser cutter. Choosing the speed and intensity of the laser correctly was quite challenging. Therefore, we used small test pieces. The final veneer was cut about 2cm larger than the base. The veneers and the inlays were held together by small strips of painter's tape.

Fiber Layer

Fibers made of basalt, flax or even carbon could be combined to achieve the calculated stiffness. The desired fibers were simply cut to the shape of the skis with a few centimeters of overlap to compensate for small shifts that might occur during lamination. The fibers were cut to shape with regular scissors, but we had to wear long sleeves and gloves as the fibers could easily irritate the skin.



Wooden Core and Sidewalls

The core was first cut to the outline shape of the skis/boards with a CNC machine. Then we glued the sidewalls, made from oak or ABS, to the sides of the core. Those who chose a soft balsa core for their skis had to cut out a piece of their core to put in a hard-wood binding plate, where the binding would be fixed with screws. This was necessary because the screws would not hold in the the soft balsa wood. Additionally, holes had to be drilled where threaded inserts were to be added later for the snow- and splitboards. With the binding plate and sidewalls added, it was time to sand the cores to the correct thickness. The cores are thicker in the middle and taper out towards the end of the ski. After sanding, the tip and tail spacers were glued to the ends of the core.

Base Sheet and Steel Edges

The first component we manufactured was the base sheet with its steel edges. After choosing the colour of our base sheet, it was cut to size according to our CAD model. Then we had to bend the steel edges to fit the shape of our base outline. In a later step, the edges were superglued to the base. At this stage, one had the option to cut the base and add inlays or to prepare an optional design veneer which could be put above a transparent base sheet. At each step we checked whether the base remained straight. The polymer has a tendency to release residual stresses after cutting and thus warp.

LAMINATION AND FINISHING

Preparing the Mold

The first step of laminating was to prepare the mold out of aluminium profiles and a steel sheet. By adjusting the height of the profiles with layers of MDF, the desired camber-rocker profile was achieved. The metal surface was cleaned prior to beginning the lamination procedure. The position and center of each ski was marked onto the sheet for alignment purposes. A tacky tape perimeter is then placed to later seal the vacuum bag. After preparing the mold, the layers required for lamination needed to be prepared. This included cutting the fibers to shape and organizing them neatly in order, as well as cutting and preparing the materials needed for the vacuum bag. Finally, materials and tools for laminating are prepared – such as gloves, paintbrushes, a full body suit and also mixing the correct amount of epoxy.

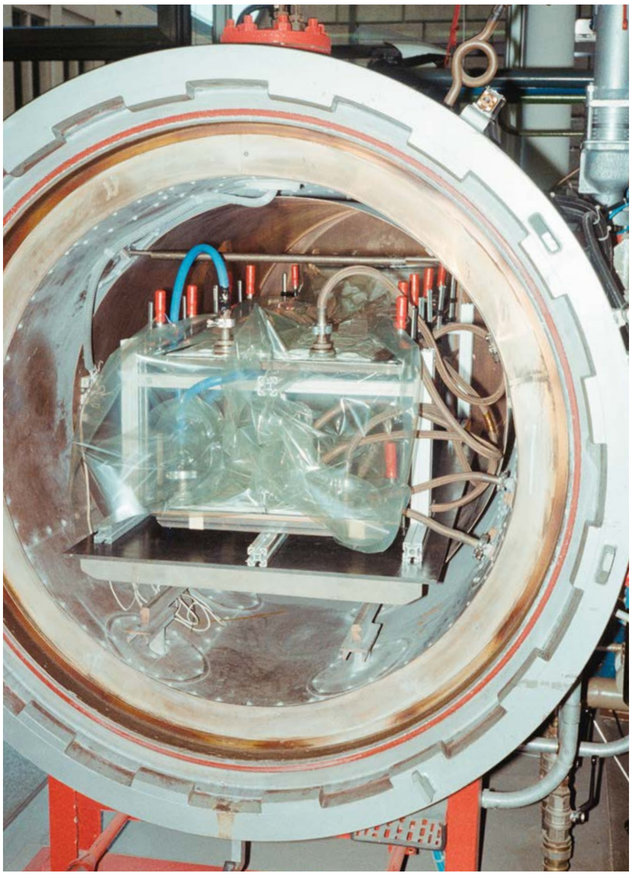
Laminating

Laminating began by taping the release film to the sheet metal. On top of that, the bases were stuck down with double-sided tape. It was important to align the skis with the marks made onto the sheet prior to help with the alignment of all subsequent layers. A layer of epoxy is then spread to cover the base. The base veneer is then covered with epoxy on both sides and placed carefully into the base, ensuring it does not overlap the edges. Rubber tape is then placed all around the edges – this prevents static charge from building up while skiing by isolating the edges, as well as providing vibration damping. The first layer of fibers is carefully placed, and then saturated with epoxy – repeating for any further fiber layers. Here it is important to add just the right amount of epoxy, as adding too much will merely add to the overall weight of the ski.

Placing the core of the ski came next. Epoxy was spread over the sidewalls and onto the tips and binding plate, but not directly onto the core – the porous wood rapidly soaks up the epoxy and increases the weight of the ski. On top of the core the remaining fiber layers were added like before. Finally, the top sheet veneer is placed onto the final layer of fiber. Following the lamination, the vacuum bag was assembled. Perforated foil is placed onto the top sheet, followed by a bleeder fleece to absorb any excess epoxy, and allow for airflow when the vacuum is applied. Finally, the vacuum foil is carefully placed on top and stuck down to the tacky tape on the edge of the mold. Holes are cut into the bag for the vacuum ports. The skis were then sent up to the autoclave room, where a vacuum was pulled, and leaks were sealed. The skis were then put into the autoclave to cure for an hour at 70°C with 2 bar of external pressure.

Post Processing

Unpacking the skis after curing was as if Christmas came early – it was amazing to see all the hard work culminating at this point. The post-processing could now begin. The skis were cut to a rough shape with a jigsaw and then sanded down to their final shape. The tape from the top sheet needed to be removed (which was incredibly painstaking) and the surface was sanded down. Finally – the skis were covered with linseed oil to protect against water. This is where the colors of the wood really popped out. Once dry, the skis were officially finished.



TESTING (LAB AND FIELD)

Every good engineering endeavor ends with a bit of testing! Before hitting the slopes, there are a few things we can look at in the Lab.

We started with a simple visual inspection and made sure the skis were safe to ride: Were the edges seated correctly? Were the tail protectors attached properly? Did the camber come out right? Armed with a simple tape measure, we measured various geometrical features, comparing each against the designed values or the meticulously designed CAD model.

Beyond safety, this helps us evaluate our craftsmanship and gives us information about what we can improve on in the following years. The weight of skis and snowboards is a straightforward but crucial metric. It is of paramount importance, particularly for touring skis and splitboards destined for uphill journeys. Beyond what can be seen with the naked eye, the stiffness of a pair of skis can have a huge impact on how they feel on the slope. Measuring this is a bit more involved: We put all the skis and snowboards through a 3-point bending test on a machine that can measure both force and displacement. The measured data is given in the table below. The test reveals an average deviation of 18.2% between the skis and their intended value. This year, most skis seem to have come out slightly stiffer than expected.

Load-Point Spring Stiffness [N/cm]				
Name	Calculated	Measured	Delta (abs)	Delta (%)
Alexandru	39.5	45.0	5.5	13.9
Fabian*	108.9	130.0	21.1	19.4
Felix	33.8	43.5	9.7	28.7
Hannes	41.1	51.1	10.0	24.3
Jan	34.3	43.0	8.7	25.4
Jonas	40.8	46.0	5.2	12.7
Katharina	39.5	43.0	3.5	8.9
Linus*	91.8	107.0	15.2	16.6
Livia	37.8	39.0	1.2	3.2
Luca	38.7	52.0	13.3	34.4
Pawel	37.9	41.0	3.1	8.2
Robert	37.0	47.0	10.0	27.0
Eva	39.0	46.0	7.0	17.9
Jakob	41.0	47.0	6.0	14.6

*Snowboard or Splitboard

There are several factors that affect how our skis and snowboards perform in field tests. The most crucial is the tester themselves, as their individual skills and style greatly influence how they perceive the equipment while riding. It is not unusual that two people perceive the same ski in a completely different way. Additionally, the tester may adapt to the gear, as this is not possible vice versa. The next important factor is the environment during the test. For instance, a flexible board might be enjoyable on soft, powdery snow but challenging to control on icy terrain. To get the most representative results, it's essential to test the equipment in the conditions it's designed for. The third factor that can significantly impact a ski or snowboard's behavior is the grinding of its base and edges. As we can regrind and repolish the finish, we can enhance (or diminish) the behavior of the equipment to our liking.

This year, we tested our gear individually. Each student could choose their ideal mountain and conditions to unlock the full potential of their sports equipment. To quantify our experiences, we tested two types of turning: short, skidded turns and carved turns, rating factors like ease in initiating a turn on a scale from 1 to 10. This allowed us to compare results and assess the performance. Overall, our expectations were high, and in most cases, the equipment met or even exceeded them with impressive results. We all agree that riding self-made skis/snowboards is special and at least doubles the fun. To wrap up our testing, we met at the beginning of February for a day on the slopes of Davos. We compared the rest of the attributes which define our skis and snowboards, and of course enjoyed our unique creations.

