Design and Manufacture of a Monitoring System for Out of Autoclave Composite Curing

Owen Foo

***Abstract*—This report outlines the design and architecture of the monitoring system designed to monitor the curing condition of Out-of-Autoclave composites curing in a PID controlled oven. The system consist of two vacuum pressure channel monitoring up to an accuracy of $\pm 1.25\,\mathrm{kPa}$ and four temperature channel monitoring up to an accuracy of $\pm 2\,^{\circ}\mathrm{C}$.**

I. Introduction

The main object of this system is to facilitate research related to curing conditions of composite materials. The design is focused on pre-impregnated carbon fibre using Out-of-Autoclave(OoA) processing, which are cured under vacuum in a oven.

II. Specification

The two key area that affect void formation most significantly during curing are pressure, and the temperature cycle. These variable needs to be closely monitored to ensure a fair experiment. The composite cure oven is PID controlled with an accuracy of $\pm 2\,^{\circ}\mathrm{C}$, and the control of the vacuum pressure is achieved by the use of a vacuum regulator. It is worth bearing in mind that deviation of a few degree or pascal would be insignificant on affecting mechanical strength, and hence this will be reflective in our specification.

- able to record temperature reading (0-200°C) in fixed time intervals with uncertainly less than $\pm 2\,^{\circ}\mathrm{C}$
- able to record vacuum pressure readings (-100 to 0kPa) in fixed time intervals with uncertainty less than $\pm 5\,\mathrm{kPa}$
- sample frequency up to 1 Hz

III. Pressure Recording

Panasonic ADP5111 pressure sensor is used to measure the vacuum pressure in the bag. The sensor is rated to $-100\,\mathrm{kPa}$ have an overall accuracy of $\pm 1.25\% FS$, equivalent to $\pm 1.25\,\mathrm{kPa}$. A voltage regulator is used to supply the required $5\,\mathrm{V}$ from the $12\,\mathrm{V}$ input common to other lab equipment. Additional decoupling capacitors have been placed to reduce voltage ripples, and the circuit diagram of the transducer circuit is shown in Fig. 1. The signal is then passed onto the data acquisition module by coaxial cables with BNC connectors.

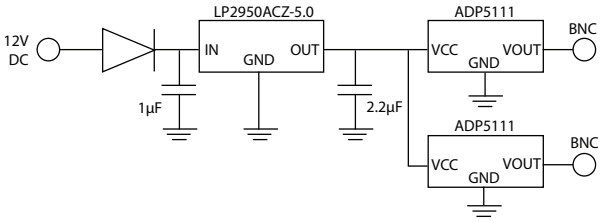

Fig. 1: *Circuit diagram of the transducer circuit.*

IV. Temperature Recording

Four type-K thermocouple is used to monitor the temperature at different locations. The SEM1610 rail transmitter is used to condition the signal for the data logger and gives an uncertainty of $\pm 2\,^{\circ}\mathrm{C}$ [3]. The signal is then passed onto the data acquisition module by coaxial cables with BNC connectors.

V. Data Logging

The data acquisition portion is done using the National Instrument USB-6009 with custom software written at Durham. Although the noise present in the system is not significant, signal averaging is used to further improve the signal to noise ratio. At each time interval, 4096 measurements are taken at 500Hz and the average is taken to be the measured value.

