TURBOMACHINE MULTICHANNEL

BLADE TIP CLEARANCE & BLADE TIP TIMING MEASUREMENTS

GENERAL DESCRIPTION
TURBOMACHINE MULTICHANNEL
BLADE TIP CLEARANCE & TIP TIMING
MEASUREMENTS

GENERAL DESCRIPTION

CONTENTS

CAPAAB: THE COMPANY

HIGH TEMPERATURE CLEARANCE & TIP TIMING MEASUREMENTS

PRINCIPLE OF OPERATION

A UNIQUE SOLUTION:
FROM SENSOR TO ACQUISITION
FROM CALIBRATION TO REAL TIME CLEARANCE DISPLAY
FROM DEVELOPMENTS TO PRODUCTION SYSTEMS

ENGINE TEST: EXAMPLE OF RESULTS
CAPAAB : THE COMPANY

The Company provides products and CAPAAB original solutions mainly around technical implementing capacitive sensors and conditioners.

Indeed, both the capacitive principle is known and has long been applied in the field of measurement, as it has never been easy to draw all the possibilities.

Indeed, the representation of a capacitive sensor is not as simple as a capacitor banal: there are the parasitic capacitances that can have values millions times greater than the value to be measured!

This is where the expertise comes in: through conditioning techniques used by CAPAAB, the parasitic elements are eliminated.

This opens the way for a variety of applications ranging from distance measurements nanoscale distance measurement or vibrations to hundreds of kilohertz, for example.

Besides the technical capacitive CAPAAB has expertise in the techniques inductive / resistive as well as acquisition and data processing.

Compared to competitors blade tip clearance measurement system, the main and determinant advantage in the principle we use, consist in its ability to allows static calibration - no spin rig needed - with high frequency and high probe temperature operation.

Thanks to the last improvements, it is now possible, using the MC1800 unit, to use coaxial probes (*) and get static measurements with a long term stability quite as good as the results get with a triaxial probe.

To end, the last CAP1802 connected to the “twin probe” unit has the ability to provide simultaneously a signal proportional to blade tip clearance and a signal link to accurate blade tip timing.

(*) with tri axial cable
HIGH TEMPERATURE BLADE TIP CLEARANCE & TIP TIMING MEASUREMENTS

Reliable high temperature clearance measurement involves compressor and turbine tip clearance, rotor shaft and disk displacement measurements and also inter-components measurements such as gas seal clearances and turbine shroud displacement.

The co-operation between CAPAAB and company which develops high temperature capacitive probe, results in the a wide range of solutions. So, from medium temperature probes to 1300 °C probes (without cooling), we can provide a complete multi-channel solution (up to 8) with real time processing and display of data in the well known Windows® software environment.


**PRINCIPLE OF OPERATION**

The principle of blade tip clearance measurement is given below:

The system includes mainly the capacitive probe(s) fitted on the casing and facing the blades which the blade tips clearance must be characterized. So, the capacitance changing between the probe inner electrode and the passing blade is related to the clearance. The maximum value the capacitance reaches is the direct result of variation in tip clearance.

The rough signal coming from the probe conditioning unit (A output) looks like the sketch below: as the probe is between two blades, the signal is close to zero (the measured capacitance is almost nil) and this signal is maximum as the blade is right facing the blade.

The A signal coming out from the capacitive conditioning unit is digitised and processed to display the min and mean clearance is engineering units thanks to a dedicated software (**BTC express soft**) developed by CAPAAB.
The processing unit is used to convert the digitized voltage into mm or inches thanks to the polynomial representation of the calibration curve, stored in the application program.

The general feature of the capacitive probe calibration curve is given below.

To get this calibration curve, **no tricky spin rig is needed**.

Static calibration is obtained by fitting a single blade (or its tip part) on a simple mechanical unit facing the probe. This blade is the same than those the engine is composed. A driving threaded device with a µm reading unit allows the measurement of the actual distance. The corresponding voltage is a DC value, read on a DC voltmeter.

Thanks to a spreadsheet, the polynomial expression of this calibration curve is obtained. The constant and the polynomial coefficients are loaded in the system software in order to display the clearance in mm or inches in real time.

The principle of blade tip timing measurement is given below:
A “twin capacitive probe” is used in order to get two identical signals but with a small phase shift due to the axial distance shift between each half sensor.

This solution avoid the limitation of the solution which consists to find when the maximum tip clearance signal occurs: this maximum is noisy and the uncertainty in the time of blade arrival is high.

