14th IAHR Symposium on Ice

Calculation of the Size of the Iceberg Struck by the Oil tanker Overseas Ohio

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ABSTRACT: The collision between the oil tanker Overseas Ohio and an iceberg in Prince William Sound, Alaska, in January 1994 provides us with information that can be used to predict the damage caused by collisions of this type. This paper is concerned with determining the size of the iceberg that was involved in the collision. Simple order of magnitude arguments result in estimates of a mass of about 7500 tons, while simulations of the collision using a deforming finite element technique show that the actual mass is closer to around 4000 tons. These iceberg masses are well within the range of sizes found in recent surveys of Prince William Sound. These simulations provide the means to develop an accurate risk assessment to tanker traffic when combined with detailed surveys of iceberg drift in the Sound.

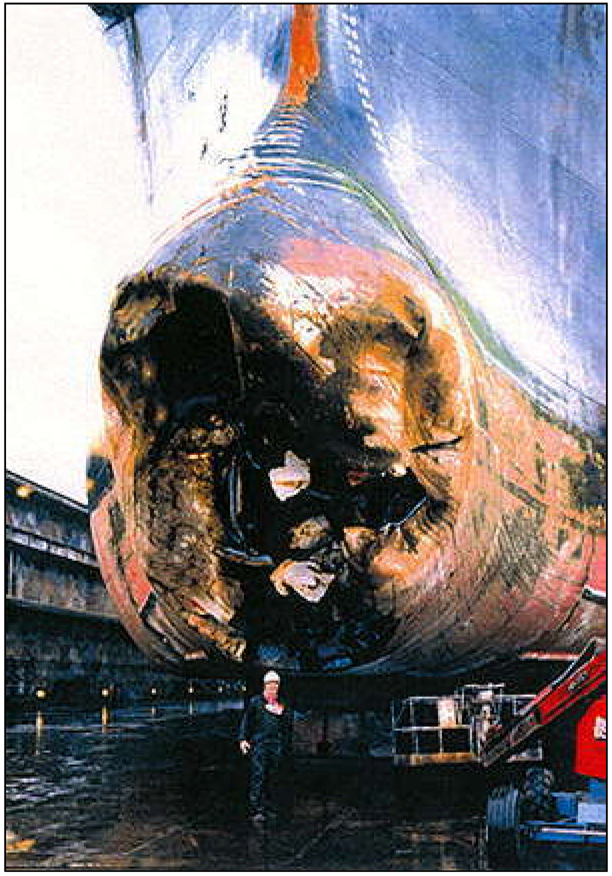
Click here to see photos of the Overseas Ohio after colliding with an iceberg

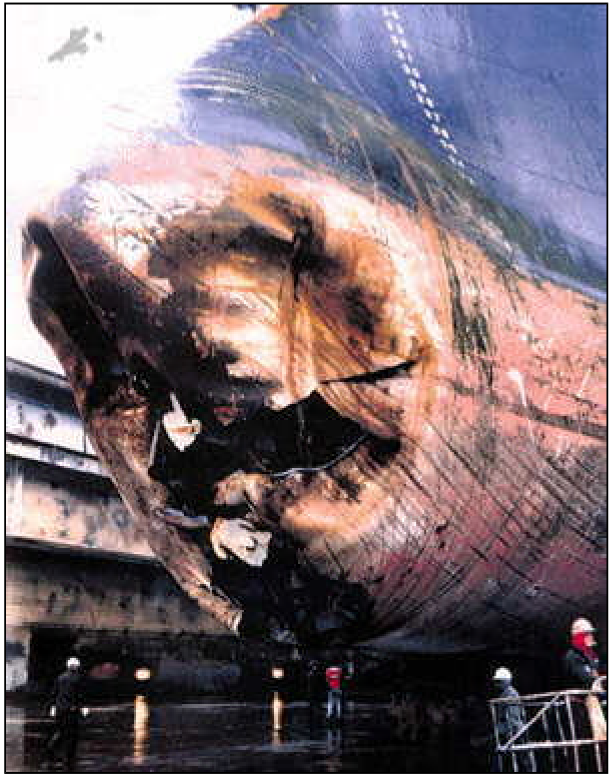
1. INTRODUCTION

Each year in Prince William Sound, Alaska, thousands of icebergs calve from Columbia Glacier and enter the shipping lanes used by hundreds of oil tankers. Icebergs have been a navigational hazard in Prince William Sound since the drastic retreat of Columbia Glacier began in 1980, and will continue to be a threat for several decades. One tanker/iceberg collision has occurred, and it is our goal to use information from this collision to study the relationship between iceberg size, ship speed and the resulting damage to the ship.

