https://doi.org/10.33261/jaaru.2020.27.4.003 *Association of Arab Universities Journal of Engineering Sciences (2020)27(4):17–21*

Association of Arab Universities Journal of Engineering Sciences

مجلة اتحاد الجامعات العربية للدراسات والبحوث الهندسية

The Effect of Attack Angle On The Vibration Suppression Of Composite Wing Airfoil NACA 0012

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Published online: 31 December 2020

Abstract— Active vibration control is presented as an effective technique used for vibration suppression and for attenuating bad effects of disturbances on structure. In this work Proportional-Integral-Derivative control were employed to study suppression of active vibration wing affected by wind airflow. Two different composite wings with different manufacturing materials had been made with specific size to be suitable for using in wind tunnel. Piezoelectric (PZT) transducers are used as sensors and actuators in vibration control systems. The velocity was 25 m/s and three different attack angles (0, 10, 20 degrees) had been taken to show their effect on the wings vibrations suppression. The results shows that the suppression of the wing amplitude is reduced when the attack angle increases for both woven and random composite wing matt and this happened due to the vortex which became more violent at the increase of attack angle and also due to the area that face the wind which will increase when the attack angle increase and this will reduces the suppression. The maximum control amplitude of woven Glass-fiber matt was 1.75cm and the damping was about 38 % at zero attack angle while it was 2cm and the damping was about 26 % at 20 degree attack angle for random Glass-fiber composite matt.

Keywords— vibration suppression , Attack angle, Piezoelectric, NACA 0012, PID Control.

1. Introduction

Aeroelasticity is a science that deals with the interaction of aerodynamic forces and structural deformations. Simply aeroelasticity can be defined as the study of the interaction of inertial, structural and aerodynamic forces on aircraft, buildings, surface vehicles etc. When a structure moves through the air, the motion will cause aerodynamic loads, leading to deformations of the structure. The deformation inturn has an impact on the airflow, thus changing the aerodynamic loading. Apparently, there is a closed loop of aerodynamic and structural interactions, and depending on the properties of the structure and the airflow different methods of controlling had been used with many applications to give the reader enough knowledge about it. It is most important to presents previous works that remarked on active vibration control techniques. Zhi-Guang Song and Li F. (2012), Derivative of velocity and proportional feedback of two different types of controllers in vibration were used with PZT as sensors and actuator. They studied the ability of suppression of composite plate used for aero elastic analysis. No experimental tests had been presented and the modal analysis of tested model was formulated by MATLAB codes. Results show that proportional regulator has high effectiveness in vibration suppression of 31% and 25% for free and forced responses respectively [7]. Xingjian Dong, et al (2014), Composite plate with PZT was used to perform controlling loop. The study was aimed to evaluating the performance of an active regulator for suppression of undesired vibrations, this suppression was carried out via controlling loop and PZT as sensors and actuators totally formulated in FE environment. Numerical simulation had been done in ANSYS environment for composite smart plate equipped with PZT. Besides FE model, real model was fabricated and tested experimental for vibration suppression. About 59% of overall model vibration was suppressed with good agreement between both experimental and numerical responses [9] Riessom W., et al (2014), In the present study used PZT to sense the strain of flexible aluminum cantilever beam and fed it back to regulator loop for actively attenuation of its free oscillation. Finite element simulation was performed besides experiments to check the acceptance of measurements. Using NI (National Instruments) cRIO 9022 in LabView was used in controlling loop. Results exhibit high level of agreement between both tests. High performance of feedback regulator to attenuate about 49% of free oscillation was noticed. The control law has demonstrated 53.91% and 62.5% reduction in vibration for the first and second mods respectively [6]. M. Kerboua, et al (2015), the unforced oscillation of any structure is attenuated by its inherently damping properties. The work invoked to present a method called "passive piezoelectric vibration shunt control". In the beginning, the numerical solver was utilized in order to estimate best design and position of PZT. Maximum attenuation that was satisfied in oscillation was leveled by percent of forty two from bending oscillation. The results shown that the efficiency of the control is sensitive to the PZT patch location and the accuracy of the shunt circuit being tuned [1]. The main objective of our research is to show the effect of changing the angle of attack on the suppression of the two composite wing of airfoil NACA 0012 when the velocity of the wind was 25 m/s.

