Case Study

Longboard Simulation with Ansys Mechanical

Developed and curated by the Ansys Academic Development Team

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Summary

This case study showcases how Ansys Mechanical, within the Ansys Workbench Interface can be used to find the ideal design of a Longboard Deck. It demonstrates how simulation can be used to assess the deck structure, compare different materials and evaluate trade-offs between different designs.

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1. Problem Statement

A longboard is a type of skateboard designed for downhill and slalom racing but also used for simple cruising and transport. Because it is longer than a regular skateboard and normally has bigger wheels, it enhances speed. The increased weight and size make them less suitable for many skateboarding tricks but contributes to stability and improved aerodynamics by providing more momentum.

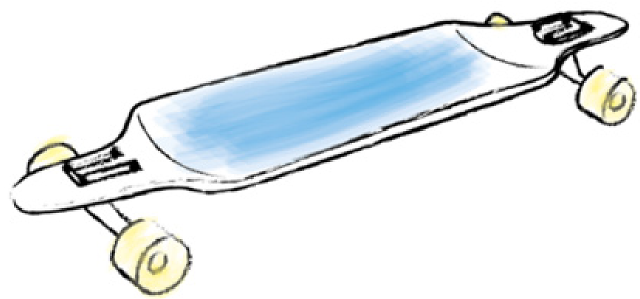

Figure 1. Longboard Deck

The objective of this case study is to find the optimal design for the longboard deck, i.e. the cheapest and lightest design not compromising safety. To carry this out, the process illustrated in Figure 2 will be utilized.

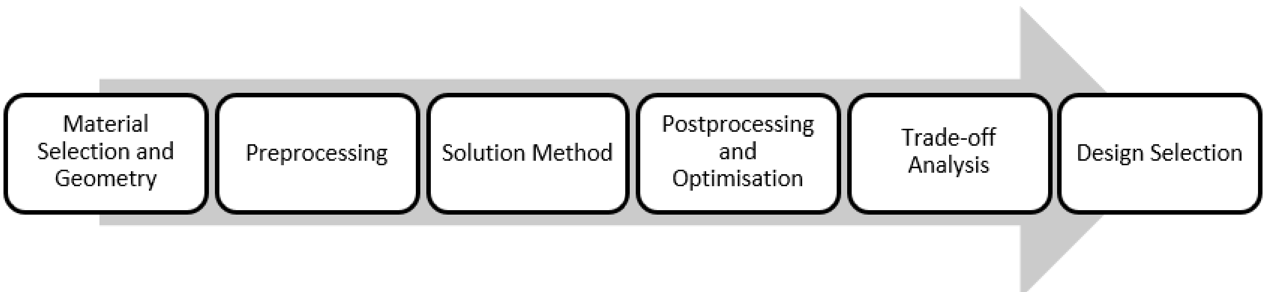

Figure 2. Structural Analysis Process

The very first step of the process is to define the initial geometry of the model (available in case study folder), and the materials to be used, then the problem is setup in the Ansys Workbench Static Structural Module. Here loading conditions acting on the geometry (*e.g.* forces), supports and connections between the different components of the model are defined. While there are different types of solution methods that can be used to solve a structural problem, in this case study the Ansys solver based on the finite element method is used. Once the simulation has been solved, outputs like stress, strain and displacement can be evaluated and consequently, optimization, using parametric analysis can be performed. In particular, the optimal design of the board will be found for different materials and then trade-offs between weight, cost and environmental impact, will be evaluated for different designs.

2. Geometry and Material Definition

A material selection project, carried out with Ansys Granta EduPack, found that the best materials for a longboard deck are Bamboo, CFRP and Plywood.

