Data acquisition and processing algorithm for total and static pressure measurement system

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Introduction

Measurement of static and total pressure is widely used to determine the flight conditions of aircrafts [1, 2]. Results of pressure measurements are used to monitor flight attitude, equivalent speed, Mach number, vertical velocity, etc [3].

The main objective of the study was to develop an improved design of an optical pressure sensor and algorithm for data acquisition and processing.

Design of developed pressure sensor

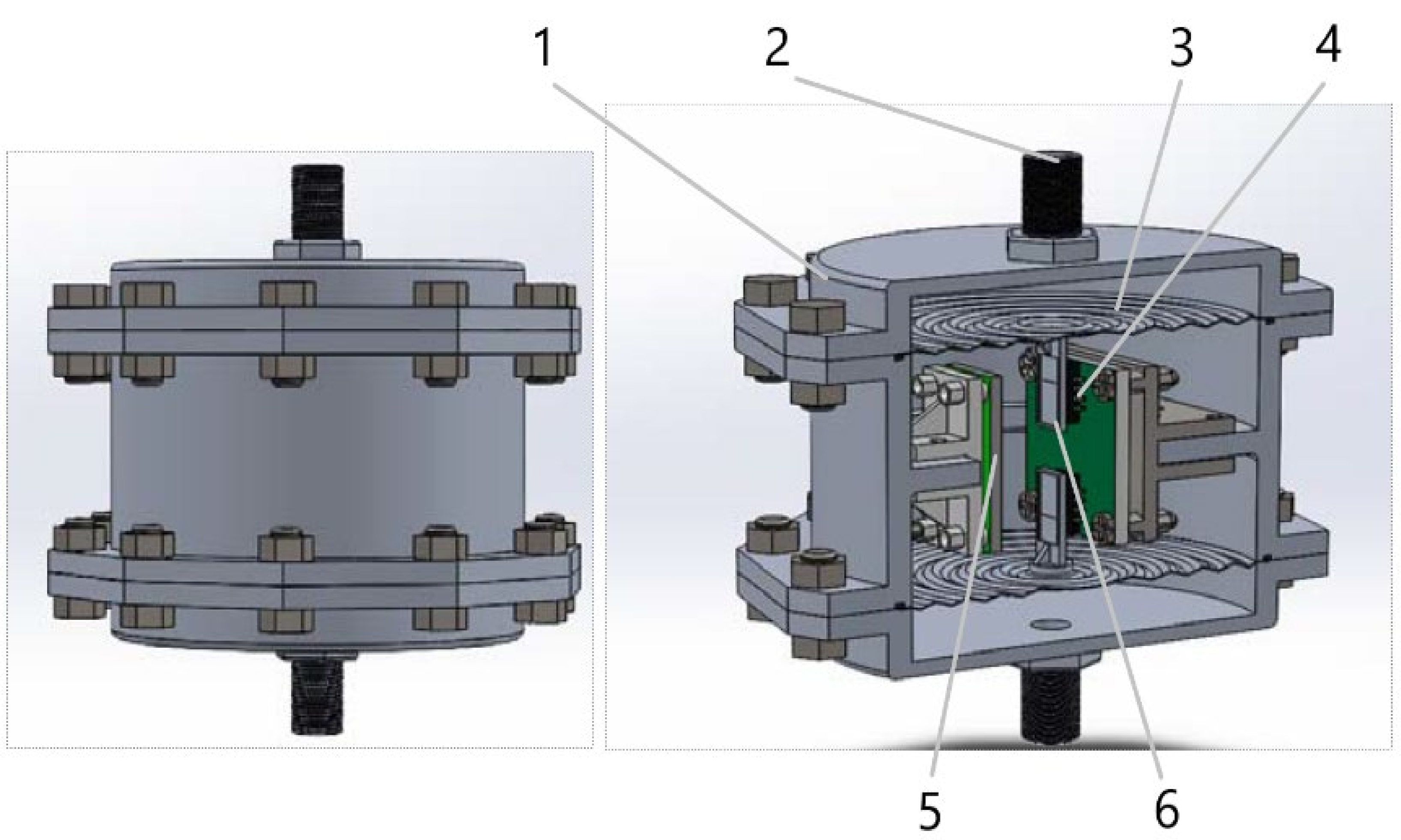

Figure 1 – Design of developed pressure sensor. 1 – steel casing; 2 – gas inlet; 3 – elastic membrane; 4 – photodetector array; 5 – LED; 6 – slotted shutter.

Data processing algorithm

We employ centroid-method in data processing algorithm to calculate positions of light spots on photodetector array.

The coordinate of the signal maximum is calculated according to the following formula:

$$MAX_n = \frac{\sum_{i=N_{\max\_n}-M/2}^{N_{\max\_n}+M/2} A_i i}{\sum_{i=N_{\max\_n}-M/2}^{N_{\max\_n}+M/2} A_i}$$

where MAX_n – coordinate of the maximum of n-th light spot expressed in the pixel number, A_i – signal amplitude from i-th pixel in vicinity of n-th optical spot, N_{max_n} – number of pixel having maximum amplitude around n-th optical spot.

Change in pressure can than be calculatedrelatively to some reference value according to the formula:

$$\Delta P_{stn}(t) = k_n (MAX_n(t) - MAX_n(0))$$

where $\Delta P_{stn}(t)$ – current value of pressure change at time t, $MAX_n(t)$ – coordinate of the n-th optical spot maximum at time t, $MAX_n(0)$ – coordinate of the n-th optical spot maximum at reference pressure, k_n – calibration constant.

Experimental results

Table 1 – Comparison of operational modes.

Number of optical spots \ number of samples for averaging	Range, μm	Dispersion, μm²	Standard deviation, μm
1\no averaging	1.233	0.0439	0.21
1\2	0.672	0.00996	0.0998
1\3	0.605	0.00981	0.0991
2\no averaging	0.477	0.00669	0.0819
2\2	0.296	0.00245	0.0495
2\3	0.259	0.00204	0.0452

Table 2 – Evaluation of measurement accuracy.

Measured pressure value P, Pa	Absolute error, ±ΔP, Pa	Standard deviation S, Pa	Membrane deflection, μm
107438	13.14	5.08	1.260
95496	11.98	4.37	1.165
70269	10.02	3.65	0.92
19481	6.49	2.36	0.27
4411	6.32	2.52	0.05

Conclusions

When using the presented algorithm for collecting and processing information, the measurement speed of the developed pressure sensor is determined by the repetition rate of the control pulses. The proposed solution provides reduced error values when calculating the altitude and speed parameters of the aircraft. Averaging of the results from n spots increases accuracy in $n^{1/2}$ times. On the other hand, when measurement speed is more important, the value of pressure can be obtained from the position of one optical spot.

The high speed of the measuring system in the future will make it possible to apply algorithms that provide compensation for various kinds of destabilizing factors (interference, vibrations, shock effects, etc.) that arise during the operation of aircraft.

References

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