Welcome to Vibrationdata

Acoustics • Shock • Vibration • Signal Processing **September 2005 Newsletter**

Greetings

We are saddened to hear of the tragic loss of life resulting from Hurricane Katrina which struck New Orleans and the gulf coast of Mississippi.

The catastrophe brings to mind the verse:

Each man's death diminishes me,
For I am involved in mankind.
Therefore, send not to know
For whom the bell tolls,
It tolls for thee.

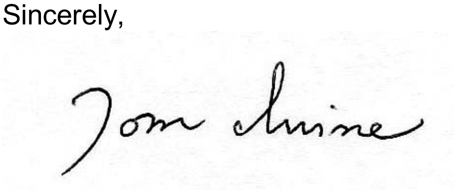
- John Donne (1573-1631)

Please donate generously to relief agencies.

This month's newsletter has an article about Rogue waves, written before the hurricane struck.

The other article describes Tibetan Singing Bowls, used in Buddhist meditation.

Sincerely,



Tom Irvine
Email: tomirvine@aol.com

Feature Articles

Tibetan Singing Bowls

By Tom Irvine

Figure 1. Singing Bowl

Introduction

Tibetan Buddhists have used singing bowls as a meditation instrument for many centuries. The origin of these bowls can be traced to the shamanic Bon Po culture of the Himalayas, pre-dating Buddhism. Hindus and other cultures in the region have also used these musical bowls.

The bowls are struck with a mallet or rubbed around the rim to produce a blend of reverberant tones. The audible tones may last 20 seconds or more. The mechanical vibration lasts even longer. The bowl is essentially an inverted bell.

Tibetan singing bowls are traditionally constructed of a metal alloy, said to include gold, silver, copper, iron, lead, tin, and mercury.

The metals represent the Sun and planets as follows:

Gold	= Sun
Silver	= Moon
Mercury	= Mercury
Copper	= Venus
Iron	= Mars
Tin	= Jupiter
Lead	= Saturn

Waterfall FFT – Singing Bowl

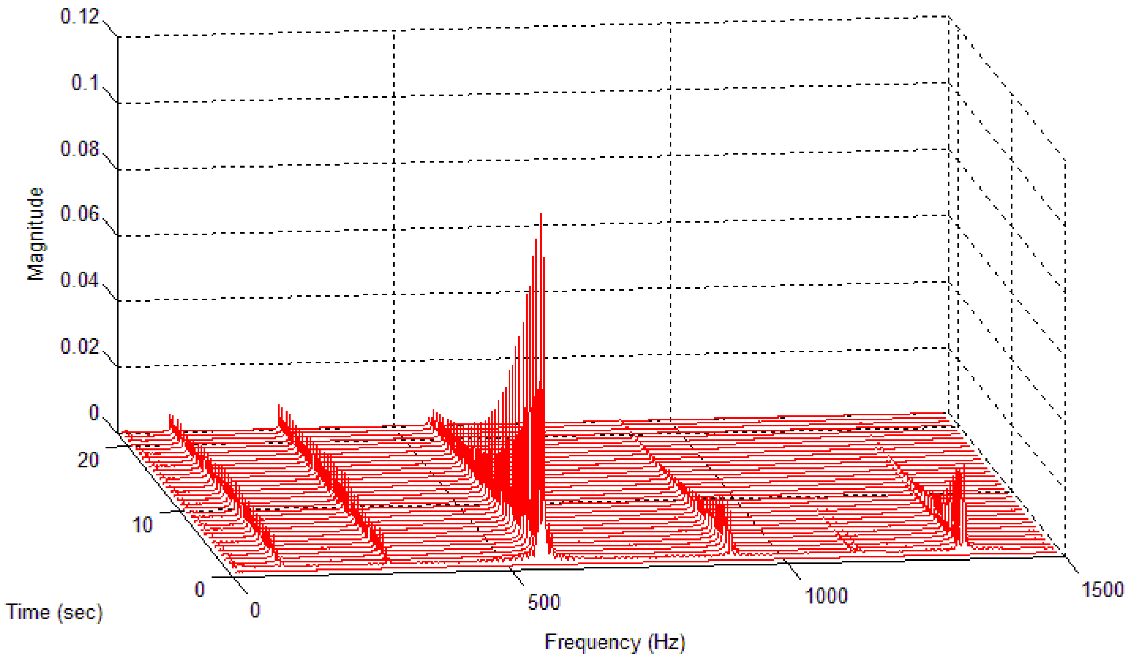


Figure 2.