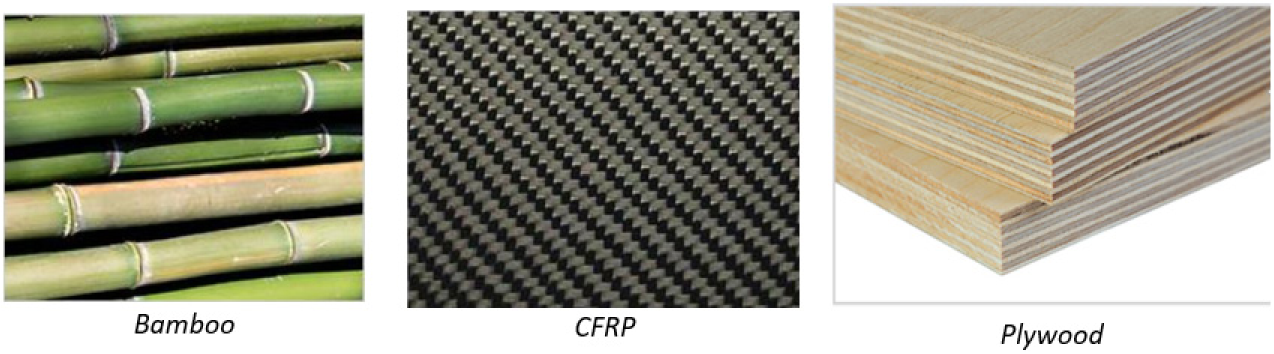

Figure 3. Longboard Deck materials

You can find a detailed description of the selection project in our Longboard Material Selection Case Study. As stated at the end of the material selection case study, a higher degree of material detail is needed in order to perform accurate simulations. Therefore, the following records from Level 3 Granta EduPack will be used in this case study: (1) Bamboo (longitudinal), (2) Epoxy/HS carbon fiber, resin infused woven fabric, biaxial lay-up, and (3) Plywood (3 ply. beech), parallel to face layer. The properties of each material can be directly transferred into the simulation model by connecting Granta EduPack and Ansys Workbench (Static Structural) modules in workbench as shown in Figure 4.

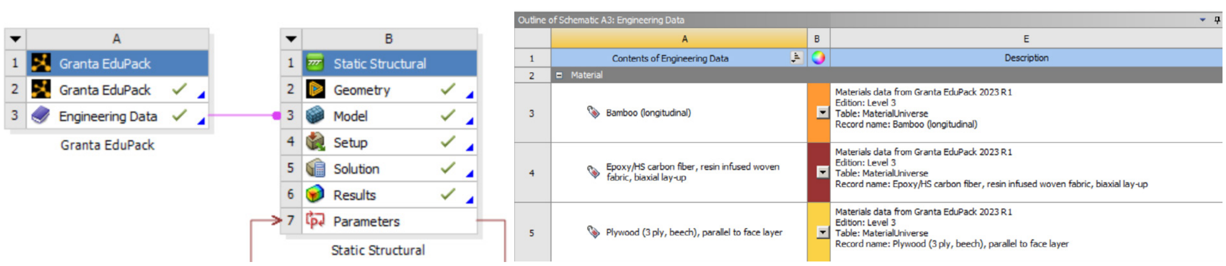

Figure 4. Workbench Connection between Granta EduPack and Static Structural Module In Ansys Workbench (Left), Exported Materials in Engineering Data (Right)

If the Granta EduPack module is not available, all three materials selected are a part of the Materials Data for Simulation package. The initial geometry, which is an assembly of several components, as shown in Figure 5 below can be also found in the case study folder under the name Longboard_Initial_Geometry.scdoc.

