Failure Angle and Distance of Climbing Camming Devices

Mech 306 Lab Section L2B Team # 35
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Abstract

The objective of our proposed experiment is to determine the maximum holding capacity of a spring-loaded camming device inserted into an obtuse-angled rock fracture as a function of the crack angle. To test this, we intend to build a frame that has incremental inserts from 90º to 100º that can be placed on a tension testing machine. We will then apply loading up to failure of the hold or maximum rated holding capacity. With the gathered data from our trials, we will be able to determine the failure load for the cam as a function of the angle.

Introduction

In outdoor rock climbing, climbers use protection equipment (just referred to as "protection") to secure their rope to the rock faces. A climber places a piece of protection in a natural formation on the rock, clips their rope to the protection, and then they continue to climb above it. If the climber were to fall, their fall is arrested by the protection they have placed.

One of the most common forms of protection is a spring-loaded camming device, or "cam" for short. Cams come in a variety of different sizes and shapes, and they are typically placed in cracks or other parallel features. A climber puts his life in the hands of these devices. It is extremely rare for a crack to have ideal geometry for maximum cam strength, therefore the purpose of this experiment is to determine the reliability of a cam in features of varying geometry. Readers who have passion in rock climbing would be interested in our work since this experiment provides some knowledge of effective cam placements.

The camming device we are using in this experiment comes from Black Diamond, which is a very popular outdoor equipment brand, and we refer to its user manual for the cam technical specifications.

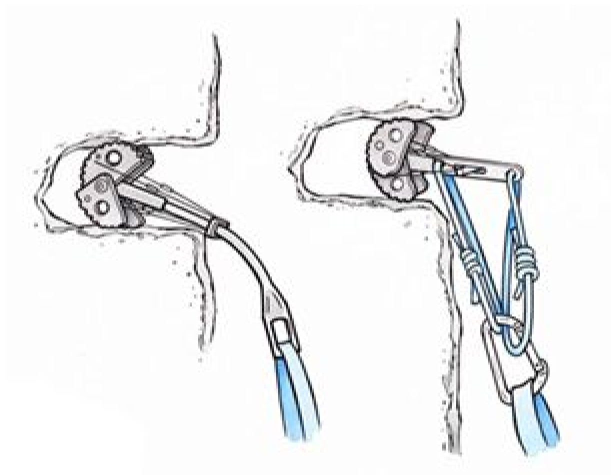


Figure 1 - Camming Device Working Mechanism

Experimental Objectives

Generally placing gear in a flaring (widening in the outwards direction) crack is avoided due to the high risk of protection failure. However, it is sometimes unavoidable and this situation is the basis for this experiment. The experimental objective of this capstone experiment is to find the effect of crack angle on the effective cam holding capacity. The angle *b (see Figure 2 below)* of the crack would be incremented between 0 and 10 degrees. The static load *T* would be increased until the cam releases from the crack, or a maximum load of 11kN is reached. The true dynamic load of our cam is around 12kN and we can achieve this load with the tension testing machine available in Kaiser.

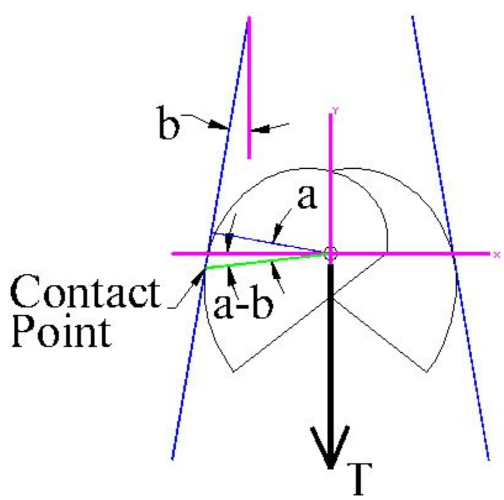


Figure 2 - Diagram of Camming Device Operation

Proposed Methods

Measured Quantities

We will need to measure two quantities for our experiment.

