Dec. 22, 1964 M. H. SILVERMAN 3,162,163

HYDRODYNAMIC NOISE REDUCTION

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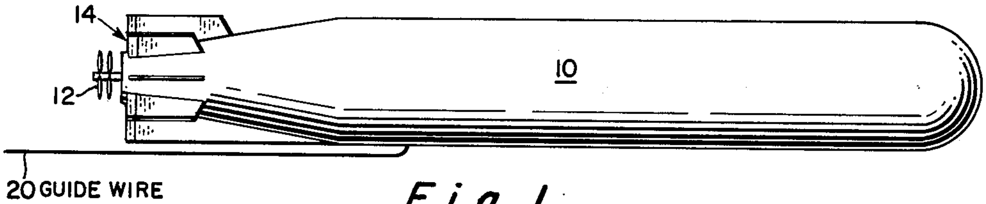

Fig. 1

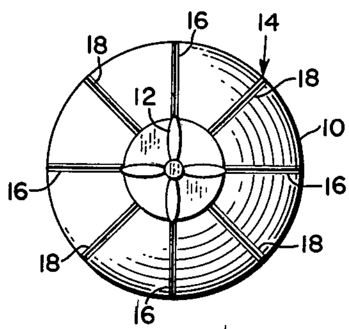

Fig. 2

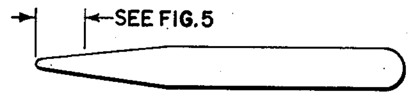

Fig. 4

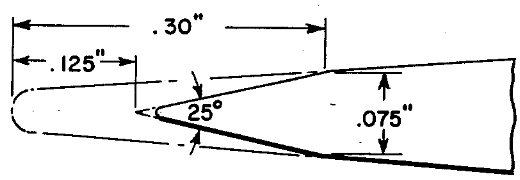

Fig. 5

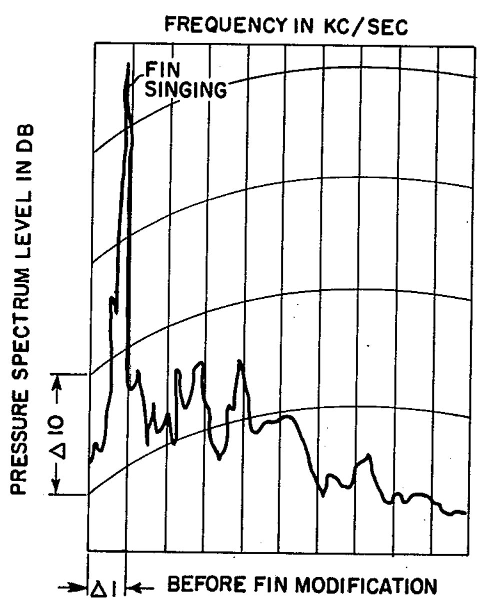

Fig. 3

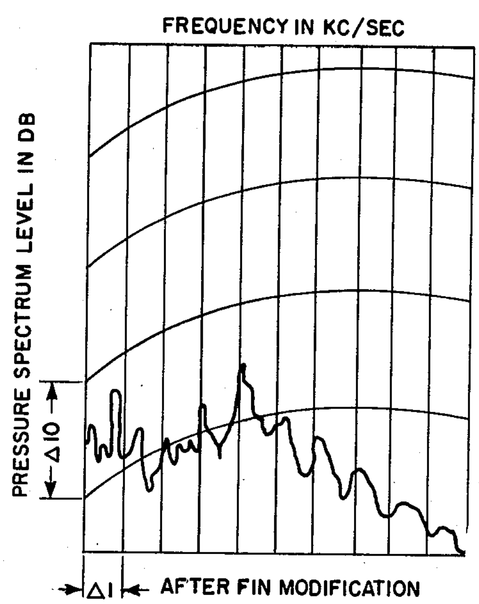

Fig. 6

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HYDRODYNAMIC NOISE REDUCTION

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5 Claims. (Cl. 114—20)

The present invention relates in general to a method and means for eliminating, or materially reducing, hydrodynamic noise resulting from the passage of an object at relatively high speed through a fluid medium. In a preferred embodiment, the invention relates to lowering the noise level produced by movement of an underwater torpedo so that the latter is rendered more difficult of detection by an enemy vessel toward which the torpedo has been launched.