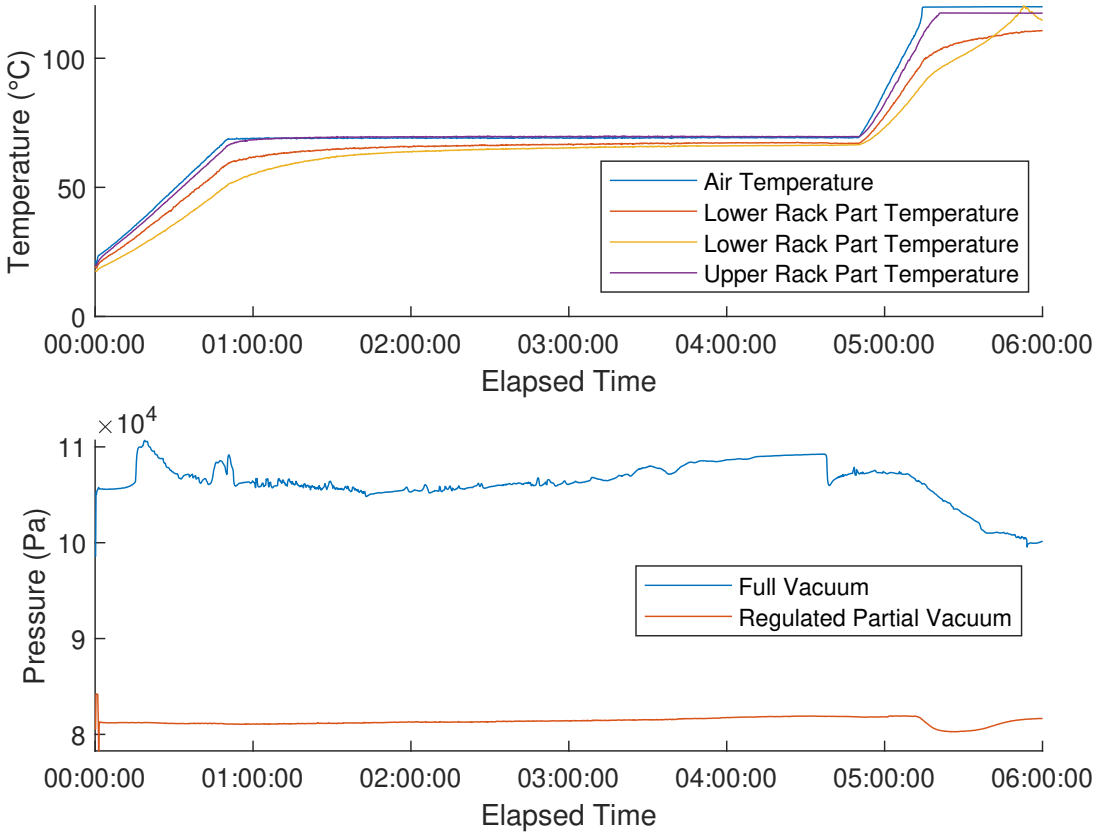

Fig. 2: *Data recorded during a typical curing cycle.*

An example of the data collected is shown in Fig. 2, as expected, the temperature on the surface of the part lags the air temperature. It is also interesting to note the amount of fluctuation in vacuum pressure in the full vacuum line with no vacuum regulator, potentially caused by dissolved volatiles vaporising; or entrapped air between the plys during the lay-up process escaping. This could be one of the area for future investigation.

VI. Conclusion

The motoring system build fulfils the specification. The data recorded reveals variations in temperature and vacuum pressure beyond previously achieved detail. This have enabled further research to be done to evaluate the effects of curing condition on voids formation and mechanical strength of the produced part.

References

[1] Panasonic Industry. *Pressure Sensor: PS-A series Datasheet*. Mar. 2020. URL: https://www.mouser.co.uk/datasheet/2/315/pana_s_a0010427456_1-2280112.pdf.

[2] Texas Instruments. *LP295x-N Series of Adjustable Micropower Voltage Regulators Datasheet*. Dec. 2017.

[3] Status Instruments. *Fine Controls Universal DIN Rail Transmitter*. URL: https://www.finecontrols.co.uk/image/data/manuals/STATUS%5C%20PDFS/sem1610.pdf.

Appendix

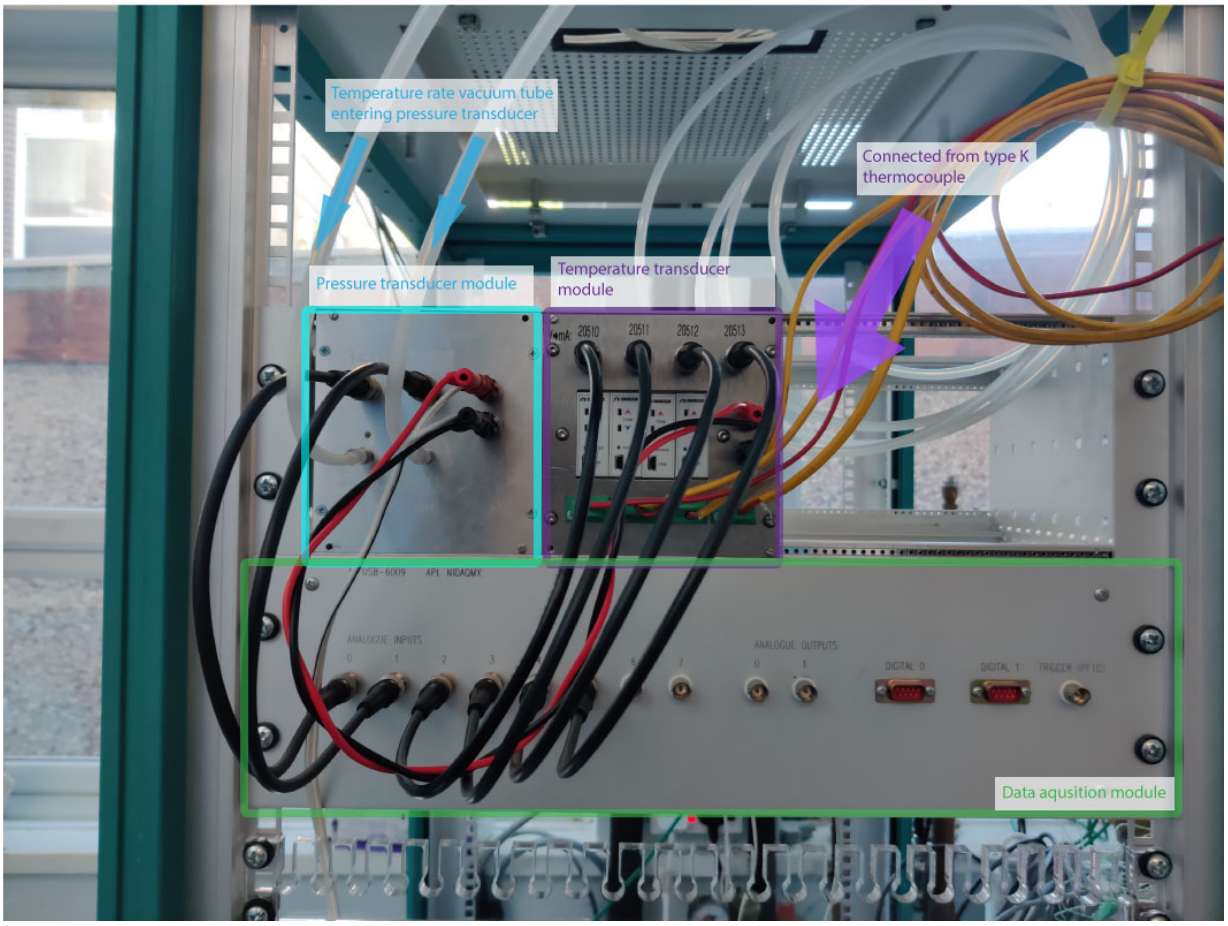

Fig. 3: *Completed monitoring system in operation.*