Technical Comments

Comment on "Canadian Advances in Surface-Piercing Hydrofoils"

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IN their paper "Canadian Advances in Hydrofoil Design,"[1] Jeffrey and Eames devote much attention to Bras d'Or's design philosophy and its relation to prior art. My interest in this paper was heightened by a sense of personal involvement—I am the originator of the Grunberg system referred to by the authors (it will be designated by the initial "G"). In this capacity, I wish to correct misconceptions regarding G, which found their way into the article, and to establish G's unacknowledged integration into the Bras d'Or design. It would appear that the authors might have lacked first hand information on G (and some other systems referred to—or passed over—in their analysis).

At the onset, I wish to congratulate the authors and their associates in the project, whose competence, ingenuity, and industry contributed to its success. However, by way of clarification, the following five points are advanced.

1) Hydrofoil craft are distinguished by the method they use to maintain the vertical component of their lift force at equilibrium with their weight, without allowing draft to fluctuate beyond narrow permissible limits. The method also insures longitudinal stabilization, since otherwise lift could not be controlled. Two such methods are known, and accordingly two major types of hydrofoil craft are recognized: those supported by foils whose lifting area is made to vary, and those whose adjustment of lift to weight is achieved by variations in angle of attack of the foils (or by flaps, or both).

The "variable area" can be subdivided into two kinds: "ladder" and "V-foils" (or "surface-piercing foils"). In both of these variants, area control is inherent in the structure—no movable parts, no outside intervention. The ladder was invented by Forlanini. It established the general principle of area variation. Eventually the ladder evolved into V-foils which were proposed by Crocco in, or about, 1907.

The "variable angle of attack" is likewise represented by two variants: inherent angle of attack control—the "Grunberg System"†; and automatic control, originally attempted by simple mechanical means, and now achieved with the assistance of sophisticated sensors and electronic circuitery and hydraulic or electric actuators.

Configurations combining variable area and variable angle of attack also exist. The principle preponderant in the control of lift determines the class of the craft, but only if its ascendance is complete and the other principle is relegated to an incidental role, or if its involvement is unintentional, as it were. Thus, Grumman's Denison balances out vertical forces essentially by area variation, though in the process the foil's angle of attack may also change somewhat. The Denison is a surface-piercing craft. On the other hand, Aquavion is an incidence controlled configuration of the Grunberg type; but since its foil is provided with surface piercing tips for lateral stability, their presence causes some unavoidable area variations associated with the change of angle of attack. Designs which are not so clearly marked should be recognized for what they are—hybrids.

Jeffrey and Eames[1] try to elucidate where Bras d'Or belongs in this scheme of things. The question can be answered only by ascertaining which of the above methods is used for lift control and the correlated longitudinal stabilization. This is the only criterion. Lateral stabilization, in particular, is not necessarily a factor.

This fact was recognized from the outset in the descriptions of the Grunberg craft. Though she was stable laterally, the article's reservations notwithstanding, the means toward that end were deliberately not entered into the definition of the principle. For emphasis, it was pointed out that alternate means of achieving G's stability in roll were available and more could be devised in the future—but whatever the lateral stabilization, it is an independent item which must stand on its own merits, and is not an intrinsic part of the basic principle, characteristic of the concept. I, myself, have disclosed several such alternate arrangements; it has not been technological objections that prevented them from reaching the hardware stage so far.

2) All this is ignored in the paper. Under the headline "Grunberg-Aquavion Principle," G is mentioned (just once), though without its principle and relevance to Bras d'Or being clarified. It is further peremptorily alleged that my lateral stability (created in one optional arrangement by splitting, as it were, the stabilizer into two lateral units) "is inadequate in practice" and that "the necessary modifications" were provided by Aquavion. In fact, Aquavion's principle is pure Grunberg. Aquavion's lateral stability in roll was obtained by adding surface-piercing tips to Grunberg's main foil. The tips, of course, were borrowed from Crocco; only their function was reduced primarily to lateral stabilization. This, of all things, was the excuse for labeling, in the caption, the Grunberg principle—Grunberg-Aquavion, and for ignoring

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†The original models of the Grunberg system were tested in the towing tank of the Aerotechnical Institute of Saint-Cyr (France). The Institute's official report summarizes the nature and operation of the models as follows:

"The Grunberg system comprises essentially the following components: a) a hull, to support the total weight at rest and at taxing speeds; b) an immersed wing system carrying a major portion of the total weight at high speed; and c) a float, or train of two (transversely spaced) floats, in located forward, carrying a minor fraction of the total weight. At hydroplaning speed the floats establish a point of substantially constant level. Having reached sufficient speed, the wing system hoists the hull causing the whole assembly to rotate about the above point. This movement reduces the incidence of the lifting area until a steady attitude is assumed at an angle of attack which is function of speed (other conditions being equal)."

The preceding summary is limited to the bare characteristics of the tested models. Variants and generalizations can be found in Grunberg's patents and other publications. These include hydroskis, partly immersed hydrofoils, etc., in lieu of floats (collectively termed "stabilizers"); optional elastic damped suspension of the stabilizers; airfoils in lieu of hydrofoils; etc.