2. Wings model

Two composite wings were fabricated by skinning foam model. The foam model were made by cutting the foam via hot wire by passing the hot wire around the aluminum airfoil's shape getting from CNC machine as shown in **Figure 1** .The two foam models were skinned by Glass-fiber matt one with random and the other with woven ({0/90} Glass-fiber). Two layer of Glass-fiber matt for each random and woven .Every layer were coated by mixture of Resin, Thickener powder and Hardener. The two wings dimensions are as shown in **Figure 2.**

Figure 1: Show the hot wire and foam block

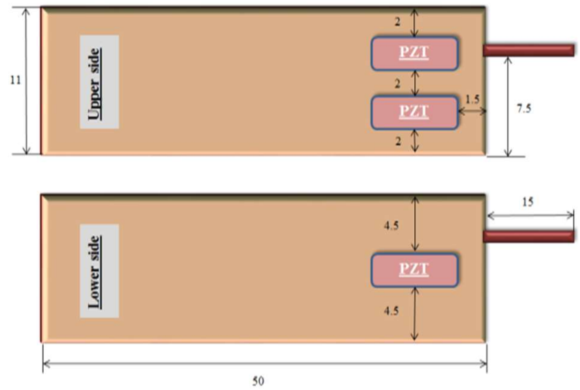

Figure 2: diagram show the diemnsion of the wing.

3. Measuring Device

3.1 *PiezoelectricTransducer*

Electrical transducer PPA-1001 can be used in this study as sensor and actuator. MID´ piezo (standard products, USA) utilize its Piezo protection advantage (PPA) to protect the piezo ceramic wafers. The PPA- 1001 is a single layer product recommended for actuating, energy harvesting and sensing applications. It also exhibits good performance as a resonant actuator [5]. PPA-1001 is presented in **Figure 3.**

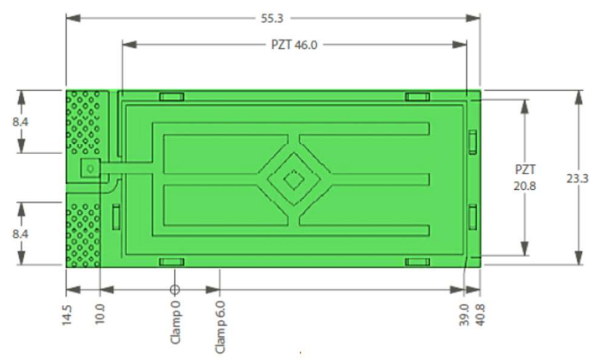

Figure 3: PPA-1001 transducer its dimension in (mm)

3.2 *Compact DAQ-9178 chassis (National Instruments)*

It is an 8-slot (National Instruments .USA) compact DAQ, USB chassis as shown in Figure 4 is designed for mixed-measurement, small, portable test systems. It combined sensor measurements with voltage, current, and digital signals to create custom mixed system with simple USB cable back to personal computer [2].

Fig

Figure 4: NI compact DAQ -9178.

3.3 Analog input (NI 9215)

Module compatible with NI compact-DAQ chassis contains four simultaneous sampled analog input channels. Channel to earth ground double isolation barrier with NIST-traceable calibration are included for system safety and noise filtering respectively. Also high range of voltage is available common mode. Range of Analog input is ±10V, 100Ks/s per channel with 16-bit sampling rate resolution [3]. NI 2915 was designed to work within temperature range of (-40 ~ 70). NI 9215 is one of national instrument products and it is presented in **Figure 5.**

Figure 5: NI 9215- Analog input voltage.

