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AIRSPEED MEASUREMENT DEVICE FOR SLOW AIRCRAFT

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ABSTRACT

A device, system, and method for measuring the airspeed of a slow moving aircraft are disclosed. The device comprises a pitot tube at the end of a rotating arm. When installed on an aircraft, the pitot tube is exposed to a relative wind that is the result of the sum of the speed due to rotation and the forward speed of the aircraft. The pressure is turned into an electrical signal by a pressure sensor. This pressure sensor's output is processed by an electronic unit which extracts the aircraft's airspeed, ignoring the speed due to rotation. The difference between the highest and the lowest pressure is an indication of the aircraft's airspeed.

BACKGROUND

Various methods have been used to measure airspeed of aircrafts. Fixed pitot tubes which are dynamic pressure measurement devices, work well to in measuring airspeed down to about 30-40 knots. However, the pressure is quadratic with airspeed, so at low speeds it becomes very inaccurate.

Anemometer, windmill type devices for measuring the speed of the wind, have also been used to measure the speed of aircrafts. The faster the speed of the aircraft, the faster the anemometer spins. However, the speed, and therefore the measurement, is very friction dependent. As the device wears over time, the speed measurement becomes less accurate.

Airspeed may also be measured using acoustic devices. This method relies on the fact that sounds travels through the air at a known speed, and thus a microphone ahead of a noise source hears the sound at a different time than a microphone behind the noise source. However, this method depends on air density, and thus works poorly at high altitude.

Optical methods have also been used to measure airspeed. This method uses a series of flashes of light to illuminate particles floating in the air. By taking photographs in succession, it can measure how far the particles have traveled during the known interval between flashes. This method works well where there are particulates in the air. At high altitude where the air is very dry and very clean, it works poorly.

Thus, there is a need for accurate systems, methods, and devices for measuring the airspeed of aircrafts at high altitudes and low velocities.

DESCRIPTION

Devices, systems, and methods for measuring the airspeed of a slow moving aircraft are disclosed. Embodiments of the device comprise a pitot tube, that is, a dynamic pressure measurement device, at the end of a rotating arm. An exemplary airspeed measurement device located at the nose of an aircraft is shown in FIG. 1. The device comprises a rotating arm comprising a pitot tube at one end and a counter weight at the other end.

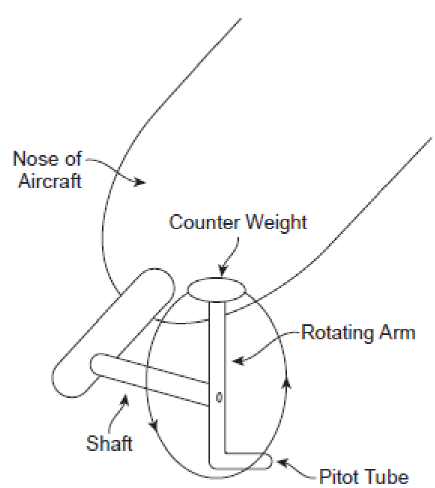

FIG. 1: Airspeed measurement device comprising a pitot tube at the end of a rotating arm

When installed on an aircraft, the pitot tube is exposed to a relative wind that is the result of the sum or difference of the speed due to rotation and the forward speed of the aircraft. An exemplary rotating pitot tube is shown in FIG. 2.

