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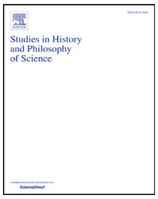

Model building with wind and water: Friedrich Ahlborn's photo-optical flow analysis

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ABSTRACT

Around 1900, several experimenters investigated turbulences in wind tunnels or water basins by creating visualizations. One of them, the German zoologist Friedrich Ahlborn (1858–1937), was familiar with the works by his contemporaries but he struck a new path. He combined three different kinds of photographs taken at the same time and showed the same situation in his water trough—but each in a different way. With this first basic operation, Ahlborn heuristically opened up a previously non-existent space for experimentation, analysis, and recombination. He generated an astonishing diversity of information by adopting the tactics of 'inversions' in which he interpreted one part of the experimental setup, or its results, in different ways. Between the variants of the 'autographs' which he developed, he defined areas of intersection to be able to translate results from individual records into each other. To this end, Ahlborn created other sets of visual artifacts such as drawn diagrams, three-dimensional wire frame constructions, and clay reliefs. His working method can be described as a cascading array of successive modeling steps, as elaborated by Eric Winsberg (1999), or of inscriptions in Bruno Latour's words (Latour, 1986). By examining Ahlborn's procedures closely we propose conceptualizations for the experimenter's various operations.

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1. Introduction—research context

The turbulence researcher Friedrich Ahlborn (1858–1937) does not surface in important surveys of the rise of hydrodynamics such as the ones by Wolfgang Merzkirch (1974) or Olivier Darrigol (2002, 2005). The contribution at hand does not claim to fill this gap and detail his role in the context of early turbulence research in Germany. Rather, it focuses on Ahlborn's intellectual agility with which he circled around his object of investigation and repeatedly set it in a new light. In my view Ahlborn is equally as insistent und inventive as Étienne-Jules Marey (1830–1904) when it comes to developing new visualization techniques in order to meet the difficulties that come up during the investigation. Some of Ahlborn's visualization methods were adopted by other researchers and institutions.

As pointed out by Michael Eckert in his chapter "The Beginnings of Fluid Dynamics in Göttingen, 1904–1914", Ludwig Prandtl's (1875–1953) boundary layer theory—first presented in 1904—was seen in retrospect as an important bridge between the theoretical and empirical factions in fluid dynamics research. In the 1920s, Ahlborn repeatedly demonstrates (Ahlborn, 1927, 1930b, p. 3, undat. h, p. 2) why he is not convinced of this account, which the theoretician Prandtl considered proven by his experiments.[1] Prandtl suspended iron mica—a mineral consisting of fine shiny

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[1] Also Margaret Morrison discusses Prandtl's boundary theory as coming from phenomenological modeling, which allowed him to deal with the viscosity of fluids, to approximate solutions to the Navier–Stokes equations as well as to integrate equations of motion for ideal, frictionless flows as proposed by Leonhard Euler. He divided the fluid conceptually into two different regions each following their laws: a laminal boundary layer and a turbulent flow (that is brought into existence by separation phenomena) that would explain the conflict between theory and experiment. Morrison assessed Prandtl's model as follows: "The model is phenomenological not because there is no theory from which to draw but because it is motivated solely by the phenomenology of the physics". (Morrison, 1999, p. 54) Ahlborn would have certainly disagreed. He accused Prandtl several times of not being able to detach himself from the concept of the ideal potential flow. This misleads him to assume an overpressure at the back of the resistance object that is unsurmountable for the boundary flow fold. This allows him satisfy the symmetry as proposed by theory. In contrast, Ahlborn believes in a threefold resistance that is responsible for the formation of vortices: a displacement or pressure resistance directed forward, a suction or tensile strength directed backward, and a lateral friction resistance. (Ahlborn, 1902a, p. 3).

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lamina—in the water in order to be able to better differentiate the water surface: “Thereby all slightly deformed areas of the water, that is especially all vortices come to the fore due to a peculiar sheen that is caused by the orientation of the lamina located there.” (Prandtl, 1905, p. 7).

According to Ahlborn’s estimation, Prandtl failed to take into consideration the adhesive nature of the tracer material he used and thus drew the wrong conclusions from the photographs, assuming a separation of a boundary layer fold (Ahlborn, undat. i, pp. 6–7). This ended in a lifelong controversy between Ahlborn and Prandtl, which appears like a fight between David and Goliath. On the one side Prandtl, director of the Institute for Technical Physics at the University of Göttingen and surrounded by a group of PhD students, and on the other hand the often unfunded high school teacher Ahlborn working mostly on his own or with one collaborator and complaining bitterly that his publications would be hampered by his influential adversary. The vivid exchange of letters between Ahlborn and the engineer Otto Krell attest that in the 1930s Prandtl offered to settle the controversy with Ahlborn at an official event. In response, Ahlborn triumphed that he finally understood who is right. That gesture definitively terminated any contact between the two.