- The crack angle in degrees. This is easily measured to a high precision by a vernier bevel protractor, available in the machine shop.
- The maximum load force in Newtons. We haven't interacted with the tension testing machine yet, but the machine is equipped with a software program to measure the applied load. This will likely be sufficient for our purposes.

Experimental Apparatus and Test Matrix

To test the different loading forces, we would create a jig that can vary opening angle. While varying the angle, we attach the cam to the jig and load it with an increasing static load until the cam fails (releases from crack), or the force limit is reached. This will be done using the large tension testing machine located in the Kaiser building. For validity of our testing apparatus, we will consult Markus Fengler and the machinists; their experience in assembling testing apparatus may lead to design changes for efficiency and strength. For preliminary design drawings, please see Appendix A. The current design features a steel box with a 90º angled insert. To conduct several tests, multiple inserts will need to be manufactured with increased angles; however, the major design features will be unchanged.

In extreme cases, the maximum load on a climbing anchor (the cam in this case) during a lead fall has the potential to be larger than 10kN. The cam itself is rated to a load strength of 14kN (loaded in a parallel crack), therefore we intend to set an upper load limit on our experiment of 11kN, to avoiding damaging the cam.

Preliminary testing has shown that the cam immediately releases from the crack for angles exceeding 10 degrees, therefore that is our current limit for the experiment. More experimentation will be conducted to refine the necessary capabilities of our jig.

Proposed Analysis

While the execution of our experiment will be difficult, the analysis should be relatively simple and any trend in the data should be easily observed. The goal is to identify and define the relationship between cam strength and crack angle, and the most simple way to do this will be to analyse a data plot between the two.

While we predict that the relationship will be linear due to the simple nature of the experiment, we do not currently have any data indicating that this is the case. By separating our data into two sets, interpolation set and verification set, we can make better approximation of what type of function the plot is. Multiple functions, S(**θ**), can be derived from interpolation set, where S is cam holding capacity (maximum load) of a certain cam crack angle in N, and **θ** is the corresponding angle. This function should be interpolated for theoretical verification set values, and compared against measured verification set values. This method should provide not only the most accurate function, but also a measure of how accurate it is compared to other methods of deriving the function.

Potential Risks

There is a significant risk of our jig being unable to support the necessary loads. The cam pushes outwards against the crack walls with a large enough normal force to create a friction force that can support the load. This means the jig will likely need to handle 3-5x the given load force. With a maximum load of 11kN, the jig will need to be very strong. The strength of the testing line used to secure the cam will also need to be sufficient to support the 11kN testing load.

Another potential source of error in the experiment is wear on the jig and cam caused by many tests. This could be minimized by having the active jig surface be removable, so it can be replaced when worn.

After talking to Dr. Schajer, we found that the best way to proceed is by making preliminary measurements. While setting up for those, more issues are going to appear and our experimental method can be adjusted to correct those issues. By processing our data as we collect it, we can identify possible systematic error caused by the above mentioned sources and adjust accordingly.

Potential Opportunities

We have a few ideas to expand our acquired dataset, but these may not be attainable given our timeframe and budget.

- Due to their high cost, we only intend to test one size of cam. More data could be acquired by using different cam sizes, or different brands of cams.
- Climbing is popular on a variety of different rock types. We intend to use a granite surface for our experiment here because granite is common in our local area, but testing other common rock types like sandstone, basalt, and limestone could expand our dataset as well.
- Another consideration could be the environmental conditions. Temperature, and surface condition have an impact on friction. For example, a wet surface could be tested.

Schedule

We would take the originally scheduled Mech 305 lab time or Thursday break between classes to discuss specific plans and conduct experiment. There are a few major tasks that we need to finish within a certain time frame before we are ready to submit capstone report:

March 5 - March 8: Design CAD model of a jig that change the crack angle where the camming device is placed. Discuss in details about the magnitude of applied load in this experiment. Finish abstract, introduction and method part of our report.

