HOKKAIDO UNIVERSITY

Title	Rupture and Vibrations of Sea Ice Sheets
Author(s)	ISHIDA, Tamotsu
Citation	Physics of Snow and Ice : proceedings, 1(1), 551-556
Issue Date	1967
Doc URL	http://hdl.handle.net/2115/20324
Type	bulletin (article)
Note	International Conference on Low Temperature Science. I. Conference on Physics of Snow and Ice, II. Conference on Cryobiology. (August, 14-19, 1966, Sapporo, Japan)
File Information	1_p551-556.pdf

Instructions for use

Hokkaido University Collection of Scholarly and Academic Papers : HUSCAP

Rupture and Vibrations of Sea Ice Sheets*,**

Tamotsu ISHIDA
石 田 完
The Institute of Low Temperature Science
Hokkaido University, Sapporo, Japan

Abstract

The flexural strength of sea ice *in situ* was measured by the key-method. When a cantilever of sea ice beam about 25 cm thick deflected and broke by flexural loading, vibrations of the sea ice sheet occurred. These vibrations seemed to be in correspondence with the internal cracking of the ice during flexural loading. From the information yielded the relation between the flexural strength and the increasing rate of stress at the surface of the joint of the ice beam was clarified.

I. Introduction

A solid substance usually breaks with a cracking sound. The characteristic of the sound depends on the shape and size, and also the material itself. Therefore, an analysis of the sound or the vibration with rupture may be a key to the explanation of the mechanical structure of the substance.

We have been measuring the flexural strength of sea ice *in situ* by the key-method at Mombetsu harbour on the Okhotsk Sea coast of Hokkaido, for several years. In this experiment the vibration of a sea ice sheet was also observed when a cantilever of a sea ice beam deflected and broke. In particular, micro-vibrations at the joint of the ice beam which occurred while the ice beam was deflecting by flexural loading, were possibly related to the internal cracking of the ice during flexural loading as observed by Gold (1960). The principal objectives of this experiment were to clarify the relation between these vibrations and the flexural strength of sea ice.

II. Experimental Procedures

The entire experimental system is illustrated in Fig. 1. Sea ice test beams were made of a sea ice sheet by sawing. The thickness of the beam h was about 21 to 29 cm and was approximately equal to the thickness of the sea ice sheet. The width of the beam b was about 30 to 46 cm and the length l was about 120 to 200 cm. Forty test beams having different dimensions within the above range were used. The average ice temperature was about -2°C. The bending force F was manually applied upward or downward to the free end of the beam and recorded with an oscillograph by the use of an electric load cell and a strain amplifier. The load rate was varied from 0.1 to 30

* Contribution No. 779 from the Institute of Low Temperature Science.
** Research Report No. 2 from Sea Ice Research Laboratory, the Institute of Low Temperature Science.

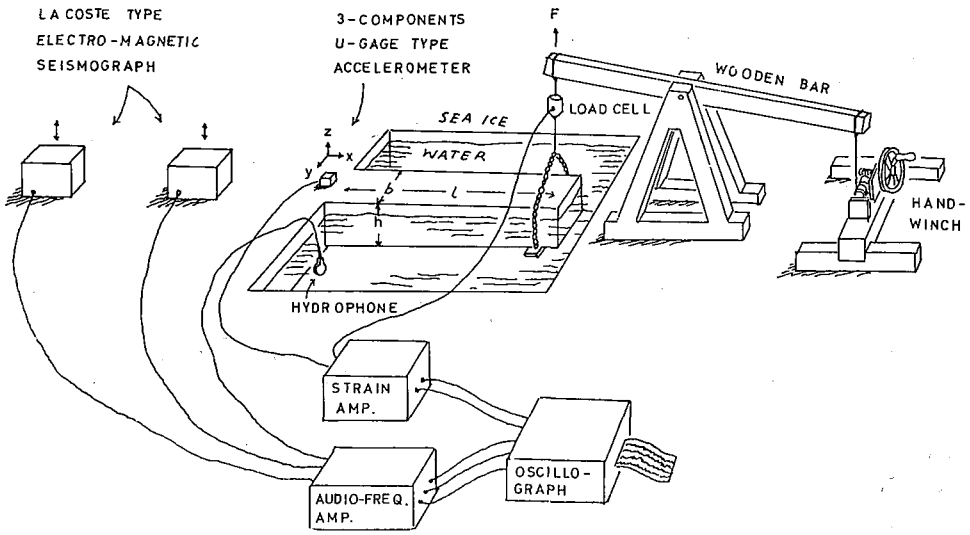

Fig. 1. Sketch of experimental system

kg/cm²·s in increasing the rate of the maximum stress $\dot{\sigma}_x$ at the surface of the joint of the beam, where σ_x was given by

