PROCESSING OF CIRCUMFERENTIAL TEMPERATURE DISTRIBUTIONS FOR THE DETECTION OF GAS TURBINE BURNER MALFUNCTIONS

* The Mechanics of Temperature Distribution.
* Temperature Patterns and Engine Operation.
* Identification of Pattern Alterations.
* Enhancing Pattern Differentiation Discrimination.
* Application to Faults on a Operating Gas Turbine.
* Implementation Aspects.
* Discussion and Conclusions.

The Mechanics of Temperature Distribution

* **Effects of combustion process**

  (i) Fuel Injection at discrete positions.

  (ii) Uneven mixing of fuel and air at the primary zone.

  (iii) Non uniform mixing at the secondary and dilution zone.

* **Effects of the flow through the turbine**

  (i) Rotation of temperature pattern due to swirl.

  (ii) Reduction of circumferential variations due to mixing.

  (iii) Distortion because of the different number of burners and blades, struts.

Temperature Patterns and Engine Operation

* **For certain operating condition the temperature pattern is determined by**

  (i) The geometry of combustion chambers and fuel injection system.

  (ii) The geometry of the turbine stages.

* **Alteration of the temperature pattern can be caused by**

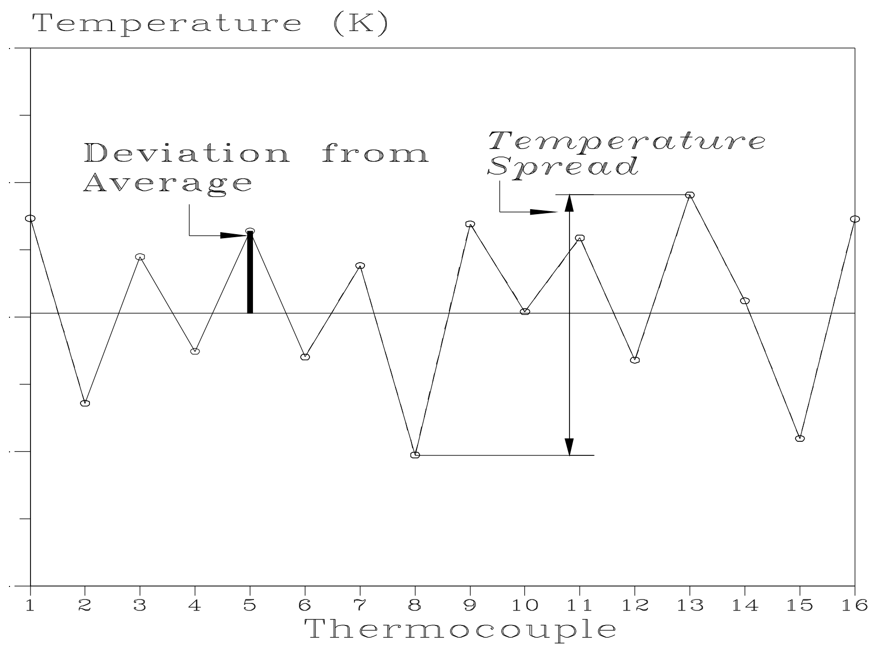
  (i) Change of operating condition.

  (ii) Engine fault.

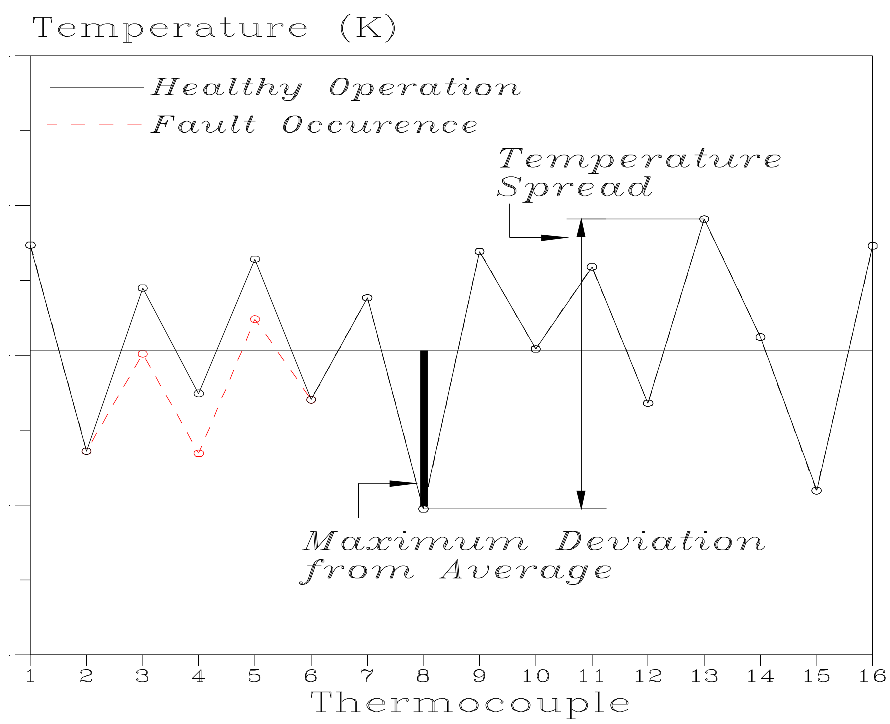
  (iii) Overall engine deterioration.

