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User centric design, data analysis and performance of snowboard bindings

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Abstract

This study focuses on soft boot snowboard bindings by looking at how users interact with their binding and proposes a possible solution to overcome such issues. Snowboarding is a multibillion-dollar sport that has only reached mainstream in the last 30 years its levels of progression in technology have evolved in that time. However, snowboard bindings for the most part still consist of the same basic architecture in the last 20 years. This study was aimed at taking a user centric point of view and using additive manufacturing technologies to be able to generate a new snowboard binding that is completely adaptable to the user.

The initial part of the study was a survey of 280 snowboarders focussing on preferences, style and habits. This survey was generated from over 15 nations with the vast majority of boarders on the snow for five to fifty days a year. Significant emphasis was placed on the relationship between boarder binding set-up and occurrence of pain and/or injury. From the detailed survey it was found that boarder’s experienced pain in the front foot/toe area as a result from the toe strap being too tight. However boarders wanted tighter bindings to increase responsiveness. Survey data was compared to ankle and foot biomechanics to build a relationship to assess the problem of pain versus responsiveness.

The design stage of the study was to develop a binding that overcame the over-tightening of the binding but still maintain equivalent or better responsiveness compared to traditional bindings. The resulting design integrated the snowboard boot much more into the design, by using the sole as a “semi-rigid” platform and locking it in laterally between the heel cup and the new toe strap arrangement. The new design developed using additive manufacturing techniques was tested via qualitative and quantitative measures in the snow and in the lab. It was found that using the new arrangement in a system resulted in no loss of performance or responsiveness to the user. Due to the design and manufacturing approach users have the ability to customise the design to their specific needs.

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1. Introduction

Snowboarding is a sport that has only been in existence for the last four decades and with that a variety of equipment has been developed, tested and embraced or discarded as technology and trends have evolved. Anecdotally with forums and discussion group there is much talk and conjecture around the boot to binding to snowboard interface and how that affects the user. This study begins to get a user perspective through survey and feedback about types of bindings that riders use and the effect on the foot and any resulting pain and injury that is caused by rider preferences and tendencies.
Background research has shown there are three main types of bindings with two essentially sharing a similar architecture being the Traditional and Fast–Entry the third style is of the Step-In function. The Step-In was quickly eliminated from the research as for the survey participants there was limited take up for this style.

![Figure 1 - a. Traditional Binding [1], b. Fast/Rear Entry Binding [2], c. Click / Step In Binding [3]](image)

Looking at how the binding interacts with the foot is interesting in the fact that if the binding set-up is not controlled it has the potential to cause pinch points around the ankle and also toes. This study chose to focus on the interaction of the bindings and not concern itself with sock / boot interface as the vast majority of riders surveyed have excellent riding experience. Figure 2 shows the interaction between the foot to boot to binding interfaces and how issues such as restricted blood flow can occur. This can be a cause of pain and numbness and a direct cause of loss of performance. For an average rider from our participant pool they snowboard an average of 10-25 days per year, this represents a significant amount of time being active with equipment strapped to their feet.

![Figure 2 - Foot to Boot to Binding to Snowboard Interface – author modified images from [4] and [5]](image)

2. Survey Results

A series of 15 questions (Appendix A) of both yes/no and short answer format where given to participants (Full question list in Appendix 1). In total 280 people responded from 15 different nations all of various abilities from people who snowboard several days a year to those who board 50+ days per year. This has allowed an insight into perceptions of snowboarders without being aligned to any brand. The results can be interrogated to see how many boarders use fine adjustment on high backs, to how much rotation they have on each foot in relation to each other.

