**ICE SCREW IMPROVEMENTS**

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**INTRODUCTION**

In the sport of ice climbing, ice screws are a crucial part of safe climbing. Ice screws provide a removable anchor system that allows the climber to attach their rope to the ice structure as they ascend.

**PROBLEM STATEMENT**

For the past 20 years, ice screw design has been largely unchanged. Ice climbing enthusiasts have mentioned that they would like to have some attributes of the ice screws improved upon within the current market. A survey of ice climbers through mountainproject.com showed that the major issues with the current design were placement speed and usable lifespan.

**DESIGN OBJECTIVES AND CONSTRAINTS**

**Objectives:**
- Decreased tooth wear by 10% compared to current market designs
- Placement is 25% faster than current market designs
- Torque required to set is not more than 5% greater than current market designs
- Design must be lighter than current market models

**Constraints:**
- Meet Union Internationale des Associations d’Alpinisme (UIAA) Safety Standard 151
  - In accordance with 2.2.2.1 of EN 568:2007 the ice screw must withstand a force at least 9kN in the radial direction without being pulled out of or breaking the ice.
  - At least one eye with a 15mm diameter for clipping
  - If another eye is included it must be 12mm in diameter
- Must be cost competitive (under $100 MSRP)
  - Similar manufacturing process to current market design

**DESIGN AND MANUFACTURING**

The redesigned ice screw features 12mm thread pitch and a double-threaded shaft. The doubled threads maintain driving and contact surface area while decreasing set time. As a result of the increased number of teeth, cutting force per tooth is decreased by decreasing the volume of ice removed per tooth. The ice screw is produced on a 4-axis CNC mill in a manufacturing process that is comparable to current production methods.

**Our Design**
- 6 cutting teeth
- 12 mm thread pitch
- Double-threaded
- Manufactured by a 4-axis CNC mill

**Current Market Design**
- 4 cutting teeth
- 6 mm thread pitch
- Single-threaded
- Manufactured by a 4-axis CNC lathe

**TESTING AND RESULTS**

**Tensile Testing**
Static radial pull test was conducted using Instron machine
- Ice Screw material bent but did not fail up to 14kN
- Wood was used as a medium
- Ice presented material limitations for lab testing

**Tooth Durability Testing**
Average season of ice climbing is 60 sets/screw
- Torque measurements taken with a new Black Diamond Express ice screw and with our prototype
- Torque measurements taken after 60 sets
- Measurements taken from a bar style inch-lb torque wrench

<table>
<thead>
<tr>
<th>Tooth Count</th>
<th>Number of Settings</th>
<th>Initial Torque [N·m]</th>
<th>Torque After Settings [N·m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our Design</td>
<td>6</td>
<td>1-3</td>
<td>1-3</td>
</tr>
<tr>
<td>Black Diamond Express</td>
<td>4</td>
<td>60</td>
<td>1-3</td>
</tr>
</tbody>
</table>

**Set Time Testing**
The set times for the ice screws were tested by using a hand drill in a low gear setting to produce a constant torque.
- 30 set times recorded
- Set a constant drill depth
- Torque held constant for each test

<table>
<thead>
<tr>
<th>Screw Length [cm]</th>
<th>Required Torque [N·m]</th>
<th>Average Drill Set Time [Sec]</th>
<th>STD of Set Time [Sec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our Design</td>
<td>8.5</td>
<td>1.3</td>
<td>1.381</td>
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<tr>
<td>Black Diamond Express</td>
<td>8.5</td>
<td>1-3</td>
<td>2.804</td>
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