Table 1. Measured Frequencies	
Freq (Hz)	Nearest Musical Note
95.5	F# to G
293	D
570	C# to D
909	A
1332	E

<u>Test Results</u>

The bowl in Figure 1 was used for an acoustics test. The precise composition of the sample bowl is unknown, although it is apparently bronze, with a mixture of copper and tin.

The waterfall FFT of the bowl is shown in Figure 2, resulting from a mallet strike.

Finite Element Analysis (FEA)

A finite element model was created using the parameters in Table 2.

Table 2. Sample Singing Bowl	
Property	Value
Mass	53.4 ounces
Thickness	0.12 inch
Rim Diameter	9.75 inch
Height	4.12 inch

The elastic modulus was adjusted so that the FEA model would match the measured result at the dominant frequency. The resulting elastic modulus was 6.39e+06 psi.

The undeformed mode shape is shown in Figure 2. The FEA model name is: bowl6.mod.

The odd modes are shown in Figures 4 through 7. Each even mode has the same shape as the previous odd mode while maintaining orthogonality.

The measured frequencies are compared to the FEA values in Table 3.

Figure 3. Undeformed Model

Figure 4. Mode 1, 109 Hz

Figure 5. Mode 3, 301 Hz

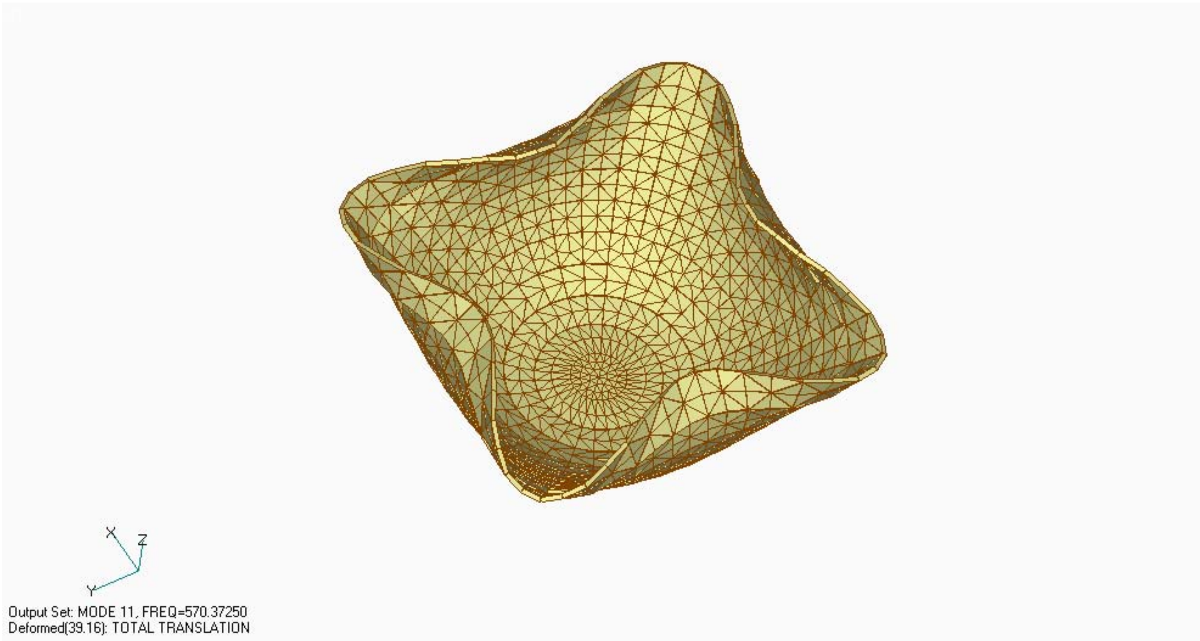


Figure 6. Mode 5, 570 Hz (Dominant Mode)

Figure 7. Mode 7, 899 Hz

Table 3. Frequency Comparison			
Mode	Measured Freq (Hz)	FEA Freq (Hz)	Error
1	95.5	109	14.1%
2	-	109	
3	293	301	2.7%
4	-	301	
5	570	570	0.0%
6	-	570	
7	909	899	-1.1%
8	-	899	
9	1332	1273	-4.4%
10	-	1273	

The error is referenced to the measured frequency.