On January 2, 1994, at 0520 hours, the inbound oil tanker Overseas Ohio collided with an iceberg in Prince William Sound. The tanker was loaded only with 220,000 bbls of ballast water, but was severely damaged and needed extensive repairs before it could be returned to service. The iceberg was one of thousands that calve each day from Columbia Glacier, which is located 25 kilometers north of the shipping lanes where the collision occurred. Currently the annual maximum calving rate of this glacier is about 100 tons per second. Determining the mass

Overseas Ohio photos after collision with an iceberg





Photos of the oil tanker Overseas Ohio after colliding with an in iceberg in Prince William Sound, Alaska - January 2, 1994. Also see related paper - Calculation of the Size of the Iceberg Struck by the Oil Tanker Overseas Ohio.

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of this iceberg is important for a risk assessment for oil tankers and other shipping in Prince William Sound and other Alaskan waters.

The tanker weighed a little under 100,000 metric tons and was moving at 5 m/s (10 knots), therefore had a momentum of 5 108 m kg s1. It is assumed that within one second after the collision, an area of approximately 36 m^2 of the bulbous bow of the tanker had been deflected 2 meters, the iceberg was accelerated to the speed of the tanker, and the tanker's speed had been reduced by a small but unknown amount (the tanker crew barely noticed the impact). The deformation of the steel bow and the acceleration of the iceberg are thought to be the main factors in calculating the iceberg's mass, although because of its great momentum, even a minute reduction in the tanker's speed after the collision may be significant. A number of large rocks were found in the damaged section of the tanker, indicating that the iceberg came from the glacier bed. These icebergs pose an even greater hazard to navigation in Prince William Sound because they are nearly submerged and extremely difficult to detect visually.

The bulbous bow of the tanker is constructed of 20 mm (0.76") steel plate, welded to 50 mm crossbeams with 610 mm (24 inch) spacing. Its shape can be approximated by an 11 m diameter hemisphere.

2. ORDER OF MAGNITUDE ESTIMATE

In order to get a rough estimate of the iceberg size, we can solve the conservation equations for the collision, with some simplifying assumptions. The conservation approach is useful both for gaining some insight into the physics of the collision and obtaining a starting point for the numerical simulations.

The assumptions applied here are that the collision is entirely plastic (inelastic) so that the ship and the iceberg have the same speed after the collision. The energy absorbed by the collision is assumed to be

$$E_{def} = F_{def}\, d$$

where F_{def} is the force of the iceberg on the ship during the collision (assumed constant), and d is the distance that the bow of the ship is deformed. Then the conservation of momentum and energy equations are:

$$v_{ship,i}\, m_{ship} = (m_{ship} + m_{ice})v_f \qquad (1)$$

$$1/2\, m_s v^2_{ship,i} = 1/2\, (m_{ship,i} + m_{ice})v^2_f + F_{def}\, d \qquad (2)$$

We use the very simplistic assumption that the deforming force F_{def} is the product of the shearing yield strength of steel (? $_{yield}$ = 9.98 x 10^7 N/m^s) and the shearing area is A_s = ? Dt where D = 6.75 is the diameter of the deformed region and t = 0.02m is the thickness of the steel plating. For the moment we ignore the crossbeam supports for this calculation. With these assumptions we get v_f = 4.54 m/s and m_{ice} = 7.38 x 10^7 kg = 8400 tons, or about 1/10 the weight of the ship.

Because of the highly simplistic assumptions made in this calculation, we do not expect this to be an accurate value for the weight of the iceberg. However, this number lies within the range of frequently observed iceberg sizes in Prince William Sound [1]. Also, the small mass of the iceberg relative to the ship is consistent to observations by crew members that they felt almost nothing on impact. A more accurate size determination is presented in the next section.