Grunberg altogether from there on. Whatever recognition the principle is conceded, the credit is assigned to Aquavion, unless it is claimed for Bras d'Or. For example, the article eventually does explain the Grunberg principle—as part of Bras d'Or concept—but only later, and it omits any reference to its originator.

The flat rejection of the method of lateral stabilization used in conjunction with the first Grunberg systems is neither substantiated nor justified. Presumably, the authors rationalize that the light loading of the stabilizers necessitates too wide a track for their liking. It is not stated what width is necessary, nor why, nor by what standards the width, such as it may be, is found to be unacceptable. The authors' opinion is not shared by impartial investigators. At least two different, manned, powered experimental G models were built and tested on two unrelated U.S. Navy contracts.[2,3] Both contractors arrived independently at favorable conclusions. The original lateral stabilization did not elicit complaints. One of the contractors experimented with stabilizers of amplified action ("acting skids"). Although the design was still not optimized, the report concludes:

"... Take-off and continued flight in both still waters and waves was no problem. ... Acting skids were shown to be superior to plate skids, although in less severe conditions plate skids are adequate ..."

The body of the report is even more positive: "The use of acting skids made feel very stable and it was believed impossible to capsize the craft."

3) Though not under its own name, the Grunberg principle and certain of G's design features are discussed in the paper. They had to be, for they confer Bras d'Or its character. Such is the case of what I called (longitudinal) "stabilizer," defined as at least one bow float, or hydrofoil, or hydroski (skid), or any device performing the absolutely essential function of providing G with an axis about which the craft trims in response to variable operational conditions. In my tests, the stabilizer was represented by skis. It reappears in Aquavion in substantially the same form, and later in Bras d'Or in the guise of more recently devised superventilated hydrofoils. Yet, whenever reference is made to this distinctive G hallmark—truly the key to the whole concept—G is consistently by-passed in favor of subsequent designs, as for example in the following: "The Aquavion uses a shape of bow float which also acts as a low-aspect ratio hydrofoil," or "The analogy between a superventilated foil (i.e., Bras d'Or's stabilizer. WG), which is effectively a submerged planing surface, and the Aquavion type of planing surface is interesting." More than interesting. Be it as it may. This is a recognition of sorts of the survival in Bras d'Or of the G principle. I accept the compliment on behalf of G; but I disassociate myself from the sentence that follows immediately thereafter: "The main difference in principle is that the superventilated foil unit provides the required degree of light damping without resort to a separate plate aft." I find no such difference. Somehow, the subsequent designers of G-type hydrofoils have overlooked a characteristic of my ski reported in Ref. 4. The working aft part of the ski was shaped into a body with considerable dead rise. As the term itself implies, deadrise deadens, i.e. flattens out, the surface contouring curve, much as superventilated foils are claimed to perform in reacting to wave orbital motion. It is possible that superventilated foils are more effective, but the principle of a stabilizer's self-damping has been established from the outset. At any rate, the tail plate is not all that important; it is certainly not indispensable to G. This system has a great innate potential for dynamic longitudinal stability[5] and for resistance to porpoising and contouring (within reasonable limits, of course). This property is due to the damping action of the main foil. The designer has complete control over several parameters. If stability has to be enhanced, he can move the main foil slightly aft. Or he can increase the main foil's area, thus reducing its angle of attack. He can also break up the single main foil into two tandem units. Their areas need not necessarily by equal, nor do they have to operate at the same angle of attack. Aquavion's "non-lifting" stern plate in association with the main foil is just a particular case of such a resolution into two units, not always, nor necessarily the most efficient of the possible solutions. In each particular case a parametric study can determine which way to go. Inasmuch as Bras d'Or is equipped with a G stabilizer, designers of this type of craft have all these choices at their disposal.

4) It is even more "interesting" to find that whatever affinity between G and Bras d'Or is indirectly acknowledged, the presentation is apt to divert the reader from the realization that G is one of the two basic principles on which Bras d'Or is built. So much so, that the abstract can reject as a mere "appearance" the reality that Bras d'Or "combines (some) characteristics of other modern designs." The following quote speaks for itself:

> "*The essence of the Canadian development* (italics mine,) lies in the use of radically different foil characteristics at bow and stern to augment the surface piercing effect and thus reduce the foil area needed to the required response."[1]

Translated into plain language, the expression "augmented surface piercing effect" simply means that both basic hydrofoil principles cooperate in Bras d'Or—variable area, under the alias of surface piercing effect; and variable angle of attack (i.e., Grunberg) unrecognizable behind the mask of "augmentation." This not only leaves G out, but it also conveys the false impression that augmentation, whatever it may be, is a mere subsidiary in the operation of Bras d'Or. And yet, "the radically different foil characteristics at bow and stern" is a Grunberg trademark. It is the absorbtion of this feature into the design that endows Bras d'Or with its essence—according to the authors themselves.