ROBERT ANDERSSON

From the start of the course, I knew the exact type of ski I wanted to design – a lightweight touring ski that provided me with the best carving experience, similar to my race skis, while also allowing me to escape the resort and be out in the wilderness exploring. During the course we learned the different aspects of ski design and how they impact performance. I chose to design a ski with a lightweight and thick core with only one layer of fiber on each side of the core to maximize stiffness without compromising weight. I knew stiffness would be important for the downhill stability. I then chose the sidecut geometry to reduce the radius of the ski as much as possible – a short radius allows for some quick carving. As a consequence, the tips and tails of the ski are quite wide – which will support me in powder. This design process was in pursuit of a seemingly elusive «all-rounder» ski.

When manufacturing the ski it is important to consider the impact it has on the environment. Performing a LCA of the ski manufacturing process reveals that materials (steel edges, wood core) account for 55% of the total ski. Typically, the resin also accounts for a significant portion of the emissions, although the resin that was used for these skis was a bio resin that was sourced renewably and includes recycled industrial byproducts, reducing the emissions by up to 33% when compared to crude oil-based resins.

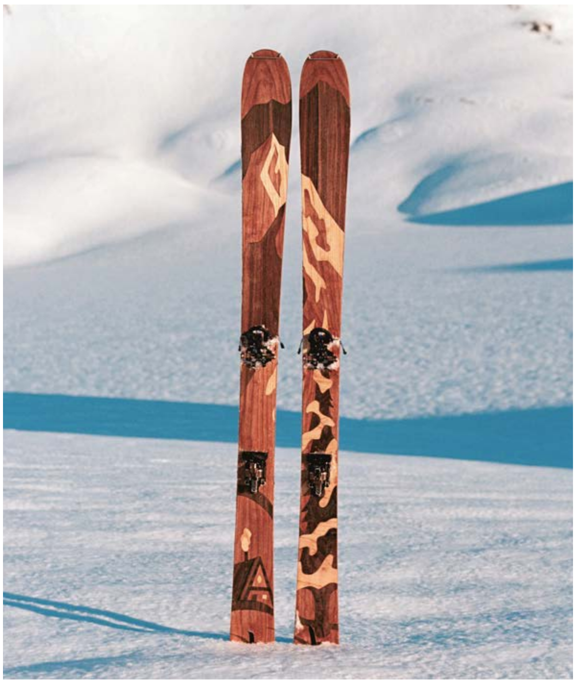
One of the more challenging parts of the design and manufacturing process was probably the post-processing of the ski. This wasn't necessarily difficult, it was just incredibly time-consuming to peel off all of the tape I had put on the ski before laminating in order to keep the top sheet in place. I think the biggest difficulty in my manufacturing process was cutting out every layer to fit perfectly to the shape of the tail protector in the swallow tail of the ski. It was incredibly difficult to follow the contour of the shape I had designed.

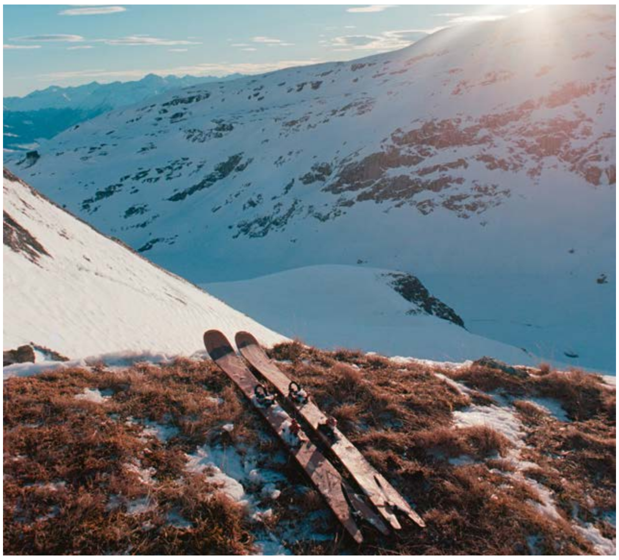
It was like Christmas morning when I finally applied the oil to the top sheet and was able to see the true colours of the wood come out. I adored how the graphics turned out. After measuring the bending stiffness of the ski, I was worried it would be too soft – fortunately it came out to be slightly stiffer than I had designed. As for the skiing performance, due to the large sidecut and short radius, carving with the skis was a dream.

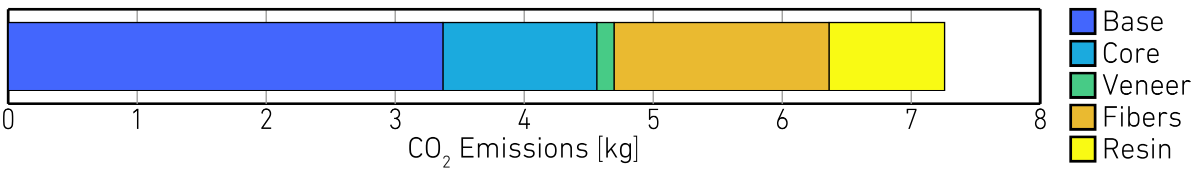
The lightweight design I chose also made the skis a delight to tour with, especially compared to my old touring setup. Although the skis could have been a bit stiffer, I wouldn't have traded this for the increase in weight as the primary purpose for these skis was to go uphill, not charge downhill with high stability.

Overall – I am very satisfied with how the skis turned out. They were exactly as I had designed them – somewhat stiff, lightweight and easy to carve. Although, if I were to make them again I would maybe have increased the stiffness of the ski a little bit – but it is difficult to say if it would be worth the weight gains. As for the design, I am very satisfied. The wood grain was meticulously oriented to the design – which was definitely worth it – and the base sheet design came out as well as I could have hoped.

Taking this course gave incredible insight into the design, engineering and manufacturing of skis. It was a fantastic opportunity to apply all of the theory we have been taught in our degree into practice. Learning the practical skills of working with wood, composites and autoclave manufacturing was a once-in-a-degree opportunity that isn't really offered anywhere else within mechanical engineering at ETH. Of course, being able to ski on a piece of work you designed and tailored from the ground up is also such a wonderful opportunity.







Ski/Snowboard Type	Length [mm]	Weight [kg]	Widths [mm]	Fiber Layup
Touring Ski	1810	1.52	114 – 68 – 100	Btriax(t) - Btriax/CS(b)

KATHARINA CORNÉE-LEPLAT

My goal was to design an all-mountain ski with a high stiffness to be more of an on-piste ski. This course was also the opportunity to try out something different by changing from the very theoretical courses which are normally taught at ETH. Coming into this course I also wanted to learn more about how different types of equipment like snowboard, touring, off- and on-piste skis are manufactured. When tuning different parameters for the dimensions I was inspired by skis that have been made in the past years which are like the one I wanted to achieve. As I wished to have a ski with slightly higher radius to do wider curves, I chose a turning radius of 16m instead of 14m which I found was chosen for most skis. To achieve a higher stiffness which is advantageous for on-piste skiing, I chose a hardwood core instead of the lighter balsa.

To make my skis more sustainable I chose to use basalt fibers which improves sustainability compared to using carbon fibers. The top sheet and sidewalls of the skis are made of wood which is also more sustainable than industrial materials. To compare the environmental impact of our materials and manufacturing processes a life cycle assessment was conducted which shows the total CO2 emission per pair of skis.

The base sheet, cut according to the CAD model, was given to us, we then bent the edges around it. This was in my opinion the most time-consuming and difficult part of the manufacturing process. Bending the edges requires quite some strength but if too much force was applied the edge could break. Making the design of the ski was also very time-consuming depending on the complexity. The designed veneer then had to be well aligned along the length of the ski during laminating to achieve the desired result. The next step was using the autoclave from which we could take out our almost finished product which made it even more obvious what the design would finally look like.

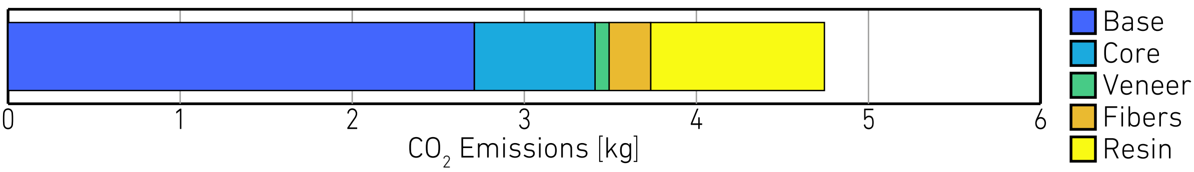
Since I have not yet had a chance to put my skis to the test on a slope, I cannot describe how they feel. However, I am very happy about the result and hope they will remain undamaged for a long time. At first, I was unsure whether the compass would end up centered between both skis as I imagined it. With the help of the organizers, I could however ensure the alignment during the lamination process which gave a pleasant result.

Even though the edges broke during bending it is barely visible. The bending stiffness of 39.6 N/cm which was predicted with the MATLAB tool is also accurate as the experimentally obtained stiffness is 43 N/cm.

