Effect of Sensitive Working Gas on the Sensitivity of the Fluidic Gyroscope

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Abstract. The paper researches the dry air, nitrogen and helium and other effects of three kinds of commonly used sensitive gases on the sensitivity of the fluidic gyroscope. By using the finite element method, the flow field in sensing element of fluidic gyroscope under the effect of the input angular velocity of 20°/S, has been obtained by a series of procedure. The results are as follow: The sensitivity of different corresponding to the different working gas sensitive, $K_{\text{AIR}}$ is 10 mV/(°/S), $K_{\text{N}2}$ is 10.5 mV/(°/S), $K_{\text{He}}$ is 2.1 mV/(°/S), $K_{\text{N}2} > K_{\text{AIR}} > K_{\text{He}}$, where $K_{\text{N}2}$ is 1.05 times of $K_{\text{AIR}}$, $K_{\text{He}}$ is 0.21% of $K_{\text{AIR}}$. This paper explained and verified the mechanism of sensitive working gas influence on fluidic gyroscope sensitivity, in order to improve the practicability of the fluidic gyroscope, meet different engineering needs to open up a new way.

Fluidic gyroscope has no rotating part of traditional gyroscope, nor solid inertial devices of piezoelectric gyro suspension components, sensitive quality of fluidic gyroscope is gas, inertia is small, not only the response time is short, and strong shock resistance, still can work normally under the impact of the 16000g. Due to the sensitive mechanism of fluidic gyroscope is based on the heat exchange between forced convection gas in sensitive element and thermal resistance wire [1], for the density, viscosity property of the sensitive working gas species in sensitive element is different, will affect the airflow speed different distribution, working gas will change in the vicinity of the thermal resistance wire flow, so species change in the sensitive working gas makes the output voltage change, lead to differences in the sensitivity of the sensor. In this paper, by using the finite element method, comparatively study of flow field in fluidic gyroscope sensitive element of dry air, nitrogen and helium and other three kinds of commonly used sensitive working gas with the input angular velocity $\omega_i=20°/S$, explaining and verifying the mechanism of sensitive working gas influence on fluidic gyroscope sensitivity.

structure principle

Fluidic gyroscope sensitive element is mainly composed of piezoelectric pump, nozzle body, nozzle and shell body, etc. The nozzle body is the main part of the sensitive element, as shown in Figure 1. The jet of sensitive element is driven by piezoelectric pump, produce a laminar
jet beam in the nozzle, then shoots to two heat resistance wire r1, r2 parallel placed in nozzle body. Once there is an angular velocity input, the jet bundle through symmetry center from two thermal resistance wire r1 and r2 formely will deviate to a direction, cause two thermal resistance wire r1, r2 different cooling, the resistance of the thermal resistance wire r1 and r2 changes, cause the current to change, detection bridge loses balance, whose output voltage $\Delta U$ is corresponding to the angular velocity $\omega_i$, as is shown in Fig.2.

The material of hot wires is platinum, which is sensitive to temperature and not easily oxidized in the air. Platinum wires diameter of 2 ~ 15 m, the resistance of the thermal resistance wire r1 and r2 is same, platinum wires parallel horizontally planted in closed cavity with the diameter of 5 ~ 25 mm.

**physical model**

Due to the jet deflection of fluidic gyroscope is in the nozzle body to achieve, so the nozzle body flow channel as the object of study. In order to facilitate the modeling and calculation, two-dimensional nozzle body structure can be simplified, through the axis of symmetry nozzle body, the two-dimensional section of airflow is obtained through the symmetry axis of the nozzle body, as is shown in Fig.3. The section of airflow has the length of 15 millimeters, of which the diameter of the entry and outlet are 2.5 millimeters and 9 millimeters respectively, with trapezoid section 5 millimeters long. Assumed that air velocity in the entrance is 1.5 m/s and Reynolds Number is 900. Free convection caused by hot wires could be neglected, because its velocity is far more less than that of forced convection.

