1. INTRODUCTION

The general search for an increase in overall performances and in efficiency of rotating machines, which is now apparent in all the new designs, requires from an experimental standpoint the introduction and a more wide-spread use of methods for detailed measurements in the rotating flow field. The eminently unsteady nature of the flow was often underestimated, because the most widely used instrument, the static-total pressure probe connected to a manometer, is essentially an averaging instrument. However, for progress in the evaluation of, for instance, boundary layer structure on rotor blades on axial machines or for the study of the jet and wake flow in centrifugal compressor, the detailed knowledge of the instantaneous flow field is the next objective of researchers in this field. Instead of instantaneous flow field, however, it is more convenient to speak of the average variation of the velocity vector over a blade pitch, obtained as an average over a large number of blade passages.
Three tools are presently available for the diagnostic of such flows : the hot wire anemometer, the laser doppler anemometer and the holographic systems.

The purpose of the present paper is to offer a survey of the possibility and problems associated with the use of hot wire anemometers for measurement in rotating machines.

Because the concern here is with unsteady measurements, a data acquisition technique particularly useful, the conditional sampling technique which was successfully applied to measurements in unsteady flows and in rotating machines, will be briefly discussed, and some relevant applications analysed in detail.

2. HOT WIRE ANEMOMETRY

2.1 General description

The hot wire anemometer has been used for many years as a research tool in fluid mechanics. In spite of the introduction of new measurement systems (e.g. the laser anemometry), it is still expanding, due to improvements of the equipment and to increased interest in detailed description of turbulent flow fields.

The hot wire anemometer consists of a sensor, a small electrically heated wire exposed to the fluid, and of an electronic equipment, which provides the transformation of the sensor output in a useful electric signal. Contrary to most measuring instruments, the electronic circuitry forms an integral part of the anemometric system, and influences the probe characteristics.

Typical dimensions of the wire sensor are 5 µm in diameter and 1 to 3 mm in length. The basic principle of operation of the system is the heat transfer from the heated wire to the cold surrounding fluid, which is function of the fluid velocity. Thus, a relationship between the fluid velocity and an electrical output can be established.

The purpose of the electronic circuit is to provide to the wire a controlled amount of electrical current, and in the most used type of operation, the constant temperature method, to vary such supply so as to maintain the wire temperature constant when the amount of heat exchanged varies.

2.2 Sensors

The heat exchange from a thin heated wire and the surrounding fluid is function of the temperature difference, the wire dimension, the physical characteristics of the fluid and its velocity. Thus it can be expected that a wire electrically heated and exposed to a free stream will reach a temperature function of the above parameters. If the power supply is kept constant, the wire temperature will change (decrease) for a change of fluid velocity (increase). An easy way to measure the temperature of a metallic wire is to measure its resistance : the two are related by a linear relationship. Thus there exists a relation between the fluid velocity and the wire resistence. If the wire is one arm of a Weathstone bridge it is possible, for a wire supplied with a constant electric power, to obtain a relation between the bridge unbalance voltage and the fluid velocity.

In practical applications, a material to make a sensor must have some properties :

- a high value of the temperature coefficient of resistance, to increase its sensitivity to velocity variations;
- an electrical resistance such that it can be easily heated with an electrical current at practical voltage and current levels;
- possibility of being available as wire of very small diameter;
- a high enough tensil strength to withstand the aerodynamic stresses at high flow velocities.

The materials which are commonly used are : tungsten, platinum and platinum alloys. Tungsten wires are mechanically strong and have high coefficient of resistance, but cannot be used at high temperatures because of rapid oxydation. Platinum has high oxydation resistance, good temperature