Overall, I am impressed by the result. Before this course I could have never imagined that one day I would build my own fully functioning skis with a self-developed design. The skis are slightly heavier than average since I chose hardwood instead of balsa as a core material to achieve a higher stiffness. The increased stiffness is advantageous for an on-piste ski to increase the grip and to make precise carved turns. The skis turned out to be all-mountain with higher stiffness to be more suitable for prepared tracks which is what I wanted to achieve. The turning radius is 16m which is about average as I rather ski making big turns. A higher radius would however be more challenging to make precise turns.

Besides having new skis, this course gave me more hands-on experience and taught me new skills. I first of all understand better how skis are structured, which dimensions are important, what has to be taken into account to achieve a desired stiffness and which materials can be used.

Furthermore, I learned a lot by gaining hands-on experience in the workshop with laser-cutting, sanding, laminating, and using the autoclave of which the functioning was well explained by the organizers. Next time I would plan more time to bend the edges and to laser cut/engrave all the parts for the design. This process would however probably be shortened as I learned how this works and how the parameters should be adjusted.



Ski/Snowboard Type	Length [mm]	Weight [kg]	Widths [mm]	Fiber Layup
All-Mountain Ski	1670	1.62	120 - 75 - 105	Btriax/B0(t) - B0/Btriax(b)

LIVIA GISLER

I have been skiing regularly since I was a small child. After a few years of skiing exclusively on the piste, I discovered the joys of ski touring at the age of 13. Since then, I've spent almost more time hunting for untouched powder slopes than on the sometimes unfortunately overcrowded pistes. As a freshman, I heard about the ski workshop for the first time from my mentor. Although, as a winter child, I had always dreamed of being able to take part in the course, the acceptance came as something of a surprise, especially since only 12 people are accepted. I had no great expectations of the course; I just wanted to be able to get hands-on for once (in my otherwise very theoretical studies) and produce a touring ski that I could actually use.

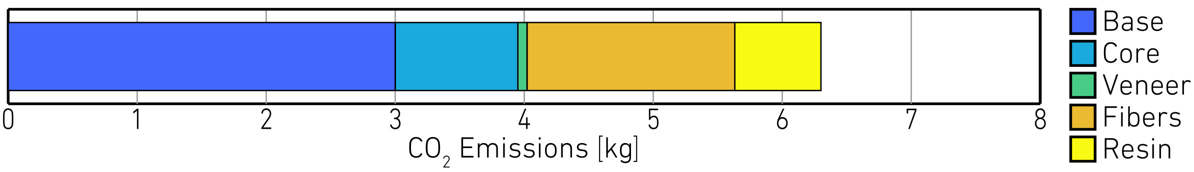
However, this requires not only skis, but also snow, and this has become a sticking point in recent years. There is hardly a sport that is more affected by climate change than snow sports. It should therefore be in the interests of every winter enthusiast to actively protect the most beautiful season of the year. The primary aim is to reduce CO2 emissions during production and through the choice of materials. The use of a carbon fiber layer for the lightness of my touring skis was certainly not a sustainable decision, but I believe I will be able to make up for it over time, as the transport routes from my home to my secret favorite tours are not very long.

The atmosphere in the workshop was very pleasant and collegial right from the start. My initial euphoria could not even be stopped by a few dampers during the design process. The design and dimensioning of my touring ski was facilitated by various tools, as explained in more detail in the building process section above. The top sheet caused me a little more concern. Once I had finally settled on a motif, I had to draw everything in Inkscape so that I could finally laser cut it. Due to the lack of Inkscape expertise, it took me a few (many) hours to implement my, in principle, simple design. I also wasted a lot of time laser-cutting, as the engravings took much longer than expected.

After several hours of work in the workshop, it was finally here: the first day of skiing with the custom-made skis. I was a bit nervous as I couldn't predict how my ski would react. After two or three runs you get used to the new material and I have to say that the ski is convincing. The dimensioned radius of 17.7 meters corresponds exactly to my expectations. You can feel some vibrations when you're going fast, but that doesn't bother me too much, as I'll probably be skiing more comfortably in powder snow. The stiffness of 39 N/cm has also proven to be a good decision, which is in line with my preferences and ability.

Looking back, I managed to achieve my relatively modest goals. I'm sure that the skis will become a faithful adventure companion. At times, the work was exhausting and a little nerve-wracking, but it was exactly the practical balance I had hoped for beforehand. Basically, I am satisfied with the decisions I made, but there is still room for improvement: I would no longer make a swallow tail, as it led to additional work during the construction process, but above all because attaching the climbing skins proved to be tedious. Also, I would start with the visual design much earlier (maybe even before the start of the course), because "suddenly" it was the end of November and the day of laminating (by the way my highlight) was just around the corner.

The manual work under the reliable guidance and help of Joël, Jakob and Eva was a lot of fun. It was very exciting to be able to go through the whole production process for once and to see that a multitude of steps lead to a distinctive, handmade ski. I only had a vague idea of how to go about building skis beforehand, but we were guided through the process step by step and were able to learn a lot of practical things. I've rarely had so much fun on a university course and what could be better than leaving with new skis that you've made yourself?!



Ski/Snowboard Type	Length [mm]	Weight [kg]	Widths [mm]	Fiber Layup
Touring Ski	1710	1.35	128 - 90 - 112	Btriax/B0(t) - Btriax/CS(b)

PAWEL GOLLA

"I'm building my own skis for a university course" is a rather unusual sentence that I happened to say to quite a few people over the last semester. As curious as the idea sounded the first time I heard about it, the workshop offered exactly what I needed in my studies: connecting engineering knowledge to hands-on experience – all while doing something genuinely exciting. When I got accepted to the course, I knew I wanted to learn as much as possible and make a good pair of skis in the process.

During the first couple of classes, I felt quite overwhelmed by the number of parameters that influence a ski's performance. However, thanks to the tools we have as engineers, such as laminate mechanics and CAD, I was able to decide on a design that I would later build without any guesswork. What I found especially useful were the MATLAB apps provided to us by Joël, allowing us to easily iterate through different dimensions and find ones that were the most optimal. When it came to choosing materials for the skis, I found it interesting to consider the environmental footprint of the materials next to their mechanical properties. This made me decide to use basalt fibers as an alternative to commonly used glass and carbon fibers. I also appreciated the properties of natural materials, such as wood, which allowed us to drastically reduce the carbon footprint of ski top sheets as compared to commercially available equipment.

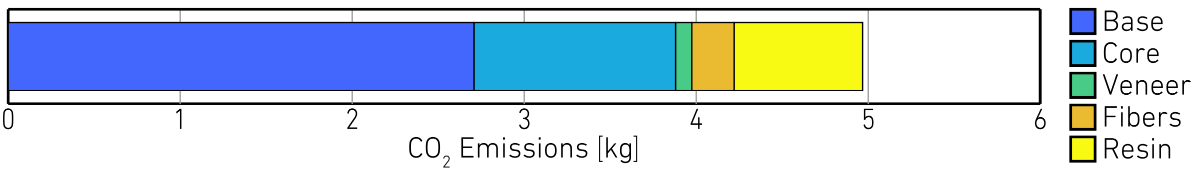
Building the skis was one of the parts of the course I was most excited about, since I really like learning about how different items are manufactured and enjoy making things myself. What I found the most impressive about the process was the sheer number of steps that had to be done to finish the skis. In my opinion, this complexity was also one of the most difficult aspects of the workshop – some operations like lamination would be incredibly difficult to do properly if not for the instructions and help provided by Joël and the TAs. This made the workshop an incredible opportunity to learn those skills.

During the course I felt really excited to finish the skis, but also a bit anxious about doing something wrong and messing them up. This thankfully did not happen and, apart from some minor, purely cosmetic imperfections, the skis turned out how I wanted them to. I am very happy with how my visual design looks on the top sheet, as it works nicely with the natural pattern of the veneer. The bending test also proved that their stiffness was very close to what I planned to achieve, meaning that the initial calculations were accurate. Right now, I am even more excited to finally try out the skis on a slope and assess their ride quality.

Thanks to the hands-on approach, the amount of practical knowledge I gained during the ski building workshop is unparalleled. Being able to make justified design decisions and accurately reproduce them during manufacturing made me appreciate the field of mechanical engineering even more. Since I'm also satisfied with how my skis turned out in the process, I can confidently say that my goals for the course have been fulfilled. I think that this success could be attributed to a couple of factors. I think that the years of experience that EDAC has with making skis have made the process very effective and reliable. The other reason would be that the course is incredibly rewarding, which kept me motivated to do my best.

Even though the project was a great success for me, there's still some ways I could have refined my workflow. A rather obvious improvement would be to start some tasks (notably laser cutting veneers and final sanding) a bit earlier to avoid stress right before the deadlines.

All in all, the ski building workshop also taught me a lot beyond its engineering aspect. Although everyone was making their own skis/snowboards, we were usually working in the lab together, learning a lot from each other and supporting one another in the process. I also realized that is it sometimes good to experiment with different ways of doing things to figure out which one works the best for you.