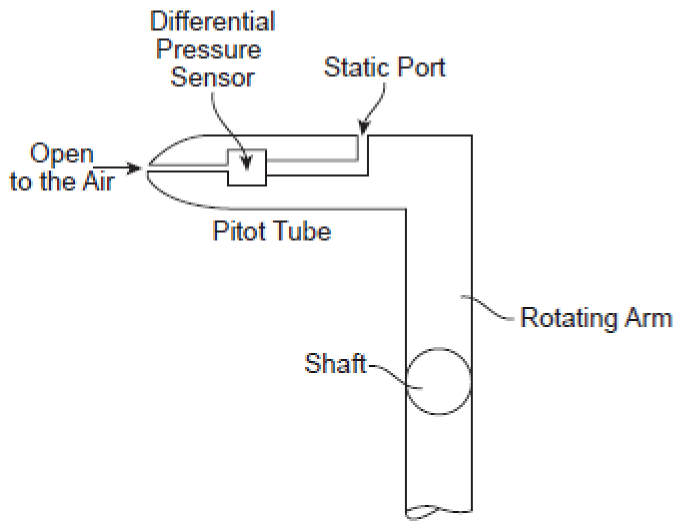

FIG. 2: Rotating pitot tube comprising a differential pressure sensor

The pressure is turned into an electrical signal by a pressure sensor. This pressure sensor's output is processed by an electronic unit which extracts the aircraft's airspeed, ignoring the speed due to rotation. The difference between the highest and the lowest pressure is an indication of the aircraft's airspeed. FIG. 3 depicts the sensors and electronics of an exemplary device.

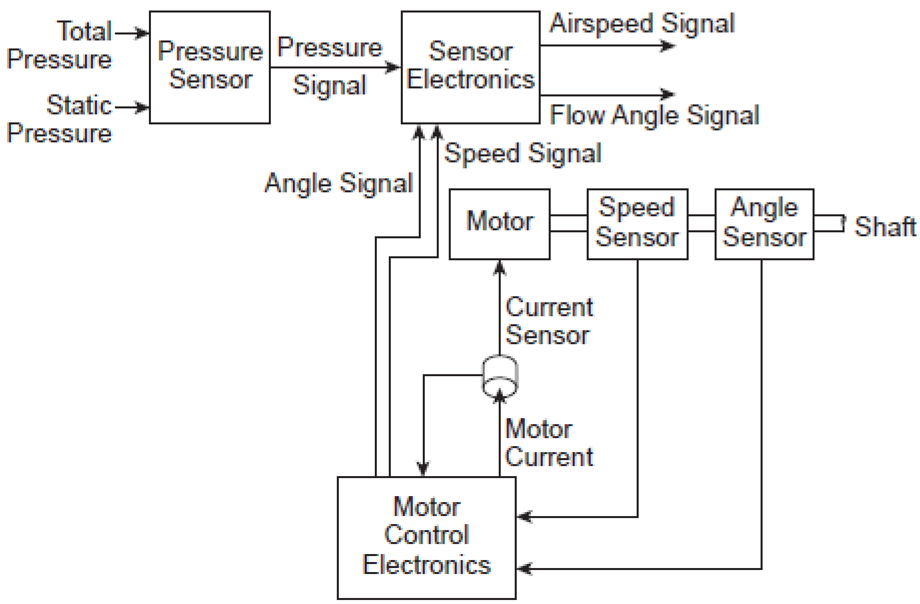

FIG. 3: Airspeed measurement device sensors and electronics

A key advantage of the device stems from the fact that dynamic pressure is proportional to the square of the airspeed. Thus “mounting” a small velocity (the aircraft’s airspeed) on top of a big one (the rotational speed) allows this device to measure a small speed accurately.

As an additional feature, the angle of the relative wind to the aircraft may be extracted from this signal, i.e. either angle of attack or angle of sideslip may be measured, depending on how it’s installed. These are collectively known as “flow angles.” The flow angle is extracted from the signal by measuring when in the rotation the pressure peaks. If it peaks when the pitot tube is facing straight ahead, the flow angle is zero. If it peaks 1/10th of a rotation later, the flow angle is 36°, etc.

Another useful feature, not shared by any other airspeed measurement device is that the device may be tested prior to takeoff to ensure it is working properly. When the device is spinning, it will measure a dynamic pressure. That pressure will be constant throughout the rotation, but it will be non-zero. Thus a preflight test could simply measure the pressure and determine if it’s correct.

