Finite Element Analysis On Traditional Camber Snowboard

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Abstract: The main focus of this paper is to analyze the behavior of the snowboard under different circumstances including the materials and the ways it is being ridden. The shape of the snowboard determines the board’s dynamic characteristics and performance [1][2]. In this research, traditional camber snowboards are analyzed by applying finite element method. Two riding conditions including normal riding on the flat surfaces and rail riding and two different kinds of materials which are beech wood and fiberglass (E-glass) are combined to be analyzed. Analyzing how the snowboards behave under different conditions allows designers to understand what they should modify to optimize the performances of the snowboard. It also gives the manufacturers a better understanding of what kinds of materials they should be using to ensure the long-lasting performance of the snowboard. Moreover, it helps riders to choose the most suitable snowboard for them based on their riding habits.

1. Introduction
Based on the ways of riding, different sorts of snowboard should be chosen in order to optimize the performance. Traditional camber has been used since the beginning of the sports of snowboarding. It has a slight upward curve in the middle with the contact points close to the ends. Traditional camber is one of the most popular choices for high-level park riders or racers because it can provide excellent springiness and edge control while carving turns on hard snow [3]. In this project, the traditional camber snowboards will be analyzed by applying finite element method. Two riding conditions including normal riding on the flat surfaces and rail riding and two different kinds of materials which are beech wood and fiberglass (E-glass) will be combined to be analyzed.

2. Finite Element Model Analysis
The following table presents the assumptions of the two calculations of the finite element model analysis.

| Calculation 1 (Normal Riding) | Calculation 2 (On Rail) |
|-------------------------------|-------------------------|
| Mass of Skier: 70 kg          | Mass of Skier: 70 kg    |
| Mass of Snowboard (including bindings): 7 kg | Mass of Snowboard (including bindings): 7 kg |
| Weight of Skier: 70kg*9.81N/kg = 686.7N | Weight of Skier: 70kg*9.81N/kg = 686.7N |
| Weight of Snowboard (including bindings): 7kg*9.81N/kg = 68.67N | Weight of Snowboard (including bindings): 7kg*9.81N/kg = 68.67N |
| Coefficient of Friction: 0.1  | Coefficient of friction: 0.4 |
| Friction: f = (686.7N + 68.67N)*0.1 = 75.537N | Friction: f = (686.7N + 68.67N)*0.4 = 302.148N |
| Mass of Skier: 70 kg          | Mass of Skier: 70 kg    |
2.1. Normal Riding
When the traditional camber snowboard is in normal riding, it experiences the main pressure on the contact points, allowing more of the effective edge to touch the snow. Weight of human will be applied to the area where the shoes are being fixed, which is shown as the shaded area in the figure below. It is a uniformly distributed load because when the boots are in contact with the snowboard, it creates a surface area that allows the force to distribute evenly.

The normal force applied by ground will be applied where the snowboard makes contact with the snow. Due to the shape of the camber snowboard, only a narrow area will maintain contacting with the snow. In reality, the exact contact area will be hard to determine, so when conducting simulations, two narrow contact surfaces are created on both sides of the bottom surface of the snowboard. They are also where the friction will be applied. The free body diagram in the following figures shows all applied forces.

![Figure 1](image1.png)
Figure 1. Location of the normal force and friction applied.

![Figure 2](image2.png)
Figure 2. Location of the weight of rider applied.

![Figure 3](image3.png)
Figure 3. Free Body of Snowboard (Normal Riding).

A fixed constraint has to be applied along the z-axis by using User Defined Constraint to fix the surface where the snowboard is in contact with the ground. While the snowboard is moving, it can be assumed that the contact points with the ground will have zero displacement along the z-axis. Thus, fixing the z-axis displacement of the contact surfaces is required.

2.2. On Rail
When the snowboard is on the rail, it is assumed that the centerline of the snowboard will maintain contact with the rail. Since the bottom surface of the snowboard is tangent to the circular shape rail, there will be a tangent line of contact between them. Theoretically, a line does not have an area which means the force should be applied on a single line. However, in reality, due to the bending of the snowboard, an extremely narrow contact surface exists, and it is created in the center of the bottom surface in Siemens NX. It is the location where the friction and the normal force will be applied. The weight of the rider will still be applied at the same place as normal riding condition. Free Body Diagram is provided below.