Ski/Snowboard Type	Length [mm]	Weight [kg]	Widths [mm]	Fiber Layup
All-Mountain Ski	1600	1.34	120 - 82 - 110	B0/Btriax(t) - Btriax/B0(b)

ENGINEERING DESIGN AND COMPUTING

LINUS KUHN

In the beginning I wasn't sure whether I wanted to build a powder board or a splitboard. Since I've started touring and always carried my board on my back, I quickly decided to build my own splitboard at the beginning of the course. One day before the first meetup I went to BlueTomato to look at different types of splitboards. One quickly caught my attention, it was then that I decided what shape my board should have. I wasn't quite sure about how stiff my board should be, but with my previous board being rather soft with around 60 N/cm I knew my Splitboard will be stiffer which is important for walking up the mountain. I also looked up the stiffnesses of the splitboards from previous years, which I heard turned out nice to ride. I played around with the MATLAB tool to find out which layers I would want in my board, but I didn't have much to choose from, so the decision was rather easy.

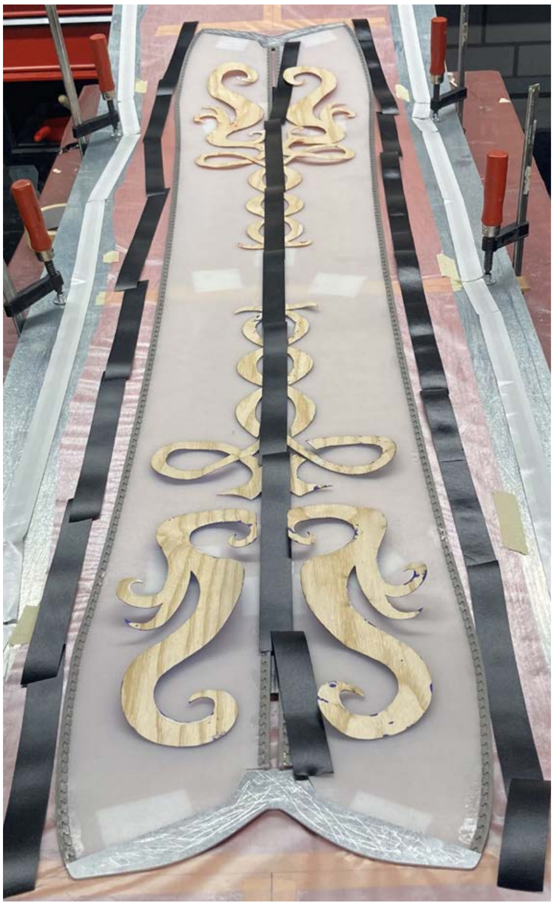
I didn't consider the sustainability aspect as much as I thought I would in the beginning. For example, I thought about choosing ABS sidewalls, which would be much worse from a sustainability perspective compared to the oak ones, but Joël also told me there might be some problems implementing them into a splitboard. So, in the end I decided to choose the oak sidewalls, but not primarily because of the sustainability aspect but rather because I liked them aesthetically more in the end and I wasn't sure if I could even put the ABS sidewalls in my board.

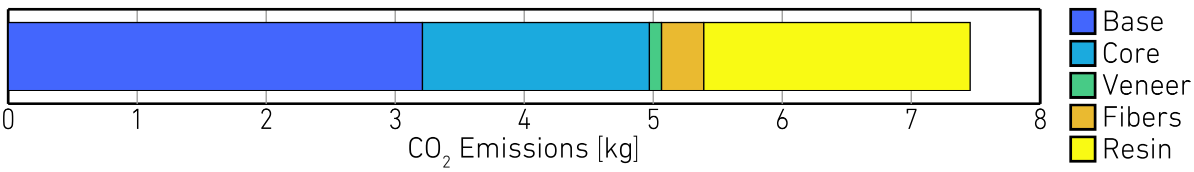
As I was the only one in the course building a splitboard and the process is quite different in some steps I was sometimes a bit lost in the process, as the only one really knowing how to build a splitboard was Joël and he was often busy. I also wanted to have my design ready early, as often suggested, but in the end, I somehow ended up having to go to Dynamo one day before lamination day on a Sunday with a special permit, as Dynamo is actually closed on Sundays. This day was quite stressful as I knew if something went wrong, I couldn't put my design on the board. Another thing that was quite time-consuming was sanding the edges in the middle so they would align perfectly to each other.

In the end my splitboard was a bit stiffer than expected but I knew it wasn't going to be exactly as stiff as the MATLAB script predicted it.

I'm really happy with how the board turned out, everything is how it should be, and I'm also impressed with the weight of it. With around 3.5kgs it's not much heavier than mass-produced splitboards, but it's a lot nicer.

Looking back at the course I've learnt a lot, ranging from the practical aspect of building a board, to the theory behind different types of boards and why they are built in certain ways, how the stiffness and different profiles influence the way it behaves in the snow or how laminating works. After the course I still had some troubles finding a place to service my board as most stores couldn't service it because of the uneven wooden top sheet. Because the board has such a special shape I had even more trouble finding climbing skins which fit my board, which is why I haven't gotten the chance to ride it yet but I'm looking forward to trying it out.





Ski/Snowboard Type	Length [mm]	Weight [kg]	Widths [mm]	Fiber Layup
Spliboard	1560	3.55	303 - 258 - 295	Btriax(t) - Btriax/Btriax(b)

ENGINEERING DESIGN AND COMPUTING

ALEXANDRU OLAREANU

I probably noticed the poster about the ski building workshop in my first week at ETH, and immediately knew I was interested. Two years later, I finally had the opportunity to join the course! I have always found that I learned more about engineering trough projects, rather than sitting through lectures, so this was an opportunity I could not pass on! There aren't many project-based courses at ETH, but even amongst them, the ski building workshop provided a unique opportunity: not only to work on a project and learn something in the process, but to actually design and build something I would use in my everyday life.

I often hear about sustainability nowadays, but I had never really considered it in any of my previous endeavours. It's one of those things engineers talk about a lot, but this course was my first real, practical introduction to designing with sustainability in mind. Using the Life Cycle Analysis, I was surprised to see how much of a difference can be made by something as simple as replacing ABS plastic sidewalls with some made out of oak.

Skis are a piece of sports equipment that seem simple enough, but, as I quickly learned, there is definitely more than meets the eye when it comes to their design and manufacturing. Fortunately, we had access to some really great tools for designing our skis. The MATLAB apps to evaluate parameters, premade CAD models and a database with all the old ski designs really sped up the dimensioning.

Almost everything that goes into the ski is made by hand, but bending the steel edges around the base was by far the most tedious part. Cutting the fibers and preparing the core was surprisingly quick. Before I knew it, we arrived at the most exciting part: laminating. That feeling of seeing your skis come out of the autoclave after a long day of laminating, is amazing. Then came the finishing: Sanding a pair of skis into the perfect shape for 3 hours might sound boring to some people, but I found the process really enjoyable: a nice break from the usual work I do at ETH.

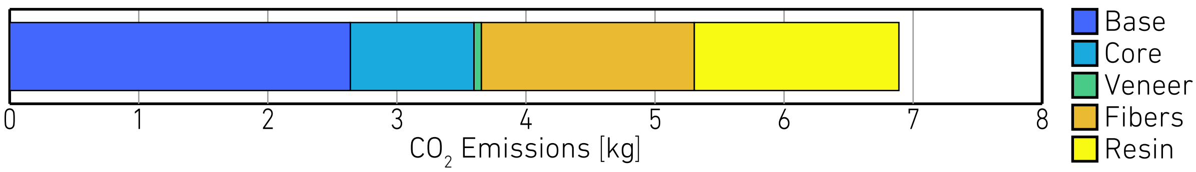
I think my skis came out great! From a structural perspective, they are almost perfect: the camber sits exactly at the designed 6 mm, the edges look perfectly seated, all the layers stayed aligned during the curing of the epoxy. Even the stiffness came out within 13% of the designed value.

This was the part I paid most attention to, as my priority was to make a safe, usable, carving ski, designed for harder snow. Unfortunately, I did not have the opportunity to try the skis out on the slopes yet, but I'm confident they'll feel great!

With the oiled veneer top sheets, our skis definitely look and feel unique. My design even shows the basalt fibers through the abstract pattern. Some of the shapes I laser cut into the veneers had very fragile features, that unfortunately snapped off in a few places. There are many small “mistakes” on the skis, but it's really only me that notices them — in the end, it is really these small imperfections that give the skis a handmade feel.

My goal with this workshop was to gain some engineering experience, develop some new skills, and learn more about a seemingly simple product I use in my everyday life. Making these skis taught me a lot: from the basics of laminate construction, wood finishing and how to conduct a basic Life Cycle Analysis, just to name a few. I can confidently say I managed to achieve everything I set out to do, and, as a bonus, managed to make myself a pair of skis which I will be proud to use for the rest of my life.

Of course, there are small things that I would do differently — but these small mistakes are not only what give the skis a handmade feel, but also where growth comes from. One thing is certain: having gone through this experience, I will definitely be making myself more pairs of skis in the future.