3.4 *Signal Amplifier*

Two signal amplifiers were used for actuators. The devices used in this work are high voltage inverted operational amplifier (model 2205.USA) presented in **Figure 6**. Each amplifier had the ability to amplify voltage up to ±500V, output current range and bandwidth are ±80mA and 75kHz with 3dB respectively with maximum output power of 40W. Safety of measurements against overloading the actuator was provided by such amplifier to protect both amplifier circuit & PZT from any damage caused by high input voltage or power [8].

Figure 6: Signal amplifier.

4. LabVIEW Program

The active control program is developed in LabVIEW and it is used to apply active vibration. LabVIEW contains an inclusive set of tools for storing data, acquiring, and analyzing. In LabVIEW software the signal input is received and processing then sent as output signal at step time (0.001s) to avoid shifting between the signals input and output [4]. Program of controller used in this work is presented in **Figure 7.**

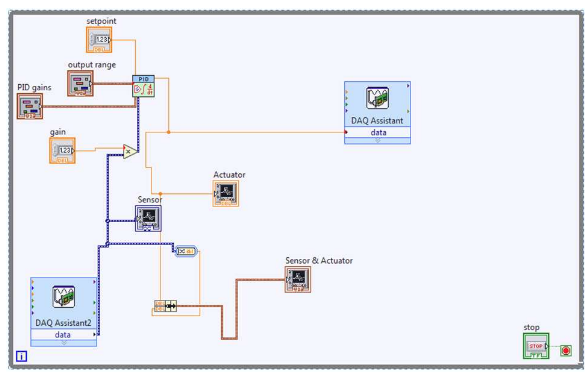

Figure 7: Block diagram of the controller used

5. Experimental Work

The experimental system used in this study shown clearly in **Figure 8.** The displacement responses of tested wing was sensed as voltage by piezoelectric, then sensed voltage (displacement) data is forwarded to analog input (NI 9215) which was used for noise filtering and acquiring date and by importing the relation between sensed voltage and displacement, voltage will be converted to its real value in lab view through DAQ which is used to convert sensed signal from analog to digital signal. The output actuators' signals are simultaneously sent through DAQ to analog output card. Then the controlling actuators' signals are sent to high voltage amplifier to drive the piezoelectric actuators which will act by opposite action to wing vibration to damping the vibration of the wing.

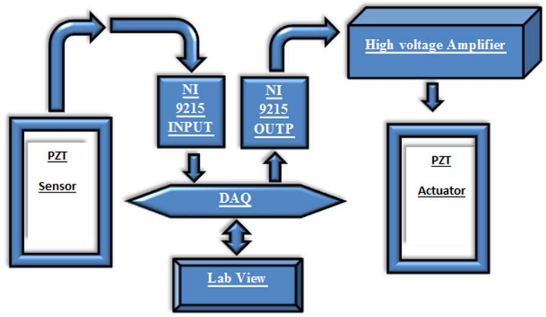

Figure 8: the diagram of experimental active vibration control.

6. Results and discussions

It had been notice that the suppression of the wing amplitude reduced when the attack angle increase for both woven and random composite wing matt as comparing with the free response and this happened due to the vortex which became more violent at the increase of attack angle and also due to the area that face the wind will increase when the attack angle increase and this will reduces the suppression as can see in figure 9and 10.

