A Flexible Crampon Design

By

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ABSTRACT

The design of crampons is studied and a new, more comfortable, flexible crampon design is proposed. A brief history of crampons is provided and then the current state of crampon design is discussed. Two major problems in modern crampons were identified. The first big problem was that the crampons are extremely hard to use and adjust especially in cold, wet conditions. The second problem was the comfort of the crampons on the hikers feet. While this issue may seem somewhat trivial, when hikers are on a multi-day expedition they need to keep their feet in the best possible condition. Therefore, a crampon design that makes use of larger safety straps operable by a person wearing gloves is proposed. The center of the crampon itself is flexible, being made from spring steel. This allows the crampon to flex with a hiker's foot, thereby improving walking comfort.

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1. Introduction

The development of cities throughout the course of history tends to be associated with the local geography of an area (www.historyguide.org). Most big cities formed near rivers because it was easy to travel on waterways to surrounding regions. Mountains and dry land has always proven challenging and oftentimes dangerous. This is especially true in cold weather areas where deep snows and subzero temperatures can cause trails to be slippery and sometimes impassible. The challenges of weather conditions lead to the development of different technology for crossing these types of terrains. Skis, snowshoes, crampons, and ice axes were all designed to aid human travel (www.grivel.com). Over the course of history the purpose of traversing such areas has changed; however the need for footwear that can safely aid people who find themselves on winter terrain remains the same.

This thesis will focus on one aspect of winter footwear: crampons. It will discuss the history of these devices, the current usage and current problems. A proposed design change is described to make crampons to be more comfortable and easier to use. The thesis concludes with a discussion of further technological changes.

2. Background

This section reviews the historical usage of crampons, evolution in their design and the materials used to construct them. It then describes the current market in crampons, covering both the need that mountaineers have for these devices and the list of what is available to climbers.

2.1 History

The earliest evidence of crampons appears on the Arch of Constantine, which was constructed in Rome in the first century AD (www.grivel.com). During that time they were called "*caligae, elevatae, seculatoriae*" which translates into "spy's shoes" (www.grivel.com). The design is shown in figure 1. This title describes their purpose, which was to allow spies to navigate safely over the treacherous terrain. The spies would need to travel off the major roads in order to approach cities without being noticed or forced to pass through checkpoints. These crampons were sandals with spikes on the bottom. These would have been only useful for slippery surfaces since they had no insulation.

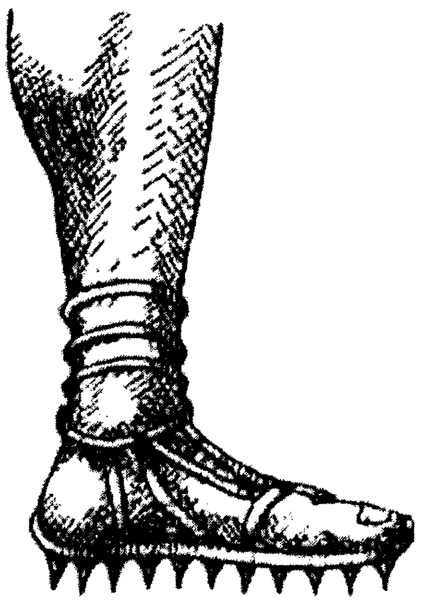

Figure 1: Roman Crampon [grivel.com]

In the late 1500's a more modern crampon design appeared. It consisted of a set of four spikes that could be slid over the front of a boot and then fastened with straps (www.grivel.com). They were worn mostly by woodsmen and hunters who traveled the mountains for livelihood. During this period mountains were regarded with fear and superstition as many people believed they had supernatural powers. After the Enlightenment these beliefs changed and people started looking towards mountains for their beauty and more leisure hiking.

