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PART 2 : SECTION 1

CHAPTER 1

THE GYROSCOPE

1. A gyroscope is a rotating mass having freedom in one or more planes at right angles to the plane of rotation. It possesses two fundamental characteristics: *rigidity* or gyroscopic inertia, and *precession*. These apply to any rotating mass, be it helicopter rotor, propeller, jet engine compressor, or revolving wheel; and any rotating mass designed to utilize rigidity and precession is known as a *gyroscope*.

Rigidity

2. Rigidity is the property, possessed by a rotating mass, of reluctance to change its plane of rotation unless acted upon by an external force. This is an application of Newton's First Law of Motion, which states that a body remains in a state of rest or uniform motion unless compelled by some external force to change that state.

3. In Fig. 1, each molecular particle in the circumference of the rotating wheel is attempting to obey Newton's Law and to fly off at a tangent. Any attempt to make an angular change in the plane of rotation will be resisted by this tendency of the particles to fly off at a tangent. In other words, the rotating wheel will tend to remain rigid in its plane of rotation.

4. Rigidity is related to centripetal force, hence it follows that the magnitude of the rigidity in any specific case is dependent upon the speed of rotation, the mass of the rotor, and the distance of the mass from the axis of rotation. Thus the

rigidity of a given mass can be increased by concentrating the mass around the periphery of the rotor.

Precession

5. Precession is the angular change of direction of the plane of rotation of a gyroscope, resulting from the application of an external force.

6. A gyroscope will resist movement in the plane in which an external force is applied; but will move in a plane at 90° to the applied force.

7. This property of a rotating body to precess is in accordance with elementary mechanical law relating to objects subjected to forces from two directions. Consider the two particles X and Y on the circumference of the rotor (Fig. 2a), which according to Newton's Law will tend to fly out tangentially. If an external force is applied at X in the direction shown in Fig. 2a, it will tend to move particle X to the left and particle Y to the right. Each of these particles is now being subjected to two separate forces, and the effect of this on particle X can be resolved as XZ. The resultant force on particle Y is in the opposite direction, and the ultimate effect is a tilt of the gyro, in this case to the left.

8. If the externally applied force is sustained from the original direction (Figs. 2c and 2d), the gyroscope will continue to tilt to the left until the axis has moved through 90° ; that is to say, until the lines along which the two forces act (the centripetal force and the externally applied force) coincide, when the tilting movement will cease. The rate of precession depends on the magnitude of the external force and the inertia of the gyroscope.

9. The direction in which the gyroscope will precess can be determined by a rule of thumb method known as the 90° rule, which states that any force applied to a gyroscope will take effect at 90° in the direction of rotation. In Fig. 2a, for example, the gyro tilted as though the external force had been applied at D rather than at X, i.e. 90° around the circumference in the direction of rotation.

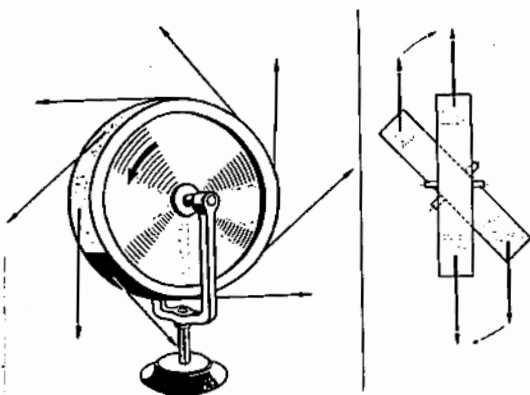


Fig. 1. Gyroscopic Rigidity.

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A.P. 129, VOL. 1, PART 2, SECT. 1, CHAP. 1

10. Any external force due to bearing friction or an unbalanced rotor will cause precession. Accurately balanced rotors and mountings free from vibration are therefore essential.

11. These properties of rigidity and precession are used to provide the pilot with certain presentations from which he can visualize the attitude of his aircraft without external visual aid.

12. Unfortunately, certain constructional difficulties arise in some gyroscopic instruments (described in detail later), which impose limits on the freedom of movement of the gyroscope. When these limits are exceeded, the gimbal system (through which the gyro obtains its freedom of movement) comes up against stops, and a precession is set up, causing the instrument to give erroneous indications. When this occurs, the gyro in question is said to be *toppled*.

Definitions of Terms

13. The terms space, tied, earth, and rate gyroscope, will occur later in this section, and each term is therefore defined below.

14. **Space Gyroscope.** A space gyro is one that has complete freedom in three planes at right angles to each other.

