

Performance Improvement of Resonant Absolute Pressure Sensors Based on Topology Optimization and Suspension Design

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Summary:

This paper proposes an innovative solution that combines topology optimization and suspension design to meet the aerospace industry's demands for high reliability, lightweight, and environmental adaptability in resonant absolute pressure sensors. Experimental and simulation result demonstrate that the temperature infection is reduced by 75% in harsh environments. The optimized sensor achieves an accuracy of 0.01% FS within a 140 kPa range under harsh temperatures (-50°C to 85°C).

Keywords: Suspension Design, Topology Optimization, Resonant Pressure Sensor, temperature-insensitive, High Accuracy

Introduction

In the aerospace field, precise absolute pressure measurement is crucial for the control systems of aircraft. Resonant pressure sensors offer excellent measurement accuracy and response speed, making them ideal pressure sensors [1]. However, traditional design methods often suffer from issues such as error accumulation under harsh conditions like environmental temperature changes, and environmental pressure changes [2]. topology optimization and Suspension design, as advanced structural design techniques, can effectively enhance the performance of sensors. This study combines both approaches and proposes a new sensor design method.

Suspension Design and Topology Optimization

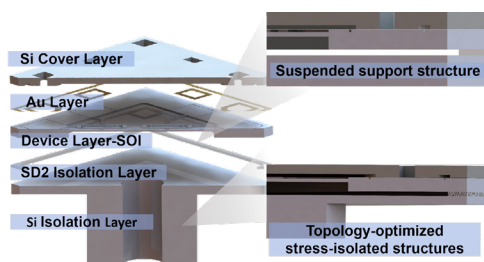


Fig. 1. Sensor Structure.

In sensor design, the commonly used GOS (glass on silicon) stress isolation structure with

a "high thickness ratio" is employed to reduce the propagation of assembly stress [3] (Fig. 1).

However, due to material property variations and process defects, temperature changes induce thermal stress in the isolation structure itself, leading to frequency shifts. Based on the Principal Stress Line topology optimization method, the optimized structure ensures the device's stiffness while reducing mass by 50%. Based on the actual process flow, three types of isolation structures are derived from the optimized isolation structure (Fig. 2).

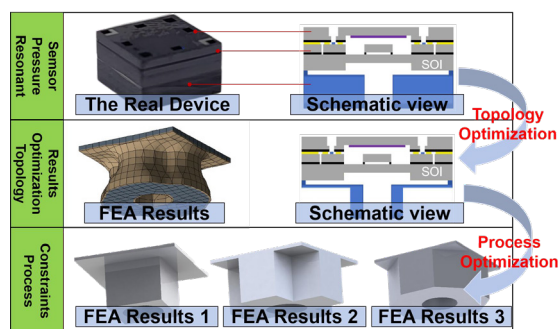


Fig. 2. The Process of Isolation Structure Topology Optimization.

After performing finite element verification of the three structures, it is found that, within the temperature range of -55°C to 85°C , the first structure exhibits the least sensitivity to thermal

stress and the strongest anti-interference capability: 6.3Hz/°C and 9.9Hz/°C (Fig. 3)

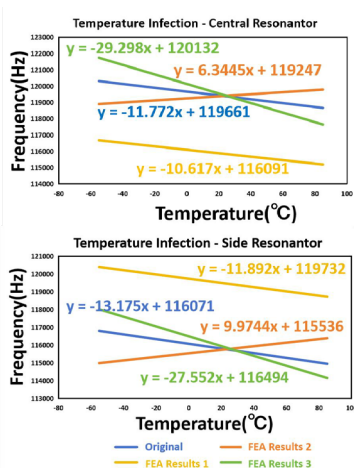


Fig. 3. The impact of temperature changes on the original structure and the three optimized structures.

In the absolute pressure sensor, the SD2 Layer in the isolation structure is visualized to achieve a suspended design, lengthening the stress transmission chain from the isolation structure to the sensor, reducing the stress experienced by the device itself, and minimizing the impact on the frequency (Fig. 4).

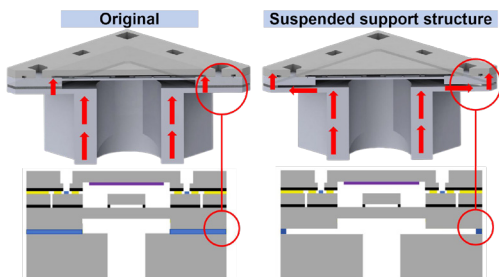


Fig. 4. Schematic diagram of the suspended structure design. The structure marked in red is SD2. And, the stress transmission chain and processing schematic diagram.

Through finite element simulation, stress is applied to devices with and without the support structure under the same conditions, verifying that the suspended support structure reduces the impact of environmental stress on the resonant frequency by 75% (Fig. 5).

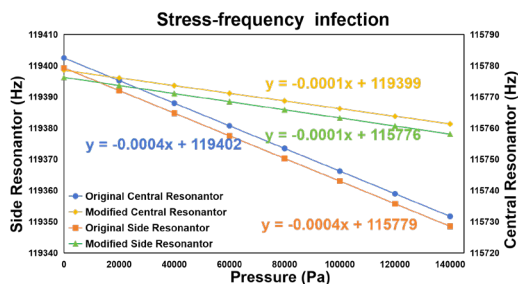


Fig. 5. The impact of environmental stress on frequency.

Results

Compared to traditional designs, the use of a suspension system effectively isolates external vibration interference and temperature changes, ensuring the sensor's stability. Experimental results show that after three temperature cycles (-55°C to 85°C), the device still maintains an accuracy of 0.01% FS (Fig. 6). The resonant absolute pressure sensor proposed in this paper, based on topology optimization and suspension design, offers significant advantages in performance, particularly in improving sensor stability and anti-interference capabilities.

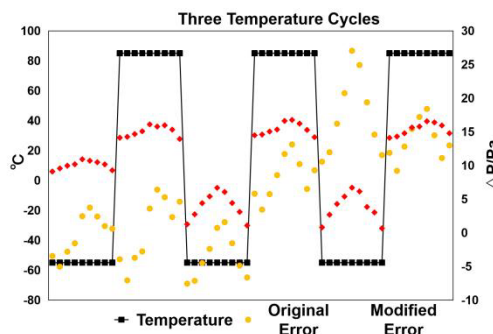


Fig. 6. Sensor Accuracy Under Four Temperature Cycles

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