The designs were further modified throughout the 19th Century. These changes

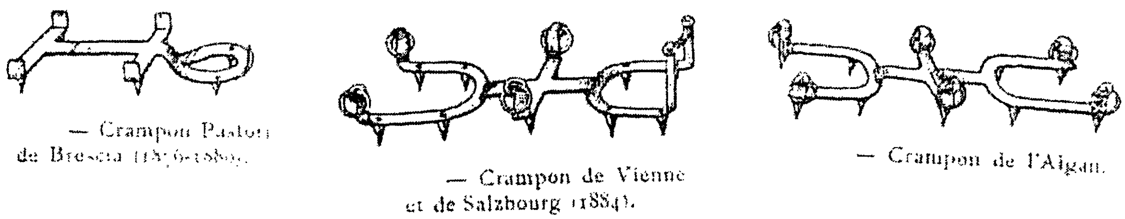

Figure 2: 19th Century Crampon Designs [www.grivle.com]

consisted of making stronger spikes and adding more, particularly under the heel. Several of these designs are depicted in figure 2. These crampons were designed for explorers who were climbing mountains for the first time and exploring unconquered areas of the globe.

2.2 Current Market Analysis

The crampons on the market today are on sale for sport climbing of various levels of danger and difficulty. The levels range from purely recreational mountain climbers who walk on icy trails and need increased traction all the way to the most serious mountaineers in the world who are climbing mountains such as Everest and K2. These climbers are constantly in danger of loosing their lives and depend on the crampon technology to keep them safe. This report will focus on crampons that are directed at recreational climbers. These crampons come in two types: strap-on and snap-on. The strap-on crampons can fit a wider variety of boots. The straps cause them to be harder to attach to the boot, and therefore harder to adjust on the mountainside. The snap-on crampons must specifically fit a type of boot because they attach to boots by applying pressure on the toe and heel, and in order to properly apply this cantilever pressure they must be sized properly (www.traditionalmountaineering.org).

Modern crampons have several areas that technology seeks to improve. A good crampon must easily attach to the boot, typically using a combination of straps and clamps. They also must be lightweight, typically around one kilogram, while being load bearing to allow for vertical ascents. The crampons must be strong enough to support the weight of the person on just the front points. This rigidity will allow a climber to dig into an ice surface and ascend it. The crampon material must also be able to withstand cold temperatures and exposure to water. Crampons are typically made from tempered stainless steel which is optimized for its strength and will resist water damage.

2.3 Field Testing

Field tests were performed to form an opinion on current crampon design. On Saturday, February 26, a test run of one set of crampons was conducted using a pair of Koflach double boots and a set of snap-on crampons. These were used on a 5 hour hike on the side of Mt. Washington, pictured in figure 3. The hike covered 2 trails on the side of the mountain. The first trail was the lower section of the Tuckerman's Ravine Trail (pictured in figure 3). The hike continued onto Lion's Head Trail. Due to the severe weather conditions the hike ended at the tree line near the top of the Lion's Head Trail. The first trail was extremely wide and well traveled. The snow on the trail was packed, with an inch or two of loose powder. The crampons worked well on this surface providing greatly increased traction over conventional boots. However, this trail was definitely not ideal for the crampons because they would slide in the loose powder. The second trail was much steeper becoming nearly vertical in several spots. Also, due to the increased altitude the snow was much drier and harder which improved the performance of the crampons as they anchored better into the harder, icier snow. The crampons also proved extremely useful in the vertical sections since it was possible to anchor them into the snow and the two toe spikes could support a climber's weight. They were also essential near the tree line when the wind picked up because they anchored the foot into the ground so well.

Figure 3: Mt. Washington from the Tuckerman Ravine Trail [photo by Nick Fahey]

This trip also made several problems with the crampons very apparent. On the side of the Lion's Head Trail one of the crampons fell off its boot. Its safety strap worked successfully and prevented the crampon from falling down the mountain, however the safety strap was extremely hard to deal with in the cold since its clasp was made from metal and so small that it required bare hands to fasten. The clasp was also frozen at this point. The major problem with the crampons was that they were uncomfortable. They are rigid so it does not allow the foot to flex normally. After several hours of hiking the crampons can cause the feet to be really sore. This indicated the need for a more flexible crampon with an improved fastening system.

3. Flexible Crampon Design

The idea of a flexible crampon design is relatively recent and presents several challenges. Crampons must be able to withstand the intense cold and exposure to water that they face being placed in snow and ice. They also must be lightweight so as not to tire climbers; however, they need to be strong enough to bear loads on vertical sections of climbs. Ease of use, especially in extremely cold and wind is also extremely important.