Ski/Snowboard Type	Length [mm]	Weight [kg]	Widths [mm]	Fiber Layup
Carving Ski	1700	1.69	123 - 66 - 107	F±45/Btriax(t) - Btriax/CS/F±45(b)

HANNES REUSSER

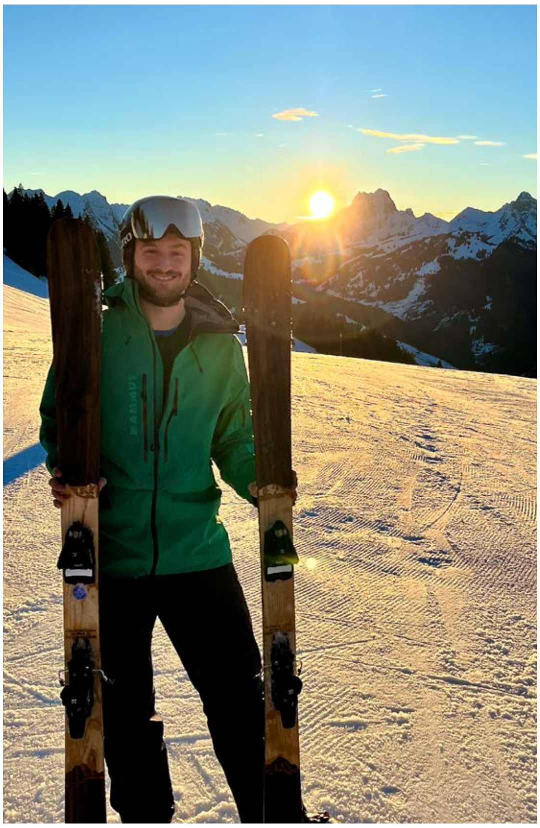
As a ski instructor in my fifth season and ski enthusiast, applying for the Ski Building Workshop was an absolute no-brainer. Once I was accepted, ideas for possible designs immediately started to flow. Because having fun is the most important thing in skiing for me, I aimed to craft a versatile and playful ski I could enjoy all over the mountain, both on and off the slopes. Balancing soft snow attributes with high-speed performance, I utilized the MATLAB and NX apps to refine and finalize my design in several iterations. In the end, I opted for the shape of a touring ski combined with the stiffness of a carving ski. In addition, I attached great importance to a high torsional stiffness to counteract the larger width. Hoping to combine these features in the best possible way, I started the construction phase with great anticipation to create something unique.

During the design process achieving a good performance and crafting a high-quality ski was my main goal. Achieving that by using natural materials wherever possible made it even more interesting. Compensating for the lower stiffness of the basalt fibers by increasing the core thickness and therefore risking a higher weight was no hard choice. In addition to improving sustainability, all natural materials (especially the wooden veneers) look amazing and give the ski an exclusive presence.

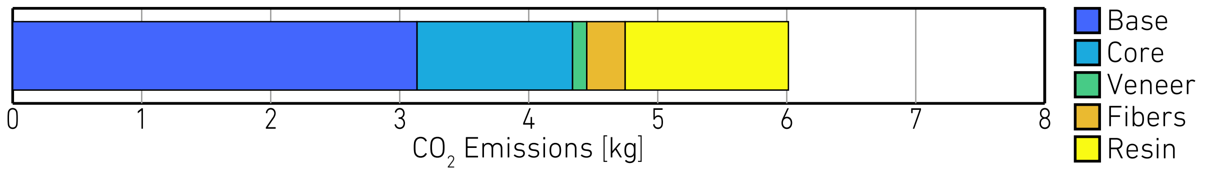
When we began fabricating the individual parts, I realized the importance of being accurate. Thankfully, I had experience with most of the tools. But using a jig saw to cut out a ski felt strange. The first thing I did not expect was how difficult it was to bend the edges without warping the base. Furthermore, I did underestimate the time needed to prepare for lamination. The third thing that surprised me was how long it took to sand both skis. However, the hardest thing for me was knowing that we only had one shot at this. So, my concentration always had to be high, and the tension grew with every week.

The precise and time-consuming work paid off, leaving me overjoyed with the outcome. Most aspects aligned with my plans, albeit with minor exceptions: the right top sheet shifted slightly during lamination and the final stiffness exceeded predictions by 20% at 51 N/cm. While the skis have a high-quality and elegant appearance, they feel somewhat delicate, likely also due to the natural structure retained by the oiled veneers. Still, the performance surpasses the elegant aesthetics. Due to the wider shape and high stiffness, it takes a little bit more effort to initiate a turn or to put the skis on the edges. This trade-off proves worthwhile for the enhanced stability, accuracy, and quietness at higher speeds.

To summarize, I built a sporty all-mountain ski with a tighter radius than most of its kind. The skis scream for party laps on empty mountains, and therefore my main goal to craft a versatile and fun pair of skis is achieved. The additional stiffness improves the performance on the slope but makes turning in the powder more demanding. During testing I was able to adapt to the skis and their shape in all conditions quickly, which left me very happy. I'm uncertain how the shifting of the cover or the higher stiffness could have been prevented. Discovering the reason for the latter would be very interesting, but I lack the expertise in the lamination process to do so.



Initially, I struggled to find anything to change. I was just too happy with the outcome. But after mounting the bindings, I realised that I had misplaced the labelling. Further I must admit that a straight, aluminium tail protector might be a more robust solution than the 3D printed swallow tail. I'm even considering adding a slim tip protector. During the workshop, I learned a lot about the ski as a mechanical system and which role the different components play. Planning and executing a project at this scale was a first for me and seeing how all the individual parts become one was a beautiful experience. Without question, building my own skis and riding them has been a dream come true.



Ski/Snowboard Type	Length [mm]	Weight [kg]	Widths [mm]	Fiber Layup
All-Mountain Ski	1780	2.00	130 - 88 - 119	B±45/Btriax(t) - B0/Btriax(b)

LUCA SCHÖB

When I looked through the course catalogue last summer, I knew that I did not want to attend only standard lectures this semester. Since I had not decided on a major yet, I had a lot of freedom in choosing my courses. That is when the ski workshop caught my eye. "A practical workshop without much lecture time? And I like skiing too? Perfect!" I was hoping to acquire a lot of knowledge and skills that are not usually taught in a regular course. As it turned out later, that hope came true. As I did not know much about skis, just being a passionate skier, sizing and designing the skis proved to be a challenge. Fortunately, we had the measurements of our own purchased skis as a reference, which greatly facilitated the design process. Using my own skis as a template and the MATLAB analysis tools, I was able to quickly complete the design of the skis.

Sustainability was not a major concern when designing my skis. The contribution that the production of my skis has on the overall environmental impact is negligible. Moreover, I did not want to limit myself in this respect. Nevertheless, it was interesting to gain insight into the sustainability of my skis through the Life Cycle Assessment (LCA).

It is safe to say that the design was the most challenging at the beginning, as I was unsure of how different design parameters would affect the skis, their appearance and performance. When choosing values, I had to rely entirely on the calculations from the MATLAB applications and have my values checked by the TAs. Over time, however, I developed a certain intuition about the various parameters, as the chosen design could also be seen in three-dimensional parts. I didn't have any major difficulties with the construction process. The supervisors provided excellent guidance and there was always someone available to help with questions or problems. The practical work, unlike the rest of my current curriculum, was generally enjoyable, except for the edge bending. That took a long time and was tiring. But I am probably not the first person to notice that.

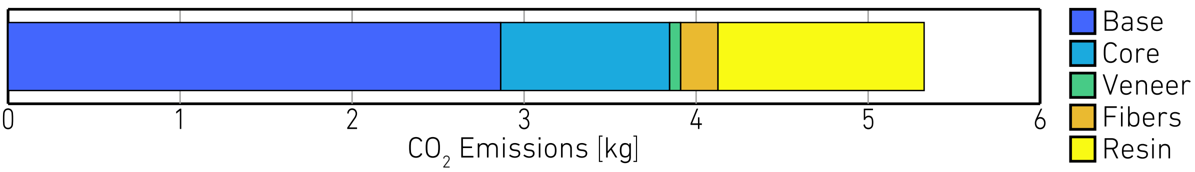
The stiffness analysis at the end of the course showed that my skis were significantly stiffer than originally calculated. Part of this can be attributed to modelling inaccuracies, as all course participants achieved a higher final stiffness. However, in my case the difference was considerably greater than I can explain. I am very happy with the design. Nothing shifted during lamination and the small errors I had to correct are almost unnoticeable.

Unfortunately, it has not yet been possible to test it on the piste, as our joint skiing session is scheduled to take place after this report has been submitted. I am really looking forward to it.

Right from the start I had a clear goal: to make skis that looked good and were easy to use. As I did not have much knowledge about different skis and designs, it was a challenge to anticipate how my skis would look. What I can say now is that I am very happy with how they turned out. The design, which I had only seen in Inkscape on the computer, looks great on the finished skis. We will see how well I can ski with them on our ski day. I am not very confident, firstly because the stiffness is much higher than I had anticipated, and secondly because the skis are a bit wider than I had expected. However, I am looking forward to the results.

Looking back on the workshop, I can confidently say that I would do it again. However, I would make a few changes. When it comes to dimensioning, I would probably be a bit more adventurous in order to design more interesting skis.

Usually you don't have the opportunity to measure skis yourself, and you can easily buy standard measurements in a sports shop. Another more specific thing I would do differently is to use less tape to secure my design during lamination. I really overdid it. I spent a whole afternoon with two colleagues scraping off the tape after lamination and it was exhausting. Despite the challenges and hard work, I can say that the project was a lot of fun and the end results are very good. I would recommend it to anyone considering this course. It has been a very educational experience.