**Solving, results and discussion**

ANSYS-FLOTTRAN CFD is an advanced facility to analyses the flow field of two-dimensional and three-dimensional fluid. The process always includes three steps: modeling, loading, and calculating.
Line AB plumbed to x-axis is made through hot wires so as to observe the distribution of jet flow velocities clearly, as it is shown in Fig.3. As Fig.4 shows, the flow velocities distribute along line AB according to the results of FEA. As you can see from Figure 4, the airflow velocity $V_i$ along line AB corresponding to the two heat source center line is the asymmetric distribution while the angular velocity $\omega_i=20 / S$, the airflow velocity $V_{r1}$ and $V_{r2}$ along the thermal resistance wire $r1$ and $r2$ respectively with the difference $\Delta V$ as shown in Table 1. Seen from table 1, the airflow velocity along the two heat resistance wire $r1$ and $r2$ corresponding to sensitive working gas is inequality, the difference $\Delta V_{N2}$ between $V_{r1}$ and $V_{r2}$ corresponding to $N_2$ is is the maximum, $\Delta V_{AIR}$ between $V_{r1}$ and $V_{r2}$ corresponding to dry air take the second, $\Delta V_{He}$ between $V_{r1}$ and $V_{r2}$ corresponding to He is the minimum. Where $\Delta V_{N2}$ is 1.05 times of $\Delta V_{AIR}$, $\Delta V_{He}$ is 0.21% of $\Delta V_{AIR}$. The difference $\Delta V$ of airflow velocity along two thermal resistance wire $r1$ and $r2$ change will inevitably lead to the difference of current flow through the two thermal resistance wire $r1$ and $r2$ change, the bridge loses its balance and outputs a voltage signal $\Delta U^{[1,2]}$ corresponding to sensitive working gas, therefore, according to the detection of bridge output voltage $\Delta U$, indirect verification the difference $\Delta V$ of flow velocity along the thermal resistance wire $r1$ and $r2$. Relationship between bridge output voltage $\Delta V$ corresponding to different sensitive working gas and the angular velocity is shown in Fig5. As can be seen from the graph, the sensitivity coefficient $K_{AIR}$ of dry air is 10mv/(°/S), $K_{N2}$ is 10.5mv/(°/S), $K_{He}$ is 2.1mv/(°/S). The different sensitivity corresponding to the different sensitive working gas, $K_{N2} > K_{AIR} > K_{He}$, where $K_{N2}$ is 1.05 times of $K_{AIR}$, $K_{He}$ is 0.21% of $K_{AIR}$. The above and finite element numerical results are consistent.
Conclusion

The paper researches the dry air, nitrogen and nitrogen effects of three kinds of commonly used sensitive gases on the fluidic gyroscope sensitivity. By using the finite element method, using ANSYS FLOTRAN CFD program, the flow field in sensing element of fluidic gyroscope under the effect of the input angular velocity of 20°/S, has been obtained by a series of procedure, such as model building, meshing, loads applying and equation solving. The results are as follow:

1) The different sensitivity corresponding to different working gas sensitive, the sensitivity coefficient $K_{\text{AIR}}$ of dry air is 10mv/(°/S), $K_{\text{N2}}$ is 10.5mv/(°/S), $K_{\text{He}}$ is 2.1mv/(°/S). The different sensitivity corresponding to the different sensitive working gas, $K_{\text{N2}} > K_{\text{AIR}} > K_{\text{He}}$, where $K_{\text{N2}}$ is 1.05 times of $K_{\text{AIR}}$, $K_{\text{He}}$ is 0.21% of $K_{\text{AIR}}$.

2) N$_2$ is corresponding to the highest sensitivity, the thermal resistance wires antioxidant, stability is better, but the cost is high; sensitivity of dry air, the thermal resistance wires easily oxidized, poor stability; He corresponding to the minimum sensitivity, the thermal resistance wire is not easy to be oxidized, the best stability.

This paper explained and verified the mechanism of sensitive working gas influence on fluidic gyroscope sensitivity, in order to improve the practicability of the fluidic gyroscope, meet different engineering needs to open up a new way.

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Reference