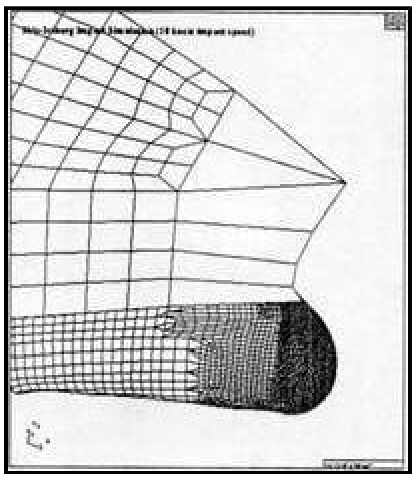


Figure 1: Finite Element model of the ship Overseas Ohio

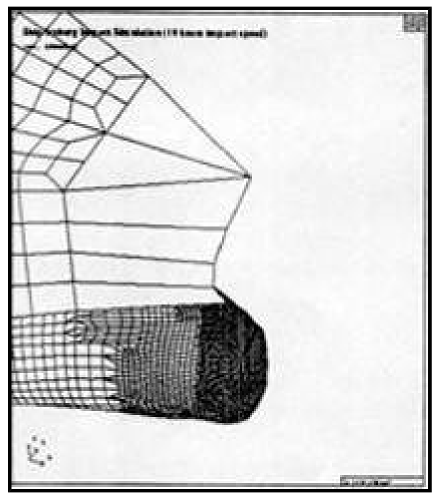


Figure 2: Damage resulting from a simulated collision with a ship speed of 10 knots and iceberg weight of 900 tons.

3. FINITE ELEMENT MODEL AND NUMERICAL SIMULATION

The finite element model of the ship, shown in Figure 1, consists of 5,258 shell elements, 1928 solid elements and 204 beam elements. The frontal lower nose portion of the ship, where the impact takes place, was modeled by shell elements with shell thickness of 0.75 inches. The internal structural support was modeled using beam elements. The rest of the ship was modeled using solid elements. The iceberg was modeled as a solid cube. The weight of ship is 75,000 tons and the iceberg weight is varied from 900 to 8000 tons. The model and its finite element meshes were generated using PATRAN. The impact simulations were conducted using LSDYNA3D [2][3], a nonlinear finite element code. This code has been used extensively at the National Crash Center at George Washington University in the simulation of automobile crashes [4] [5][6]. The BelytshcaTsai Shell element was used with stiffness hourglass control. Five integration points were used throughout the thickness. Constantstress solid elements were used for all solid elements.

The impact speed used in the simulation was 10 knots (5 m/s) constant speed for the ship, and the iceberg is initially at rest. The iceberg was placed symmetrically in front of the ship nose section. The total simulation time is 320 ms and the simulation was conducted on SGI PowerChallange SMP Machine with 54 min of CPU time using 2 processors. Figures 2 shows the result of the collision with an iceberg with a weight of 900 tons. The deflection in this case is 1.64 m and the diameter of the damaged area is 3.4 m, which is smaller than the actual values of 2 m and 6.75 m. Figures 35 show the bow deformations for 2000,4000 and 8000 ton icebergs. As expected, the size of the deformed region increases with iceberg size. Figure 6 shows the bow deflection as a function of iceberg size and indicates that an iceberg with a weight of 4000 tons most closely matches the 2 m deflection that resulted from the Overseas Ohio collision.

4. DISCUSSION

The results of the preceding section show that finite element simulation can be used to obtain an estimate of the iceberg size, and the results are consistent with a simple order of magnitude estimate obtained from the conservation equations. These initial results do not include some physical effects that may effect the results, including fracturing of the iceberg (which would tend to lessen the damage to the ship) and icebergs of different shapes. Further, there is some uncertainty over the exact speed of the Overseas Ohio at the time of the collision. A lower speed, for example, would require a larger iceberg to result in the same level of damage.

Our conclusion that the Overseas Ohio struck a 4000 ton iceberg needs to be related to conditions in Prince William Sound. Recent work by the Iceberg Monitoring Project (Tangborn and Post [1]) has resulted in a detailed survey of iceberg sizes found in the tanker shipping lanes. A 4000 ton iceberg would have an approximate top surface area of 252 m 2 if its shape were cubic. The survey results indicate that there were 490 (7.1 percent) of this size in Prince William Sound on September 15, 1997. The likelihood of striking an iceberg in this range is therefore relatively small on any particular day.

This work on simulating ship/iceberg collisions is still in the early stages. Future work will include a wide range of ship speeds and iceberg sizes. We will use these results to make an assessment of the level of damage, and likelihood of oil spills resulting from iceberg collisions. This work will be done in conjunction with ongoing studies of iceberg drift models and predictions of iceberg concentrations in Prince William Sound.

