7
Single-Degree-of-Freedom Gyroscopes

In Chapter 6 we described the Law of Gyroscopics, so now we can see how instruments put this law to work and how they are designed. We begin with the single-axis, or single-degree-of-freedom gyro (SDFG). There are two types to consider, the rate gyro, an open-loop sensor, and the rate-integrating gyro, a closed-loop version. As usual, the closed-loop gyro has higher accuracy, whereas the open-loop gyro is less expensive. The most common SDFGs are filled with a fluid to provide damping and sometimes flotation; why and how this is done will be a subject of this chapter. The SDFG is the most common type in the field; more than a million have been put into service, and even though optical technology will make them obsolete, they will be in the inventory for many years.

An accelerometer can be made from a single-axis gyro in two ways, which we will also describe. One of them, the pendulous integrating gyro accelerometer (PIGA), is currently the most sensitive and accurate accelerometer available.

The Rate Gyro

A rate gyro provides a signal proportional to rate of rotation (angular velocity). The heart of the SDF rate gyro is a wheel running at high speed on low-noise ball bearings, usually driven by an electric motor. There are models used in guided weapons, where the wheel is spun up by a gas jet and allowed to coast, but because of the practical limits to the gas supply, these are useful only for short missions. Because the scale factor depends on the angular momentum, which is proportional to the wheel speed, gas-driven instruments can only be used where accuracy need be no better than a few percent.

The wheel is mounted in a frame or gimbal that is attached to the instrument case by one or two torsion bars; if one is used, the other end of the gimbal is connected to the case by a low-friction ball bearing. Figure 7.1 illustrates this construction; the torsion bar and bearing are on the instrument output axis (OA), the axis about which the gimbal turns in response to a rate about the input axis (IA). The wheel and motor assembly is sealed inside a housing filled with an inert gas such as helium, which allows the gyro to be filled with damping fluid. This housing forms the gimbal, to which are attached the torsion bar, an OA bearing,
Figure 7.1. The single-axis rate gyro.

and perhaps the rotor of a damping compensator. A pickoff measures the gimbal angle and will provide an electrical output (usually AC) whose magnitude is proportional to the gimbal angle. A gimbal with its pickoff can be seen in Figure 7.2. Let us assume in the following that the pickoff has a sensitivity of $K_{po} \text{ V/rad}$.

**The Scale Factor**

We can construct an expression for the gyro's scale factor using Equation (6.2), opposing the gyroscopic torque due to a steady rate $\Omega$ with a torsion bar of stiffness $K_{tb} \text{ N-m/rad}$:

$$T = H\Omega = \theta K_{tb}$$

where $\theta$ = gimbal deflection. The pickoff provides an output signal, $S$, given by

$$S = \theta K_{po}$$

Therefore, the gyro scale factor [Equation (2.1)] is

$$K = \frac{S}{\Omega} = \left(\frac{K_{po}}{K_{tb}}\right)H \quad (7.1)$$