ICE-MICROTOME DESIGN FOR PROCUREMENT AND CRYSTAL ANALYSIS OF ICE THIN SECTIONS

Steve Bruneau, Ashley Sullivan, Zetian Zhang, and Bruce Colborne
Faculty of Engineering and Applied Science
Memorial University of Newfoundland
St. John's, Canada

ABSTRACT

In this paper, a novel device called an ice-microtome is introduced to be used to produce thin sections of ice for the study of internal structure. The ice-microtome provides an easy and precise procurement of ice thin sections, thus making the further analysis more efficient and accurate. Important features of this device include a scissor-lift mechanism, oblique blade design and low cost. This device has been fabricated and tested, showing a great functionality and portability.

INTRODUCTION

Analysis of ice thin sections is a frequently used method for examining the internal structure of ice. Within the STePS^2 research program at Memorial University the ice in question is used in laboratory investigations of high energy collisions between marine ice and steel structures. The study aims to develop validated practical tools that will permit the safe design and assessment of ships and offshore structures for arctic conditions [1]. Ice thin sections are acquired from the ice samples in damaged and undamaged zones to be examined in terms of their crystal structure to investigate properties such as crystal orientation, size and overall size distribution.

Thin Section Analysis

Once ice thin sections have been prepared, a set of two polarizers is used to acquire images of the sections. Two polarizing filters are arranged perpendicular to each other, with a light source installed underneath the lower polarizer. A polarizing filter only allows light waves of the same orientation to pass through, which means two perpendicularly positioned filters block visual light waves completely.

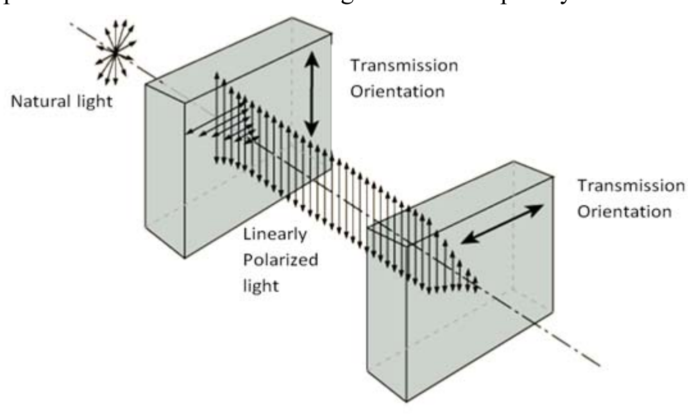

Figure 1: Perpendicular Polarizing Filters Blocks Visual Light [2]

As can be seen in Figure 1, the light source goes through the first polarizer and becomes linearly polarized light, which is totally blocked by the perpendicularly arranged second polarizer.

When an ice thin section is placed between the two polarizers, the polarized light is refracted to multiple directions due to the different orientations of individual ice crystals in the ice sheet. This technique reveals the otherwise transparent and indistinguishable crystal morphology.

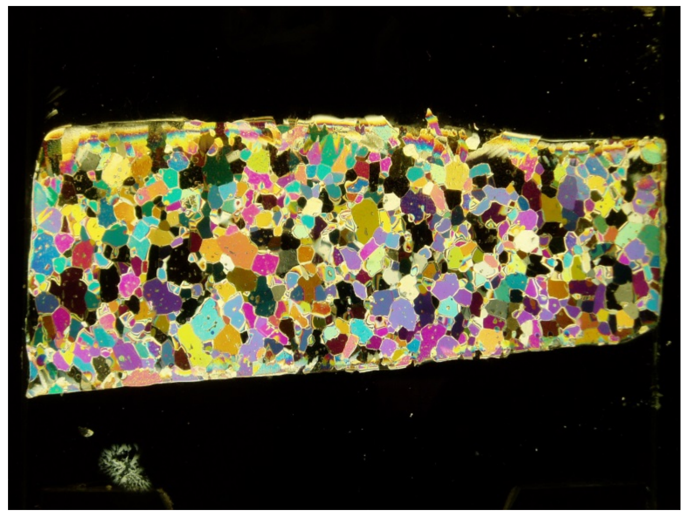

Figure 2: Polarized Ice Crystal Morphology [3]

Ice Crystal Counter

Once the pictures of polarized ice thin sections are obtained, a program may be used to analyze the images, one such is called Ice Crystal Counter. This program retrieves the number, density and average area of crystals in the section, it also levels the image horizontally and overlays a 1cm2 grid on the image. While much is automated, many manual adjustment options are available to ensure the accuracy of the processing of each unique thin section image [4].