15. **Tied Gyroscope.** A gyroscope that has freedom in three planes at right angles to each other, but is controlled by some external force.

16. **Earth Gyroscope.** An earth gyro is a tied gyro that is controlled by gravity in order to maintain its position relative to the earth.

17. **Rate Gyroscope.** A rate gyroscope is a gyro which has one plane of freedom at right angles to the plane of rotation and is so constructed as to

indicate rate of movement about the plane at right angles to both the plane of rotation and the plane of freedom.

Air-Driven Gyroscopes

18. Some gyroscopes are driven by using the suction at the throat of a venturi to exhaust air from the case of the instrument. The replacement air is directed by a system of jets into buckets cut in the periphery of the rotor, thereby causing the rotor to revolve at a high speed. At a low air-speed, however, such as that experienced during the initial stages of taking off, the suction obtained from a venturi may be insufficient to operate the instruments. Furthermore, the venturi is susceptible to icing and is inefficient at high altitudes owing to the decreased air density. Therefore, except on the lighter types of aircraft, suction is normally obtained by means of an engine-driven suction pump.

19. The engine-driven suction pump is of the vane type and is capable of providing a maximum suction equivalent to ten inches of mercury at normal engine operating speeds. Since this is a greater suction than is required to operate the instruments, a relief valve is provided in the form of an adjustable spring-loaded valve vented to the atmosphere.

20. The valve is set to give the desired suction in the line leading to the instruments, and the tension on the spring is so adjusted that any suction in excess of that required is reduced by allowing atmospheric pressure to enter the system through the valve opening.

21. Should the suction pump cease to function correctly, either through the engine that is driving it experiencing mechanical trouble or through the pump itself developing a fault, an alternative

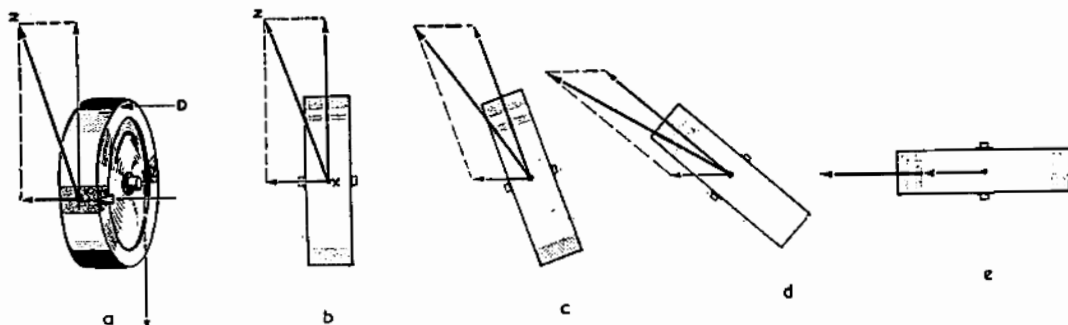


Fig. 2. Precession.

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THE GYROSCOPE

suction source is available on most aircraft. On single-engined aircraft and on some twin-engined aircraft, the alternative source may take the form of a venturi, but on twin- and multi-engined aircraft it is usually a second engine-driven suction pump. On some of these aircraft the failure of one suction pump necessitates manual selection of an alternate pump. On others both pumps are working continuously, and the suction system arrangement is such that, should one suction pump fail, the remaining pump will provide enough suction to drive the instruments without manual selection.

22. The degree of suction in the system is indicated to the pilot by a gauge, graduated in inches of mercury.

23. The rotors of some suction pump-driven gyroscopes attain their correct rotational speed after four to five minutes' running at the correct suction after the appropriate engine has been started up, but they will gain enough speed to provide instrument indications in the correct sense after one and a half to two minutes' running time. Artificial horizons are considered to be

entirely reliable after one and a half to two minutes' running time at the correct suction.

24. An inherent characteristic of air-driven instruments is their inability to maintain the full rotor speed in rarefied air, and a further disadvantage is that in spite of filtering, foreign matter and atmospheric moisture may get into their mechanisms and affect the bearings adversely.

Electrically-Driven Gyroscopes

25. In electrically-driven instruments the gimbal system can be constructed along simpler lines, thereby permitting greater working limits. Moreover, the rotor bearings are not subjected to inducted dust or moisture, and the driving medium is unaffected by the reduced air density at altitude. Therefore, sustained high rotor speeds and consequently a high degree of rigidity are obtained.

26. Power for operating electrically-driven instruments is drawn from the aircraft supply, which is a direct current system, and for those instruments which require alternating current an inverter is used to convert D.C. to A.C.

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