Evaluation of Propeller Cuts Documented in Right Whale Necropsy

Field No.: GA 2006 025

By

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Abstract

The propeller that struck this animal was about 39 inches (100 cm) in diameter with 6 blades. This type of propeller is not common and is often used on high speed vessels to reduce vibration. Because of the expense of this type of propeller, it was probably not a common "working" boat. The propeller rotated clockwise and was probably the starboard propeller of a twin propeller design. The vessel traversed the whale from head to tail, and the whale passed outboard of the starboard propeller. Cut #21 that runs the length of the cut series is probably not from a keel or rudder and may not even be associated with the propeller cuts. The vessel was traveling about 1.4 times the speed of the whale and probably below 5 knots.

Propeller Diameter:	39 inches (100 cm)
Number of Blades:	6
Rotation:	Clockwise
Path:	Head to tail
Vessel Speed:	1.4 x Whale’s speed (probably < 5 knots)

Introduction

Photographs, drawings and field measurements of the propeller cuts were provided by Tom Pitchford (FWC). The cuts were well documented. The photographs of the cuts were well suited for analysis. Image “DSC_0367.JPG” was selected for evaluation specifically because the camera angle was approximately perpendicular to the surface of the animal, both ends of several contiguous cuts were clearly visible, and reference scales were clearly visible at several points in the image. A section of this image showing cuts 15 through 18 was copied to “DSC_0367_Crop.JPG” for analysis. This image is reproduced below as Photo 1.

Gross Analysis

The cut pattern consists of 20 propeller cuts along the right dorsal surface of the animal's head and down the right lateral side of the body. The cuts are numbered from 1 to 20 beginning with cut 1 at the anterior end of the series. Cuts 1 through 15 are the longest in the series, averaging 89 cm in length. Cuts 16 through 20 become progressively shorter, ending with cut 20 which is the shortest in the series at 36.6 cm. This reduction in cut length is due to the tapering of the animal's body in this region. The z-shape of all of the cuts indicates that they are relatively deep and created by a propeller with a clockwise (right hand) rotation.

An additional, non-penetrating, cut runs along the length of the series and is labeled cut 21. This cut begins at the anterior right side of the animal in the vicinity of cut 8, it curves toward the mid dorsal region in the vicinity of cut 12, and then it curves toward the ventral right side of the animal until it ends just dorsal and anterior of cut 20. This cut crosses the dorsal ends of cuts 8 and 9. It is up to 15+ cm away from the dorsal ends of cuts 10 through 19, and if its ending point is projected, it would cross the dorsal end of cut 20. This scrape curves in two dimensions – from the animal's right to the left and back to the right as well as from dorsal to ventral. The analysis of the propeller cuts indicates that the vessel traversed the animal's surface in a relatively straight line. It is difficult to imagine a part of the vessel that would traverse the animal's surface in a curving motion in two dimensions, remaining in contact with the animal's surface without penetrating the surface, while the rest of the vessel traveled in a straight line. It appears that cut 21 may not be associated with the propeller cut series.

The propeller cuts were well formed, evenly spaced and well photographed. The ends of several contiguous cuts were clearly visible. This allowed an analysis with few anomalies.

Propeller Diameter

The propeller that created the observed cuts was either approximately 39 inches (100 cm) in diameter with 6 blades or approximately 46 inches (116 cm) in diameter with 7 blades. By convention, the propeller with the smaller number of blades will be used in the remaining discussion.

Blades	3	4	5	6	7
Dia. (in)	20	26	33	39	46
Dia. (cm)	50	66	83	100	116
Max Length (cm)	~~47~~	~~62~~	~~78~~	94	109
Max Depth (cm)	16	22	27	33	38

Table 1.

Table 1 shows the propeller sizes calculated from the analysis of the cuts. The propellers with 3 through 5 blades can be eliminated from consideration because the longest measured cut length was 93 cm which is beyond the maximum cut length these propellers are capable of creating.