Identification of Pattern Alterations

Global index monitoring parameters



Pattern alteration and corresponding modification of the monitoring parameters



Identification of Pattern Alterations

* Established by monitoring all individual temperature readings. For example, by means of the normalised temperature deviations

$$\mathbf{dT_i^{\,n}} = \left| \frac{\mathbf{T_i}}{\mathbf{T_{av}}} - \left(\frac{\mathbf{T_i}}{\mathbf{T_{av}}} \right)_{\mathbf{ref}} \right|$$

* The identification of the burner condition is based on the comparison to pre-set limits

$\mathbf{dT_i^n}$ **p** $\mathbf{DEV_{lim}}$ **Healthy Condition**

$\mathbf{dT_i^n}$ **f** $\mathbf{DEV_{lim}}$ **Faulty Condition**

Features

- Fault detection and localisation

- Reduced dependence on absolute values

Enhancing Pattern Differentiation Discrimination

*** Evaluation of deviations from a reference temperature pattern**

$$\mathbf{dT_i = T_i - T_{i,ref}}$$

*** Reduction of the deviations**

$$\mathbf{dT_i^r = \frac{dT_i}{dT_{av}} \frac{|dT_i|}{dT_s}}$$

where

$$\mathbf{dT_{av} = \frac{\sum_{i=1}^{N} |dT_i|}{N}}$$

dT_s: measure of maximum expected dT_i due to statistical behavior.

*** dT_i^r compared to threshold for condition determination.**

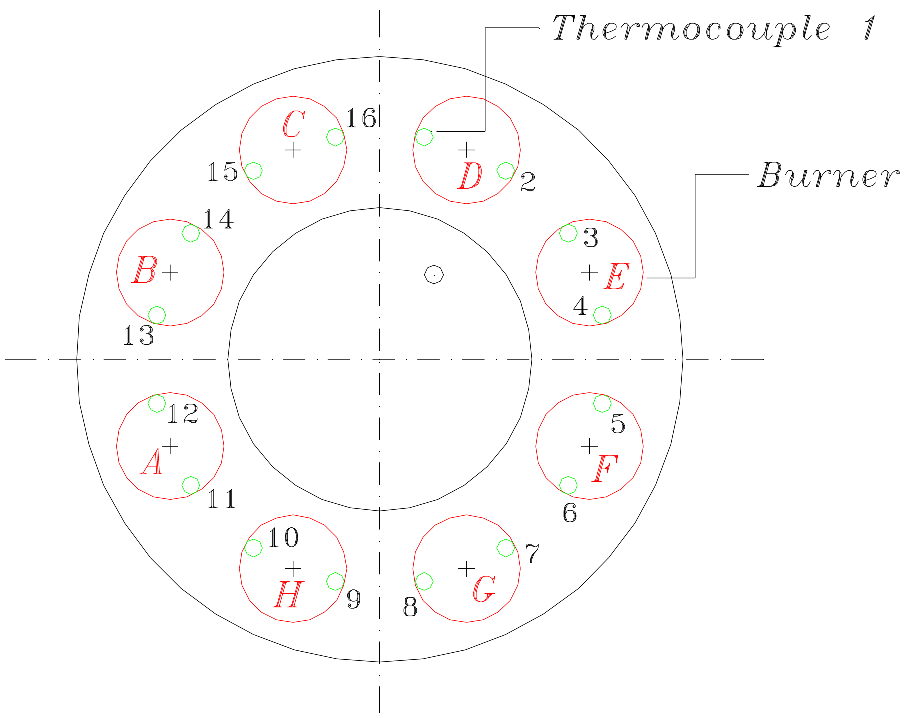
*** Thresholds established from healthy condition patterns.**

Application to Faults On An Operating Gas Turbine

* Test Vehicle: EGT TORNADO

* Temperature pattern registered by a set of 16 Thermocouples at the exit of the core turbine.