The constraints, in this case, is almost the same as the normal riding. The only difference is the location of the contact surface. It changes from the two sides of the snowboard to the center of the bottom surface.
3. Finite Element Simulation
During the simulation, the snowboard will be analyzed in four different cases. Two different types of materials and two riding conditions will be considered. For each of them, the mesh will be continually refined by changing the size of elements for five times to optimize results. When the conditions of monotonic convergence are satisfied, the finite element strain energy always underestimates the strain energy of the actual structure.

Table 2. Properties of Materials [4].

| Properties                  | Wood (Beech) | Fiber glasses (E-Glass) | Unit  |
|-----------------------------|--------------|-------------------------|-------|
| Young’s Modulus             | 14.31        | 72                      | GPa   |
| Poisson’s Ratio             | 0.3          | 0.21                    | -     |
| Ultimate Tensile Strength   | 5.24         | 1950                    | MPa   |

3.1 Simulation Results

Table 3. Simulation Design.

| Simulation Identifier | A     | B     | C     | D     | E     |
|-----------------------|-------|-------|-------|-------|-------|
| Mesh Type             | 3D Tetrahedral |
| Element Size (mm)     | 31/4  | 31/6  | 31/8  | 31/10 | 31/12 |

Case 1 Normal riding with wood (Beech)

| No. Elements | 50087 | 180003 | 350695 | 689576 | 1055654 |
| Max Elem. Stress (MPa) | 10.15 | 10.45  | 12.04  | 20.34  | 24.51   |
| Strain Energy (N*mm)   | 39.1237 | 56.6257 | 63.3665 | 70.6571 | 76.1564 |

Case 2 Normal riding with fiber glasses (E-Glass)

| No. Elements | 50087 | 176937 | 345900 | 684786 | 1055149 |
| Max Elem. Stress (MPa) | 10.15 | 10.45  | 12.04  | 20.34  | 24.51   |
| Strain Energy (N*mm)   | 39.1237 | 56.6257 | 63.3665 | 70.6571 | 76.1564 |

Figure 4. Free Body Diagram of Snowboard (On Rail).
| Case 3 On rail with wood (Beech) |       |       |       |       |       |
|---------------------------------|-------|-------|-------|-------|-------|
| No. Elements                    | 50087 | 176937| 345900| 684786| 1055149|
| Max Elem. Stress (MPa)          | 7.34  | 10.30 | 23.7  | 36.73 | 69.91 |
| Strain Energy (N*mm)            | 19.0198| 29.2925| 33.4546| 37.217| 40.398|

| Case 4 On rail with fiber glasses (E-Glass) |       |       |       |       |       |
|-------------------------------------------|-------|-------|-------|-------|-------|
| No. Elements                              | 50087 | 176937| 345900| 684786| 1055149|
| Max Elem. Stress (MPa)                    | 7.05  | 9.56  | 22.5  | 34.57 | 64.86 |
| Strain Energy (N*mm)                      | 3.98478| 6.01576| 6.86953| 7.66156| 8.31299|

Figure 5. Normal riding deformation comparison.  
Figure 6. On rail deformation comparison.

Figure 7. Strain Energy Convergence Plot.  
Figure 8. Sample Strain Energy Convergence Plot.
4. Discussion

After the analysis was completed and relevant plots were generated, the results of four different cases were further compared.

4.1. The Displacement Plots

By comparing both displacement plots of snowboards composed of different materials and under the same riding condition, it shows that the snowboard made of wood has a larger displacement than that made of fiberglass in general. Hence, it can be concluded that wooden snowboards have higher ductility than fiberglass.