3.1 Design Description

This design seeks to make the crampon easier and more comfortable to use. In order to achieve this goal two areas of the crampon were focused on for improvement. The first was an improvement in the safety strap so that it would be easier to operate and would not require the user to remove their gloves when using this part of the equipment. The second area for improvement was the metal base. Allowing it to flex with the hikers foot would greatly improve the users comfort.

The most important part of making the crampons more easy to use, especially in cold conditions is making all the moving parts larger so that they can be easily handled by a person wearing gloves. This design uses a ratcheting mechanism on the safety strap, similar to the mechanism in a snowboard binding. This large lever should be easy to manipulate with gloves on and it also should be able to withstand the cold temperatures that the crampon will be exposed to.

Making the crampons comfortable is the more challenging design innovation. The solution to this is to make the crampons somehow flexible. The challenge is to do this while maintaining the rigidity of the crampon so that it can still support a climber. There are two main ways to go about gaining this flexibility, either build in a hinge or make the crampon from flexible material. The problem with putting a hinge in the crampon is that hinges are complicated and can easily jam. The other problem with hinges is that there needs to be a secondary system that can be activated and deactivated to allow the crampon to become rigid when it needs to be. Therefore, for the sake of simplicity this design uses a flexible material—tempered spring steel. This material is strong and durable, while possessing the necessary flexibility. The design, pictured in figure 4, shows the 3 part construction of this flexible crampon. The center part is made from the flexible spring steel while the remainder of the device is standard low carbon steel. In an actual production model this material would definitely be made from stainless steel so it would not rust, however, for the sake of prototype construction regular carbon steel, which is easier to work with, was selected.

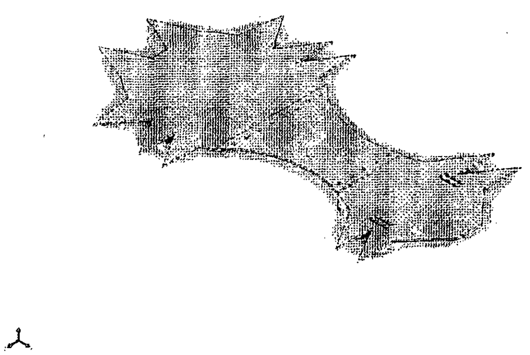

Figure 4: Flexible Crampon Base Design

Figure 5 shows the finished design, which includes the straps used to attaché the crampon to the hiking boot. The picture on the right of figure five demonstrates how the crampon

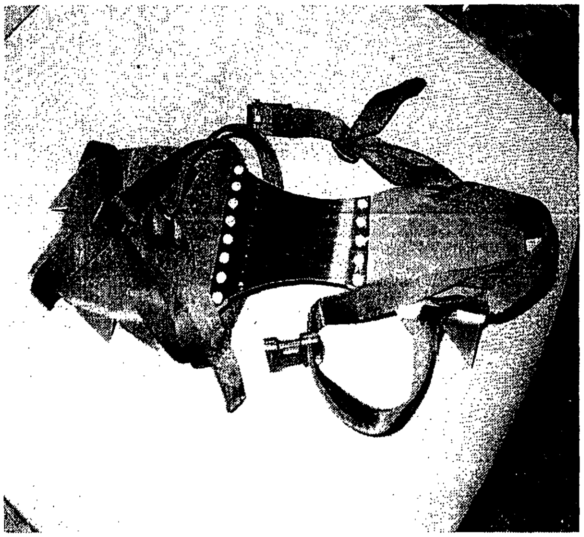

Figure 5: Photo of Crampon Prototype Alone (left) and Attached to Boot (Right)

can be connected to a boot. The three pieces of metal are connected by pop rivets, these are easy to use and durable. Welding the pieces together was also considered but after a test run it was found that welding made the spring steel too brittle. The steel easily snapped around the area that had been welded, this brittle fracture is depicted in figure 6. The light colored areas on the right of the metal are the parts made brittle by the weld.

