The Dynamic Shear Modulus of Blubber for Selected Large Whale Species

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Abstract

Whale blubber is the insular tissue layer located between the dermis and the superficial fascia layer which sheathes the whale’s musculature. It is made up of a lipid matrix ramified with strong, structural collagen and elastic fiber bundles, but little is known of its mechanical properties. Knowing these properties adds to the morphology of blubber and research that focuses on its physical response. Specifically, two current fields of research would gain from measurements of the dynamic shear modulus (\(G^*=G'+iG''\)), a viscoelastic mechanical property, of blubber. The first is drag reducing, compliant coatings, which seek to minimize the sonar signature and energy loss of submersibles. The second is subdermally attached satellite tracking tags that are remotely deployed into the dorsal region of large whales near the dorsal fin. The tags are used for defining whale migration patterns and behaviors to help reduce potentially harmful human interactions. In this study, the dynamic shear modulus was measured at different depths and oscillating frequencies of blubber samples taken from a humpback whale, sperm whale, and two gray whales. A semi-quantitative staining assay was also performed to determine relative changes in collagen and non-collagen proteins with depth. Trend lines were fit to all of the data at 3.1 Hz to characterize the change in properties over depth. The humpback whale had \(G'\) and \(G''\) values of \(~80,000\text{Pa}\) and \(~10,000\text{Pa}\) at \(~2\%\) depth and increased logarithmically to \(95,000\text{Pa}\) and \(16,000\text{Pa}\) at \(~79\%\) depth. The sperm whale had \(G'\) and \(G''\) values of \(~67,500\text{Pa}\) and \(~9,450\text{Pa}\) at \(~15\%\) depth that linearly decreased and increased (respectively) to \(~60,000\text{Pa}\) and \(~11,250\text{Pa}\) at \(~75\%\) depth. Lastly, the average \(G'\) and \(G''\) values for the two gray whales were \(~94,875\text{Pa}\) and \(~16,650\text{Pa}\) at \(~8\%\) depth and decreased logarithmically to \(~56,250\text{Pa}\) and \(~10,500\text{Pa}\) at \(~68\%\) depth. The depth profiles for the all of these whales showed similar linear fits for their \(G''/G'\) ratios. All tested samples had values of \(G'\) and \(G''\) that followed a positive linear relationship with frequency (0.31-25 Hz). In conclusion, the results showed that different whale species have distinctly different depth profiles of \(G'\), \(G''\), collagen protein, and non-collagen protein, but also show a similarity in the orders of magnitude of these metrics. A potential correlation exists between the ratios of non-collagen/collagen protein and \(G''/G'\). However, an obvious direct relation could not be found between modulus components (\(G'\) and \(G''\)) and a change in the individual protein contents (non-collagen and collagen protein).

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11:00am, The Valley Library (RM 3622-West)