CONDUCTION AND INERTIA CORRECTION FOR TRANSIENT THERMOCOUPLE MEASUREMENTS. PART II: EXPERIMENTAL VALIDATION AND APPLICATION

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ABSTRACT

Thermocouples are often used for temperature measurements. Under transient conditions, measurement errors can occur due to capacitive inertia and heat conduction along the stem of the thermocouples. To correct such errors, in Part I a Matlab tool is presented that uses a simplified analytical approach and its numerical solution. In the present work, this tool is applied to experiments for validation. A comprehensive parameter study was performed to investigate different experimental conditions such as installation depth, thermocouple type and transient temperature rises. Additionally, a numerical parameter study was conducted. The simulations deal with the reproducibility and the sensitivity of the results to different input values. The presented results show the applicability of the method and allow an estimation when such a correction of transient measurement errors is appropriate and in which orders of magnitude the errors are otherwise.

INTRODUCTION

Thermocouples are the most commonly used measurement technique for local temperatures. The pairing of two different metallic wires generates a temperature-dependent voltage through the Seebeck effect [1]. However, the sensor reading is always the temperature of the measuring tip and may differ from the actual temperature of the surrounding heat source. The thermal inertia of the thermocouple material and heat conduction along the thermocouple stem can cause measurement errors. Part I describes a tool that allows the correction of measured temperature curves by taking into account both the conduction and inertia effect.

To validate this tool, temperature measurements are made with two thermocouples of different installation depths at the same test position. By experimentally finding thermocouple-specific installation parameters, a much better approximation of the fluid temperature can be recalculated.

RESULTS AND DISCUSSION

Several transient temperature measurements were performed having thermocouples of different types mounted in a Perspex model with extreme aspect ratio of 15.5. As shown in Figure 1, the thermocouples are at different installation depths, while the tips are positioned so that they come as close as possible without touching each other. In several experiments with always the same flow conditions, a fast change of the fluid temperature was forced by heating the fluid electrically by a mesh heater. Both the the inertia of the thermocouples and the stem effect can be found in the time-dependent measurements of the fluid temperature and are shown in Figure 2. While the former occurs at the very beginning of a transient temperature change, the latter is still present, when the temperature reaches an almost constant level. The measured fluid temperature curves and some previously calculated properties of the thermocouples are used as input value for the before mentioned tool.

The recalculated fluid temperatures for both thermocouples should be identical, as the thermocouples measure at the same position. Indeed, the agreement between both curves is well. The inertia effects of the used thermocouples cause high errors in the temperature measurement within the first seconds of an experiment. In contrast, the stem effect remains as long as heat is conducted along the stem of the thermocouple. By using the tool, the installation parameters of the thermocouples can be determined. Once they are found, it is possible to correct the measurement data of the respective thermocouple for the capacitive error and the heat conduction error without the need for a comparison measurement. By conducting experimental and numerical parameter studies, it has been found that the magnitude of the stem effect varies according to the type of thermocouple and the temperature change among others.

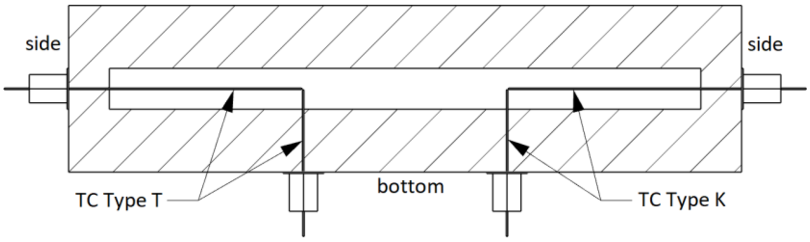

Figure 1. Temperature measurement with two thermocouple types in two positions with different installation depth

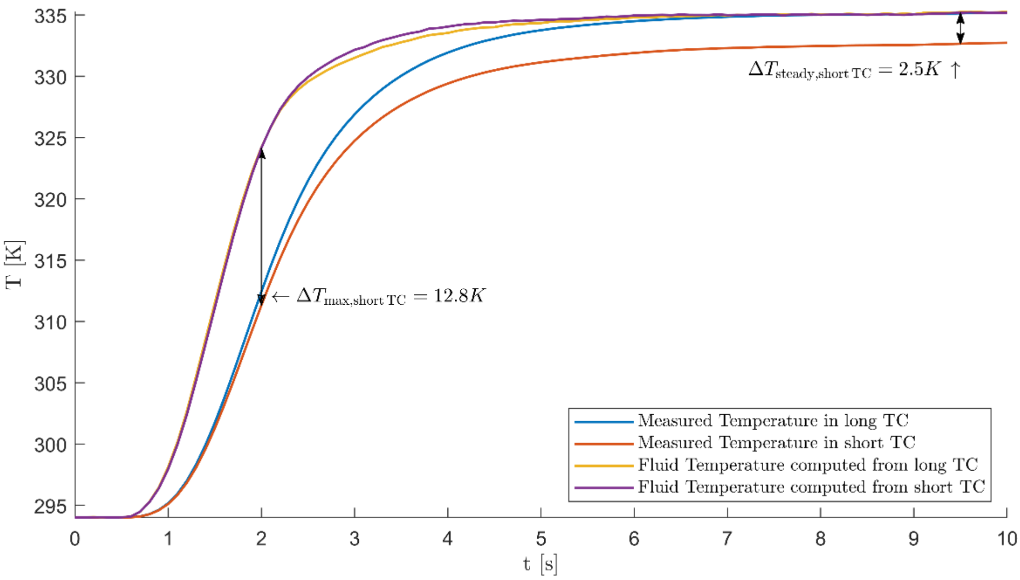

Figure 2. Real fluid temperature estimation by a simulated fit of two thermocouples embedded in a test channel with different installation depths at same local measurement position

REFERENCES

[1] F. Bernhard. *Handbuch der Technischen Temperaturmessung*. Second Edition. Springer. 2014.