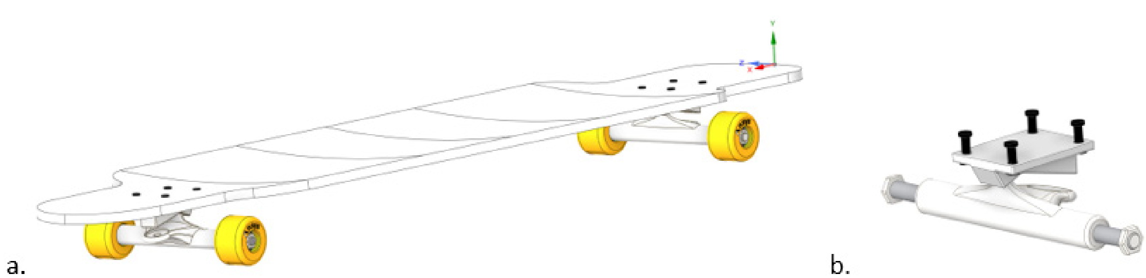

Figure 5. (a) Longboard Assembly, (b) Truck Assembly Detail

3. Pre-processing

In this section, the simulation set-up to solve the longboard problem will be discussed in detail. If you are new to Ansys Workbench and Ansys Mechanical, the free Ansys Innovation Course: Get Started with Ansys Mechanical is recommended to learn the basics of the software interface.

For the initial set up, Bamboo was chosen as the material for the deck, while Plastic (TPU) was selected for the wheels and Steel for the rest of the assembly. As the imported geometry is an assembly of different components, the software will automatically generate contacts between them. Depending on the geometry and/or settings used, inaccuracies in the generated contacts may be found (e.g., wheels shown in contact with the bottom part of the deck). To solve these, the automatically generated contacts can be deleted, and new ones can be defined. In this case study, the contacts were redefined using a contact tolerance value of 0.5mm which yielded realistic contacts. Bonded connections were used for this demonstration, assuming all parts are clamped with sufficient bolt force such that there would be no separation of surfaces. As it can be seen from the assembly in Figure 5(b), the bushing is missing. To simulate this component, an idealized spring element (the spring response can also be modeled as non-linear) with longitudinal stiffness 3.15e+07 N/m (high rigidity) and no damping was modeled. After the definition of the components and interfaces, the meshing can be carried out. In this investigation, given the small size of several components a global mesh with a maximum element size of 0.5mm, with a Multi-zone Method, was used for the board. The quality of the meshing in the board, which is the main object of interest, was evaluated through the element quality mesh metric in-built in Ansys Mechanical (minimum quality 0.38, with an average of >0.8 compared to >0.2 recommended).