The presence of hydrodynamic noise constitutes one of the major problems involved in the operation of modern high-speed underwater missiles. In many instances this noise is of sufficient amplitude so that the missile is detachable by the enemy in time to allow evasive maneuvers to be successfully carried out. Consequently, it is desirable to eliminate to the maximum possible extent the external noise developed by such a missile in order that its combat efficiency may be increased.

One of the more serious forms of hydrodynamic noise is singing noise and it is with this particular phenomenon that the present invention is concerned. Singing is of particular importance since it is tonal in nature and is usually very intense in water. Such a tone can significantly raise the detection level of an otherwise relative low noise energy spectrum. Singing is caused by the same physical phenomenon as the commonly noted vibration of iced telephone wires or car aerials in high winds when their axes are transverse to the wind. Although the flow ahead of the wire is relatively smooth, there is an unsteady flow in its wake caused by vortices periodically shed alternately above and below the wire. This unsteady flow is known as the Von Karman vortex street and produces an oscillatory force resulting in "singing" of the wire. In other bodies, if the frequency of one of its natural modes coincides with the frequency of the street, singing will occur.

It has been found that this undesirable effect is due in large measure to the design of certain auxiliary fins located on the aft section of the torpedo just forward of the propellers. The usual cruciform fins on a torpedo are employed primarily to create a lift in the proper direction, which tends to reduce the attack angle resulting from the static turning moment inherent in the torpedo during its passage through the water. However, because of the initially severe stability requirements of a torpedo of the type being described, additional fins are desirable, and the latter are positioned at a 45° angle to the cruciform fins. Although these added fins are designed for stability and hence possess a rather flat profile, nevertheless they were found to "sing" in such fashion that a substantially constant pure tone was produced of a nature readily detectable by an enemy. In accordance with a feature of the present invention, the design of these supplemental fins on the torpedo is such as to materially reduce the over-all noise output of the torpedo through a reduction in the turbulence brought about by passage of the torpedo through the water.

One object of the present invention, therefore, is to effect a material reduction in the hydrodynamic noise output of an underwater torpedo during operation.

Another object of the invention is to render an underwater torpedo more difficult of detection by an enemy by eliminating, or substantially reducing the amplitude of, any peaks in the noise spectrum caused by "singing" of one or more of the torpedo's hydrodynamic surfaces.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a side view of an underwater torpedo of the type to which the present invention is particularly applicable;

FIG. 2 is an aft view of the missile of FIG. 1, showing the angular relationship of the various fins with which the missile is provided;

FIGS. 3 and 6 are graphs illustrating the change in noise output of the missile of FIG. 1 when the 45° fins thereof have been modified in accordance with the invention;

FIG. 4 is a view showing the normal profile of one of the 45° fins illustrated in FIGS. 1 and 2; and

FIG. 5 is an enlarged view of the trailing edge of the fin of FIG. 4, showing the manner in which the configuration of this portion of the fin is modified in accordance with the principles of the present invention.