We will also expand these simulations to include a wider range of ice populations. Relatively small pieces of ice, called growlers, can also impart significant damage to ship hulls. Crocker and Cammaert [7] carried out a study of growler populations off the east coast of Canada. Simulations of collisions with so-called growlers will also be carried out to determine the likelihood of damage occurring where populations are significant.

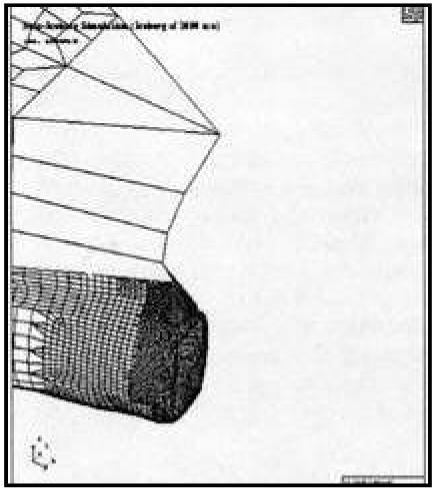


Figure 3: Damage resulting from a simulated collision with ship speed of 10 knots and iceberg weight of 2000 tons.

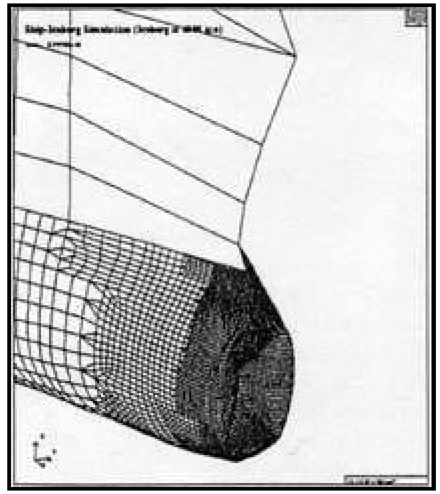
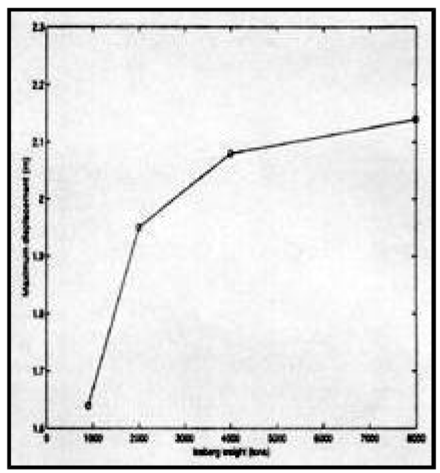


Figure 4: Damage resulting from a simulated collision with ship speed of 10 knots and iceberg weight of 4000 tons.



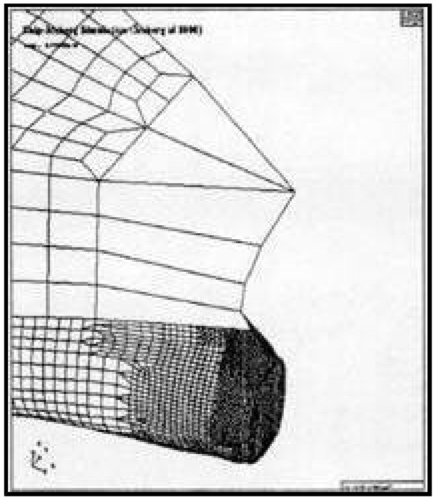


Figure 5: Damage resulting from a simulated collision with ship speed of 10 knots and iceberg weight of 8000 tons.

Figure 6: Maximum bow displacement vs. iceberg weight.

5. CONCLUSIONS

A determination of the mass of the iceberg struck by the tanker Overseas Ohio by two different methods produced similar results. A conservation of momentum and energy approach 7500 tons, and a finite element method gave 4000 tons. Both methods used the deformation of the ships bulbous bow as a measure of the energy dissipated by the collision. The risk of another collision of this severity appears to be minimal because the frequency of icebergs with a mass this great in these waters is low. In addition, this iceberg was the less frequently occurring "dirty" type. However, these preliminary results suggest that much smaller icebergs, which are more numerous can still inflict significant damage to steelhulled tankers.

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