It should be noted that the 39 inch 6-blade propeller could also be eliminated because it is theoretically only capable of creating a 33 cm deep cut and field measurements indicate that cut 10 is 36 cm deep. However, cut depth measurements are notoriously inaccurate, and deeper cuts are particularly difficult to measure. This case is a good example of the problems associated with depth measurements. Cuts 9, 11, and 13 are all recorded as 90 cm long and should be approximately the same depth. Cut 9 is recorded as 31 cm deep. This is a reasonable approximation of the expected depth of a 90 cm long cut created by a 39 inch (100 cm) diameter propeller. However, cuts 11 and 13 are recorded as 21 cm and 12 cm deep respectively. Also, cut 12 is recorded as 93 cm long and 17 cm deep. Clearly, depth measurements are not very reliable. Anyone that has attempted to measure cut depths will understand why this is so problematic. Propeller cuts are messy things. The 6-bladed propeller should not be eliminated based on these depth measurements.

The use of 4-blade and 5-blade propellers is fairly common. Increasing the number of blades on a propeller will reduce noise and vibration at higher rotation speeds. The tradeoff for using more blades is that the propeller is by necessity weaker and generally more expensive. It also requires more power to use a given size propeller with more blades. These 6-blade and 7-blade propellers are not in common use; however, some yacht manufactures are currently selling vessels equipped with 39+ inch (100+ cm) propellers with 6 and 7 blades. These vessels are usually over 55 feet in length and up to the range of 70 to 80 feet. They are exclusively planing hulls equipped with twin propellers. This type and size propeller may also be found on military vessels. They are probably not found on "working" vessels unless the vessel was specifically designed to operate at high speeds. Some significantly larger vessels may also be equipped with 6-bladed or 7-bladed propellers, but those propellers would be much larger than the sizes considered here.

The propeller that created these cuts had a clockwise (right hand) rotation. Since these multi-blade propellers are usually found on large planing hulls equipped with twin propellers and since the starboard propeller of a twin propeller design usually rotates clockwise, it is probable that the whale was struck by the starboard propeller of a twin propeller design. Analysis of the cuts indicates that the vessel traversed the animal in a relatively straight line, and the unusually high advance coefficients presented in Table 2 indicate that it traversed the animal from head to tail. The whale was positioned on the vessel's starboard side and outboard from the starboard propeller. The even spacing of the cuts indicates that the speed of the vessel and the speed of the whale did not change abruptly throughout the duration of the accident.

Vessel Speed

The advance coefficients calculated for the cuts that were analyzed are listed in Table 2. These values are a function of the relative speed of the vessel. Since the vessel and whale approached directly toward each other, the relative speed is the sum of the speed of the whale and the speed of the vessel. The calculated advance coefficients are unusually large which indicates that the speed of the whale is a significant portion of the relative speed. .

Cut	Adv. Coef. (J)
15	1.93
16	1.76
17	1.60
18	1.61

Table 2.

The smallest calculated advance coefficient of 1.60 for the vessel and whale combined is probably most representative of the steady state conditions at the beginning of the accident. The size of the vessel and whale make it unlikely that the speed of the vessel or the speed of the whale decreased significantly during the accident, and it is equally unlikely that the rotation speed of the propeller increased significantly over pre-strike conditions. These are the only changes that would cause the advance coefficient to drop below its initial value. Using this value and some typical advance coefficients for vessels operating at specific speeds, it is possible to estimate the speed of the vessel as a function of the speed of the whale.

The relationship between the vessel speed and the whale speed can be calculated by assuming a specific advance coefficient for the motion of the vessel independent of the motion of the whale. A high performance planing hull large enough to be equipped with a 39 inch (100 cm) propeller will typically have a relatively high advance coefficient in the vicinity of 1.2 when it is operated at wide open throttle. Using this value and the calculated advance coefficient of 1.60, it can be estimated that the vessel must have been traveling less than 3 times the speed of the whale. If it is assumed that the whale was traveling at approximately 3 knots, then the vessel was traveling under 9 knots. This is well below planing speed, so it would appear that the vessel was not on plane.