Rogue Waves By Tom Irvine

Figure 1.

Introduction

Numerous ships are severely damaged or lost at sea every year. The cause is unknown in many cases. Some ships and entire crews simply vanish with little or no explanation. Rogue waves are responsible for at least some of these losses.

Rogue waves are huge, steep waves towering up to 30 meters in height. Rogue waves are also known as freak or monster waves. They may occur in either calm or stormy weather. They are rare but potentially deadly.

Rogue waves are considered separately from waves generated by earthquakes and landslides, including tsunami waves.

The rogue wave in Figure 1 was photographed by first mate Philippe Lijour aboard the supertanker Esso Languedoc, during a storm off Durban in South Africa in 1980. The mast seen starboard in the photo stands 25 meters above mean sea level. The wave approached the ship from behind before breaking over the deck, but in this case caused only minor damage. The mean wave height at the time was between 5-10 meters.

Figure 2. Cargo Ship World Glory

Note that the largest wave marine architects are typically required to accommodate in the design strength calculations is 15 meters (50 feet) from trough to crest.

The first part of this article gives some case histories of ships that were either known or presumed to have encountered rogue waves. The second part discusses possible sources of these waves.

1933 USS Ramapo

The US Navy steamship Ramapo sailed into a Pacific storm en route to Manila from San Diego. The wind howled at an unremitting 60 knots for seven days, lifting the sea into huge 15-meter swells.

The ship encountered a rouge wave on the morning of February 7. The wave came from behind, tossing her into a deep trough then lifting her stern-first over a steep ascent to the wave's crest.

As the stern of the 146-meter ship hit the bottom of the trough, the officer on watch triangulated the wave against the crow's nest. The resulting height was 34 meters, about as tall as an 11-story building. It remains the tallest wave ever reliably measured at sea.

1942 Queen Mary

The Queen Mary was hit by a 23 meter (75 foot) wall of water while carrying 15,000 troops in December 1942. The ship nearly capsized, but the occurrence was kept secret at the time.

1965 USS Pittsburgh

The heavy cruiser USS Pittsburgh had 27 meters (90 feet) of her bow torn off by a wave.

1966 Michaelangelo

The passenger ship Michaelangelo was struck by a wave that broke through ports 25 meters (81 feet) above her waterline. The bow section was flooded. Three passengers were killed.

1968 World Glory

The World Glory encountered a rogue wave off the East coast of South Africa on June 13. The resulting wreckage is shown in Figure 2.

1978 München

The München was a state-of-the-art cargo ship. The German crew was not concerned by storms predicted when she set out to cross the Atlantic.

The voyage was routine until 3 am on December 12, when the captain sent out a garbled mayday message from the mid-Atlantic. Rescue attempts began immediately. Over a hundred ships searched for survivors.

The ship was never found. She went down with all 27 hands. An exhaustive search found just a few bits of wreckage, including an unlaunched lifeboat that bore a vital clue. It had been stowed 20 meters above the water line yet one of its attachment pins had twisted as though hit by an extreme force.

The Maritime Court concluded that severe weather had caused an unusual event. Other seafarers concluded that the specific cause was a rogue wave.

1995 Draupner Oil Rig

A wave of 26 meters struck the Draupner oil rig in the North Sea off Norway on New Year's Day. The wave swept across the deck at 72 kilometers per hour. These measurements were made via a laser device.

This rogue wave occurred in a zone without currents and in an otherwise normal sea state.

1995 Queen Elizabeth II

The cruise liner Queen Elizabeth II met a 29-meter high rogue wave during a hurricane in the North Atlantic in February. Captain Ronald Warwick described as "a great wall of water… it looked as if we were going into the White Cliffs of Dover."

2001 Bremen

The Bremen had 137 German tourists aboard when she faced an awesome wall of water in the South Atlantic. The impact knocked out all the instrumentation and all power, leaving the vessel helpless in the tumultuous sea.

There was a serious risk the ship would sink because the captain was unable to maintain the ship's course into the waves.

Furthermore, the crew knew that none of the passengers would survive in lifeboats in such freezing conditions.

The crew battled to restart the engines with emergency power only. Fortunately, the captain and crew were able to save the ship.