The rotation of the pitot tube is driven by a speed-regulated motor. The speed is held constant by a governor circuit, and is monitored. The current required to drive the motor is also monitored. Keeping the rotation speed constant is useful because it makes it easier and more accurate to extract the airspeed. Additionally, keeping the airspeed constant makes it easier to detect an impending failure.

A failure detection mechanism may be included. This measures the current drawn by the motor. Increases in current are a sign of increase in friction, probably due to an impending bearing failure, or debris in the mechanism.

FIG. 4 depicts an exemplary airspeed measurement device with a true airspeed v_T and a measured airspeed v_m. What is desired is the unknown true airspeed v_T. The angular speed of the arm ω as well as the radius of the arm r are both known. The measured airspeed v_m is equal to $\omega\mathrm{r} + v_T$. Two methods of extracting v_T are described herein.

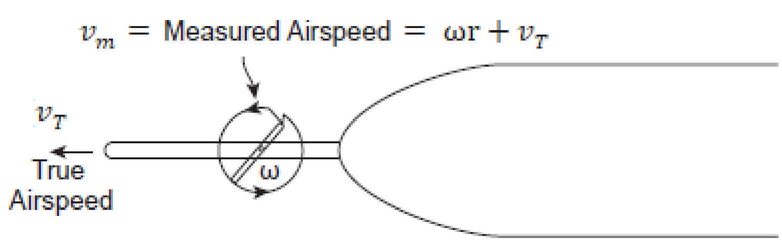

FIG. 4: Airspeed measurement device showing true airspeed and measured airspeed

FIG. 5 shows a graph of the dynamic pressure q. The dynamic pressure can be calculated with the following formula, where p is the fluid density:

$$\text{Dynamic Pressure} = q \begin{cases} q = \frac{1}{2} p {v_m}^2 \\ q_1 = \frac{1}{2} p(\omega\mathrm{r} + v_T)^2 = \frac{1}{2} p(\omega^2\mathrm{r}^2 + {v_T}^2 + 2\omega v_T) \\ q_2 = \frac{1}{2} p(\omega\mathrm{r} - v_T)^2 = \frac{1}{2} p(\omega^2\mathrm{r}^2 + {v_T}^2 - 2\omega v_T) \end{cases}$$

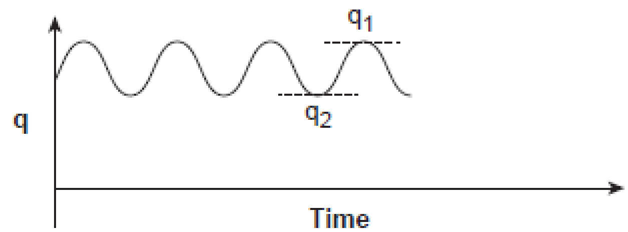

FIG. 4: Dynamic Pressure

One method of determining v_T is to subtract q_1 - q_2, to find the difference between the highest and lowest dynamic pressures:

$$q_1 - q_2 = \frac{1}{2}p\big(2\omega r v_T - (-2\omega r v_T)\big) = 2p\omega r v_T = \Delta q$$

$$v_T = \frac{q_1 - q_2}{2\omega r p}$$

An alternative method to of determining v_T is to ignore q_2 and just derive v_T from q_1:

$$q_1 \ = \frac{1}{2}p(\omega^2 \mathrm{r}^2 + {v_T}^2 + 2\omega v_T)$$

v_T can then be determined by solving the quadratic equation for v_T.

To determine the flow angle, the system measures the angle between the pressure peak and the rotation. This device can measure either angle of sideslip (AoS or beta) or angle of attack (AoA, or alpha) depending on how it's mounted. In the FIGs. shown above, it measures AoA. Alternatively, or additionally, if the rotating shaft is vertical, it measures AoS. In various embodiments, multiple airspeed measurement devices may be installed. In an embodiment, three devices may be installed for redundancy wherein the devices are installed at three different angles so that we can always extract airspeed, AoA, and AoS despite one failure.