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RESEARCH ARTICLE

Air pressure sensor using fiber bragg gratings

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Abstract

This work was performed to investigate the feasibility of using Fiber Bragg Gratings (FBGs) strain sensor in detection of air pressure on aeroplane model known as Generic UTM Half-Model. The FBGs was attached on the surface of the aeroplane model where its position is as near as possible to the location of static conventional pressure sensor. Then, the sensing performance was tested inside UTM Low Speed Tunnel (UTM-LST) with the wind speed set at 30 ms^(-1), 40〖 ms〗^(-1), and 50 ms^(-1). The direction of wind was arranged to be in perpendicular to the FBG and the position of wing model was varied at angle of 0°, 5°, 10°, 15°, and 20°. The measured pressure coefficient, Cp based on Bragg wavelength shift was compared with Static FKPS 30DP Pressure Measuring Module data. The results reveal that the shift in Bragg wavelength was found to increase linearly from angle 0° until 10° and after that the wavelength shift become saturated. The pressure coefficient obtained by FBGs has well agreed with the value obtained by pressure coefficient of pressure sensor module at low angle of attack from 0° to 10°.

***Keywords*:** FBGs strain sensor, air pressure, air-flow

INTRODUCTION

The study of pressure measurement is important for the design and developement of transportation including automotive, aircrafts, and ships. In order to get a better image of the pressure distribution of the desired vehicle, a scaled model and wind tunnel test is needed to analyze its multipoint pressure coefficient, *Cp*. The *Cp* is very useful to describe the relative pressure at each point of the wing model. Every point in a fluid flow field has its own unique *Cp*. By plotting the *Cp* around the wing model system, the air flow separation can be visualized. Thus, the aerodynamic of the wing model can be profiled and further improvement of the design can be performed to obtain the best aerodynamic system.

A few sensors and control mechanisms have been studied in the past to investigate the aerodynamic drag in order to optimize in-flight conditions[1]. For example, Pressure Sensitive Paint (PSP) and static pressure sensor has been used for years to study the dynamic of various aircraft and automotive models in wind tunnel test [2]. For active control mechanism, MEM-based actuators were used to reduce the skin friction drag around the model [3].

However, there are some limitations using the conventional pressure sensors as it requires a customized model that have fixed holes on the surface and hollow body to allow installation of pressure tubes to measure pressure distribution. Not only costly, it might miss out significant points during the *Cp* measurements.

On the other hand, the Pressure Sensitive Paint (PSP) is less precise since it only visualized the pressure distribution using the intensity of luminesecence emitted by excited oxygen molecules [2]. This technique is also limited to a scaled model since it depends on the coverage area of illumination light and the resolution of charged couple device (CCD) camera.

Since the beginning of 20th century, research attention have been moving toward optical strain sensors using Fiber Bragg Gratings (FBGs) due to its advantages. It has very high sensitivity, stable spectrum reflectivity, and is not affected by electromagnetic field. The FBGs strain strain sensor is simply attached on the desired location on the model, without significant customization to the installation area. The air pressure is determined by calculating the Bragg wavelength shift caused by strain exerted on the gratings.

This work is carried out to design an array of FBGs sensor to predict the pressure coefficient measured on scaled aircraft model known as Generic UTM Low Speed Tunnel (LST) Half model. The outcome is compared to *Cp* obtained by static pressure sensors. With the completion of this project, the outcome may enhance the knowledge of FBG strain sensor as pressure sensor and improve the airpressure measurement technique.

EXPERIMENTAL DETAILS

An FBGs with central wavelength of 1550 nm, and 5 mm grating length fabricated in Universiti Malaya, Malaysia was attached in perpendicular position to wind direction to increase the impact surface for FBG experience strain effect due to the wind as shown in Figure 1. The FBGs was attached at the leading edge of wing model using invisible tape as shown in Figure 2. It was placed as close as possible to the static pressure sensor hole respresent by black dot on the wing model. The wing model used in this experiment is the generic Universiti Teknologi Malaysia, Malaysia Low Speed Wind Tunnel (UTM-LST) half model. It is scaled as 9% of generic transport and also able to withstand higher wind speed. This UTM-LST half model has fuselage length of 2.362 m, and half span of 0.983 m.