4.2. The Worst Principal Elemental Stress Plots

- Under the situation of Normal Riding, there are stress concentration areas spreading over the contact surface between the snowboard and ground. Since the contact surfaces with the ground are further away from the centerline of the snowboard than the contact surface between boots and the snowboard, the normal forces exerted by ground will produce a larger bending moment. In this case, it can be ideally considered as a model of pure bending.
- Based on the outcome of the simulation of riding on a rail, the stress concentration areas are spread over the contact surface between the snowboard and the rail. Since the contact surface between the snowboard and the rail is along the centerline of the snowboard, all the forces will be acting along the axis which results in 0 bending moment. On the other hand, the weight of the human will produce significant bending moments on the two ends of the snowboard, which will bend downwards two ends significantly.
- Compared to the wooden snowboard, the fiberglass one has a relatively smaller worst principal elemental stress, which means the fiberglass snowboard can endure a smaller bending. It accords to the result of the displacement simulation that reveals the lower ductility of the fiberglass.

4.3. The Strain Energy Convergence Plots

According to strain energy convergence plots, it is easy to visualize whether the numerical results converged in general. An $h$-refinement method was applied in all four simulation cases, which keeps diving elements into smaller ones to optimize results [5]. From the convergence plot shown above, it indicates an obvious trend of convergence, meaning that discretization error is getting close to 0 as the mesh is made infinitely fine [6].

4.4. The Stress Distribution

According to the stress distribution that was generated in Siemens NX, the maximum stresses mainly exist on the bottom contact surfaces. Thus, for designers, these locations are what they need to focus on in order to further improve the properties of the board, such as strengthening the max stress locations with composite materials. In reality, such improvements have already been widely used. After looking at the cross-section view of today’s snowboard, it can be found that the snowboard is made of composite materials in general, which has several layers of different materials, including carbon fiber, nylon, bamboo and so on. Carbon fibers or fiber glasses which are much stronger and lighter than other materials have been used at the contact surface of today’s most snowboards to improve the toughness and performance of the board, which is consistent with our simulation results [7]. The core is usually filled with bamboo because of its higher ductility, which is able to prevent some irreversible deformation under the instantaneously high stress.

5. Further Consideration

In order to obtain a more accurate and practical result, one of the improvement methods is keeping refining its mesh method. While the size of elements keeps decreasing, the number of elements will increases, which leads to a more exact meshed model and a lager calculation for the computer. The speed of calculation depends on the clock rate of the CPU that the computer has. To illustrate, the
computer that was used in this simulation has a clock cycle of 2.8GHz, meaning in a single second, it is able to complete 2.8 billion processing cycles. Even though a larger data size from Siemens NX for the CPU is going to take a much longer time completing the calculation, it can produce a much more accurate result.

The other way of improving the accuracy of the simulation results is to develop a more practical mesh design before setting up the simulation. The simulation that resulted from meshing an exact model instead of an idealized one could be closer to the reality. For example, different materials can be applied to the different parts of the snowboard in this research project, which will make the entire much more complicated and time-consuming. Firstly, a detailed model that includes all different components of the snowboard is a must so that different materials can be applied to each part individually. Then, each part needs to be meshed separately based on its shape and junction points between parts. Nonetheless, such simulation design requires high-performance computers (HPC) or work stations to compute the result, which has a higher cost including time and electricity. Therefore, a trade-off always exists, which requires researchers or businesses to balance the cost and the output or come up with a more optimal simulation plan.

6. Conclusion
The finite element method (FEM) is one of the most reliable computational methods for solving problems of engineering and mathematical physics, and it has been greatly used in this research project [8]. Even though computational models and actual models did not exactly correspond, overall results can be deemed satisfactory. In order to finalize the results, more types of snowboard also need to be tested in order to achieve more reliable data.

During this research, several assumptions and conditions were made while analyzing the snowboard. Although the snowboard used in this case does not have uniform stiffness throughout the entire structure due to the composition of multiple materials and was assumed to be a simple homogeneous beam in dynamic motions, the results provide some useful cues about the properties of different materials for designers [9]. It could be found that the strength and the ductility of materials have an inverse relationship. Thus, balancing the strength and ductility of snowboards would be a crucial point for designers and manufacturers to concentrate on. Furthermore, after finishing the prototype of the snowboard, besides the theoretical simulation on computers, actual field testing can also be utilized to provide more valuable information regarding the performance of the snowboard.

Acknowledgments
Special acknowledgements are given to the author’s colleague and advisors Haocheng Zheng, Prof. Ali Shahsavari, and Prof. Jeff Morris, for assistance and instructions at Rensselaer Polytechnic Institute.

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