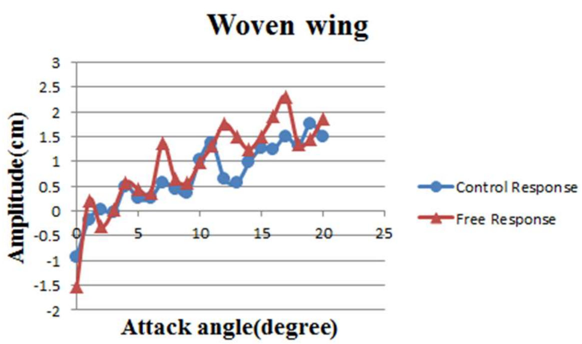

Figure 9: Relation of attack angle and Controlling Aplitude

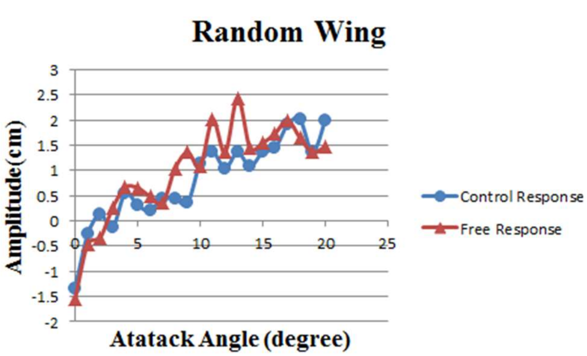

Figure10: Relation of attack angle and Controlling Amplitude

7. Conclusion

The suppression of the wing amplitude reduce when the attack angle increase for both woven and random composite wing matt. The composite wing which is made of woven Glass-fiber matt has high resistance more than random Glass-fiber composite matt and maximum control amplitude of woven Glass-fiber matt was 1.75cm and the damping was about 38 % at zero attack angle while it was 2cm and the damping was about 26 % at 20 degree attack angle for random Glass-fiber composite matt.

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تأثيرزاوية الهجوم على تخميد اهتزازات جناح مركب ذو برفايل نوعNACA 0012

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نشر في: 31 كانون الاول 2020

الخلاصة – السيطرة النشطة على الاهتزاز هي تقنية فعالة لتخميد الاهتزاز وكذلك تقليل التاثيرات الغير مرغوبة الناتجة من الاضطراب المؤثر على الهيكل الميكانيكي .هناك نوعين من الاجنحة المصنوعة من المواد المركبة تم أستخدامها في هذا البحث حيث صنع الجناح الاول من مادة الفايبركلاس ذات الحصيرة العشوائية توزيع الالياف وصنع الجناح الثاني من مادة الفايبركلاس ذات ألياف متعامدة .أسنخدم نظام سيطرة من نوع PID لدراسة تخميد الاهتزاز النشط والناتج عن تغيير زاوية الهجوم حيث وضع الجناح داخل نفق هوائي موجود في مختبر الهندسة الميكانيكية / جامعة بغداد. أستخدمت قطع كهروضغطيه في نظام السيطرة كمتحسس ومؤثر. زاوية الهجوم تغيرت على ثلاث مراحل 0, 10, 20 درجة في حين تم تثبيت السرعة عند 25 م/ثا لمعرفة تأثير تغير زاوية الهجوم على تخميد الاهتزاز. كانت النتائج أن تخميد سعة اهتزاز الجناح تقل عند زيادة زاوية الهجوم لكلا الجناحين وذلك بسبب كون الدوامات الهوائية المتكونة حول الجناح ستكون أعنف كما ان مساحة سطح الجناح المواجه للرياح يزداد ايضا كلما زادت زاوية الهجوم الجناح . كما لوحظ أن الجناح المصنوع من ألياف متعامدة لدية مقاومة أهتزاز أكبر من الجناح الاخر وكان مقدار أكبر سعة مخمدة للجناح المتعامد الالياف 1.75 سنتيمتر ومقدار التخميد 38% بالنسبة للاهتزاز الحر للجناح عند الزاوية صفر درجة. بينما كانت سعة الاهتزاز المخمد 2 سنتيمتر والتخميد 26% بالنسبة للاهتزاز الحر للجناح عند الزاوية 20 درجة للجناح ذو الياف عشوائية التوزيع.

الكلمات الرئيسية –" زاوية الهجوم ، سيطرة من نوع PID، حساسات كهرضغطيه ،بروفايل نوع NACA0012"