2001 Caledonian Star

Like the Bremen, the Caledonian Star carried over one hundred tourists across the South Atlantic. The Caledonian Star's First Officer saw a 30 meter wave bearing down on them, at 5 am on March 2.

The wave broke over the ship, flooding the bridge and destroying much of the navigation and communication equipment. Fortunately, the Caledonian Star was able to limp back to port.

2005 Norwegian Dawn

A storm in the Caribbean began tossing the 305 meter long Norwegian Dawn like a cork as she sailed to New York from Miami and the Bahamas on April 15, carrying 2200 passengers.

A terrifying 21 meter (70-foot) rogue wave then struck the Norwegian Dawn on April 16.

Dawn Lepore, 47, said she felt the roar of the wave that smashed windows as high as the ship's 10th floor Sunday morning.

At least four passengers were injured from flying glass when the huge wave crashed aboard. Furthermore, 62 cabins were flooded.

The Norwegian Dawn docked in Charleston, S.C., for repairs. Some of the passengers left the ship at this port.

Generation Mechanisms

A simple explanation is that a rogue wave is the coincidence of several wave trains, the crest of one train superimposed and amplifying others.

The underlying characteristics of rogues, however, are more complex than linear wave theory.

Theory 1: Wind Opposing Current Flow

The Agulhas Current is located off the East coast of South Africa. The current is the meeting point of two opposing flows, mixing warm Indian Ocean water with a colder Atlantic flow. The resulting current is about 60 miles wide and attains rates of up to 5 knots on occasions

Rogue waves may occur if a strong or gale force wind direction opposes the current flow.

A very deep trough may precede the crest of the wave, with the result that a ship steaming against the sea suddenly and without any warning plunges into it. The bow may thus become buried in the oncoming wall of water.

Numerous ships have sunk in this region due to rogue waves, including the World Glory shown in Figure 2.

Theory 2: Quantum Physics

The characteristics of the Agulhas current are not present in other regions where rogue waves have been know to occur, however.

Another theory has thus been derived in terms of quantum physics.

The Schrodinger equation in quantum mechanics is a way of expressing the probability of something happening that is far more complex than simple linear models.

Al Osborne is a wave mathematician who has used the Schrodinger equation to describe open ocean wave patterns.

Osborne's theory is that in certain unstable conditions, waves can steal energy from their neighbors. Adjacent waves shrink while the one at the focus can grow to an enormous size.

Scientists initially rejected Osborne’s modified Schrodinger equation as implausible. Radar data from the European Remote Sensing Satellites is now supporting his theories, however.

Osborne’s work suggests that there are two kinds of waves out on the high seas;

1. The classical undulating type described by the linear model.
2. An unstable non-linear wave that can start sucking up energy from waves around it at any time to become a towering rogue wave.

Theory 3: Eddies

A new theory suggests that rogue waves are likely to form when a swell is opposed by a current following a curved path, such as an eddy. A field of random eddies can apparently focus the energy of waves much like a lens focuses light.

Theory 4: Storms

Rogue waves are simply the result of severe storms.

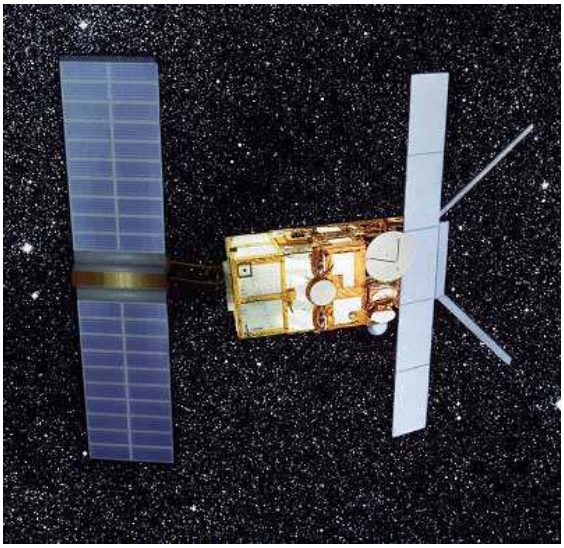


Figure 3. ERS Satellite

Monitoring

The European Space Agency (ESA) launched the ERS-1 weather satellite in July 1991 via an Ariane 4 booster. The ESA launched ERS-2 in 1995.