The first paragraph of p. 87,[1] dealing with the crucial principle of Bras d'Or's longitudinal behavior, expands on the same subject. I cannot reproduce it in full. Suffice it to note that it reveals nothing that has not been acquired by Bras d'Or through G's transplant into the Canadian design. It is G's "stiff" bow stabilizer that is responsible for Bras d'Or's incidence control; and when the article states that this is done "without moving parts by using the trim of the whole craft," it is merely repeating G's standard descriptions. This paragraph is illustrated by Fig. 3b bearing the caption DREA Concept. I certainly do not imply intentional misattribution; it is rather a sign of such thorough self-identification with the Grunberg principle that the mind ceased to recognize the boundaries between the old and the new creations. Nevertheless, it is a fact that Fig. 3b represents G as faithfully—if anything, more faithfully—as it represents the Canadian Concept, only it was G that came first. Text and figure emphasize the stiffness of the bow spring. With a spring as stiff as it possibly can be (in other words, with the spring totally eliminated) Fig. 3b would be descriptive of G's best known version. Its stabilizer is rigidly connected to the bow. My earliest publications disclose also an optional arrangement featuring a bow elastically supported by the stabilizer—a spring (or equivalent) and damper are incorporated into the suspension, truly the prototype of Fig. 3b. A word of caution to whoever would like to experiment with such an arrangement. The spring introduces an extra degree of freedom into the kinematics of the system; and depending on spring and damper properties, longitudinal stability could possibly be adversely affected.

The paragraph under review says that the bow foil provides "some measure" of incidence control. I feel that the words between quotation marks cannot possibly express the authors' real views. As far as I can judge, Bras d'Or's incidence is under complete control. All that these words do is belittle G's role in Bras d'Or's operation. The whole article tends to convey the impression that Bras d'Or functions on the surface piercing principle, augmented by something unnamed, which on analysis appears to be G's angle of attack control. No data are furnished to show in what measure the two principles actually divide between themselves the task of controlling lift. That would be inconsequential if Bras d'Or were presented as a hybrid configuration. But under the circumstances, there is a need for more precise data. One is reduced to conjectures. I have reasons to believe that Grunberg's contribution to lift control is not secondary at all, and I would not be surprised if variable angle of attack were the senior partner in its association with area variations.

5) Having covered my own case, I feel the responsibility to add a few words on behalf of those whose voices are stilled. The undisputed father of area control is Forlanini, but his was the ladder version. Crocco substituted surface piercing for the ladder. It would seem that research into the other (not-Grunberg) branch of Bras d'Or's family tree should have lead either to Forlanini, the distant progenitor, or, closer, to Crocco. Our admiration for the father of the telephone cannot be dimmed by the recognition that in hydrofoils Bell and Baldwin were only apostles of Forlanini's gospel. They visited Forlanini in Italy, studied his boat, purchased his patents. After several less successful models, thanks to sound engineering and with some improvements, by no means basic, they produced the excellent HD-4, of the ladder type. The HD-4 does not even appear to be in direct line of Bras d'Or's ancestry. I have sympathy for Forlanini and Crocco, who more than anyone else deserve to be remembered in their descendents of the surface-piercing type.

References

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Comment on "Ram Wing Surface Effect Boat"

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THE paper by R. W. Gallington[1] points out that even if the configuration of a ram-wing boat described in the paper has an aspect ratio of "less than one half of Dr. Lippisch ... the lift over drag ratio is the same or better" than the Aerofoil Boat configuration used by Lippisch.

The statements of Gallington are based on our work done in 1962 with tow tank tests[2] and the flight tests of the experimental Aerofoil Boat X-112.[3,4]

As can be seen from the drag measurements of the boat in tow of a motor boat, the resistance after takeoff from the water surface was 20 lb at a gross weight of 510 lb which corresponds to an $L/D = 25.5$. This value is certainly higher than the measurements shown on Fig. 11 of the paper by Gallington, even if the measurements on the X-112 correspond to $H = 1.0$ ($h/b = 0.05$) of the Fig. 11 of the paper.

The flight tests made in 1972 with the Aerofoil Boat X-113 Am of the Rhein Flugzeugbau GmbH (Germany) have confirmed the performance as well as the stability characteristics of these configurations. But, it must be noted that performance numbers at these low h/b or h/c values are not very essential, since the water surface is seldom so smooth that cruising flight at such small distances from the water surface can be maintained.

It is much more important to obtain high L/D values at distances from the water surface which can be maintained over waves and it is quite obvious that the aspect ratio for such "average sea state conditions" cannot be too small unless increase in power requirement at the larger distances from the water surface is too high for economical flight conditions.

References

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[2]Lippisch, A. M. and Colton, R. F., "Tow Tank Tests of a Low Aspect Ratio Ground Effect Surface," Rept. (CER) 1117-8 1963, Collins Radio Eng., Cedar Rapids, Iowa.

[3]"Dynamic Air Cushion Vehicle," *Flight International* (Supplement), June 1964, pp. 80–81.

[4]Lippisch, A. M., "The Aerodynamic Ground Effect and the Development of the Aerofoil Boat," *Luftfahrttechnik Raum fahrttechnik,* Okt. 1964.

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