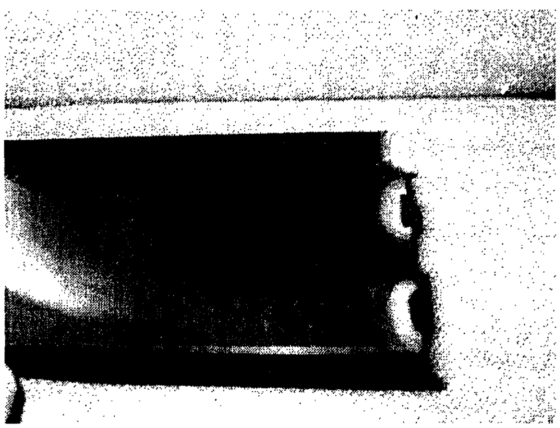

Figure 6: Photo of Brittle Spring Steel `

These fairly simple design modifications should make crampons easier and more comfortable to use. The change is simple enough so that it will not compromise the safety of a hiker.

3.2 Design Test

The design test of the flexible crampons demonstrated that it is possible to produce a crampon that can flex with a boot and stay attached to it. The design test consisted of light walking with the crampons across grass and dirt. This test was selected since there is no easy way to access the snow and ice conditions that these devices

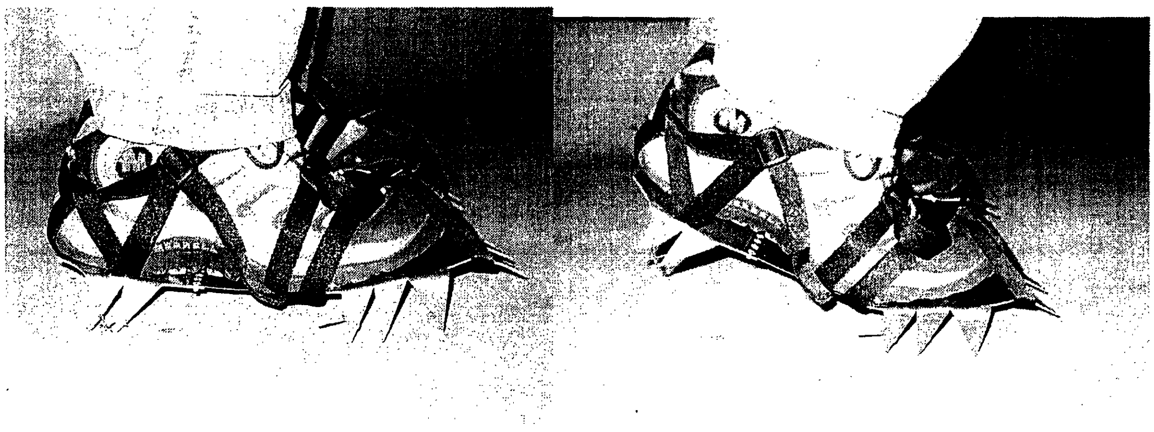

Figure 7: Flexible Crampon Test Standard (left) and Flexing (right) Position

will typically be used on. However, the point of the test was to check the comfort of walking in them and make sure the attachment points held the crampons in place. Figure 7 depicts the crampons attached to boots and shows them flexing. The design test probed that the flexing was extremely successful. The heel plate stayed attached to the heel of boot while the front plate remained planted. As the picture on the right of figure 7 shows most of the flexing in the steel takes place near the front plate. In future models the spring steel should be placed closer to the front of the crampon to allow it to flex even better. Another interesting property of this design is that the front plate, with the front spikes, is extremely rigid, and is able to support the weight of a hiker. This means that even in vertical areas the flexible crampon will still offer the same performance as a typical rigid crampon.

3.3 Future Thoughts for Second Model

The design test also showed some drawbacks in the design. The biggest problem observed was that the steel was not nearly strong enough. Several of the points on the crampons bent during tests. This proves, as was previously thought, that a hardened steel is necessary. Rust also quickly forms on the typical carbon steel, therefore, a future design should be made from stainless steel. The straps were generally easy to use; however, if they were held in place with some rigid rubber or plastic bases, they would have less of a tendency to get tangled on the boots or the crampon spikes themselves. Future designs should also use improved geometry in the spikes. Future spikes should be slightly bent so that the shape increases their strength, future spikes also do not need a complete plate, removing the metal in the center of the toe and heel plate will significantly reduce weight without altering performance. Several other improvements should be considered.

The flexible crampon design proposed in this paper can still be substantially improved. The biggest other area of improvement would probably be the material side of the design. A thorough analysis of the current materials and their heat treatment could provide insight into possible changes in this area. Especially with newer alloys becoming available, it seems possible that creating a lighter yet sturdier and more durable crampon will be possible in the future.