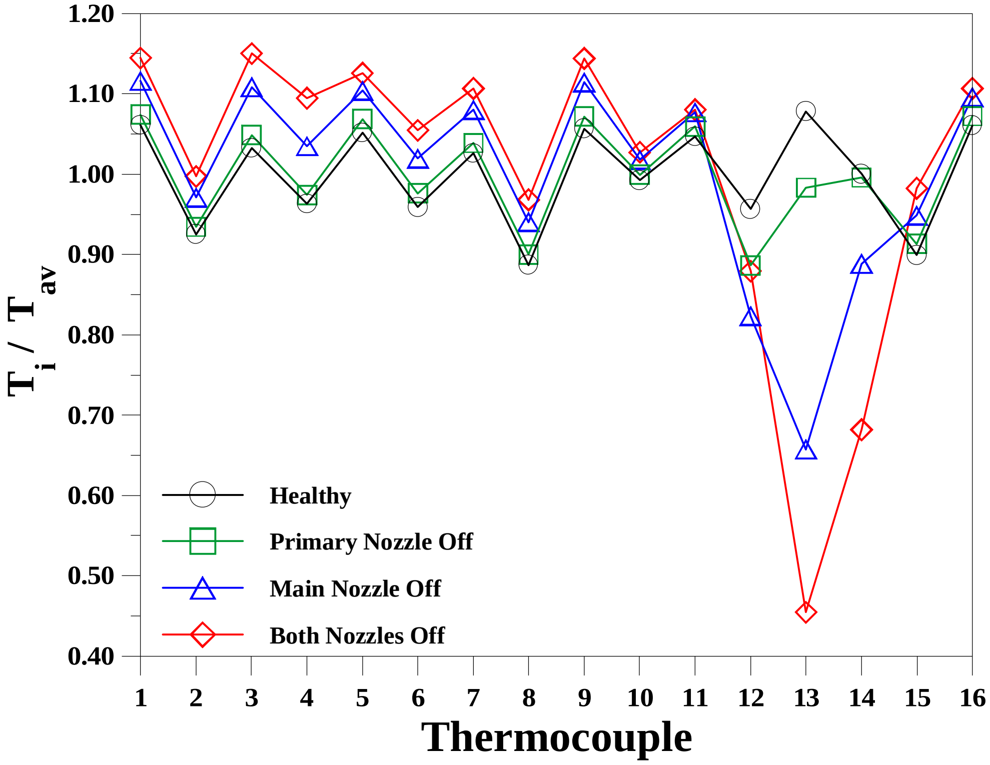
Circumferential location of thermocouples



* Faults Experimentally Investigated: Restriction of fuel supply to the (a) Primary (b) Main and © Both nozzles.