$$\sigma_x = \frac{6Fl}{bh^2} .$$

Micro-vibrations corresponding to the internal cracking of sea ice were detected in x, y, and z directions by three U-gage type accelerometers placed at the joint of the beam. A hydrophone was also used as an auxiliary detector of cracking. The output of the accelerometers and the hydrophone were recorded with the oscillograph through each amplifier.

III. Micro-Vibrations Followed by Internal Cracking of Sea Ice

An example of micro-vibrations detected during a load test is shown in Fig. 2. In this case the applied force increased almost linearly and the beam broke when the force reached appoximately 66 kg after 4.2 s from the start of the bending run. As can be seen in this figure, each component of the vibration which seemed to be raised by one internal cracking, took the form of a wave pack which damped oscillation of about 70 to 80 c/s continued for about 40 ms maximum. Accordingly, the composition of the x, y and z components of the maximum amplitude of the wave pack was taken as the magnitude of the vibration corresponding to the power of internal cracking of ice. The total magnitude of the vibration which occurred until each beam broke down by loading, decreased as the load rate increased, as shown in Fig. 3. Next, Fig. 4 shows the number of cases in which the vibration occurred until each beam broke down by loading. It was small at a load rate above 1 kg/cm²·s, but increased steeply at a load rate less than 1 kg/cm²·s.

On the basis of these experimental facts shown in Figs. 3 and 4, it was concluded

that at a low load rate less than about 1 kg/cm²·s many cracks occurred until a beam broke down and the effective thickness of a beam became small as a result, thus, the