Thin Section Preparation and Rationale for Microtome

In the STePS^2 program crushed or uncrushed large scale (1m) ice samples are retrieved from an aluminum frame holder with the use of heating belts. The sample is then cut into large chunks with an electric chainsaw. These chunks are further cut into 6-10mm thick sections with the use of a typical woodworking bandsaw. These thick sections are finally trimmed to produce a relatively flat sample featuring the ice region under consideration. Ice samples are then mounted to a glass slide (approx. 100x150mm) by placing the flat ice surface onto a cold glass slide, applying pressure and then dropping small water droplets with a pipette on the perimeter of the section.

Previously, ice thin sections (0.5-1.5mm) were then procured by slowly melting down the thick ice specimen via manually rubbing the surface with a thick, warm aluminum plate [5]. However, this method needed improvement since melting creates a non-uniform surface of ice and a blurring of ice crystals. Thus, a new procedure of shaving ice thick sections with a microtome was introduced, which overcomes the flaws and tedium of the melting procedure.

IMPORTANT FEATURES

Scissor-Lift Microtome Design

The microtome design is based on a scissor-lift platform, which is moved vertically by a mechanism with the issue of linked, folding supports in an "X" pattern (scissor mechanism). The upward motion is achieved by applying pressure to the outside of the lowest set of supports, elongating the crossing pattern, and propelling the platform vertically. The contraction of the scissor action is mechanical via a lead-screw. This design achieves the desired action by a ½"-10, left-handed Acme platform nut coupled with a ½"-10, left-handed Acme threaded rod. This rod is controlled by a crank handle located on the back of the device and is secured by flange bearings on each end that allow the rod to rotate.

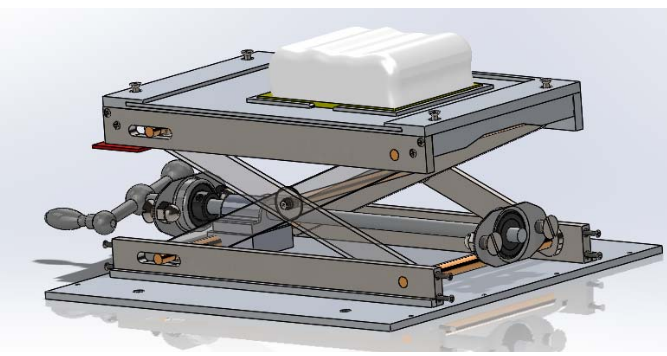

Figure 3: Isolated View of Scissor Lift Mechanism

Ease of Use

To minimize accidental impact of the shaving assembly with the main frame, rubber stops are located on the contacting points.

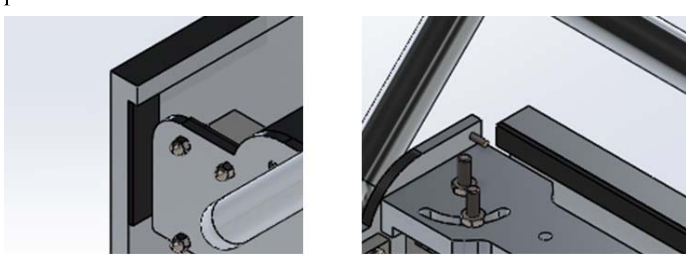

Figure 4: Rubber Stops

The shaving assembly is designed to ride along 3/4" diameter hardened shafts with four pillow block linear bearings that give a smooth and fast slide.