Chart 1 below is a plot of estimated vessel speed, as a function of the calculated relative advance coefficient of 1.60 and the assumed whale's speed of 3 knots, for various assumed advance coefficients. It also includes a plot of actual vessel speeds at specific advance coefficients for a large planing hull. These two plots cross at about 4.2 knots. This indicates that the vessel was probably traveling at a rate of about 1.4 times the assumed whale's speed of 3 knots. If these calculations are repeated based on the assumption that the whale's speed was 7 knots and a new chart created, the vessel's speed would only be 1.0 times the whale's speed or about 7 knots. This indicates that the vessel would have been traveling at a rate very near its idle speed or possible slightly faster. It should be noted that this is a general approximation of the vessel's speed and is based on a series of assumptions. It does not allow a precise determination of the vessel's speed, but it does allow a general representation of the vessel's state of operation. It was operating below planing speed and probably operating near its idle speed.

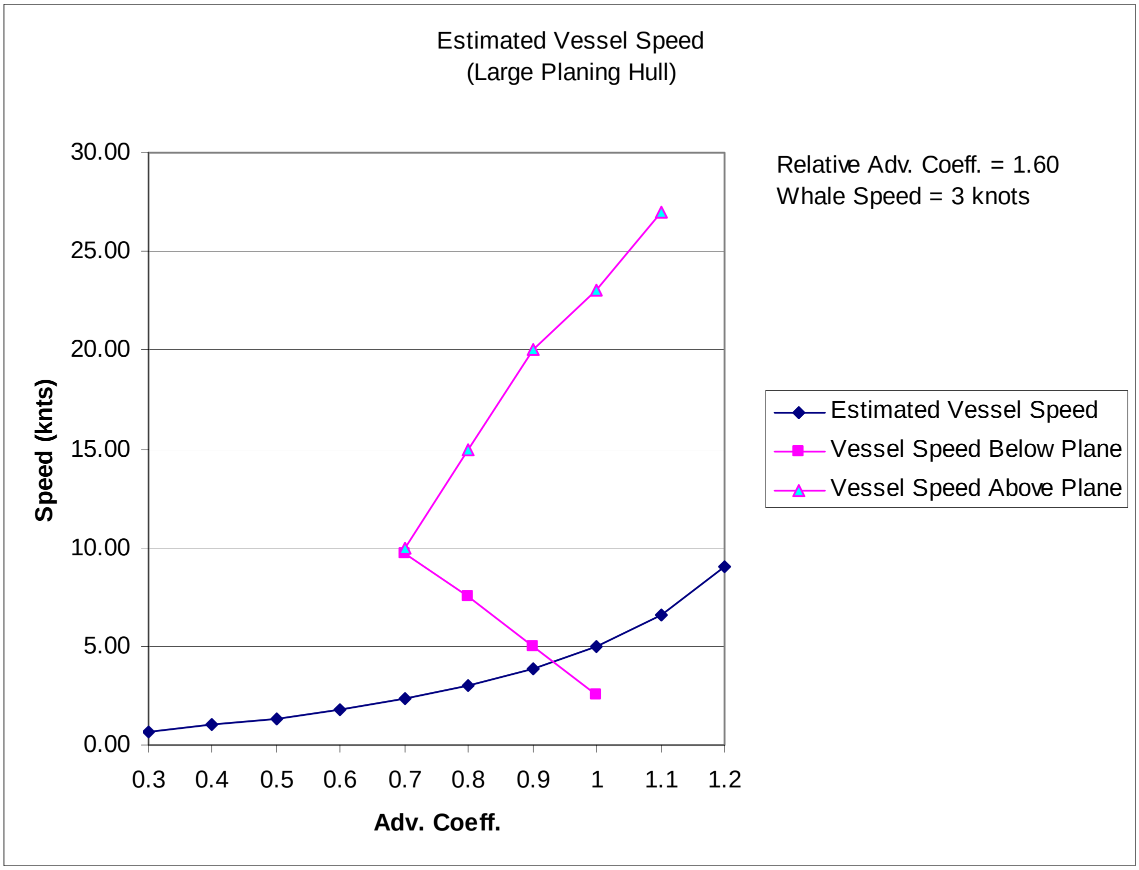

Chart 1.

Conclusion

This whale was struck by a clockwise rotating propeller approximately 39 inches (100 cm) in diameter with 6-blades. The vessel traversed the animal from head to tail. The vessel was traveling at approximately 1.4 times the speed of the whale and was probably traveling at less than 5 knots.

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Photo 1: DSC_0367_Crop.JPG was used for analysis of the propeller cuts.