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Magnetic Correction of Aircraft Navigation Instruments

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Abstract:

The paper deals with new possibilities of magnetic correction of the aircraft navigation instruments (direction gyroscopes, inertial reference units etc.) which are given by application of new micro-magnetoresistive sensors.

Keywords:

magnetoresistive sensor, accelerometer, gyroscope, compass, inertial reference unit, MEMS

1. Introduction

Common analog aircraft navigation instruments such as gyro-magnetic compasses contain usually three or two fluxgate sensors as a source of the magnetic heading correction signal. Fluxgate sensors are of great external size and have relatively high exciting electric current. Application of the micro-magnetoresistive sensors considerably eliminates these disadvantages.

In order to secure correct measurement of the magnetic heading, it is necessary to stabilize sensitive axes of magnetic sensors in horizontal plane. This is usually not possible in common analog gyromagnetic compasses, as the magnetic sensors are placed on a cardan-suspended pendulous base which is stabilized horizontally due to the gravity of the Earth. This gravitational stabilization is correct only in case of directional and uniform motion. If the aircraft is accelerating or turning the base with magnetic sensors, it is deflected from horizontal position and the measured signal of the magnetic heading is incorrect in consequence of the projection of vertical component of the geomagnetic field.

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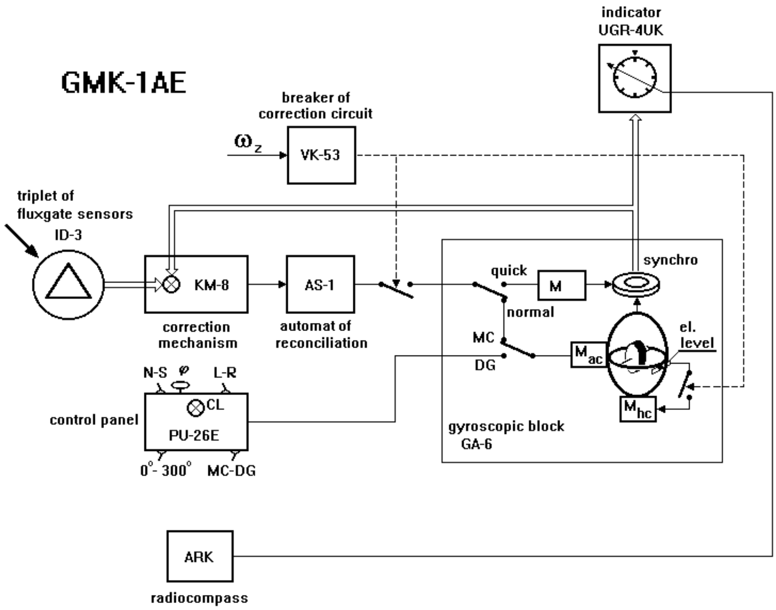

Fig. 1 Structure of the analog gyromagnetic compass

2. Magnetic Compass with Micro-Magnetoresistive Sensors

Modern digital attitude and heading reference systems based on microcontrollers and micro-electro-mechanical systems (MEMS) technology of the sensors can have sensitive axes of all the three magnetometers orientated according to the aircraft coordinate system. Measured components of geomagnetic field intensity vector $\mathbf{I}_A$ are transformed from the aircraft coordinate system (ACS) into the Earth coordinate system (ECS) $\mathbf{I}_E$ by means of the reduced (roll $-g$, pitch $-J$) direction cosine matrix (see formula No.1) or by means of the quaternions.

$$\mathbf{I}_E = \begin{bmatrix} i_{Ex} \\ i_{Ey} \\ i_{Ez} \end{bmatrix} = \begin{bmatrix} \cos J & -\sin g \cdot \sin J & \cos g \cdot \sin J \\ 0 & \cos g & \sin g \\ -\sin J & -\sin g \cdot \cos J & \cos g \cdot \cos J \end{bmatrix} \cdot \begin{bmatrix} i_{Ax} \\ i_{Ay} \\ i_{az} \end{bmatrix} \quad (1)$$

The magnetic heading y can be gained from the horizontal components i_{Ex} i_{Ey} of $\mathbf{I}_E$ by means of the following formula:

$$y = \mathrm{arctg} \frac{i_{Ey}}{i_{Ex}} \quad (2)$$

This magnetic compass measures the correct magnetic heading in all types of the aircraft motions.

One of the main disadvantages of this type of magnetic compass is a difficult compensation of magnetic deviation in the three-dimensional space with respect to the common analog systems, which require only two-dimensional (plane) compensation of the deviation.