Application to Faults On An Operating Gas Turbine

Temperature Pattern at Different Burner Conditions

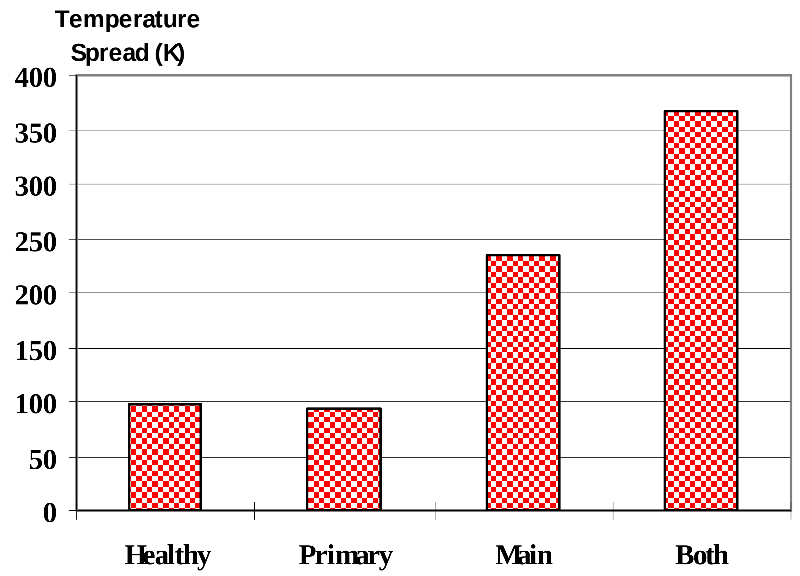


* Effects of Burner faults

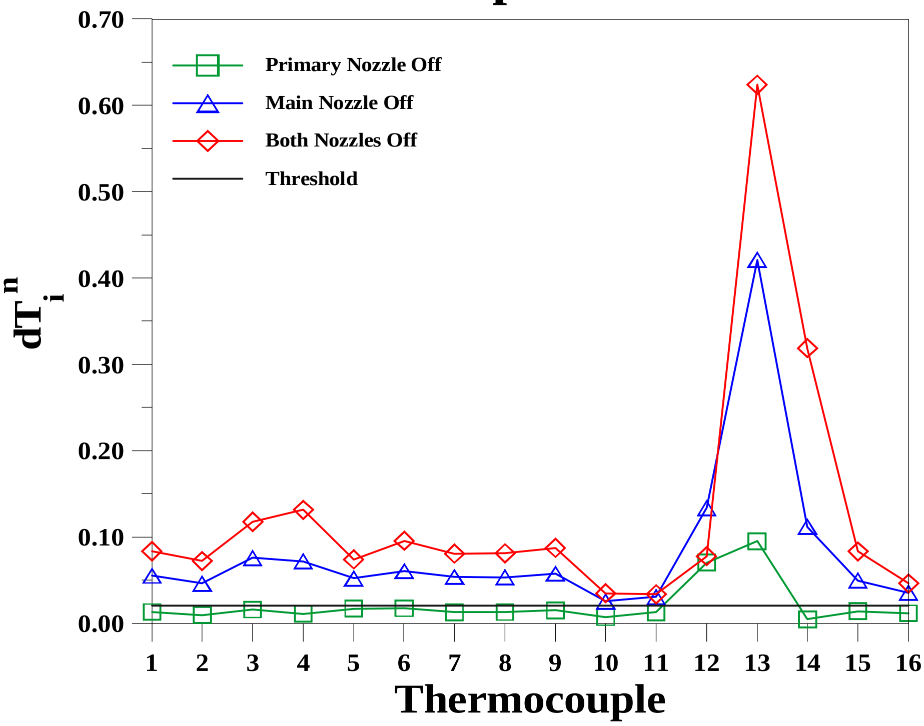
- Reduction of temperature registered by a number of thermocouples.
- Increase of the temperature registered by the rest thermocouples.
  - The deviation amplitude is directly related to the fault severity.