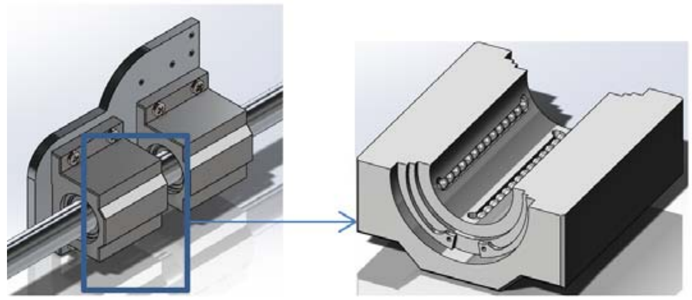

Figure 5: Pillow Block Bearing Mechanism

Footprint

Overall, the design was developed to have a small footprint allowing for ease of portability and use in confined locations. This type of device is normally used in a cold room environment where space is usually limited. The device was designed to be compact, having a footprint of 15"x14"x7.25".

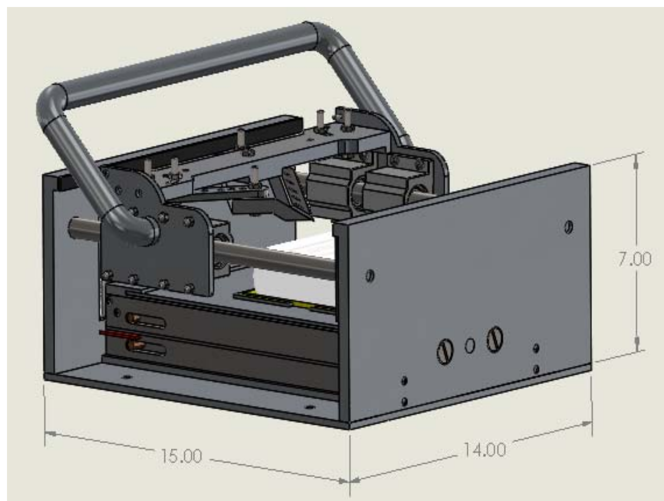

Figure 6: Footprint of the Microtome

PERFORMANCE EXPERIMENTS

Adjustable Blade Design for Experimental Purpose

In order to get the best performance of ice shaving, an experimental design with adjustable blade was made to determine the ideal geometry of blade that will create the smoothest surface of ice. The adjustable blade design gives a great control on yaw angle of the blade in order to study how the oblique angle affects the cutting performance. When talking about other parameters that affect cutting performance, the rake angle, Gunay et al. [6] have discovered that main cutting force has an increasing trend with the increasing in feed rate and a decreasing trend as the rake angle increase.

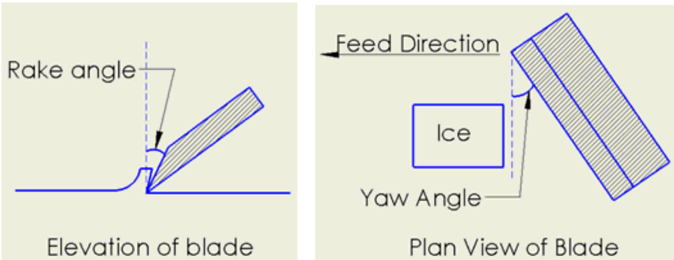

Figure 7: Rake Angle and Yaw Angle

With different yaw angle and rake angle of the blade, the different fluency on cutting and different smoothness of the shaved surface can be achieved. With the design shown in Figure 8, the blade can be adjusted from perpendicular to 45 degrees to the travel direction, with 6 choices of angle. The middle supporting bar provides the main driving and supporting force to the knife, while the two side arms fix the knife in the desired angle. The blade being used on this device has a tip angle of 30^{0} and the aluminum plate that supports the blade needs a minimum 20^{0} angle to provide the strength. As a result, the rake angle of blade was fixed to 40^{0} for this device.