Illustrated in FIGS. 1 and 2 of the drawings is an underwater missile or torpedo which is designed to be guided toward a target by control information supplied to the torpedo over a wire which trails behind the missile in the manner shown. The torpedo of FIGS. 1 and 2, therefore, is formed with a body **10** which contains the usual components for propelling the missile toward an objective as well as an explosive charge and a source of energy for carrying out its prescribed functions. However, these components form no part of the present invention, and hence neither an illustration nor a detailed description thereof is deemed necessary. It need only be noted that the torpedo of FIGS. 1 and 2 is driven by a pair of propellers **12**, and, for purposes of stability, is provided with a plurality of fins **14** which are spaced apart circumferentially about the longitudinal axis of the missile in a manner best brought out by FIG. 2. In addition to the usual cruciform fins **16**, a plurality of auxiliary fins **18** are employed, each of these fins **18** being disposed at an angle of 45° to the principal cruciform fins **16** as clearly brought out by FIG. 2. It has been determined during actual operation of the torpedo being described that one of the principal sources of hydrodynamic noise is the "singing" of the fins **14** as the result of oscillatory forces produced by the unsteady fluid flow past the fins **18**, particularly when the missile is traveling at a relatively high speed. There is an interdependency among the effective depth of the fin trailing edge, fluid velocity and oscillation frequency, and this relationship is designated by the Strouhal Number. This Strouhal Number is defined as

$$f\frac{d}{v}$$

where f is the oscillation frequency, d is the effective depth of trailing edge of the fin (for cylinders and spheres d is the diameter) and v is the velocity of the fluid. As above mentioned, singing of the fins 18 is in the nature of a steady or constant tone, and, since this tone is very intense in water or other fluid, it is readily detectable by a device such as a hydrophone.

The interdependency of the factors involved permits the frequency of the exciting force to be changed by varying the thickness of the trailing edge of the fin and/or its boundary layer, and, in the same manner, a change in in the fin's structural characteristics can also change its resonant frequency. In such situations, the quantity d is usually considered to be a function (the thickness) of the trailing edge of the fin.

Applying the above approach to the particular torpedo design set forth in FIGS. 1 and 2 of the drawings, the initial factor to be determined is the frequency at which the singing of the fins occurred. This information was readily derived, and, as shown in FIG. 3 of the drawings, a high noise peak is present in one particular region of the frequency spectrum. Utilizing the formula above given showed that this fin excitation occurred in the last .30 inch of each 45° fin and that, if excitation could be eliminated in this region, practically all of the objectionable singing would disappear. Following this avenue of approach, the terminal .30 inch on both surfaces of each of the 45° fins was modified by applying to each such surface a thin coating of an adhesive in which were dispersed minute particles of silica. It was found that these silica or sand particles disturbed the fluid flow over the trailing edge of each fin sufficiently to eliminate its magnitude. Since a similar modification to each of the 90° cruciform fins produced no additional improvement, it was concluded that only the 45° fins were contributing to the hydrodynamic noise effect. This discrepancy in the mode of vibration of the 45° and 90° fins might possibly be due in part to the fact that whereas all of the 45° fins were 8.5 inches long in the example being given, the upper vertical fin, on the other hand, was 13.5 inches long and the lower vertical 48.5 inches long.

Although this change in the surface characteristics of the 45° fins of the torpedo yielded the results desired, the process by which such surface changes were brought about is not capable of being carried out by readily available means. Consequently, an attempt was made to produce similar results by sandblasting the critical area of the 45° fins, but it was found that the singing was reduced only to half its previous value instead of being completely eliminated. A crackling process was then tried, which consists of applying several coats of paint to the fin surface (the fin being fabricated of aluminum) and the element then raised to a temperature of 450° F. Due to the unequal coefficients of expansion of the paint and aluminum, the former expanded faster to form ridges on the fin surface. However, most of the ridges thus formed were parallel to the fluid flow rather than transverse thereto, and consequently their effectiveness was not significantly high.