Application to Faults On An Operating Gas Turbine

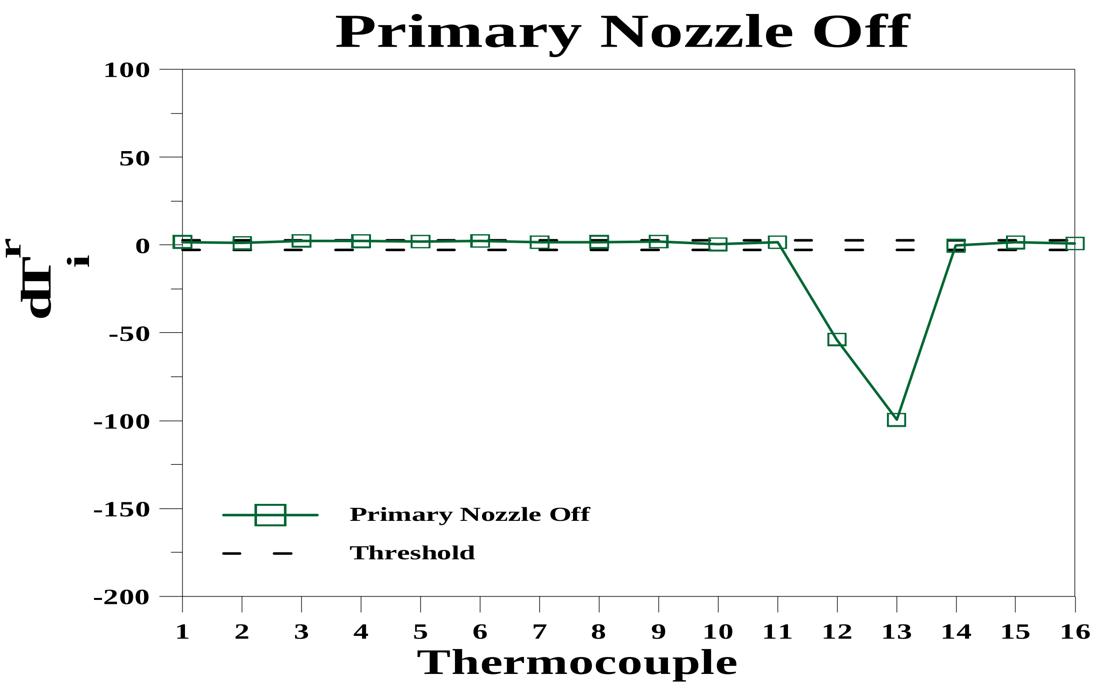
Temperature Spread Modification

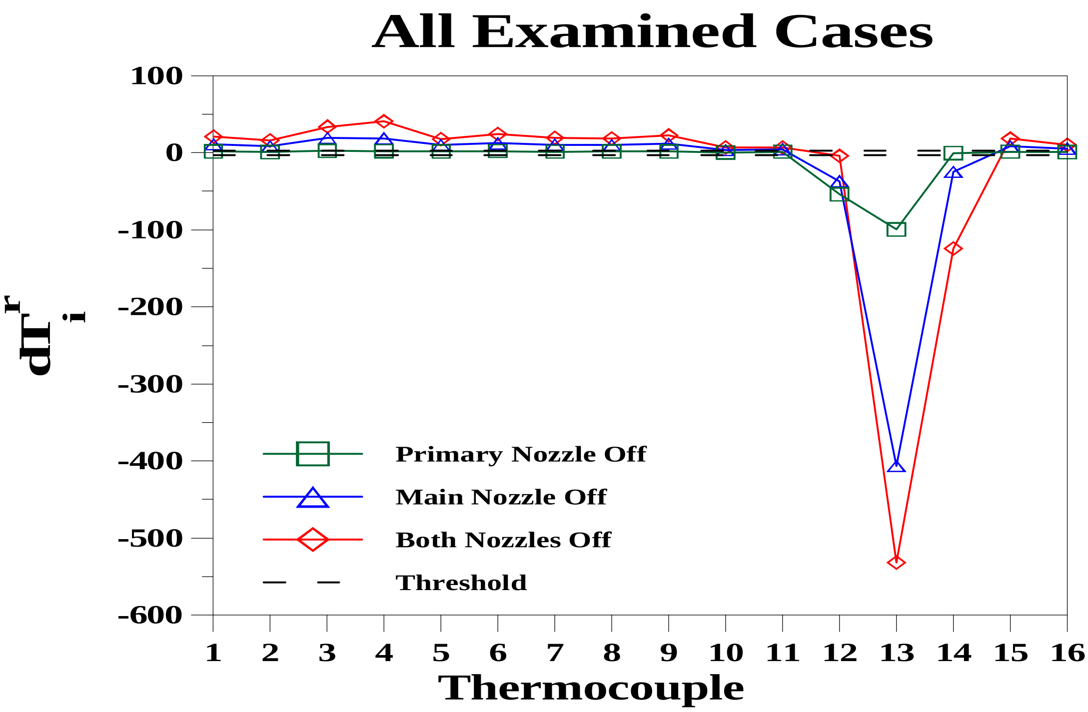


Normalized Temperature Deviations



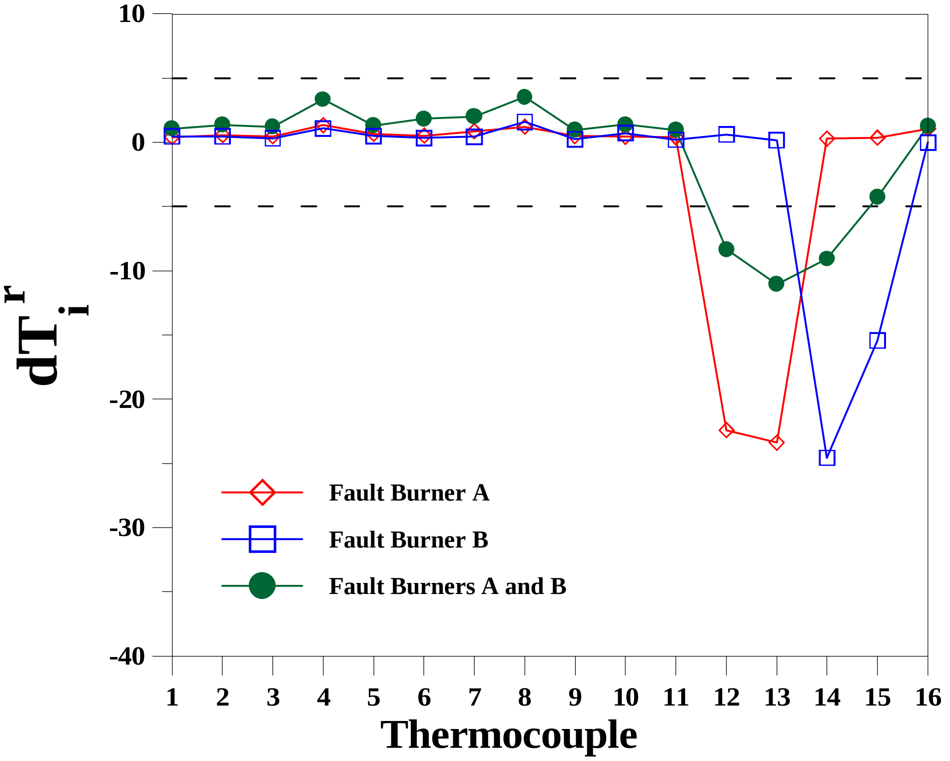
Reduced Temperature Deviations





Reduced Temperature Deviations