Then the two signal get are combined and processed that gives an accurate resulting signal from which it is easy to obtain tip timing information.

Blade Tip Timing & blade Tip Clearance solution:

The above figure gives an example of the signal get on a typical compressor.
THE MAIN ADVANTAGES OF THIS TECHNIQUE MAY BE RESUMED:

With comparison to conventional capacitive system, this technique allows to:

- use a grounded target and static calibration

- use very small probes (down to 0.5 mm for the diameter of the measuring electrode)

- use long probe to electronics cable without reduced performances

- measure simultaneously capacitive, differential capacitive (for tip timing application)

- have extended probe range due to the extremely low leakage equivalent input capacitance

- have a wide frequency range (up to 250 khz for the output signal)

- have a very low drift and a high accuracy due to the servo loop technique

- works in harsh environment due to the full guard ring probe and cable (with triaxial probes)

- accommodate high temperature capacitive triaxial or coaxial probes (up to 800 °C)

- accommodate very high temperature capacitive coaxial probes (up to 1300 °C)

- be uninfluenced by magnetic field, gas ionization and ionizing radiation
A UNIQUE SOLUTION:

**FROM SENSOR TO ACQUISITION**

**FROM CALIBRATION TO REAL TIME CLEARANCE DISPLAY**

**FROM DEVELOPMENTS TO PRODUCTION SYSTEMS**

Two different capacitive conditioning electronics are available: the first one is dedicated to R&D field, the second one for industrial applications. The main features are given below.

**CAPACITIVE CONDITIONNING UNIT FOR R&D SYSTEMS:**

- **MEASURING RANGE:** FROM 0 → 0.5 mm to 0 → 12 mm according to the diameter of the sensor inner electrode used (triaxial or coaxial probes)
- **LINEARITY:** < +/- 0.5 % (F.S.O) OF THE PROBE RANGE
- **TEMPERATURE DRIFT (/ °C) < 0.05 % (F.S.O) OF PROBE RANGE
- **FREQUENCY RANGE:** 0 to 220 kHz typical
- **DYNAMIC RESOLUTION AT MAXIMUM PROBE DISTANCE:** 50 µm @ 100 kHz bandwidth
- **SIGNAL OUTPUT:** 0 / +10V LINEAR VARIATION vs PROBE CAPACITANCE
- **AUTOMATIC OR MANUAL OFFSET ADJUSTMENT
- **ADJUSTABLE GAIN:** RATIO FROM 1 to 4 (JUMPER)
- **PACKAGING:** 3U 7F MODULE FOR 19’ RACK; +/-15 V supplies or STAND ALONE IP55 CASING

- **COMPATIBLE WITH HIGH TEMPERATURE TRIAXIAL & COAXIAL CAPACITIVE SENSORS** (temperature range : from -270°C to +800°C)

The CAP 1000 a & b units are dedicated to triaxial capacitive probes / tip clearance applications

The CAP 1800 a & b units are dedicated to coaxial capacitive probes / tip clearance applications

The CAP 1802 a & b units are dedicated to coaxial capacitive probes for tip timing and tip clearance applications
CAPACITIVE CONDITIONING UNIT FOR INDUSTRIAL APPLICATIONS:

This unit is calibrated for each probe and its output can be connected to the digitizing unit. Usually, the module is located in the test chamber, and is DC powered. The general metrological features are similar to the MC 1000 ones. The size (mm) is 220*140*70.

This unit is dedicated to Blade Tip Clearance and Blade Tip Timing measurements.

A specific “twin probe” is used in order to get 2 output signal: the first one is related to clearance and the second one can be used to accurate tip timing measurement.

The same digitizing and processing unit can be used with the two previous conditioning unit. Build around a Pentium® PC, running under WinXP®, up to 8 units can be connected to digitizing channels with simultaneous sampling. The application software is developed under LabView® from National Instrument. An example of the M.M.I is given below.

M.M.I EXAMPLE OF THE BTC EXPRESS SOFT (BLADE TIP CLEARANCE APPLICATION)
ENGINE TEST: EXAMPLE OF RESULTS

Results can be displayed in real time on the PC monitor, but also printed very simply because data are also saved in compatible spreadsheet format.

CAPAAB BTC & BTT MEASUREMENTS COMPLETE SOLUTION

UP TO FOUR ACQUISITION CARD = 16 CHANNELS PER SYSTEM

CAPAAB
22 / 32 Sentier des Torques BAT 8
92290 Chatenay Malabry Tel / Fax : 01 71 22 73 72 www.capaab.fr