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P5_3 Supersonic Torpedoes

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Abstract

In this paper, the feasibility of a supersonic torpedo is determined. This study uses the specifications of the MK-48 torpedo to calculate the force resistive to motion, and subsequently, the power needed for the torpedo to sustain travel at the speed of sound. This power is calculated to be 275.9 GW, rendering the concept unfeasible.

Introduction

A sonic boom occurs when an object, such as a bullet or a plane, travels faster than the speed of sound in the medium in which it is travelling. When an aircraft travels through the atmosphere, air-pressure waves are constantly produced, similar to those from a ship's bow [1]. Figure 1 below displays the pressure waves of an aircraft as it travels through the air.

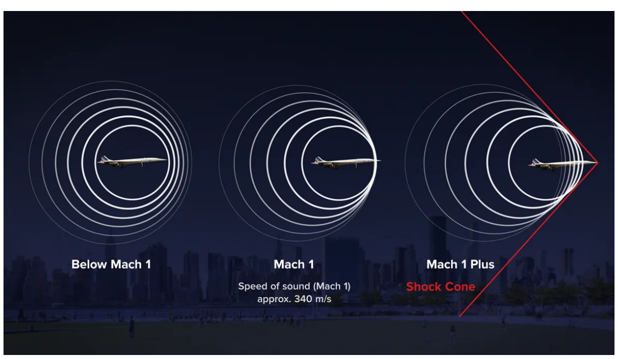

Figure 1: Graphic of pressure waves at speeds below, at, and above Mach 1 [2]

In air, sound travels at 344 ms^{-1} [3] and it is not uncommon for aircraft to break this speed, referred to as 'Mach 1'. The MK-48 torpedo is used in this paper to investigate the feasibility of a torpedo breaking the sound barrier in non-turbulent water.

As the densities of seawater and air are different, it is important to calculate the new speed of sound. The speed of sound in a fluid medium can be calculated as shown by the equation below for the speed of sound in seawater:

$$v = \sqrt{\frac{B}{\rho}} \tag{1}$$

where 'B' is the bulk modulus (20°C, 2.34 GPa [4]) and 'ρ' is the density of the fluid (1026 kg m^{-3} [5]). In seawater at 20°C, this results in sound travelling at 1510 ms^{-1}.

Method

To determine the feasibility of a torpedo breaking the sound barrier, the force of propulsion must be considered. The equation for drag can be shown below, determining the resistive force of motion through the water that would occur [6]:

$$F_D = \frac{1}{2}\rho v^2 C_D A \tag{2}$$

where 'v' is the velocity, 'C_D' is the drag coefficient of a torpedo (0.7 for the MK 41, [7]) and 'A' is the frontal area shown below:

$$A = \frac{\pi d^2}{4} \quad (3)$$

where the diameter, 'd', is 533 mm [8]. This calculation finds the resistive force of the water when the torpedo is travelling at the speed of sound in seawater.

Assuming the torpedo is self-propelled, the power required to maintain this speed can be found using the equation below.

$$P = F \times v \quad (4)$$

When substituting in equations 2 and 3, the equation for power becomes:

$$P = \frac{1}{8} \rho v^3 C_D \pi d^2 \quad (5)$$

Using the values previously stated in this paper, the power required for an MK-48 torpedo to reach the speed of sound in water is 275.9 GW.

Discussion

The power required to propel an MK-48 torpedo to the speed of sound in seawater is tremendous when compared to the 57.5 GW peak energy demand of the UK in 2012 [9]. Therefore, producing enough energy to propel a torpedo to these speeds is not possible given the capabilities of current technology.

The calculations in this paper do not take into account the effects of supercavitation, an effect whereby an object travelling at extremely high speeds produces and is encapsulated by a cavity within the liquid it is travelling through [10]. This cavity is primarily caused by a significant drop in pressure; in regions of high flow speed the pressure drops below the vapour pressure of the liquid, promoting supercavitation.

Conclusion

Without the effects of supercavitation, the power requirement for a torpedo such as the MK-48 to reach speeds high enough to break the speed of sound is too great. In instances where supercavitation occurs, the sonic boom would be created within the gas cavity surrounding the torpedo and this raises questions as to the likelihood of a sonic boom occurring within the water.

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