Scientists have used ERS-1 and 2, to determine how frequently the rogue waves occur.

ERS-1 and ERS-2 both have a Synthetic Aperture Radar (SAR) as their main instrument. This collects "imagettes" of the ocean surface, taking five-by-ten kilometer snapshots every 200 meters. Scientists use these images to produce ocean-wave spectra from which they can identify anomalous waves.

Sample data is shown in Figure 4.

And there shall be signs in the sun, and in the moon, and in the stars; and upon the earth distress of nations, with perplexity; the sea and the waves roaring;

Luke 21:25

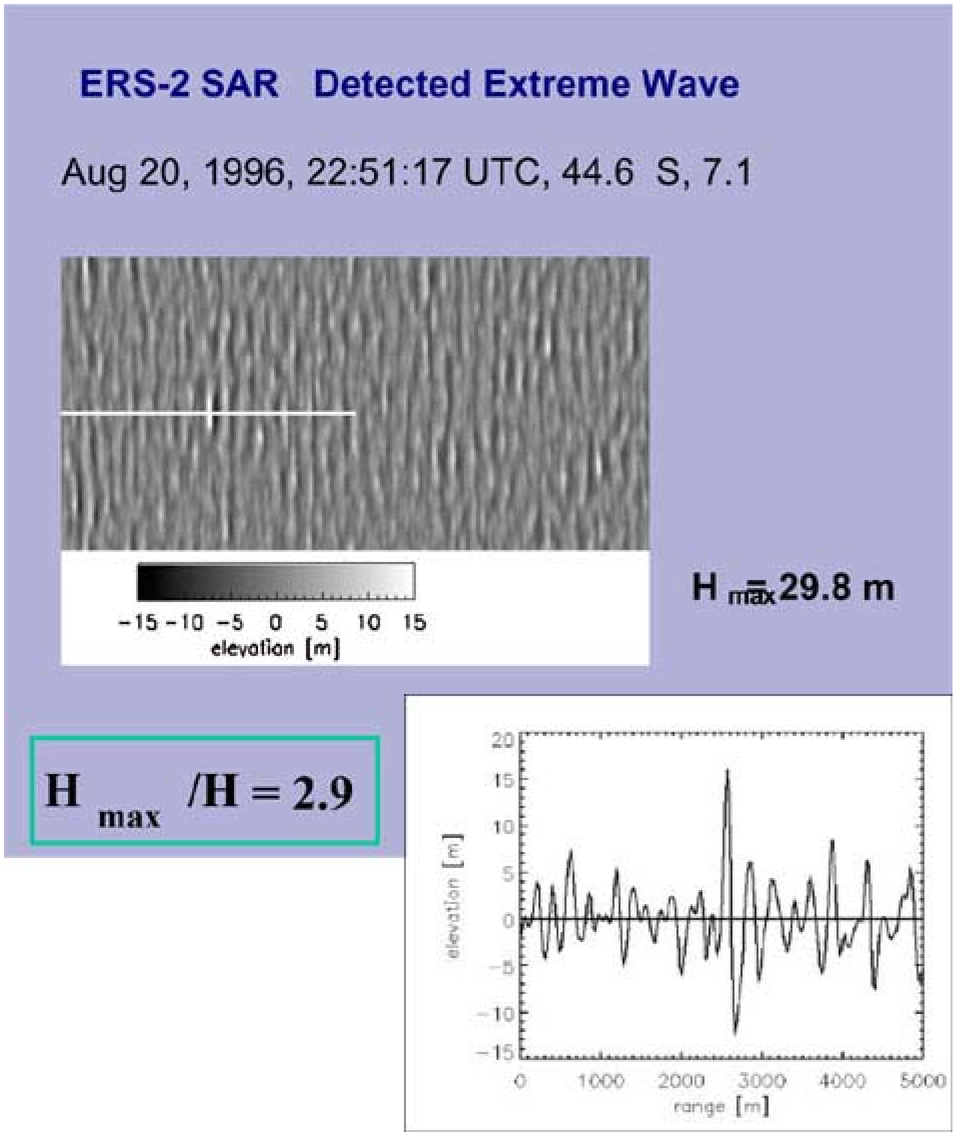


Figure 4. Data Courtesy of European Space Agency