Ski/Snowboard Type	Length [mm]	Weight [kg]	Widths [mm]	Fiber Layup
All-Mountain Ski	1700	1.383	131 - 81 - 120	Btriax(t) - B0/Btriax(b)

FELIX SCHOELLER

The possibility to create a ski with an individual design and tweak every parameter to my individual riding style is what fascinated me the most coming into the Ski Workshop. My goal was simple: create the perfect mixture between a slope ski and a freeride ski. I took full advantage of the possibility to customize the ski. I cut the base, added inlays, used different woods to get a 3D effect and engraved the top sheet with details. I used CAD to see if the ski is optically pleasing and did not have any weird jumps in curvature. I used the stiffness calculation and laminate theory to stay in the normal range of an all-mountain ski. To get a perfect mixture between slope and freeride, I decided to go for a larger width in the tip and tail to get better performance in deep snow and a smaller underfoot width to get a smaller turning radius and better slope performance.

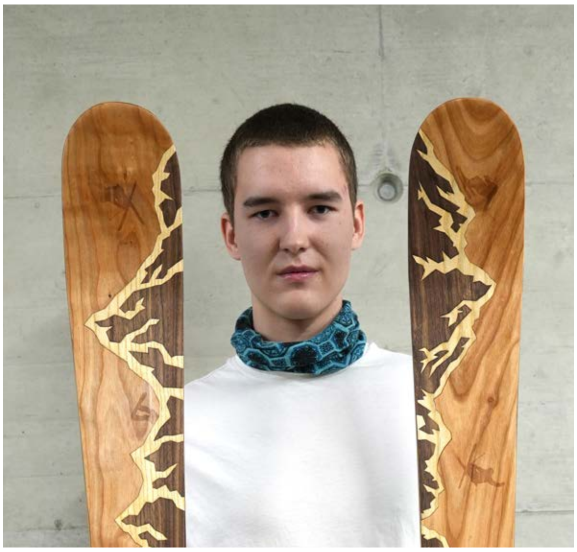
Sustainability played a significant role in the design of my ski. I selected the minimum amount of laminate layers, to reduce the total amount of resin used, as resin contributes the most to the total CO2 emission of our skis. Furthermore, I tried to reduce the amount of wasted veneer, by trying out the laser settings on small test pieces.

At the start of the ski workshop, I decided to go for a base design. This meant cutting the base and adding base sheets of another color with different shapes to visualize the design. This step was extremely time-consuming, especially the smaller pieces. After laser cutting a template, one had to draw with the template the design on the base sheet. Cut the base. Use another template to draw the inlay shape on a different base sheet. Cut the inlay. Hope it fits. It would almost never fit right away. Therefore, one had to adjust the shape with a box cutter. If the inlay gets too small or rips, repeat the process on another base sheet until it works.

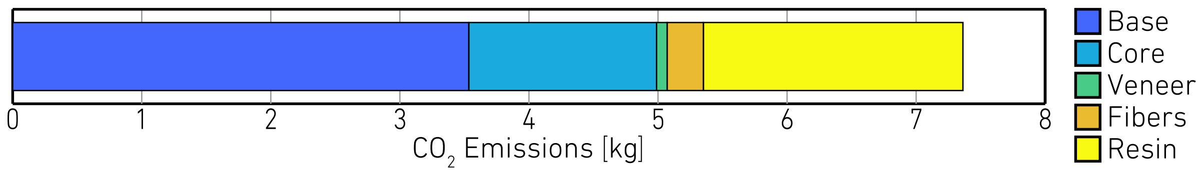
I am very satisfied with the final result. It was quite a nerve racking process to sand away the beautiful colors of the top sheet. Fortunately, the bright colors came back after applying a few drops of linseed oil. The skis feel very good in hand and seem robust. The final stiffness of the ski is 43.5 N/cm. No major mistakes are visible that stand out to other people. Still some failure is visible if inspected closely. Such as sanding too much veneer off the top sheet, engraving not deep enough or the brown color of the donut not popping out enough.

I cannot say much about the ride performance yet, as I have unfortunately not had the opportunity to test the skis. I believe I can say that I have succeeded in fully customizing the design of the ski on the top and bottom of the ski to my liking. The stiffness turned out to be greater than originally calculated, which is most likely because I added another laminate layer last minute, as I have misjudged that one needs at least two laminate layers between the base sheet and the core to hold the different components strongly together.

The most eminent lesson I learned was to be more patient when it comes to sanding material off the ski, no matter how late and tired you are. You always have the chance to take off more material the next day, but you do not have the opportunity to add material.



Furthermore, the Ski Workshop made me mindful when it comes to considering the time needed for the manufacturing step. One always imagines the easiest way, but problems always appear. Next time, I would not cut the base, as the effort is enormous, and the final result can rarely be appreciated as it is at the bottom of the ski.



Ski/Snowboard Type	Length [mm]	Weight [kg]	Widths [mm]	Fiber Layup
All-Mountain Ski	1840	1.60	136 - 101 - 126	Btriax(t) - B0/Btriax(b)

JAN WEBER

I always heard about workshops, where you can build your own skis, but never thought about signing up for one since they are quite expensive. When I saw the poster of the ski building workshop at ETH in the CLA building, I knew I had to apply for this course. When I got accepted, my first thought was to make a freeride ski. With the MATLAB and CAD software it was quite easy to set the dimensions of the skis however you wanted to. Mine ended up on the wider side but with a small radius, so that they are still fun to ride on the slopes. Also, with the stiffness calculations it was rather simple to sort out the core thickness, the type and the number of fiber layers used in the ski. I tried to make a flexible and light ski.

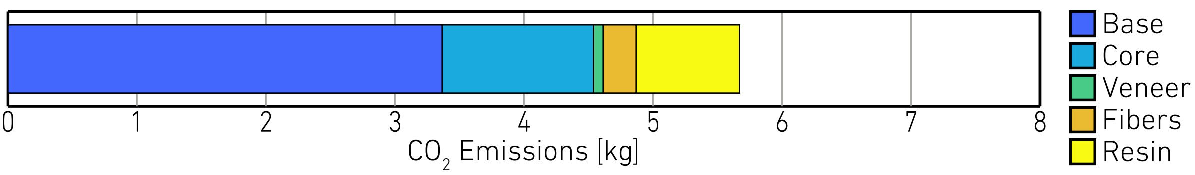
Since the ski is quite wide and uses a lot of materials in that perspective, I tried to compensate for it with the materials used. For the sidewalls I chose oak wood instead of ABS. It also looks better in combination with the top design made out of wood in my opinion. I tried to avoid carbon fibers and used basalt fibers instead. I didn't use flax because of the weight since it soaks up a lot of resin. The final stiffness from the calculations was 34.32 N/cm.

Building the ski was the most exciting part of the workshop. It was cool to see the progress of the ski from start to finish. Bending the edges of the skis was probably the part I struggled the most with. It was quite difficult to get the curvature just right so that it fits the base of the ski. Designing the top sheet was the most time-consuming but also the most fun part because there are so many options and in the end it's the design that makes the ski really your personal ski. Also fitting the base to the 3D-printed tail protector was quite a bit of work to get that (almost) perfect fit.

I'm very happy with how the ski turned out. I like the combination of walnut and cherry wood. It makes the ski stick out even with a simple design. The ski has a low bending (43 N/cm) and torsional stiffness. This also leads to vibration at higher speeds. Surprisingly, it is not difficult to turn with the skis even though its quite wide. I guess the small radius keeps it agile and maybe even the swallow tail adds to that. The base isn't completely flat, and the skis start to wobble at higher speeds if you're going straight. They also lose speed quite fast on the slopes. Unfortunately, I couldn't test them in deep snow but they're still fun to ride on the slopes.

I'm positive that the skis will also perform well on a powder day so I would say that I achieved my goal in making a good powder ski. I also wanted to make a ski which is fun to ride on the slopes and it sure is. As stated before, the base isn't completely flat and at the shop they didn't sand down the entire base flat because of the risk of sanding through the base. I'm not sure how this could be avoided but it's a thing to improve the next time.

In this course I learned about all the small details that matter to adjust a ski for every special use and how to adjust the dimensions and types of materials to achieve the desired properties of the ski. I enjoyed learning all the processes involved in the making of a ski. Especially using a laser cutter and laminating was something new for me. Looking back, I wouldn't change anything of the ski except maybe shorten it by a little bit. I also sanded down the top sheet a bit too much so that at some spots the fibers came through. Fortunately, this doesn't affect the performance of the skis and other than that I'm really happy with how the skis turned out.



Ski/Snowboard Type	Length [mm]	Weight [kg]	Widths [mm]	Fiber Layup
Freeride Ski	1690	1.46	150 - 105 - 138	Btriax(t) - B0/Btriax(b)

JONAS ZAHNER

When I saw the poster advertising the ski building workshop in my first year at the CLA building, I knew I wanted to take part in this course. I've been skiing since childhood, but I had never been involved in making skis before. The course was a great opportunity to learn about the manufacturing and the materials needed to make a ski. My goal was to build a touring ski that was light but still stiff enough to ski on the slope. For this reason, I decided to use a lightweight Bcomp core. To achieve the desired stiffness, I chose a fiber layup consisting of two layers of basalt triaxial, one layer of basalt uniaxial and a carbon stringer. This gave me a stiffness of 40.75 N/cm. As I wanted a ski that was easy to turn, I chose a radius of 16.2 metres. I oriented myself on my slalom ski, which I had brought with me for measuring.