It was identified through the survey that 67% of snowboarders use fine adjustments. Comments stated that the majority of surveyed snowboarders find fine adjustments on a snowboard binding are critical to getting a correct boot-to-binding fit. Fine adjustments include the ability to change high back position, high back angle, heel cup location, strap position, and foot position within the binding. Also identified was that 40% of participants are using binding angles (left to right foot angular displacement – parallel feet represent zero degrees) equal or greater than 30 degrees, it has been studied previously that this level of angular displacement can lead to knee injuries [6].
Table 1 - Participant response of riding style vs pain occurrence

<table>
<thead>
<tr>
<th>Riding Style vs Pain Location</th>
<th>Groomers</th>
<th>Powder</th>
<th>Kicker/Jump</th>
<th>Rails / Boxes</th>
<th>Half-Pipe</th>
<th>Backcountry</th>
<th>Racing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Arch/Sole</td>
<td>13</td>
<td>14</td>
<td>9</td>
<td>8</td>
<td>4</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Ball of Foot</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Calf</td>
<td>14</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Pressure Points</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Toes</td>
<td>7</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Top of Foot</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Overall / General Pain</td>
<td>18</td>
<td>17</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td>15</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 1 highlights some interesting responses all highlight in bold. The two conditions worthy of highlighting is the fact that groomers tend to have a higher response for pain and that overall / general pain seem to be common across half of the riding styles. Two things we can infer from this are that groomers tend to be the domain of beginner and lower skilled riders. Poor fitting gear, fatigue and muscle soreness will be common in this group. However the overall / general pain which is exhibited in riding styles that tends to be in the domain of more advanced rider categories such as backcountry and kickers/jumps.

Table 2 – Participant response of binding angle vs riding styles (participants may have answered more than once as set-up will change with respect to style)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Groomers</td>
<td>18</td>
<td>13</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>16</td>
<td>40</td>
<td>60</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Power / Off piste</td>
<td>13</td>
<td>9</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>36</td>
<td>52</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Kickers / Jumps</td>
<td>10</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>32</td>
<td>45</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Rails / Boxes</td>
<td>8</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>25</td>
<td>36</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Half Pipe</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>8</td>
<td>11</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Back Country</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>19</td>
<td>31</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Racing</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>9</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2 based on participant responses also provides some interesting insights into how people set-up their equipment. There is a huge bias to 23 – 33 degrees of duck angles with binding set-up and considering literature has stated that 30 degrees or greater can cause injury especially of the knee. This proportion of people who have quite large binding angular range is of concern especially when all instructors doing training courses are warned about these potential injury issues.

When specifically questioned if participants have had pain from bindings 31.7% responded to say yes, from that the common complaints were as follows:
- Top of foot/toe pain due to over tightened toe strap
- Foot cramping
- Ankle pain
- Pressure points
- Calf muscle pain

It can be inferred that incorrect binding setup can be a cause of over tightening, ankle and pressure point pain. It was a common response in the comments of the survey that participants would tighten the straps to increase responsiveness of the boot to binding to board interface.

3. Ankle kinetics and kinematics in snowboarding

Snowboarding relies on ankle movement and body weight transfer to provide direction and control. The fact that participants are experiencing a variety of pain responses suggests that the body is not working in conjunction with equipment. It has been found that ankle movement in snowboard boots and bindings are isolated to plantar flexion and dorsiflexion in which there is a
maximum of three degrees of rotation within these movements [7], then that is contrasted with another study [8] that suggest rotation up to 20 degrees. This is in contrast to the ankle’s maximum flexion of 50 degrees and dorsiflexion of 30 degrees.

In another study it has been found that snowboarders are prone to a higher rate of ankle injury compared to skiers, this is mainly due to the style of boots the boarders (soft boots) wear to skiers (hard boots), however the rate of injury does mimic that of when skiers used softer boots that were common pre 1980. Hyper-dorsiflexion and inversion are the most common injury mechanism [9, 10].

Looking at the kinematics of the motion generated by the body weight and control of the board through a turn both front and back side has an impact on the rider, as more force generated will increase the load through the foot to boot to binding interface. A study looking at the torque generated [11] it is entirely possibly for riders to generate over 500 N.m of loading through a front or back side turn under either flexion or dorsiflexion (Figure 3).

4. User Centric Design Response

In response to the survey a design thinking approach [12] was used to determine the best ways of overcoming the pain response a significant amount of the participants tend to perceive. The process focused on limiting toe and ankle strap placement to overcome the possibility of over tightening. This resulted in reducing the possibility of blood flow restriction, impacting pressure point and general foot pain as a function of improper strap tension.