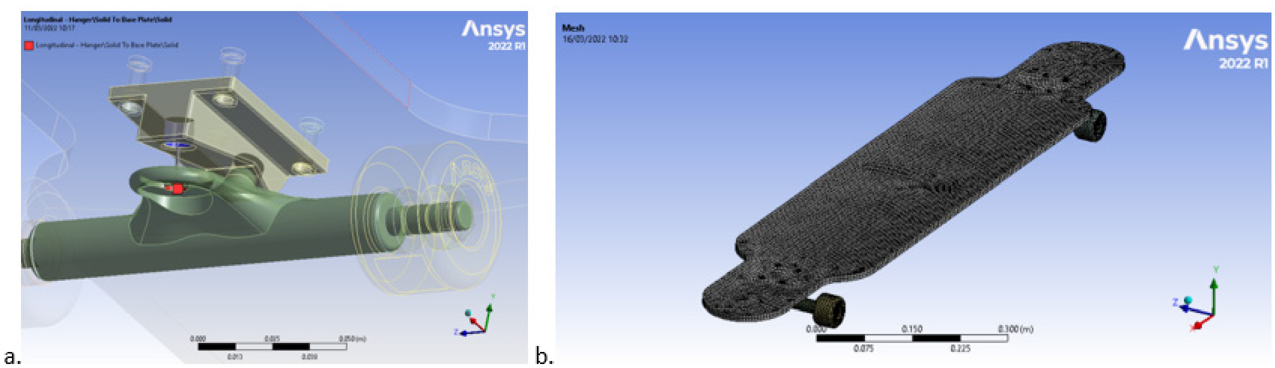

Figure 6. (a) Modeling Bush with Spring Element, (b) Meshing of the Longboard

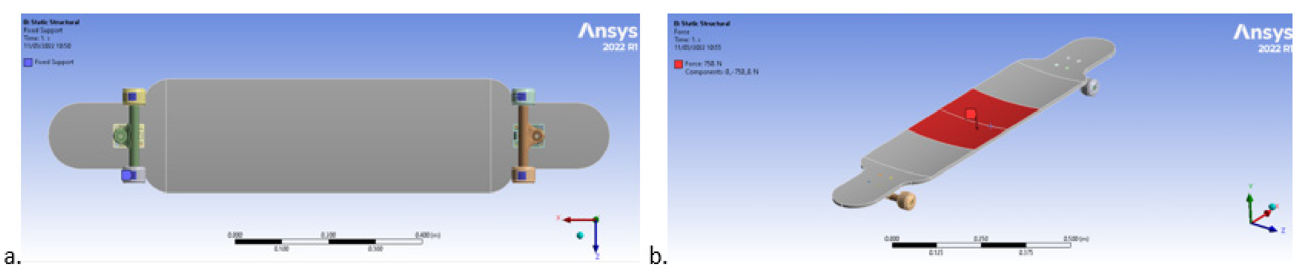

Figure 7. (a) Fixed Support Location, (b) Applied Load Location and Direction

The next step is to set up boundary conditions such as loads and supports. To limit the movement of the board, fixed supports were assigned to the four pre-marked areas under the wheels (representing the contact with the ground). Then a load of magnitude 750 N (representing a mass of 75kg with gravity) was applied to the central faces of the deck. The location of the load was chosen as the most challenging loading scenario to maximize safety. In a fixed beam loaded in bending, the critical areas more prone to fail are found at the center of the beam and at the supports. This load placement provides the highest moment in the center of the beam and also at the supports due to the longer levers.

Lastly the required outputs have been defined. In this case, the total deformation and equivalent stress for the whole assembly as well as the deck and the safety factor have been chosen. It can be noted that these results can also be defined after the problem has been solved.

4. Solution Method, Post-processing, and Optimization

The model has been solved using the Ansys Static structural solver. The outputs of the simulation can be seen in Figure 8. Highest deformation is found in the board, however the maximum value reached is relatively low (10.4 mm) and thus it would not impact the use of the longboard. High stress areas can be found as expected close to the bolts area and in the center of the board where the load is applied. In the bolts area the stress reaches critical values, leading to a Safety Factor <1 which means that the current design is not safe.

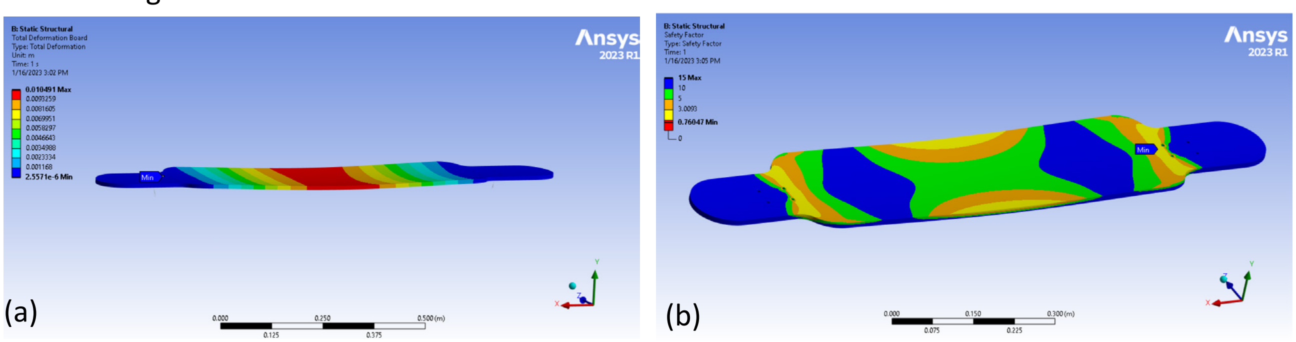

Figure 8. Simulation Results: (a) Total Deformation, (b) Safety Factor in the Board