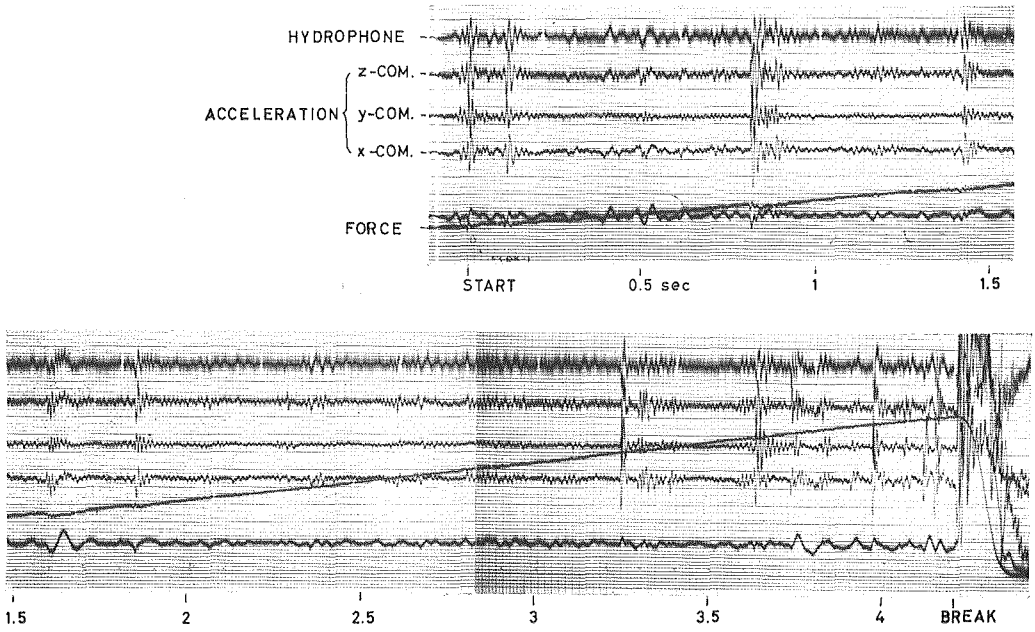

Fig. 2. Record of underwater sound, acceleration of ice, and applied force

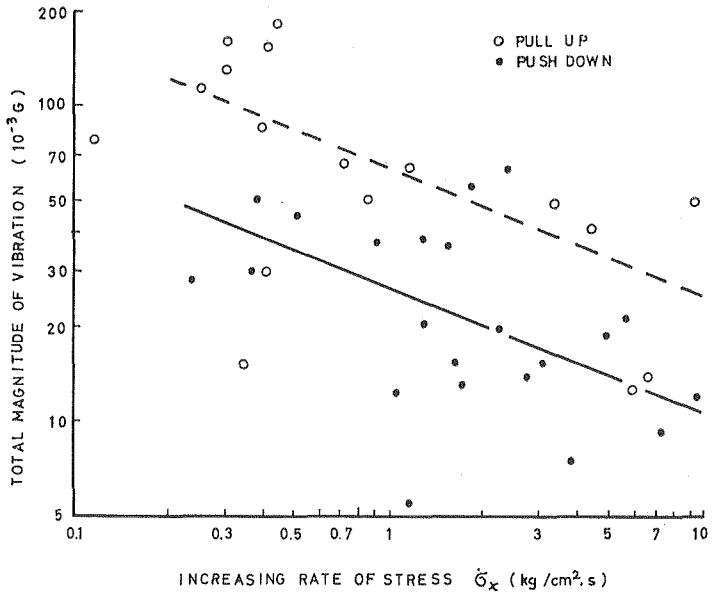

Fig. 3. Total magnitude of vibration versus increasing rate of stress

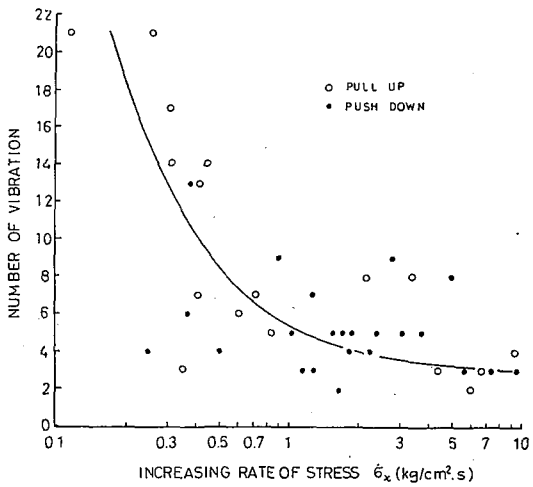

Fig. 4. Number of vibration occurence versus increasing rate of stress

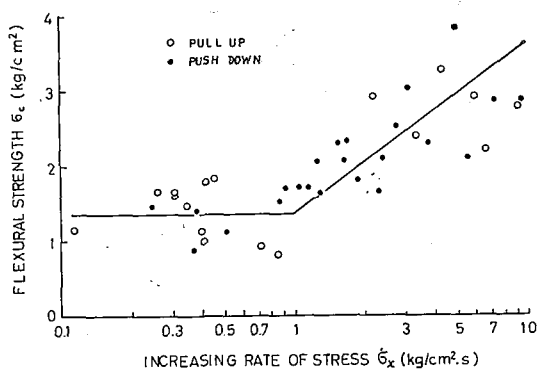

Fig. 5. Flexural strength versus increasing rate of stress

flexural strength observed finally was small in this case; while, at a high load rate above 1 kg/cm²·s the occurrence of cracking was limited and the effective thickness of the beam hardly ever changed, thus, a greater flexural strength was finally observed as compared to the former case. In fact, the relation between the observed flexural strength of a beam and the increasing rate of the maximum stress at the surface of the joint of the beam showed the tendency mentioned above, as can be seen in Fig. 5 (Tabata *et al.*, 1967).

