

A short history of hydraulics

Hydraulics is a very ancient science. The Egyptians and Babylonians constructed canals, both for irrigation and for defensive purposes. No attempts were made at that time to understand the laws of fluid motion. The first notable attempts to rationalize the nature of pressure and flow patterns were undertaken by the Greeks. The laws of hydrostatics and buoyancy were enunciated, Ctesibius and Hero designed hydraulic equipment such as the piston pump and water clock, and (of course) there was the Archimedes screw pump. The Romans appear, like the Egyptians, to have been more interested in the practical and constructional aspects of hydraulics than in theorizing. Thus, development continued slowly until the time of the Renaissance, when men such as Leonardo Da Vinci began to publish the results of their observations. Ideas which emerged then, respecting conservation of mass (continuity of flow), frictional resistance and the velocity of surface waves, are still in use, though sometimes in a more refined form. The Italian School became famous for their work. Toricelli et al. observed the behaviour of water jets. They compared the path traced by a free jet with projectile theory, and related the jet velocity to the square root of the pressure generating the flow. Guglielmini et al. published the results of observations on river flows. The Italians were hydraulicians in the original sense of the word, i.e. they were primarily empiricists. Up to this point, mathematics had played no significant part in this sort of scientific work. Indeed, at that time mathematics was largely confined to the principles of geometry, but this was about to change.

In the 17th century, several brilliant men emerged. Descartes, Pascal, Newton, Boyle, Hooke and Leibnitz laid the foundations of modern mathematics and physics. This enabled researchers to perceive a logical pattern in the various aspects of mechanics. On this basis, four great pioneers - Bernoulli, Euler, Clairaut and D'Alembert - developed the academic discipline of hydrodynamics. They combined a sound mathematical framework with an acute perception of the physical phenomena which they were attempting to represent. In the 18th century, further progress was made, both in experimentation and in analysis. In Italy, for example, Poleni investigated the concept of discharge coefficients. However, it was French and German thinkers who now led the way. Henri de Pitot constructed a device which could measure flow velocity. Antoine Chezy (1718-98), followed by Eytelwein and Woltmann, developed a rational equation to describe flow in streams. Men such as Borda, Bossut and du Buat not only extended knowledge, but took pains to see that the available knowledge was disseminated. Woltmann and Venturi used Bernoulli's work as a basis for developing the principles of flow measurement.

The 19th century was a period of further advance. Hagen (1797-1884) constructed experiments to investigate the effects of temperature on pipe flow. His understanding of the nature of fluid viscosity was limited to Newton's ideas, yet so careful was his work that the results were within 1% of modern measurements. He injected sawdust into the fluid for some of his experiments, in order to visualize the motion. He was probably the first person knowingly to observe turbulence, though he was unable to grasp its significance fully. At almost the same time, a French doctor (Poiseuille) was also making observations on flow in pipes (in an attempt to understand the flow of blood in blood vessels), which led to the development of equations for laminar flow in pipes. Further contributions were made by Weisbach, Bresse and Henri Darcy, who developed equations for frictional resistance in pipe and channel flows (the first attempts to grapple with this problem coincided with signs of an incipient awareness

of the existence of the 'boundary layer'). During the later part of the century, important advances were made in experimentation. The first practical wind tunnel, the first towing tank for model testing of ships and the first realistic attempt to model a tidal estuary (by O. Reynolds) were all part of this flowering of knowledge. These techniques are still used today. Reynolds also succeeded in defining the different types of flow, observing cavitation and explaining Darcy's friction law in greater detail.

Even at this stage, studies of fluid flows were subdivided into 'Classical Hydrodynamics' (which was a purely mathematical approach with little interest in experimental work) and experimental 'Hydraulics'. Navier, Stokes, Schwarz, Christoffel and other hydrodynamicists all contributed to the development of a formidable array of mathematical equations and methods (including the conformal transformation). Their work agreed only sporadically with the practitioners (the hydraulicians) and, indeed, there were frequently yawning disparities between the results suggested by the two schools. The rapid growth of industry in the 19th and 20th centuries was by now producing a demand for a better understanding of fluid flow phenomena. The real breakthrough came with the work of Prandtl. He proposed (in 1901) that flow was 'divided into two interdependent parts. There is on the one hand the free fluid which can be treated as inviscid (i.e. which obeyed the laws of hydrodynamics) . . . and on the other hand the transition layer at the fixed boundaries' (the transition layer is the thin layer of fluid within which frictional forces dominate). With this brilliant insight, Prandtl effectively fused together the two disparate schools of thought and laid the foundation for the development of the unified science of Fluid Mechanics.

The 20th century has, in consequence, seen tremendous advances in the understanding and application of fluid mechanics in almost every branch of engineering. It is only possible to give the barest outline here. Prandtl and Th. von Karman published a series of papers in the 1920s and 1930s, covering various aspects of boundary layer theory and turbulence. Their work was supplemented by increasingly sophisticated laboratory research (e.g. the work of Dryden and his colleagues at NACA in the USA). These efforts had an impact on every aspect of engineering fluid mechanics. In the 1930s, the efforts of Nikuradse (in Germany), Moody (in America), Colebrook (Great Britain) and others resulted in a clearer understanding of pipe flows and, in particular, of the factors affecting pipe friction. This led directly to the modern methods for estimating flows in pipes and channels.

Since 1945, the advent of the electronic computer, and advances in sensing and data logging equipment have revolutionized many aspects of hydraulics. Our understanding of the nature of turbulence, steady and unsteady flows in channels, sediment transport and maritime phenomena have developed rapidly. This has been matched by developments in software. Today's engineer, with a modern personal computer or workstation at his or her disposal, has the tools to achieve more effective and economic designs.

International research continues at an intensive pace, as our world faces many problems, social and environmental. On the threshold of the 21st century, there is every reason to suppose that engineers and scientists will face exciting and difficult challenges that will place the fullest demands upon their skills.