Before moving forward with the investigation, it is important to evaluate if the results obtained of our analysis are realistic. It is important to note that FEA software provides results independent of the correctness of the model, therefore it is the role of an engineer to understand if the simulation can be trusted based on the assumptions made (*e.g.* material properties, contacts etc.). This can be done in different ways, for example by performing a quick simplified analytical calculation (Booklet: Approximate Solution to Standard Problems) to check if the results are in the right order of magnitude. In this investigation, a simple imagination exercise can provide information of whether the set-up has been done correctly. Imagining the bending of a longboard with a person standing on top and comparing the maximum deflection of the deck 10.4 mm), gives us confidence that we are in the right order of magnitude and no major errors were made in the set-up.

Now that the preliminary simulation results have been found and the simulation set-up has been validated, this investigation can proceed to the design improvement phase in which the optimal geometry of the board deck is found for each of the chosen materials from section 2 of this case study. One important question to ask is however, what is meant by optimal? Similar to many designs, the objective is to build a board which is as light and as cheap as possible, *i.e.* using the least amount of material. Some limitations must however be taken into consideration, the most important being, areas where material can be removed. For example, the outer shape of the board cannot be changed because this influences its functionality. However, there is the possibility of changing the thickness of the board. Thus, the optimal design in this investigation is considered to be the minimum thickness of the board which provides a safe design (safety factor >1). To find this value in the most efficient way for each of the three materials, the parametric feature of Ansys can be used. Through this, different simulation settings (*e.g.* boundary conditions, material, geometrical features) can be selected as parameters to run back-to-back simulation and quickly find the effect of these parameters on the outputs without having to set up multiple simulations. In this study, the thickness of the board and the material were chosen as parameters, such that safety factors and deflections for the varying board thicknesses could be compared for each material.

Table of Design Points

	A	B	C	D	E	F
1	Name	P1 - Group6	P6 - Board\Solid11 Assignment	P3 - Safety Factor Minimum	P4 - Total Deformation Board Maximum	P5 - Board \Solid11 Mass
2	Units	mm			m	kg
3	DP 0 (Current)	10	Plywood (3 ply, beech), parallel to face layer	0.76047	0.010491	1.8145
4	DP 1	12	Plywood (3 ply, beech), parallel to face layer	0.95647	0.006835	2.175
5	DP 2	14	Plywood (3 ply, beech), parallel to face layer	1.2373	0.0047294	2.5347
6	DP 3	10	Bamboo (longitudinal)	0.89334	0.004602	1.6799
7	DP 4	12	Bamboo (longitudinal)	1.1589	0.0030655	2.0136
8	DP 5	14	Bamboo (longitudinal)	1.5269	0.0021771	2.3466
9	DP 6	1	Epoxy/HS carbon fiber, resin infused woven fabric, biaxial lay-up	0.62909	0.079286	0.36919
10	DP 7	2	Epoxy/HS carbon fiber, resin infused woven fabric, biaxial lay-up	1.2536	0.026965	0.73789
11	DP 8	3	Epoxy/HS carbon fiber, resin infused woven fabric, biaxial lay-up	2.2464	0.014281	1.1062

Figure 9. Parametric Analysis in Ansys Workbench

The parametric analysis has shown the approximate optimal thickness of the board and its corresponding weight for each material is:

Table 1. Optimal Thickness (mm) and Weight (kg) of the three material candidates.

Material	*CFRP*	*Bamboo*	*Plywood*
Optimal Thicknesses (mm)	1.75	11.5	13
Weight (kg)	0.65	1.93	2.36

5. Trade-off Analysis

As a result of this investigation, we found the optimal thickness and weight of the different boards, however the question of the actual cost of each board design in terms of price and environmental impact remains unknown. In Ansys Granta EduPack, in addition to engineering properties such as mechanical, thermal, and electrical, are also present price and environmental impact information (*e.g.* carbon footprint) information. For the chosen materials these amount respectively to *0.579 USD/kg, 0.65* CO_2 *kg/kg* for plywood (3ply, beech), *1.64 USD/kg, 0.327* CO_2 *kg/kg* for bamboo (longitudinal), and *55.7 USD/kg, 47.8* CO_2 *kg/kg* for CFRP. As observed, these values are defined per kg of material, in order to obtain the total values for each design, they can be multiplied by the weights found in table 1, leading to the three possible optimized board designs shown in table 2.

