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Research Paper

ROTATING TRANSLATING CONES

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ABSTRACT A first attempt has been made to confirm experimentally a theoretical concept, recently published, involving a rigid cone rotating about its long axis under still water: it

: it should tend to translate along that axis blunt end leading and apex trailing. Two identical hollow cones, neutrally buoyant, with equal weights attached to the apexes, were released simultaneously at the surface of a swimming pool. One cone had a thin light weight spiral vane vertically attached to the cone's outside surface in order to cause it to rotate as it sank. Several trial runs were made in the shallow and deep ends of the pool, and in every case, the non-rotating cone without a vane hit the bottom of the pool first. These comparisons qualitatively and indirectly validate the prediction.

KEYWORDS :Rotating Cones, Translate in Fluids, Blunt End First

INTRODUCTION

Batchelor [1] found out theoretically that a solid cylinder rotating about its long axis at a constant rate in a still fluid of constant density makes a velocity field that has no friction, and the cylinder itself experiences no friction. Each circle on the surface of the cylinder along which the fluid velocity sticks is a closed Bernoulli loop [2], which is a streamline along which Bernoulli's law holds

p=const−12ρu2p=const−12ρu2 (1)

where p is the pressure, ϱ is the density and u is the velocity tangent to the surface of the cylinder that varies inversely as the radius from the axis of rotation. Such a velocity function has no associated friction according to the Navier-Stokes equations in polar coordinates.

Now consider a solid cone rotating about its long axis. There are similarities. The flow field has no friction and the cone senses no friction. But each Bernoulli loop on the cone's surface is different: smallest rotational velocities are at the apex and the largest speeds are at the base. Therefore the lowest pressures are at the base and the largest pressures are at the apex. Consequently at the cones surface, there are pressure gradients which make the cone translate parallel to the rotation axis, blunt end first. And the faster the rotation rate is, the greater the translation force becomes.

For a solid cone that is hollow, the translating force is larger yet due to the additional pressure gradients along the inside surface.

2. METHOD

Demonstrating by observations that this concept of a rotating and translating cone is true is not so easily carried out, mainly due to the rotation part of the problem. However, a somewhat indirect method of so doing is reported on here.

Two initially identical hollow cones, made of stiff orange plastic and barely buoyant, were subjected to trial runs in a calm swimming pool by adding equal weights to the apex of each in order to have them sink apex first. Base diameters were 10.5 cm and altitudes were 18 cm. One cone had a light weight plastic vane vertically attached to the outside surface in a spiral that had three revolutions and had the purpose of making the cone rotate as it translated. The vane was cut from a thin transparent film sheet normally used in overhead projectors. Its height was 1.5 cm and it was attached by 12 equally spaced paper clips injected into holes in the plastic cone. (12 paper clips were also added to the weight on the apex of the cone without a vane. The weight of the vane itself was considered negligible).

Since the tendency of a rotating cone is to translate base first, the cone with the vane should theoretically sink apex first more slowly than the cone without a vane. If released simultaneously from the surface, and side by side, the cone with no vane is anticipated to hit the bottom of the pool first.

3. RESULTS

Five trials were carried out in both the shallow and deep ends of the pool. In every case, the cone without a vane hit bottom first. These results are consistent with what was expected from the concept of the translation of a submerged rotating cone mentioned above.

A logical suggestion from a colleague for an additional type of trial was to have the bases of the cones go first during sinking. By shifting the weights to the inside rim of the bases this arrangement was carried out. But the results were not satisfactory because of an unexpected wobbling motion of the bases so that the long axes of the cones did not sink along straight vertical lines. Also the wobbling interfered, sometimes stopped, the rotation of the cone with a vane. The prediction that the cone with the vane should hit bottom first in this case was hinted at in only one trial run. A way to stop the wobbling was not figured out, so this method was dropped from further consideration.

4. DISCUSSION

More definitive comparisons between observations and the translation of a rotating cone in water are needed. In the above discussion, the configuration of a spiral vane on a cone to make it rotate while translating was copied from nature: the unusual looking egg case of the ocean's horn shark [3].

On the other hand, a cone falling and rotating in air provides another possibility for observations, and the badminton birdie probably can be used. It has a natural rotation while sinking due to the way the feathers overlap, which is counter-clockwise as viewed from above [4]. If the rotation rate is increased above the natural one, will it stay longer in the air before hitting the ground? That question can be answered without advanced laboratory equipment but perhaps with tools not usually available in the home. That is a project for the future. Although air is a compressible fluid, it is not anticipated that the cone falling and rotating would be qualitatively different than predicted above if compresibility had been included in the method.

CONCLUSION

Previously proposed is the notion that a rigid cone rotating underwater should translate blunt end first. Indirect agreement has been achieved by timing pairs of cones, one rotating and the other not rotating. When both cones are made with weights to sink apexes first, the rotating cones in several trials always sank more slowly, which provides qualitative verification of the concept.

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