Some crampons have the ability to snap into a snowshoe, which can be purchased as a package. This feature is extremely useful, especially for people who do a lot of hiking on trails that are not frequently used, where loose, unpacked powder is common. The ability to snap into a snowshoe allows the climber to change from wearing their snowshoes to their crampons with a minimal amount of difficulty. If the climber buys these two items separately then he must take the snowshoes off and then put the crampons on, where as if they are part of a system the snowshoes simply need to be unclipped.

4. Conclusion

Crampons have been around for thousands of years. Invented for Roman spies who wanted to travel away from the major highways, improved by woodsman and hunters in the 1500's, they became a staple of the modern explorer and mountaineer in the 19^{th} and 20^{th} Centuries. Despite their age, crampons still appear to have a number of flaws. The modern crampon is difficult to adjust during a hike, especially in cold conditions. It is also uncomfortable. These two facts detract from it safety, a quality which is paramount to the success of a crampon. Solving the usability issues is the easier problem. These pitfalls can be avoided by making the adjustment points larger and making the safety strap with a ratcheting lock that is similar to a snowboard binding. This will allow for adjustments to be made to the crampon without the removal of the climber's gloves. Making the crampon more comfortable is extremely difficult. Comfort can be dramatically improved by making the crampon flex with the boot, however, it is extremely important that the crampon remain rigid enough to support the weight of a climber. The two ways to provide flexibility in a crampon are putting a hinge in the crampon or making the crampon from a flexible material. Since hinges tend to be complicated and made from a lot of moving parts, this design avoided them in favor of using flexible material and a secondary support that could be added or removed at will. Therefore this design uses spring steel in the middle of the crampon to allow it to flex with the boot. The design test demonstrated that the proposed design worked. The crampons flexed with the boot and improved the comfort of the system. The straps also did a good job holding the crampons to the boots. Although this design makes some improvements on previous ones there are still several ways to improve it. The materials that the crampon is made from can undoubtedly be improved in favor of lighter, stronger, more durable materials. The crampon can also be built to better mate with other climbing gear such as snowshoes, which will allow the climber to more easy adapt to the surrounding environment.

5. References

http://coin-pomme.chez.tiscali.fr/RANDO/crampons.gif. May 5, 2005.

http://www.grivel.com/Storia/Storia_Det.asp?Cat=R. May 5, 2005.

Selters, Andy. *Ways to the Sky: A Historical Guide to North American Mountaineering.* The American Alpine Club Press: Golden, Colorado, 2004.

http://www.talisman-activities.co.uk/winter/images/crampons.jpg. May 5, 2005.

http://www.traditionalmountaineering.org/Photos_Crampons_sm.htm. May 5, 2005.

I would also like to think Professor David Wallace, for his advice on the design and construction of the flexible crampons, Mike Bromberg, an avid hiker who gave me advice on current problems with crampons, and the Pappalardo Laboratory Staff who helped me fabricate the prototype.

6.0 Appendices

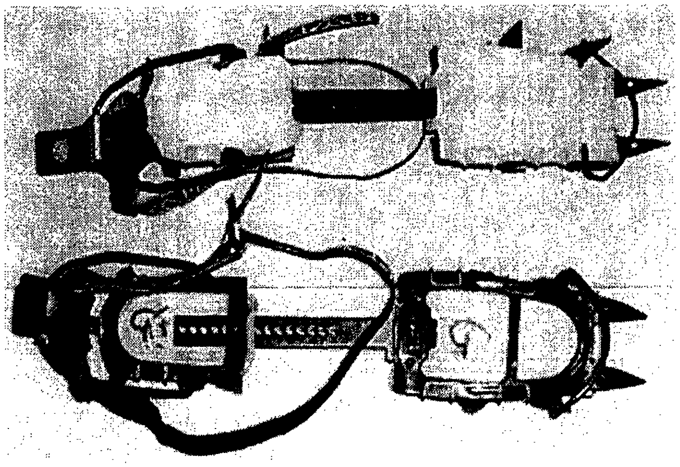

Figure A1: Typical Modern Crampon (http://coin-pomme.chez.tiscali.fr/RANDO/crampons.gif)

Figure A2: A climber wearing crampons (http://www.talisman-activities.co.uk/winter/images/crampons.jpg)