March 11 - March 20: Source parts from local supplier and manufacture parts in MECH machine shop. Assemble camming device and jig to check if our design is ready for load test.

March 21- March 29: Mount our device to the tension testing machine in Kaiser to collect data under different load for a series of angles. Ideally, conduct three test sessions and modify the design reflecting the problems in the previous test. Begin report content and record data and observations in report format.

April 1 - April 5: Analyze the testing result using relevant knowledge we learn in Mech 306 lectures, tutorials, and labs. Finish the remaining part of the capstone report, revise draft sections, and submit.

Conclusion

In conclusion, we propose this capstone topic due to the need for objective, external evaluation of spring-loaded camming device. The team will evaluated the relationship between crack angle and cam strength. The main time investment in this project will be gathering and manufacturing the testing apparatus, while analysis would be relatively straight forward. While there are potential risks, such as apparatus failure due to high, repeated load, there are many potential opportunities to expand on the project as well.

References

Cam Manual

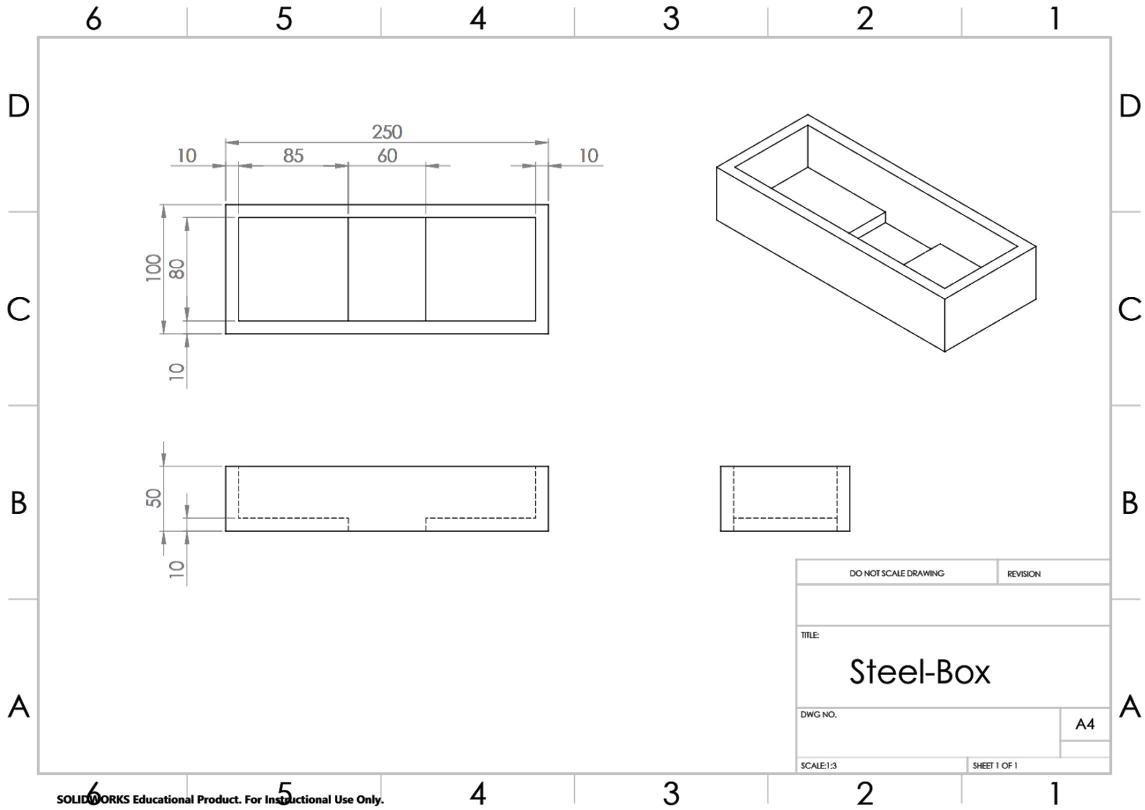
https://www.blackdiamondequipment.com/on/demandware.static/-/Sites-bdel/default/dw4ed898ac/instructions/F16/MM5865_F_Camalot_IS-WEB.pdf?fbclid=IwAR3MxpknFenUtpViUMAHB3GEv_DCmtT6nbK3cGxZHfgylS6zT1YZcA8Clnk