I didn't really pay attention to sustainability because otherwise I would probably have had to choose a different fiber composition. I opted for a carbon stringer because of the stiffness. I also decided in favour of an aluminium tail protector because I like the look of it better than the plastic one. The only thing I paid attention to when making my choice was the consumption of veneer so that I could use as many leftovers as possible for my individual parts.

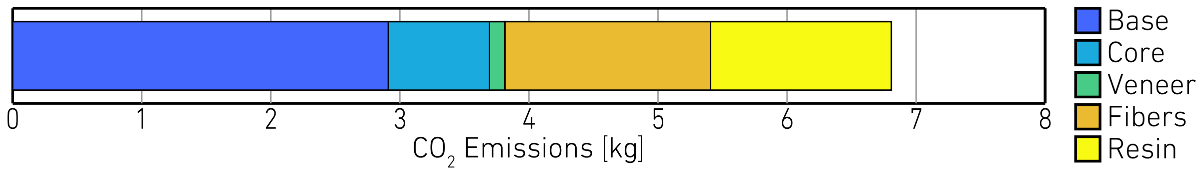
Once I had determined the contour and the fiber layup, the manufacturing process started. I wanted to achieve a 3D effect with geometric shapes. However, I wasn't sure which shapes to use and how to arrange them. I also wanted a motif on the ski that reminded me of my home. After creating several designs in NX, I decided on cubes and a mountain silhouette. Synthesizing those ideas into a final product took me longer than expected. After cutting the individual parts of the top sheet they had to be taped together. This was done to ensure that the parts wouldn't shift during lamination. It was a Sisyphean task and therefore took me a lot of time and nerves.

Visually, I am very happy with how the ski turned out. The shape and design of the ski is unique. I wouldn't have thought that the individual parts would fit together so precisely. After the stiffness test, I also knew that my ski fulfilled the necessary requirements and even slightly exceeded the desired value of 46 N/cm. I have done one short ski tour so far. The skis are nice and lightweight, and I had no problems on the ascent. On the descent, the ski behaved well, but I would have expected them to allow tighter turns. At higher speeds, the ski becomes a little unstable as it doesn't dampen as well, but that's not a problem in fresh snow.

All in all, I achieved my goals, and I was able to manufacture a wooden touring ski that's both light and stiff. I am very happy with my visual design which was of utmost importance to me, and I invested a lot of time in it.

A lot of effort was put into bending the edges, which paid off, since the result were two identical ski moulds. The bending stiffness turned out to be slightly higher than expected. I can't attribute this to any particular reason, as most of the skis in the test had a higher bending stiffness than expected.

The course taught me a lot about skis and their manufacturing process. I was surprised at how many steps it takes and how time-consuming some steps can be. You also have to work very precisely at each step, for example when bending the edges or sanding the top sheet. Otherwise, mistakes will be immediately visible. Next time I would start earlier with the design of the top sheet or do an easier design so that I have more time for the base design. Overall, I am grateful that I was able to take part in the course and I am looking forward to more ski tours with the new skis.



Ski/Snowboard Type	Length [mm]	Weight [kg]	Widths [mm]	Fiber Layup
Touring Ski	1700	1.40	126 - 86 - 112	Btriax/B0(t) - Btriax/CS(b)

FABIAN ZANGGER

My goal for the Ski Building Workshop was to build my own snowboard on which I could learn how to ride. I have been skiing my whole life, but I always wanted to try snowboarding as well. Since I had no idea what my preferred riding style was going to be, I decided to go for a true twin shape, meaning the board is symmetrical and should be easy to ride in both directions. For the profile of the board, I chose a Hybrid-Rocker profile, which is said to be especially beginner friendly. The shape and profile of the board was designed with a MATLAB tool and a CAD model, allowing us to visualize many different variations before settling on the definite shape.

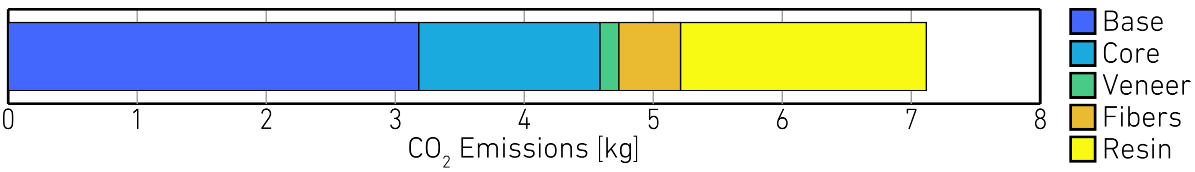
I did not specifically consider sustainability in my design, other than choosing wooden sidewalls instead of ones made from ABS. For the top sheet design, I also choose wooden veneers, however the main reason was that I much preferred the look of it to other materials. I spent a lot of time to arrange the parts as efficiently as possible before laser cutting, to create as little waste as possible.

For me, the most difficult and time-consuming part of the building process was creating the design of my board. I engraved some of my favourite artists album covers on oak veneer and cut different wood kinds to make the top sheet look like it's covered by vinyl records. I had to cut the veneer for the bottom design, that shows a part of the river Rhine where I grew up, by hand because the parts were too big for the laser cutter. After laminating, the inserts for the bindings were covered by veneer and had to be uncovered again by drilling into the board at the right positions, which was quite nerve wrecking.

I am very happy with how my board turned out in the end, especially because I managed to express myself with my design. The resulting stiffness of 130 N/cm is quite a lot higher than the anticipated 108.9 N/cm, which might make it more difficult to ride. Since I've never snowboarded before, I can't really compare the riding qualities of my board to others. After spending a week practising in the mountains however, I have nothing negative to say about the performance of the board. It had to endure countless falls and crashes caused by my bad riding and only suffered a few scratches in the veneer.

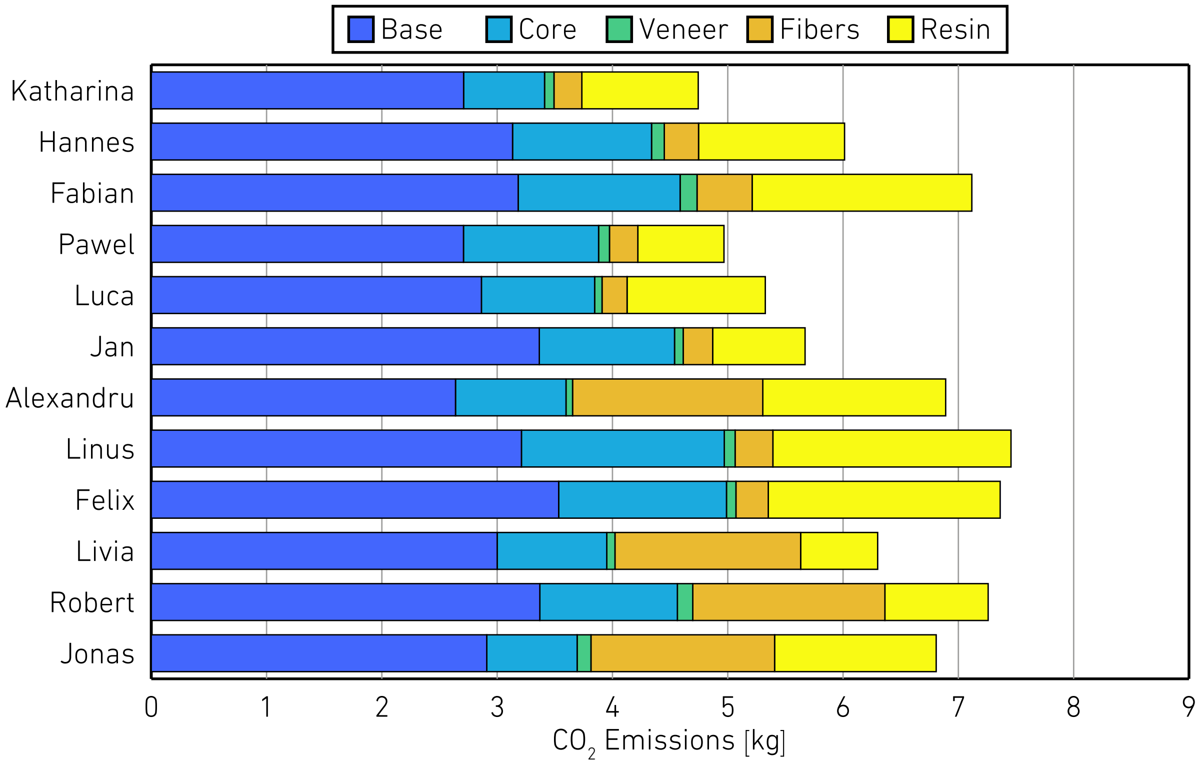
I can safely say that I achieved my goals for this course. The board turned out to be very beginner friendly and I have learned how to snowboard a lot quicker than I expected. The resulting stiffness is much higher than calculated and I do not know why. One reason could be that more resin was used than expected. The board is still very much rideable with the higher stiffness though, so this is not a big problem. There are a few points around the edges where I have not grinded the resin off completely, but I have not noticed an impact on the riding performance.