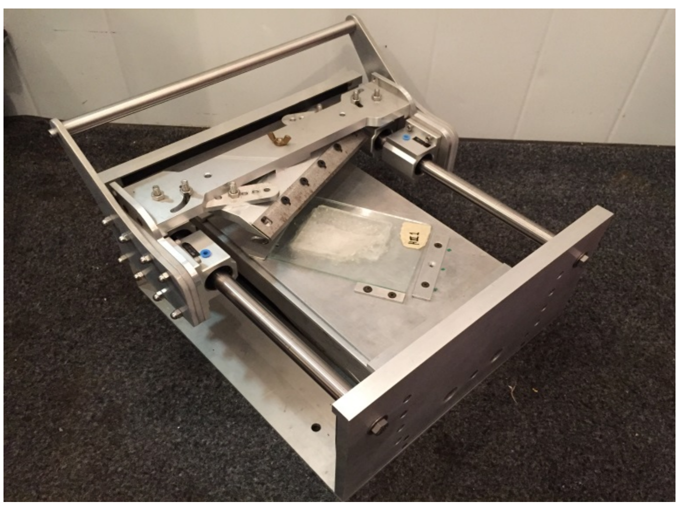

Figure 8: Adjustable Blade Design for Experimental Purpose

Expectations of the Experiment

A. Moufki et al. [7] have discovered that with an increase trend in the yaw angle, the lateral force will increase while the cutting force and thrust force will decrease, resulting in easier shaving. It was predicted that the bigger the yaw angle, the more fluent the shaving performance will be, and thus the smoother the ice surface will appear.

Experimental Settings

A set of experiments were conducted to test the performance of the microtome, based on the fluency of cutting and smoothness of shaved ice surface.

The blade yaw angle was set to be 0°, 22.5°, 30°, 37.5° and 45° to perform the shaving procedure in a cooler with $-7^{\circ}C$ air temperature. A camera was used to record the shaving process and take pictures of the shaved surface. The fluency of cutting was determined based on the personnel's feeling and the video recorded. One other way to determine the fluency of shaving was by looking at the ripples formed parallel to the cutting edge on the ice surface due to intermittent shaving motion caused by the friction force and chatter.

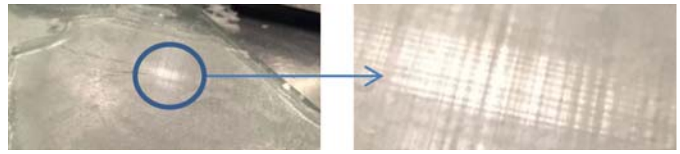

Figure 9: Ripples Developed Due to the Friction and Chatter

Experimental Results

Table 1: Experimental Results

	Fluency of shaving	Space between Ripples (parallel to cutting edge)
Orthogonal	Intermittent	0.0565 inch
22.5°	Fluent	0.0705 inch
30°	Fluent	0.0703 inch
37.5°	Fluent	0.0698 inch
45°	Fluent	0.0762 inch

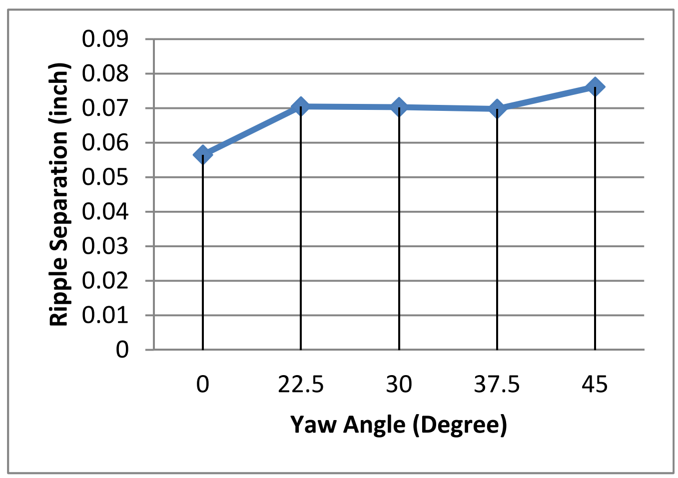

Figure 10: Ripple Separation Distance vs Yaw Angle

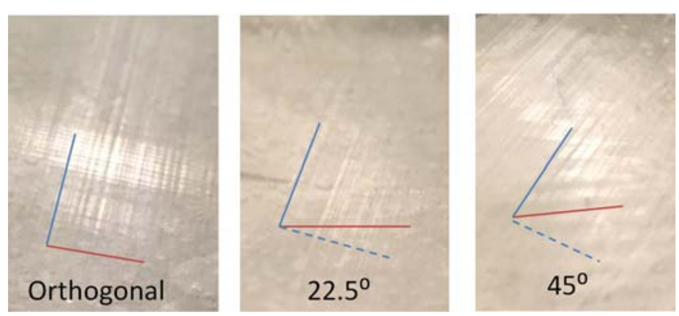

Figure 11: Comparison of Ripples Formed by Intermittent Shaving with Different Yaw Angles (Red Lines)

