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On a Generalized Theory of Lifting Surface

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In a flow field each point of the lifiting surface is proposed to be replaced by three hydrodynamical point-dipoles with mutually perpendicular axes and mutally independent intensities. The theory is conveniently applied to explain the interference among aerofoils.

The classical vortex theory(1) of an aerofoil is now commonly used to calculate the lift force acting on a body in an *incompressible* fluid. Its alternative, the theory of lifting surface,(2) was developed in 1936, which was followed by a generalized theory(3) of lifting surface so as to explain the lift of an aerofoil in a *comperssible* fluid. The theory of lifting surface, being based upon the idea of distributed hydrodynamical dipoles over the aerofoil, found many applications to the theories of screw propellers" ' and of aerofoil-lattices,(6),(7) as well as to the theory of jet flaps.(8) The theory can be also applied to explain the effect of wall-interference of aerofoils in a wind-tunnel. The linearized theory of lifting surface(3) can be also carried out, resulting in the *Prandtl-Glauert* correction added to the results hitherto obtained, though the precise calculations of aerofoil-lattice systems in a compressible fluid seem to be not yet appeared.

In the existing theory of lifting surface, the aerofoil in a flow is replaced by an assembly of singular points in the flow field, *i. e.* the aerofoil is replaced by an assembly of hydrodynamical dipoles (doublets), whose axes are orientated downwards to the aerofoil, perpendicular both to the camber-line and to the span-wise direction of the aerofoil, while the flow field itself around the aerofoil has no singular point. The resultant force acting on the aerofoil is calculated by integrating the pressure around the aerofoil surface.

If we want to take into account precisely the phenomena(5),(6),(7) in the flow field around an aerofoil which is one of the members of an aerofoil-lattice system, we could replace every point of the aerofoil by a set of three dipoles whose axes are orientated downwards to the aerofoil surface, parallel to the span-wise direction, and parallel to the camber-line, respectively. Generally speaking, an aerofoil in a flow field could be replaced by an assembly of point-dipoles, every point of the aerofoil corresponding to three mutually perpendicular dipoles, with mutually independent intensities. In other words, the present author proposes to consider three mutually perpendicular dipoles whose intensities are also mutually independent at every point of the aerofoil. By extending this idea, we can say that an aerofoil in a flow could be replaced by an assembly of singularities in the flow field, namely, a simple pole (positive or negative), dipoles, quadrupoles, etc., which are situated at every point of the aerofoil with arbitary orientation.

The idea of replacing every point of the aerofoil by three dipoles can be useful especially to explain the interference between aerofoils in a lattice system, and also the wall-effect of a wind-tunnel as well as the effect of a chordwise split in an aerofoil. If we want to take into account the effect of thickness of an aerofoil, we can also consider a simple source (positive or negative) and three dipoles at every point of the aerofoil at the same time. The theory of jet flap by Spence(8) with circulation and dipoles, seems to the author to contain some ambiguities in the sense of the generalized theory of lifting surface presented here. The mathematical theory of the lifting surface cited above can be easily formulated and will be published later in detail.

(1) L. Prandtl: Tragflügel-Theorie, 1. und 2. Mitteilung. Nachrichten von d. Königl. Gesells. d. Wissens. Göttingen. Math.-Phys. Klasse 451 (1918); und 107 (1919). Reprinted in "Vier Abhandlungen zur Hydrodynamik und Aerodynamik." Göttingen 9 (1927).
(2) L. Prandtl: Zeits. f. Angew. Math. u. Mech. 16, 360 (1936).
L. Prandtl: Luftfahrt-Forschung **13,** 313 (1936).
(3) H. G. Kiissner: Luftfahrt-Forschung 17, 370 (1940).
(4) K. Kondô: Memo. Fac. Engineering, Kyûsyû Imp. Univ. Japan 9, 145 (1942).
(5) Th. von Kármán and H. S. Tsien: Quart. Appl. Math. 3, 1 (1945).
(6) M. Honda: Proc. Roy. Soc. A254, 372 (1960).
M. Honda: Pro:. Roy. Soc. A265, 46 (1961).
(7) for example, R. Hürlimann: Zeits. f. Flugwissens. 13, 463 (1965).
(8) D. A. Spence: Proc. Roy. Soc. **A238,** 46 (1957).