With survey participants tightening binding straps to increase “responsiveness” the effect on the boot and foot would be to compress the fore foot to create an almost rigid body. Rethinking how a boot can be restrained within a binding the previous literature held few alternatives, but the rubber sole of a snowboard boot is almost a rigid member thus encapsulating it in the fore/aft and lateral directions would create a near rigid connection to the binding and thus the board. The angle strap would remain in a conventional position. It was found through experimental testing of the binding that once the bottom of the boot was restrained in an almost rigid fashion that the ankle strap was there as a secondary measure used to restrict vertical movement.
Figure 4a shows how the rigid encapsulation was generated via a BOA system steel cable that wrapped through the binding to the front slider section; this generated the necessary restraint without placing any undue force on the foot. Figure 4b displays the binding with a boot in-situ. The majority of the load will be transferred through the semi-rigid sole of the boot into the binding; the arrows display the main contact point, of the front toe encapsulation, the ankle strap and the heel being locked into the heel cup.

5. Additive manufacturing and final in-field testing

To get validation for the final design a process of additive manufacturing or 3D printing was used to produce a final series of prototypes. A Stratasys Objet500 Connex using “ABS-like” material was used; this material and poly jet printing technique produced the closest representation to an injection molded component. Using 3D printing also yield a secondary advantage with the fact that internal channels for the BOA system were easily integrated into the design, in reality these channels would be difficult and expensive to produce. A series of test fitments with a variety of boots were trialed. Since a “medium” set of prototype bindings were developed it did fit the vast majority of people on hand for final testing. The bindings managed to handle boot sizes ranging from US men’s 6 up to US men’s 11 with no degradation of performance. The binding were trailed on several downhill runs, kickers and groomers, which when referring to the participant survey makes a large proportion of the surveyed activities. The final advantage of using additive manufacturing for user centric development process is that design can be changed easily to suit the individual if needed.
6. Summary

This study has contributed to the field of snowboarding technology by looking at the interaction the boarder has with respect to the foot to boot to binding and finally to the snowboard. The levels of compliance that is possible between boots and bindings can lead to a decrease of performance and in the case of many survey participants and occurrence of pain. It was found that by introducing a design change in the binding architecture with the realignment of the toe strap to encapsulate the boot a more effective connection can be achieved through a semi-rigid interaction of the boot’s sole and binding.

Further to this the survey highlighted some disturbing trends that people will continue to ride through pain; this will restrict performance in the majority of cases. With the ability to create personalized equipment through concepts such as moldable insoles in shoes and also additive manufacturing of hardware there should be little reason why snowboarders will continue to have discomfort.

This study set out to achieve a design centric review of snowboarding habits with respect to bindings and to create a solution that will overcome certain aspects. The novel integration of the boot to binding interface with the production via additive manufacturing has contributed to the democratization of the product develop process with respect to sport technology.

Appendix A. Survey Questions

Question 1 – What is your age?
Question 2 – What is your sex?
Question 3 – How often do you go snowboarding per year?
Question 4 – What bindings do you currently use or what binding have you used on the past?
Question 5 – Do you use highback rotation on your bindings?
Question 6 – Do you use other fine adjustments? (strap length, heel cup, forward lean, gas pedal etc)
Question 7 – What are your stance/binding angles most commonly set at? (eg. Front: xx deg, rear xx deg)
Question 8 – Have you experienced any problems in the past with snowboard bindings? (broken parts etc)
Question 9 – Have you experienced pain caused from your bindings?
Question 10 – What type of snowboarding do you do?

• Groomers/Cruising
• Powder/Off-Piste
• Park (kicker/jumps)
• Park (rail/box/jib features)
• Half pipe
• Backcountry
• Racing

Question 11 – Have you snowboarded competitively?
Question 12 – How much would you be willing to spend on a pair of snowboard bindings?
Question 13 – Would you buy high performance/high-end snowboard bindings?
Question 14 – Do you wear protective gear while snowboarding e.g. helmet?
Question 15 – Do you integrate wearable technology into boarding experience e.g. run mapping, speed, time, vertical etc?
Question 16 – Do you see a place for wearable technology in snowboarding or do you think it’s a gimmick?

References