I have learned a lot about the construction of skis and snowboards in this course. Bending the edges by hand must be done very carefully, otherwise they might brake due to material fatigue. When cutting the veneer for the bottom inlays by hand you also need to be very careful, otherwise the wood can fray easily. Next time, I would make the profile a bit more pronounced since the tension is lost rather quickly when the board is used. I would also use less tape to hold the top sheet veneers together during lamination, as the tape is very annoying to remove after the resin has cured.



Ski/Snowboard Type	Length [mm]	Weight [kg]	Widths [mm]	Fiber Layup
All-Mountain Snowboard	1650	4.01	310 - 270 - 310	Btriax/Btriax(t) - Btriax/Btriax(b)

SUSTAINABILITY OVERVIEW

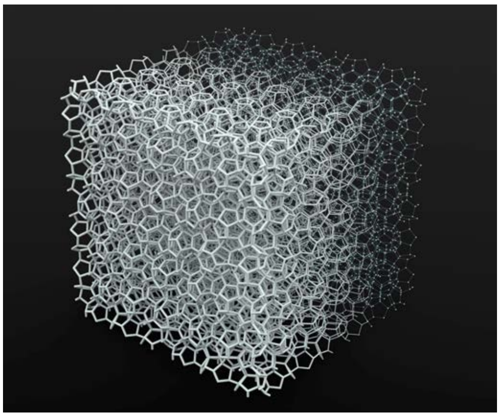


When drawing a general comparison of the CO_2 emissions of all the skis produced in the workshop certain observations can be made:

- The CO_2 contribution of the base and core are relatively consistent across all skis and snowboards and are usually related to the overall length. Snowboards have slightly higher contributions relative to their core size due to the threaded steel inserts.
- The CO_2 contribution from the veneers is negligible compared to the other contributions.
- The CO_2 emissions from the fibers are significantly higher if carbon is used.
- The CO_2 emissions from the resin are related to the core type, overall length, and number of fiber layers. The balsa core tends to absorb more resin than the hardwood core.

CO_2 Comparison							
Name	Type	Core	Fibers	Length [mm]	Total CO_2 [g]	Weight [g]	CO_2 / Weight [g/g]
Katharina	Ski	Ash/Poplar	Basalt	1670	4744	3233	1.47
Hannes	Ski	Ash/Poplar	Basalt	1780	6013	3992	1.51
Fabian	Snowboard	bCore	Basalt	1650	7117	4010	1.77
Pawel	Ski	bCore	Basalt	1600	4967	2676	1.86
Luca	Ski	bCore	Basalt	1700	5326	2767	1.92
Jan	Ski	bCore	Basalt	1690	5671	2919	1.94
Alexandru	Ski	Ash/Poplar	Basalt/Carbon	1700	6890	3357	2.05
Linus	Splitboard	Ash/Poplar	Basalt	1560	7457	3550	2.10
Felix	Ski	bCore	Basalt	1840	7363	3200	2.30
Livia	Ski	bCore	Basalt/Carbon	1710	6300	2706	2.33
Robert	Ski	bCore	Basalt/Carbon	1810	7258	3038	2.39
Jonas	Ski	bCore	Basalt/Carbon	1700	6808	2823	2.41

EDAC RESEARCH

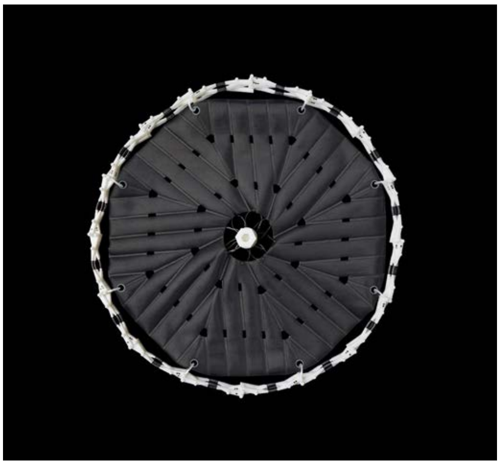


Computational Design

We support designers in their discovery of new, innovative solutions to engineering tasks, and help them gain a better understanding of solution spaces through the interactive and automated generation of optimized design alternatives. For example, crystallographic network topologies are analyzed from a structural point of view for the design of architected structures for engineering applications. In the area of origami-based structures, computational methods and mathematical conditions are developed to determine origami patterns.

Design for Additive Manufacturing (AM)

We investigate new design methods for AM, e.g. supporting conceptual design with design heuristics for AM and 3D printed objects to visualize each heuristic. On the computational side, we develop new representations and optimization methods for multi-material distribution, anisotropy of mechanical properties and topology, shape and size optimization. This research couples computational design and the mechanical testing of 3D printed materials and optimized structures, for example the design and optimization of shape-morphing structures that are actuated pneumatically. An application-driven topic includes the multi-material optimization of personalized, artificial spinal discs that are 3D printed.



Designing Novel Structures and Machines with 4D Printing

4D printing is the 3D printing of functional materials, e.g. in a multi-material process, to create parts that actively reconfigure themselves in response to the environment. This creates a new paradigm for the design of novel machines that do not use conventional components. We investigate how we can design new structures and machines that can morph their shape in response to temperature change. We also advance the state-of-art in the design of novel machines that use 3D printed, bistable mechanisms as actuators to assemble themselves, propel a swimming robot and automatically deploy a solar panel.

Development Engineering

A new research area focuses on design for low-resource settings. An initial focus is the design of a new, low-cost mechanical ventilator for field use. In collaboration with industry, we are also developing a new sustainable design and fabrication process for dwellings made of mortarless Compressed Earth Bricks (CEB).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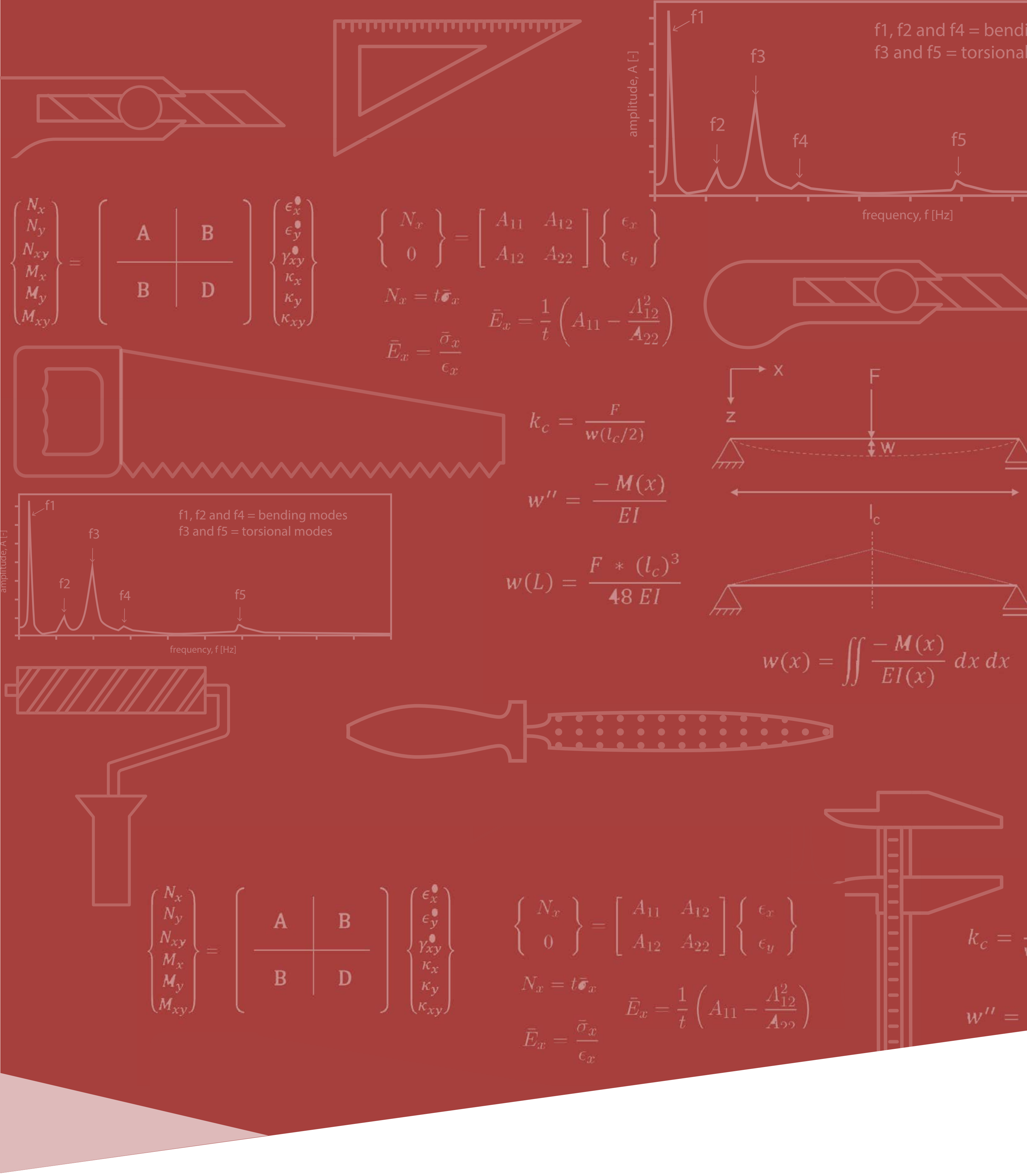

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