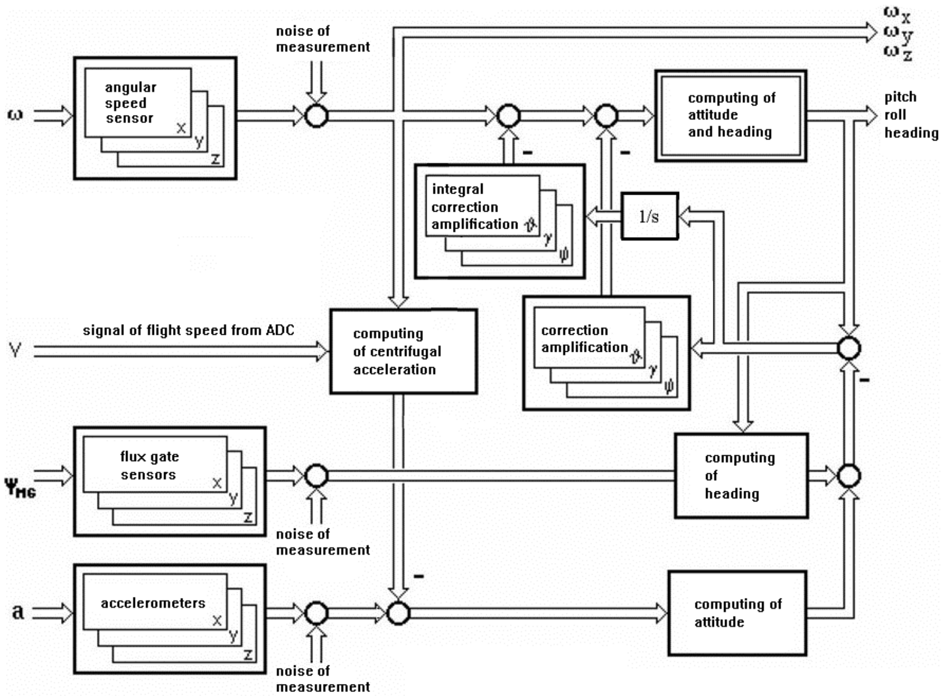

Fig. 2 Structure of the Inertial Reference Unit

The optimal value of amplification of the magnetic correction of the gyroscopic measurement channel is possible to be determined, for example by means of the statistic dynamic theory of systems.

At present our workplace participates in the development of a similar type of the IRU in collaboration with the firm OPROX, Ltd. The research project is supported by the Ministry of Industry and Trade of the Czech Republic.

The magnetic compass of the developed IRU uses micro-magneto-resistive sensors Philips KMZ-51

3. Contemporary Situation in The IRUs Development

The designed IRU was created in two variants and both of them were statically and dynamically tested.

Paralelly with the IRU, the company OPROX, Ltd., developes a special digital computer controlled testing device „TZ-IRJ". This testing device – three axes rotation platform – is necessary for calibration of the IRU and for precision measurement of the static and dynamic qualities of the IRU and similar devices.

The basic part of the TZ-IRJ is shown in the figure 4.

Figure 3: IRU – variant 2

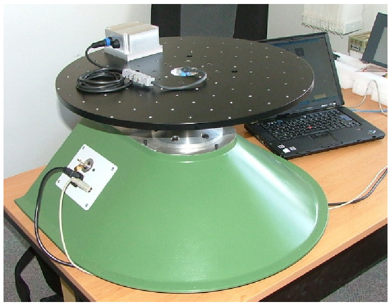

Figure 4: The basic part of the TZ-IRJ

The IRU was succesfuly tested in flight on board of an experimantal ultralight aircraft „COZY-IV“.

Figure 5: Aircraft COZY-IV

4. **Conclusion**

The IRU is now fully functional and may by successfully used on board of the UAV, similar robots, etc.

In the future, the research work of our workteam must be focused on optimization of the amplification of correction feedback of the IRU.

References

[1] Kolektiv autorů, Výzkum a vývoj high-end technologií pro zvýšení bezpečnosti a komfortu letu lehkých a ultralehkých letadel, OPROX, a.s., Renneská tř. 35, 639 00 Brno.

[2] JALOVECKÝ, R.: Možnosti měření IRJ a návrh testovacího zařízení IRJ, Dílčí výzkumná zpráva projektu MPO ev. č. FT-TA3/104, Výzkum a vývoj technologií pro řízení ultralehkých a lehkých letadel, 30 str., OPROX, a.s. prosinec 2006, Brno.

[3] ČIŽMÁR, J.: Vývoj inerciální referenční jednotky, Dílčí výzkumná zpráva projektu MPO ev. č. FT-TA3/104, Výzkum a vývoj technologií pro řízení ultralehkých a lehkých letadel, 60 str., OPROX, a.s. prosinec 2006, Brno.

[4] LAZAR, Tobiáš, ADAMČÍK , František, LABUN, Ján. *Modelovanie vlastností a riadenia lietadiel*. Technická univerzita v Košiciach. Košice : Popradská tlačiareň, vydavatel'stvo, 2007. 316 s. ISBN 978-80-8073-839-6.

[5] SOTÁK, Milan, et al. *Integrácia navigačných systémov : Monografia*. Róbert BRÉDA. 1. vydané nákladom vlastným. Košice : [s.n.], 2006. 344 s. ISBN 80-969619-9-3.

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