Comments

The experimental results agreed somehow with the expected results. There was an obvious difference between orthogonal shaving (yaw = 0) and oblique shaving (yaw ≠ 0), nevertheless the degree of yaw angle did not make a noticeable change to the performance. There were two kinds of ripples appeared on the shaved surface of ice, one parallel to the traveling direction while another parallel to the cutting edge. The ripples parallel to traveling direction were caused by the bur on the blade edge, which can be minimized by sharpening the blade. The ripples parallel to the cutting edge were formed by the intermittent motion of shaving due to friction and chatter. When the blade is inclined at an angle to the traveling direction, the shaving process became much more fluent than orthogonal shaving, and the ripples parallel to cutting edge were reduced.

Final Design with Fixed Blade Angle

Based on the experimental results, a final design with fixed yaw angle was made. The yaw angle of blade was designed to be 22.5^0 and the rake angle is 40^0, which resulted in good travel range, fluent shaving performance and a smooth ice surface.

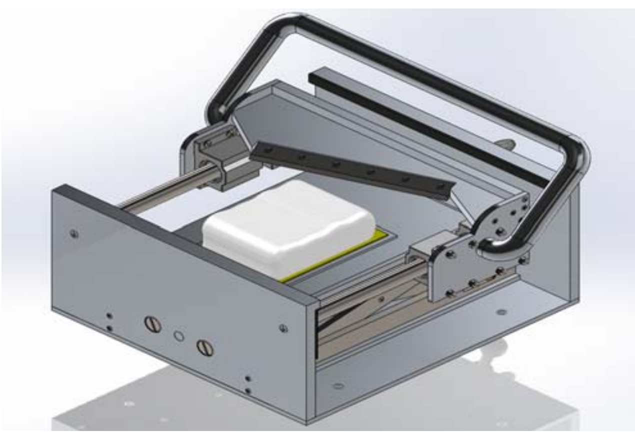

Figure 12: Final Design with Fixed Blade Yaw Angle

Cost

This device is mainly made from 6061 Aluminum alloy, which is widely used in the industry applications for its low density, corrosion resistance and low price. The blade is a commercially available blade (DW7332), which is originally used in a wood cutting device with great sharpness and hardness. The cost of the whole device is below $2000, which is very budget friendly, comparing to the commercially available microtomes that are around $10,000.

Safety Considerations

Working with microtomes, whether preparing or cutting a sample, is an acquired skill. Hands-on training is required from trained personnel before using a microtome. Because of the associated hazards, safety must be incorporated into every step of the process to keep fingers and hands protected. The blade is covered with a blade cover when not being used. Long handled brushes should be used when cleaning the device to avoid accident injure to the personnel.

CONCLUSIONS

In this paper, the entire procedure of ice thin section procurement and analysis has been introduced. The device that involved in the procurement process of ice called ice-microtome is designed and manufactured to shave ice samples into thin sections that is 0.5~1.5 mm thick. Several experiments have been carried on to test the performance of this microtome, based on the fluency of cutting and smoothness of shaved surface. The results of the experiments led to a final design of the microtome that has a 22.5-degree blade yaw angle and 40-degree rake angle. It was observed that the ice-microtome is a capable and inexpensive device to be used in ice thin section analysis procedure.

ACKNOWLEDGEMENTS

This research has been done under STePS2 project and was supported by: ABS, Atlantic Canada Opportunities Agency, BMT Fleet Technology, Husky Oil Operations Ltd, Research and Development Council, Newfoundland and Labrador and Samsung Heavy Industries.

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