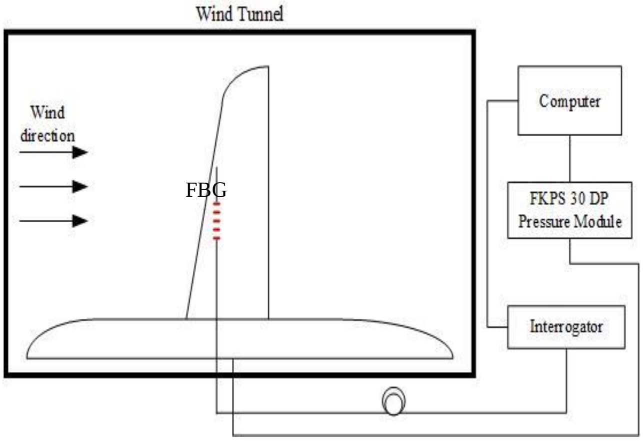

Figure 1 Experiment Setup

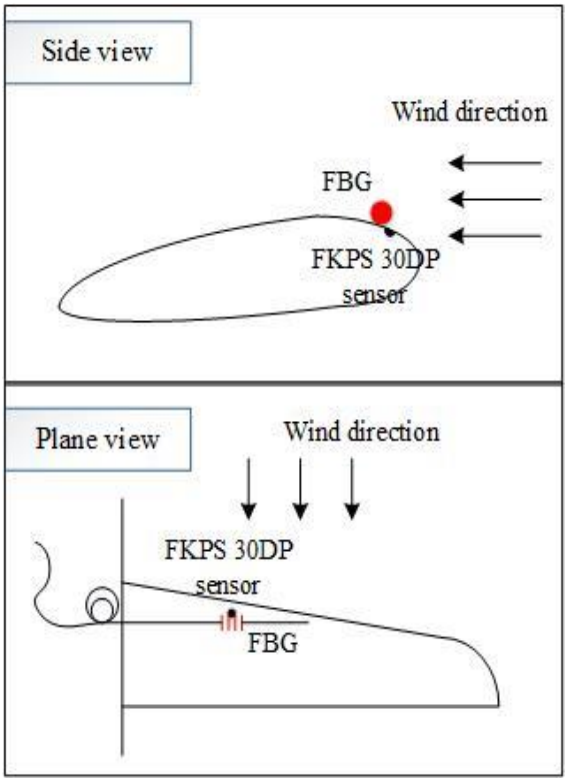

Figure 2 Position of FBG strain sensor

To monitor and record the spectrum changes, an interrogator (SmartFiber, USA) was used. The interrogator can detect and display any changes in central wavelength ranged from 1528 nm to 1568 nm at a scan rate 2.5 kHz. This device can display up to 8 optical channels simultaneously. The spectrum has a peak at 1550 nm that will shift when air pressure acts on the grating causing strain effect to the sensor.

The model was mounted in a 2.0 × 1.5 × 5.5 meter wind tunnel test section located at Faculty of Mechanical (Aeronautics) Universiti Teknologi Malaysia, Malaysia such that the angle of attack was adjustable and for each angle of attack, 0°, 5°, 10°, 15°, and 20°, the wind speed is set at 30 ms^{-1}, 40 ms^{-1}, and 50 ms^{-1}[4]. The data recorded is compared to the data obtained from FKPS 30DP pressure sensor module to justify the feasibility of FBGs sensor as air pressure strain sensor. With calibration data made before the experiment, the pressure represent by the wavelength shift is subtituted into the formula of *Cp* as shown in equation below,

$$C_p = \frac{P - P_o}{\frac{1}{2}\rho {v_o}^2}$$

where,

P = Pressure at the point of interes
Po = Free stream pressure
ρ = Free stream density
v_o = Free stream velocity

The graph of pressure coefficient is plotted and compared with FKPS 30DP pressure sensor module data.

RESULTS AND DISCUSSION

Figure 3 shows the results obtained from the experiments performed in the wind tunnel. The Bragg wavelength shift was calculated and plotted against the angle of attack. The shift in Bragg wavelength fo all speed is found to be linearly increased as the angle of attack increases from 0° to 10°. At angle of 15° and 20°, the wavelength shifts become saturated because the FBGs sensor has reached maximum strain limit.

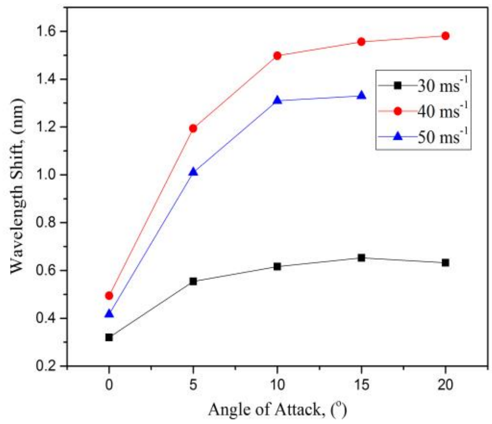

Figure 3 Bragg wavelength shift against angle of attack

The *Cp* was calculated and the graph is plotted as shown in Figure 4. The graph shows the pressure coefficient obtained by FBGs strain sensor measurement and pressure sensor module at the wind speed of 40 ms^{-1}. It was found that the FBGs strain sensor has approximate *Cp* as obtained by pressure sensor module from 0° up to 10°.

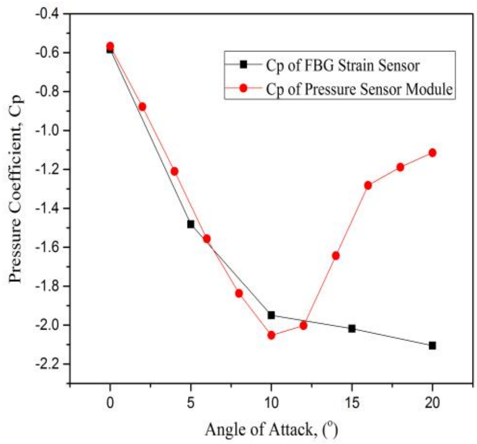

Figure 4 Pressure coefficient comparison of FBG strain sensor with FKPS 30DP pressure sensor

CONCLUSION

FBGs strain sensor has demonstrated to be feasible in measuring *Cp*. Result has been presented on the pressure coefficient obtained by using Bragg wavelength shift compared to FKPS 30DP pressure sensor on generic UTM-LST half model inside UTM-Low speed wind tunnel. The results follow the expected linear relation with the wind speed and angle of attack. However, it is found that the FBGs agrees the pressure coefficient relation at low angle (0° to 10°). . At angle of 15° and 20°, the wavelength shifts become saturated because the FBGs sensor has reached maximum strain limit.

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