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Design of a Hot-wire Rake for Measurements in Temperature-varying Flow Fields

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Abstract

The present work deals with the design of a multi-probe support for simultaneous multi-point measurements. The article analyses the effects of the insertion of a hot-wire rake in a test section where the flow shows not constant temperatures. The constant temperature anemometry technique is known to have a relevant sensibility to both fluid temperature variations during the measurements and temperature differences between calibration and testing conditions. Therefore a technique to take into account for the flow temperature drifts influence is proposed and validated. The temperature correction presented allows reducing the influence of temperature variations on the measured velocity. This is achieved introducing a correction term, namely the temperature-loading factor that can be optimized for the individual probe and measurement conditions. The correction also takes into account for variations in fluid property values (Prandtl number, dynamic viscosity, heat conductivity and density) with temperature.

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Keywords: Constant temperature anemometry; non-uniform temperature flow field; temperature correction calibration; probes rak

1. Introduction

The simultaneously measuring the velocity at different points in a test section requires the use of rakes for simultaneous multi-point measurements [1] even for a large amount of probes [2]. A probes rake is commonly conceived and manufactured according to a specific experimental set-up and a specific need.

The measurement technique chosen to characterize the flow field in the test section is the Constant Temperature Anemometry (CTA) [3–5].

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Nomenclature

A, B, n	King's law coefficients
CTA	Constant Temperature Anemometry
E	measured voltage
Tw	wire temperature of the probe
$\boldsymbol{T_a}$	ambient temperature
$\boldsymbol{T_{ref}}$	reference temperature
$\boldsymbol{T_{f_a}}$	film T with respect to the ambient T
$\boldsymbol{T_{f_0}}$	film T with respect to a reference T
Nu	Nusselt number
Pr	Prandtl number
D	probe wire diameter
R	CTA bridge resistances
Θ	temperature difference
U	velocity
U_corr	corrected velocity
U_act	actual (known imposed) velocity
m	temperature-loading factor
α_ref	hot-wire probe specific parameter
OHR	Over Heat Ratio
r	recovery factor

2. Multi-probe rake design

The designed support is a hot-wire rake shaped out as a symmetrical 4-digits NACA profile, in which it is possible to insert up to five probes and up to two thermocouples.

After the validation of a three probes support [6] shown when installed in the test section in Figure 1 a five probes support is proposed. This latter could grant the measure of the whole velocity profile in test section at once.

The conceived rake is a NACA 0026 profile with a maximum thickness (t) of 12 mm, a chord length (c) of 46.15 mm and a total height (h) of 59 mm as shown in Figure 2.

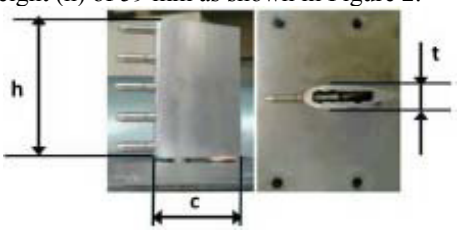

Fig.1. Dimensions of the hot-wire rake

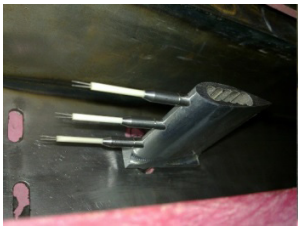

Fig.2. Manufactured three-probes rake

To improve the manufacture process and the adaptability of the rake, different materials and manufacturing procedures are tested. A short summarize in pictures is reported in Figure 3.

Eventually the best compromise resulted to be a rake of polyurethane, milled out by means of a "Computer Numerical Control" (CNC) machine. The probe holders are installed at a distance of 12.5 *mm* from each other. The material chosen for the manufacture is the Obomodulan® 500, which is a polyurethane based material for model, tool making, manufacturing of checking fixtures and test units and it is widely used in the field of rapid proto-typing.