Nonetheless, Prandtl’s institute in Göttingen adopted the ‘Ahlborn-method’ (moving the object through still water with lycopodium sprayed on the water surface, recorded as photographs or as films (Prandtl & Tietjens, 1925)) beginning in 1925 at the latest. This can be seen as a further bridge between the disharmonious factions of theoreticians and experimenters in the field.[2]

2. The early stages of turbulence research

Many of Ahlborn’s experiments until about 1905 are to be seen as mere basic research dealing with the qualitative mechanical relationships and causes of resistance. Nonetheless he keeps an eye on applied problems. In his 1903 proposal to establish a Hydrodynamical Institute of Hydraulic Engineering for the Navy in Hamburg, Ahlborn mentions the British naval engineer William Froude (1810–1879) as a role model (Ahlborn, 1903, p. 2). With model tests in his research center in Torquai, Froude succeeded in determining the required machine power for planned ships. Researchers in other contemporary testing laboratories with large water basins—in Dumbarton, Haslar, Spezzia [La Spezia], Washington, and Uebigau—dedicated themselves to the influence of the depth of the shipping channel or immersion on the speed of the ship; the reciprocal effect of neighboring vehicles in danger of collision; the discovery of the best profiles for channels, etc. These were also fields of application for Ahlborn. In 1917, his experimental setup was transferred to the aircraft maintenance facility in Berlin-Adlershof. During the First World War, Ahlborn mainly investigated the flight capabilities of aircrafts there and thus he was able—if not in terms of methods, but thematically—to catch up on his earlier research from the field of biology.

2.1. Renouncing the rotating arm

Ahlborn, holder of a PhD in zoology, initially studied flying fish and the flight of birds. In the 1890s, he performed experiments in the courtyard of the Deutschen Seewarte[3] in Hamburg with the so-called ‘Combeian Rotational Device’ installed there, in which an arm bearing a pressure gauge rotates around a central post at an elective speed (Georgi, 1957, pp. 7–8). The objective of his research was to determine the effect of air resistance upon tilted surfaces. With its rotating arm five meters long, this instrument must have looked quite different from the substantially smaller device that had been used somewhat earlier by the Parisian physiologist Étienne-Jules Marey (Nogues, 1933). The experiments with the rotating arm did not yield exhaustive results, since both Marey and Ahlborn, two scientists devoted to making the invisible visible, soon abandoned the contraption. Ahlborn made the following statement: “As important and indispensable the measurement of resistance of fluids is for questions of technology, it does not reveal anything about the causes of these effects. A true understanding of the mechanical relationships is not possible without a certain knowledge of processes that unfortunately elude immediate, subjective observation.” (Ahlborn, 1905, p. 69) In addition, both researchers knew how easily the object of their observation could be influenced. For this reason, they concluded it was preferable not to introduce measuring instruments into the sensitive medium itself. Instead, they switched to optical technologies.

Marey—also a type of ornithologist—continued to meditate on how one could make visible not just flight itself, but also the air turbulence caused by flight. A very light material would be needed to show the currents of air. He gave some thought to goose down (Braun, 1992, p. 217), and then, in 1896, remembered a lecture given by Émile Müller eleven years earlier. In his experiments, Müller had used smoke from a burning cotton string to indicate the effects of the beating of an artificial wing on the surrounding air. Right next to the rising smoke, by mechanical means, the scientist suddenly lowered a flat, wing-shaped object. Because of the mass of air moving laterally away from the wing, the smoke—which in an undisturbed environment streamed vertically upwards—was horizontally displaced or disrupted, with the area of the break framed by vortices rotating outward. The effect was clear, but a desire for further defining attributes could plainly be felt. This very simple demonstration was nowhere near a useful implementation of parameters that could be varied systematically. Nonetheless, Marey had been given a vital clue with respect to the tracer material. Regarding the experimental setup, Marey developed an alternative model to the manometer with the rotating arm: namely, the wind tunnel.

His wind tunnel consisted of a vitrine with air piped in from above through equidistant nozzles, and suctioned out from below. An object was placed approximately in the center of the vitrine, so that turbulence could develop in the moving air. As compared with the manometer, Marey changed the object of motion: in his wind tunnel, the object no longer rotated through the air, which was never completely still—this was one of the problems with the rotating arm. Now, it was the air, tamed as much as possible in terms of direction and movement, which flowed around a static object. This mode offered the considerable advantage that the involved factors could be controlled: in the closed chamber, a situation was created that to a certain extent made it possible to ensure a mono-causal motion. Experimental setups based on this principle are standard procedure in the aerospace and automotive industries to this day.

As his records indicate, Ahlborn followed Marey’s hydro- and aerodynamic studies closely. Fig. 1 shows an extract from Ahlborn’s notebook in which he sketched Marey’s wind tunnel with a few

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[2] In contrast to Prandtl’s independently made recordings of the water basin from 1904, the Ahlborn method sets out to avoid registering the unevenness of the water surface in the photographs. Ahlborn addresses the roughness of the surface in other recording methods without camera. He interprets these records (backwater lines, cf. Section 4.2.3) as ‘profile’, while the photos show the same phenomenon ‘en face’ (Ahlborn, 1901, p. 123).

[3] Until 1945, the central German institute for maritime meteorology.

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