The most successful and practicable solution to the problem was to form a wedge on the trailing edge of each of the 45° fins. The profile of a standard 45° torpedo fin is substantially as shown in FIG. 4 of the drawings, and an enlargement of the trailing edge of one such fin as subsequently modified is illustrated in FIG. 5, the original fin outline extending for the distance shown by the broken lines. In accordance with the present concept, a wedge was established by removing ⅛ inch from the trailing edge of the standard fin, machining the angle of this wedge to 25°, and then carrying the wedge slope forward until it intersects the respective fin surfaces near a point $\frac{3}{10}$ inch forward from the rear-most point of the original fin. Consequently, the angle actually "seen" by the fluid stream lines is less than 12½° because of the symmetric configuration of the fin profile. To preclude possible injury to personnel handling the fin, the sharp trailing edge was slightly rounded to a radius of $\frac{1}{64}$ inch. Extensive tests of a torpedo, the 45° fins of which were modified in accordance with this procedure, showed essentially no extreme peaks of oscillation, and the noise output throughout the frequency range was essentially uniform as brought out in FIG. 6 of the drawings. Consequently, detection of such a projectile by an enemy is rendered much more difficult than was the case prior to the modification which constitutes the essence of the present invention.

The change in fin configuration herein disclosed is readily achieved by standard commercial practices and is carried out simply and at low cost. It was further found that a substantially complete elimination of the Von Karman vortex street in the manner disclosed does not measurably increase the cavitation effect which, when present to any appreciable degree, is itself a source of hydrodynamic noise.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

I claim:

1. The combination of an underwater torpedo having standard horizontal and vertical cruciform fins disposed circumferentially around the longitudinal axis of the torpedo and in addition four auxiliary fins respectively disposed between the cruciform fins and lying at an angle of essentially 45° thereto, each such auxiliary fin normally having an aft portion which exhibits a constant progressive decrease in thickness rearwardly of the torpedo, and hydrodynamic noise-reducing means for modifying the fluid flow along the surface of the aft portion of each said auxiliary fins during torpedo operation to change either the frequency of the vortex street which is developed in the wake of such fin or the resonant frequency of the body in accordance with the Strouhal Number, where such number is represented by the expression

$$f\frac{d}{v}$$

in which

f=the vortex street frequency
d=the effective thickness of the auxiliary fin aft portion
v=the velocity of the fluid

whereby such change in vortex street frequency is in a direction away from the natural resonant frequency of vibration of said fin, to result in a decrease in that portion of the hydrodynamic noise level of said torpedo caused by said fins.

2. The combination of claim 1 in which the aft portion of each auxiliary fin is modified to exhibit a certain constant progressive decrease in thickness for a first part of its length and a constant progressive decrease in thickness for a remaining part of its length which is greater than but which differs from the constant progressive decrease in thickness of its said first part.

3. Means in accordance with claim 2 in which the angle formed by the two surfaces of the said remaining part of each auxiliary fin aft portion is approximately 25°.

4. Means in accordance with claim 2 in which the surface of the said first part of the aft portion of each auxiliary torpedo fin joins the surface of the said second part at a point lying approximately $\frac{3}{10}$ inch forward along the longitudinal axis of the torpedo from its rearmost point prior to modification thereof.

5. The method of reducing the hydrodynamic noise level of a missile designed to pass through a fluid medium during operation, said missile being stabilized by a plurality of longitudinally-disposed fins arranged circumferentially in spaced-apart relation, each of whose 45° fins create an oscillatory turbulence in its wake during passage of said torpedo through said fluid medium, such turbulence bringing about a vibration of the fins when

the natural resonant frequency of the latter approaches the turbulence frequency, said hydrodynamic noise level being reduced by modifying the fluid flow along the aft portion of the surface of said fins to alter the frequency of the resulting turbulence in accordance with the formula

$$f\frac{d}{v}$$

where

f=the turbulence frequency
d=the effective thickness of the auxiliary fin aft portion
v=the velocity of the fluid

said method including the steps of removing ⅛ inch from the trailing edge of each fin, forming a wedge which opens

forwardly with an angle of approximately 25°, and then extending the wedge slope until it intersects the respective fin surfaces at points each approximately ³⁄₁₀ inch forward from the rear-most point of the original fin.

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