It seems that the load rate of 1 kg/cm²·s is a threshold value for flexural strength and that the appearance of cracking varies according to the direction of the applied force as seen in Fig. 3. From this fact vibration phenomena were divided into four cases according to the method of the applied force, which are given as follows:

Direction	Load rate	
	Quick (>1 kg/cm²·s)	Slow (<1 kg/cm²·s)
Upward	Q-U (6)	S-U (11)
Downward	Q-D (18)	S-D (5)

Figure 6 shows the relation between the stress at the joint of a beam σ_x and number of occurrences of vibration n, during flexural loading, where n is given by the quotient

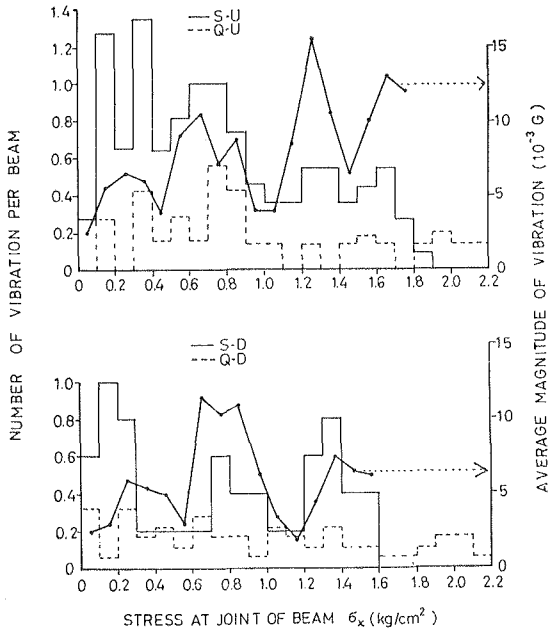

Fig. 6. Number of vibration per beam and average magnitude of vibration versus stress at the joint of beam

of the total number of occurrences in the interval of 100 g/cm^2 in stress, divided by the number of beams tested (the number in parentheses in the above table). For instance, if $n=0.5$ at $\sigma_x=1.0$, it shows that vibrations occurred in half the beams tested, when the stress at the joint of each beam reached to a value between 0.9 and 1.0 kg/cm^2 by flexural loading. In both cases of Q–U and Q–D in this figure, the number of vibrations per beam was small. Therefore, the patterns of occurrence of vibration were not very reliable. While, in the cases of S–U and S–D the number of vibrations per beam was relatively great in the three following stress ranges: around 0.3, 0.7 and 1.3kg/cm^2. The average magnitude of vibration in these cases also took high values in the same stress ranges. It may be understood from this result that cracks were apt to occur in the sea ice tested when the stress at the joint of the beam reached about 0.3, 0.7 and 1.3 kg/cm^2 in the process of increasing the bending force.

The sea ice tested consisted of snow-ice in the upper part, granular ice of relatively

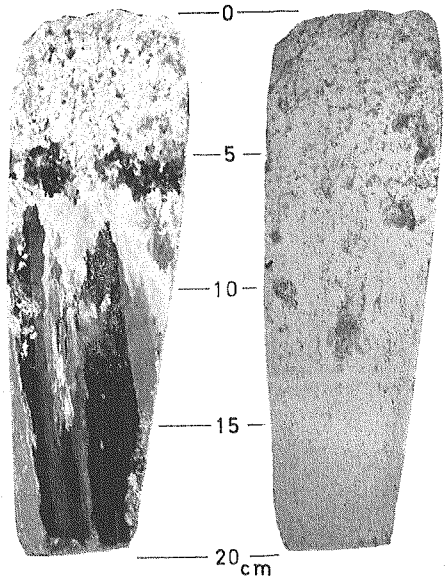

Fig. 7. Vertical thin section of sea ice in crossed polarized light (left) and in ordinary light (right)

large grain in the middle part, and typical sea ice mosaic structure in the lower part, as can be seen in its vertical thin section (Fig. 7). Such a structure of ice was not directly connected with the result shown in Fig. 6, because the load test was not individually conducted with a sample of each part. However, it is probable that patterns of occurrence of vibration followed by cracking of sea ice must be derived from its structure.

References

1) GOLD, L. W. 1960 The cracking activity in ice during creep. *Canad. J. Phys.*, **38**, 1137–1148.

2) TABATA, T., FUJINO, K. and AOTA, M. 1967 Studies of the mechanical properties of sea ice. XI. The flexural strength of sea ice *in situ*. *In* Physics of Snow and Ice, Part 1 (H. ÔURA, *ed.*), Inst. Low Temp. Sci., Sapporo, 539–550.