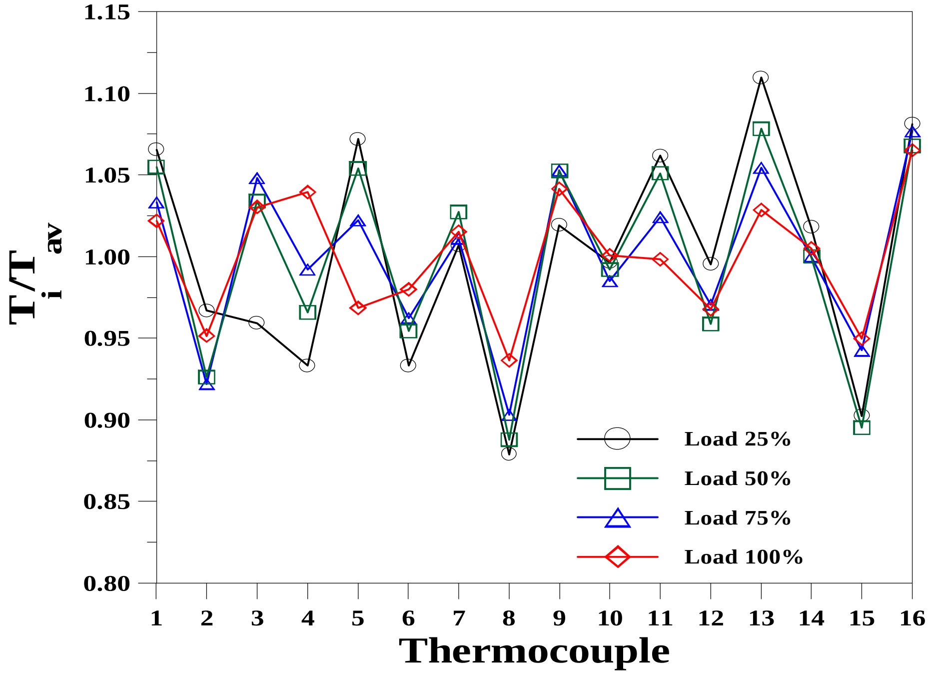
Different Burner Primary Nozzle Faults



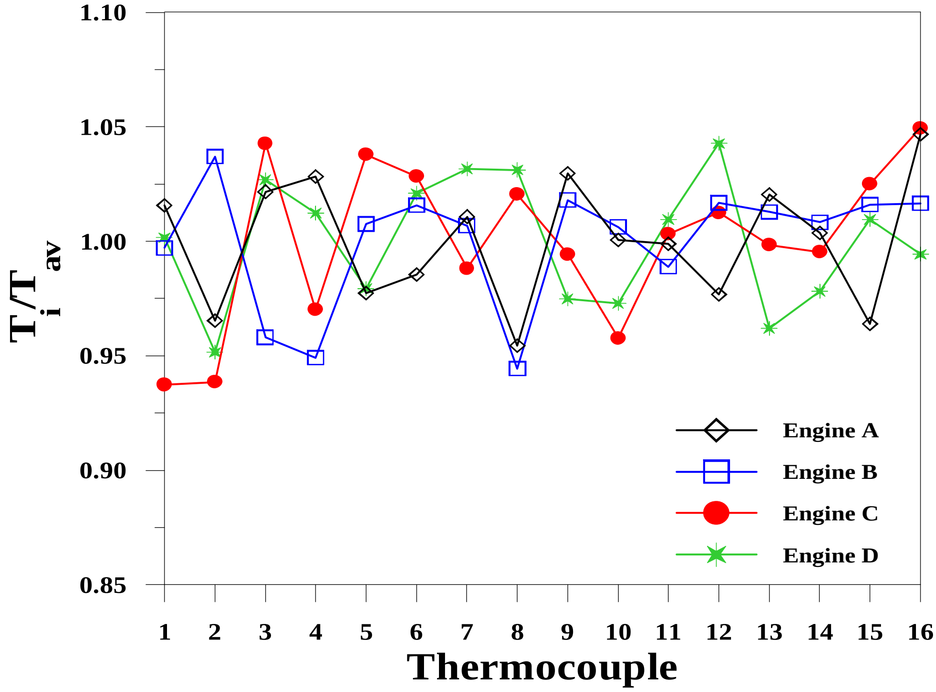
Implementation Aspects

Baseline Information

Temperature Pattern Modification with operating load

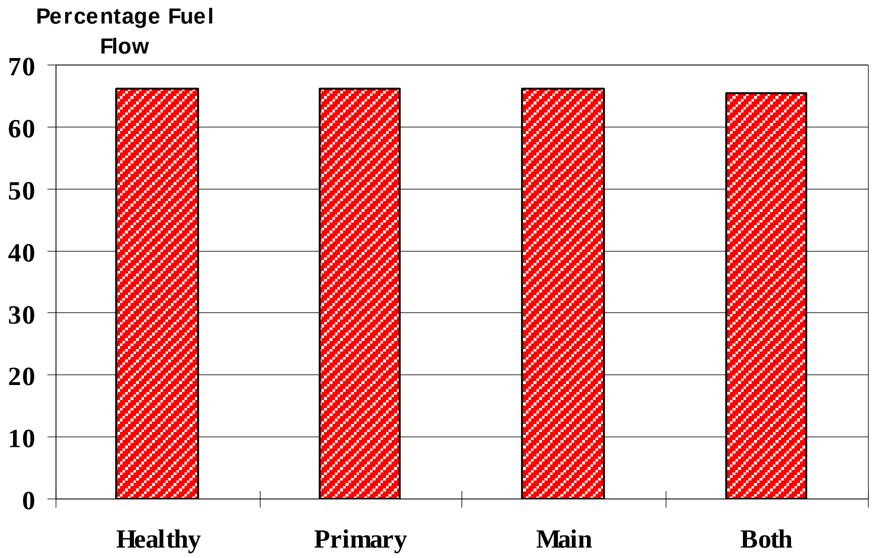


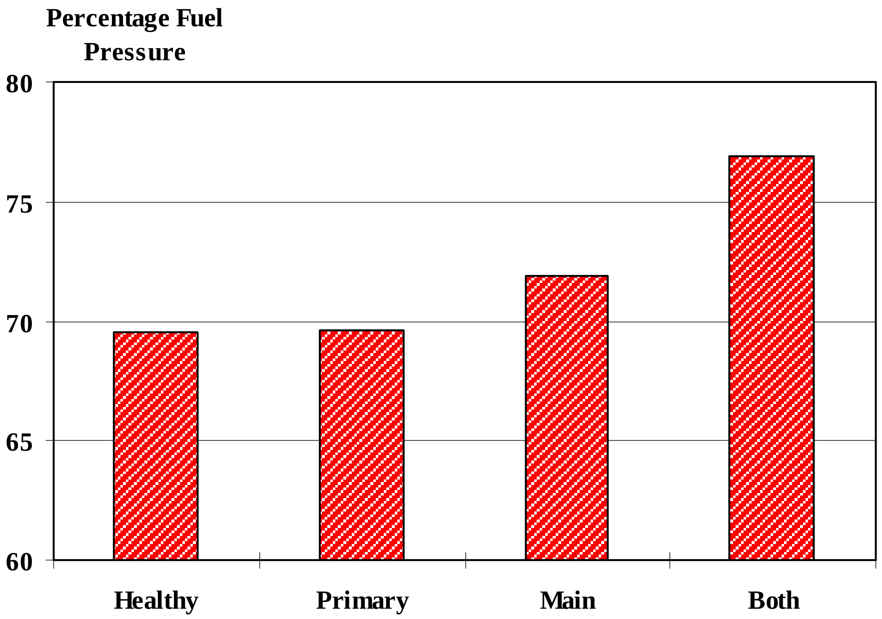
