High-Speed Temperature Measurement

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Abstract. In certain applications where temperature changes rapidly, e.g., compressor cylinder or explosion chamber, it is necessary to obtain temperature data with a sample rate high enough to register the change, i.e., the temperature probe response time must be very low. Type E coaxial thermocouples with response time in the range of µs can be an example of such a temperature probe. This paper describes several approaches for high-frequency temperature data obtained using coaxial thermocouples. Individual approaches are described together, as well as their shortcomings. Furthermore, the possible method of data evaluation is discussed.

1 Introduction

Fast response thermocouples are used in wind tunnels, explosion chambers, and other cases where the temperature change is sudden [1,2]. They are robust and offer better longevity in these types of environments compared to thin-film thermometers that are also sometimes used [3]. Regardless of the application, they must always be connected to hardware capable of acquiring signals at a high sample rate to be able to register the change. In day-to-day instances, the thermocouples would be connected to modules designed specifically for them, that is, with built-in cold junction compensation (CJC). However, their low sample rate (up to 100 S/s) makes them unusable in the applications described in this paper. For this reason, oscilloscopes are often used [3]. They offer a very high sample rate (in the range of GHz) and an adjustable range, meaning that with a low bit rate analog-to-digital converter (ADC) they do not produce very noisy data even when measuring low voltage coming from a thermocouple. On the other hand, they seem to be more prone to picking up noise from their surroundings. Newer versions of voltage modules seem to produce promising results; nevertheless, in research they are barely used. In this research, several NI voltage modules were considered. Module 9222 appeared to be the best option due to its high sample rate (up to 500 kS/s), but 16 bits with ±10 V range made the ADC noise higher than the signal itself. The best results were achieved with the 24-bit ±5 V module NI 9234 with IEPE (Integrated Electronics PiezoElectric Signal Conditioning) turned off paired with a signal amplifier.

2 Materials and Methods

2.1 Experimental setup

For this paper, an experimental setup (Fig. 1.) has been built. It consists of a water supply, two water boilers, a three-way valve, and a temperature measurement set-up. Two tanks, one with hot water and the other with cold water, provide 2 L/s of water. A three-way valve periodically switches between the two tanks, serving as a source of temperature that varies over time. The valve is controlled by a computer with LabVIEW software installed to make the switch every 5 seconds.

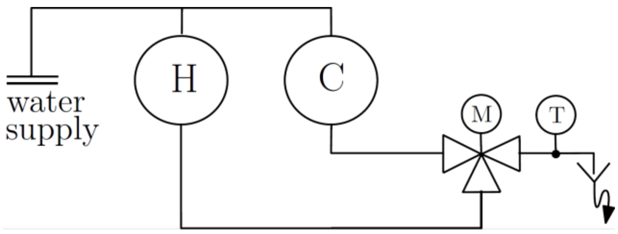

Fig. 1. Experimental setup

The temperature measurement setup consists of two Müller MT 19 type E coaxial thermocouples (Chromel - Constantan) from Dr. Müller Instruments. The probe is 26 mm long and is equipped with M2 thread on its 1.9 mm outer diameter. The thermocouple offers a response time of 3 µs and a sensitivity of 60 µV/K. Because the two metals are insulated one from another by a very thin layer of nonconductive material, the thermocouple joint is formed only at the tip of the probe by lightly sanding it with sand paper.

The first thermocouple is attached to the pipe surface and the other one is placed inside a zero point thermostat with a constant temperature of 0 ° C. The two are connected differentially. The voltage generated by the thermocouples is amplified and collected by the data acquisition system (DAS) (Fig. 2). This type of differential connection compensates for the lack of cold junction compensation, which is usually necessary when using thermocouples [1].

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