Table 2. Comparison of Weight, Price and CO_2 of the three material candidates.

Material	*CFRP*	*Bamboo*	*Plywood*
Weight (kg)	0.65	1.93	2.36
Price (USD)	36.21	3.17	1.37
Carbon Footprint (kg)	31.7	0.63	1.53

The question of which is the best overall design among them is inherently a difficult one and cannot be answered without answering another important question, which is how much are we willing to compromise in terms of economic and environmental cost to achieve a much lighter design. The answer will vary depending on the usage intended for longboard. For examples a mass-produced longboard for children will need to be fairly economical, while a professional longboard used by a sports-person will more likely value a much lighter design above that of the cost to ensure maximum performance.

6. Possible further Analyses

It is important to mention that the above analysis was performed with various assumptions and simplifications. For example, the material properties were taken as bulk linear elastic but often board materials are layered, and material properties can be anisotropic. By using the Ansys Material Designer or the Synthesizer module in Granta EduPack it is possible to simulate composite and layered material structures. Moreover, while contacts were modeled as perfectly bonded, some sliding may occur altering the accuracy of the results. On the hand with regards to the trade-off analysis further inferences can be made by collecting more information on processing costs and end of life considerations. Further analysis can also be performed by considering topology optimization (Figure 10 (a)) and investigating how to optimize all the longboard components. Lastly by introducing plasticity and fracture properties into the material data, it is possible to model behavior of the deck at mechanical failure (e.g. 3 point-bend tests as shown in Figure 10 (b).

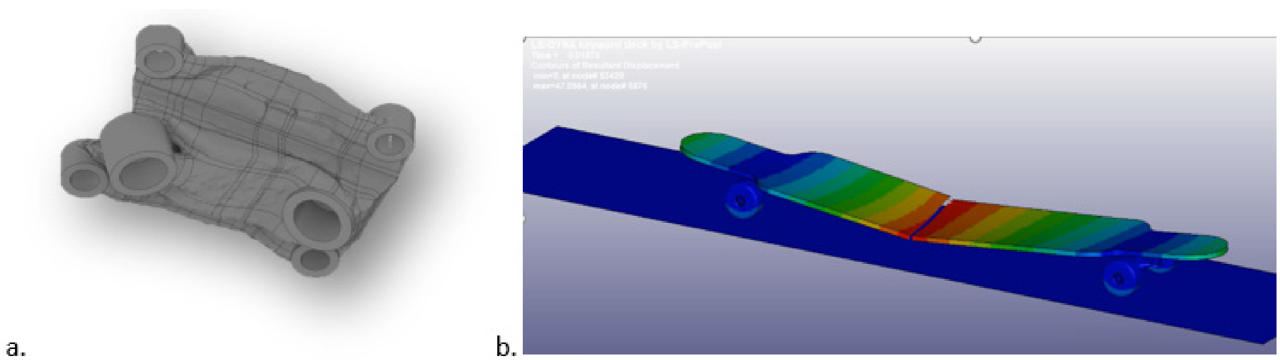

Figure 10. Examples of Further Analysis. (a) Topology Optimization of the truck (b) 3 Point-Bend Test

7. Conclusions

In conclusion, in case study it was shown how Ansys can be used to find the cheapest and lightest design of the longboard deck for different materials. A simulation, together with a parametric analysis, was set up using the static structural analysis module in Ansys workbench to compare different materials taken from a previous material selection case study. Lastly, a trade off analysis was performed to take into consideration cost and environmental impact of the design choices, and suggestions for further analyses were given.

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Feedback

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