Introduction to Force Balances

There are many circumstances in which there is a need to measure the forces and moments imposed by a flow on an object or the reverse. Examples range from the desire to measure the lift, drag and moments on an airfoil or hydrofoil, to the forces generated by a propeller, pump or turbine impeller to the fluid forces causing the vibration of a oil-drilling rig. Sometimes the solution is to mount strain gauges on the object itself and to use a combination of those measurements and a structural analysis code to develop understanding of the detailed mechanics. Sometimes, for example with foils, the airfoil or hydrofoil is mounted on a force balance and installed in a tunnel for direct measurement of the forces under investigation. Sometimes, as in the example described in the next section, a propeller, pump or turbine impeller is mounted on a force balance designed to measure the forces communicated between the impeller and the drive shaft.

While it may be difficult to generalize the series of steps involved in the design of such a force balance, there are a number of basic considerations that feature in many such designs. One of the first considerations is to recognize that almost all balance designs represent a compromise between rigidity and sensitivity: the rigidity must be sufficient so that the deformation of the balance under the measured forces does not change the flow being measured. However, an excessively rigid balance leads to deflections that are too small to measure accurately. Some of the older force balances designed for use with airfoils and hydrofoils featured a compensation feed-back mechanism that acts to return the deflection to zero. These were complex and expensive balance mechanisms which also had some disadvantages such as the inability to measure oscillatory forces at all but the lowest frequencies. The development of more sensitive strain gauges allowing much reduced deflection magnitudes reduced the need for such compensation devices and we will not dwell further on these in this exposition.