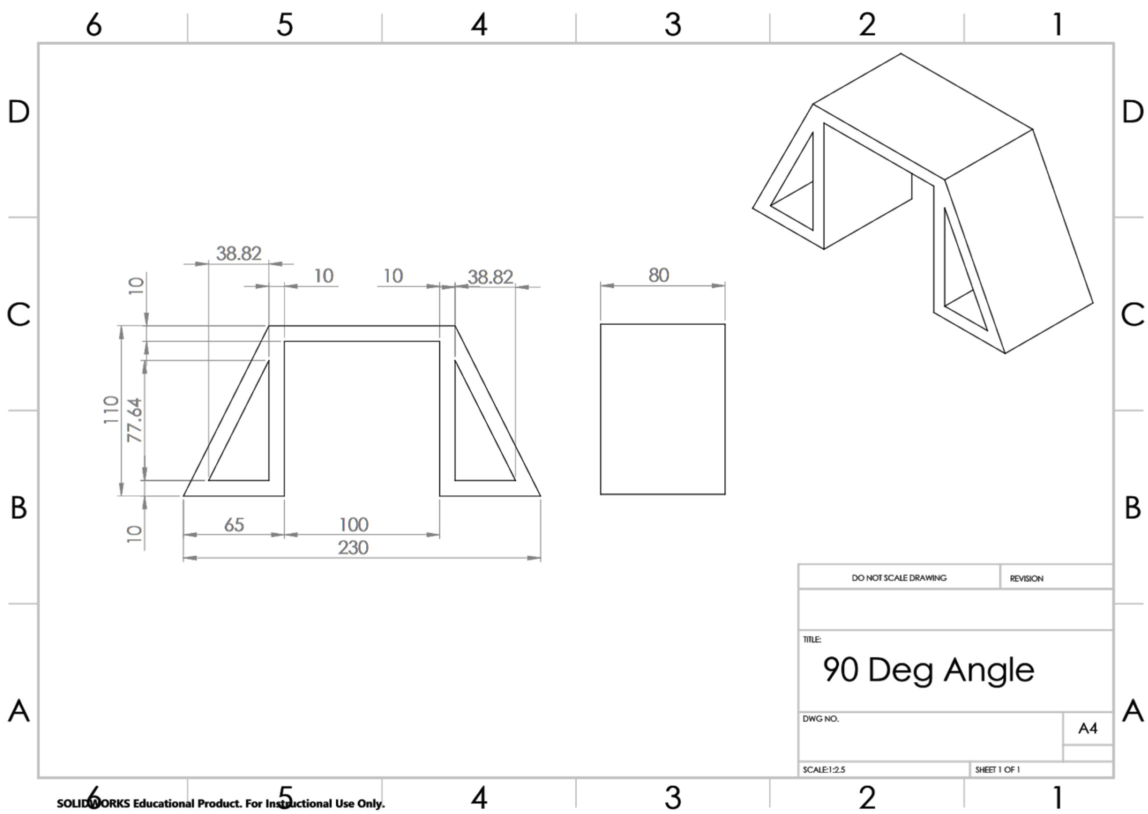
Image Sources

http://thetravelingnaturalist.com/resources/cam%20placement.jpg

http://www.vainokodas.com/climbing/spir2.gif

Appendix A: Preliminary Design Drawings





Appendix B: Bill of Materials

Material	Quantity	Measure
1cm Thick Steel Sheet	1	Sq. m
Camming Device	1	Each
Nylon Climbing Rope	1	Each