Development and retrospect of classical rotor theories (historical review)

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The development of research in rotor aerodynamics (screw propeller, propeller, wind turbine, helicopter, etc.) has always been associated with an intensive development of the appropriate branch of industry. The first attempts to solve problems of the steamship navigation using screw propellers should be considered as the starting point for the elementary rotor theory. This resulted in the simple Rankine-Froude one-dimensional momentum theory of the screw propeller, called also the one-dimensional slim-stream or actuator disc theory.

In the early XX century, the development of rotor aerodynamics was motivated by creation and intensive evolution of aviation. At that time, all famous aerodynamic research schools in England, Russia and Germany studied this subject, but the Joukowsky's school from Russia and Prandtl's from Germany dominated in the creation of new concepts in aerodynamics and for an optimum rotor theory (Fig. 1). Their work as well as efforts of their contemporaries resulted in a development of the blade element momentum (BEM) theory to design rotor blades; in a creation of the general momentum theory of the actuator disc and in a formulation of a new vortex concept of rotor, originally designed for screw propellers with a finite number of blades. After the intensive and fruitful period in the evolution of the rotor aerodynamics for aviation needs, research activity has somewhat weakened due to change of aircraft propulsion from rotor to jet.

Current development of the rotor aerodynamics are undoubtedly associated with the rapid progress of wind energy whose status has been transformed from a minor performance capabilities of an alternative energy with small and individual wind turbines to the main branch of power economy as the most important renewable source of the global energy. In accordance with industry needs, interest of researchers to the rotor aerodynamics has significantly enlarged. Today a new stage of intensive scientific development is underway, similar to the fruitful aviation era by the scientific schools of Joukowsky and Prandtl. State-of-the-art of the investigation advances by a creation of the numerical simulation tools for the rotor optimizations, modeling of wind turbine wakes and establishing of numerical aerodynamics of the wind farms. Though most development of aerodynamic methods in wind energy concerned numerical methods, the wind-turbine era has brought a development of analytical approaches too. An explanation for the anomalous behavior of Joukowsky's infinite-bladed rotor[1] and new theories for optimum performance of finite-bladed rotors[2] have been developed. These give some simple guidelines for how to design optimum rotors.

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[1] Sørensen J.N., van Kuik G.A.M. *Wind Energy.* **14(7)**; 821 (2011).

[2] Okulov V.L., Sørensen J.N. *J. Fluid Mech.* **649**; 497 (2010).

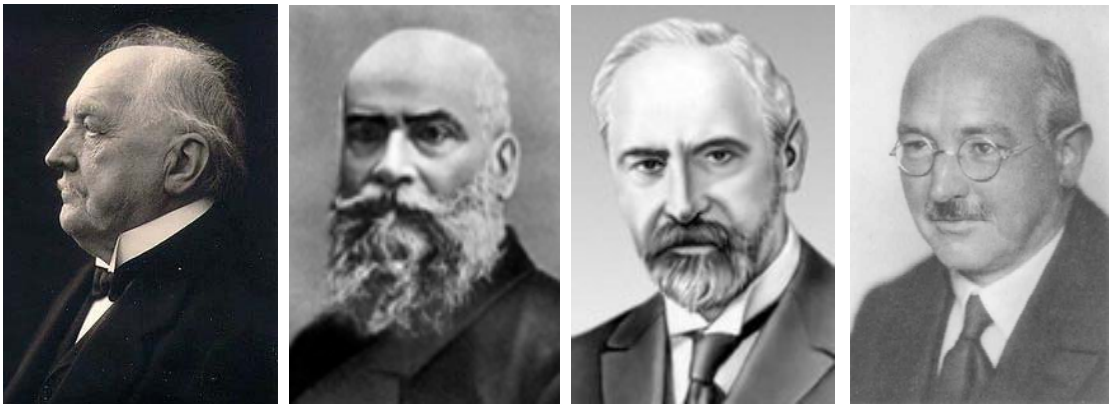

Figure 1: M. Kutta; N.E. Joukowsky; L. Prandtl and A. Betz (from left to right)