Temperature pattern for different engines



Implementation Aspects

Additional Information for Fault Identification





Other Aspects of Temperature Pattern Processing

* Applicability of the proposed method to other type of faults. Fault identification requires reference information about fault signatures.

* Applicability of the method to different engines.

* Ways of obtaining and handling the temperature profiles at different operating conditions

* Measurements techniques and information detail.

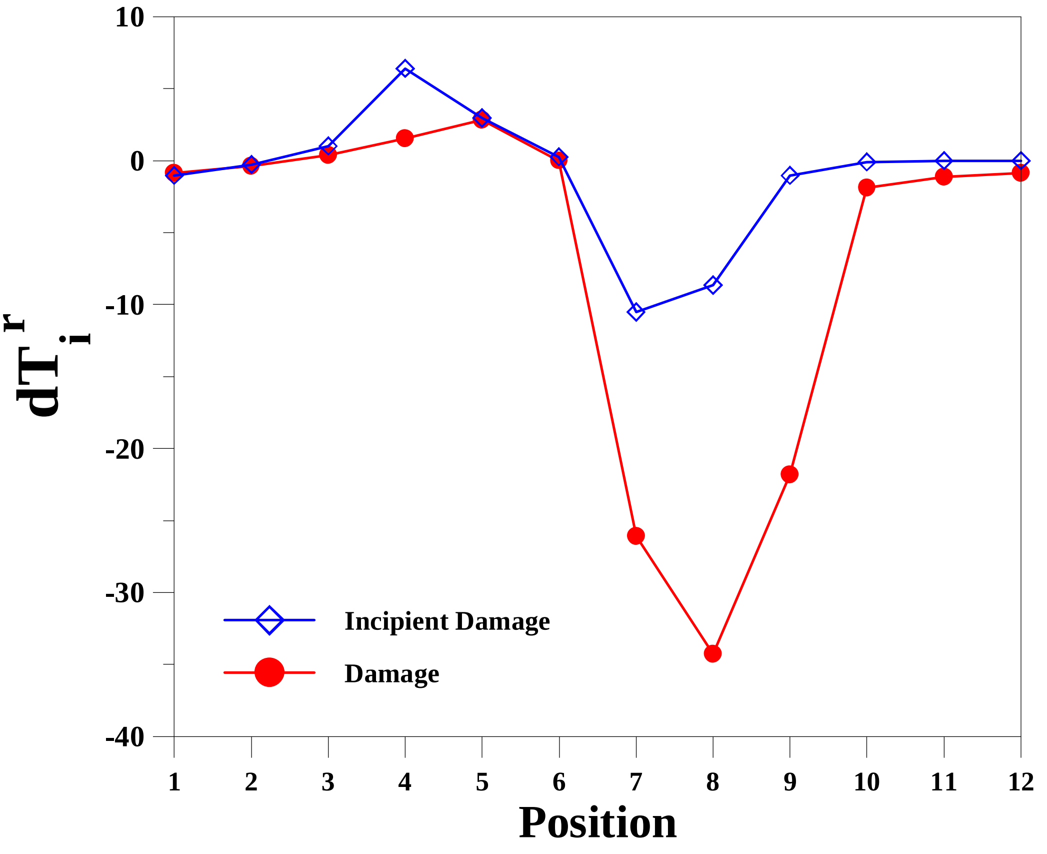
* Practical Application:

  (a) The method is suitable for integration in computerized systems.

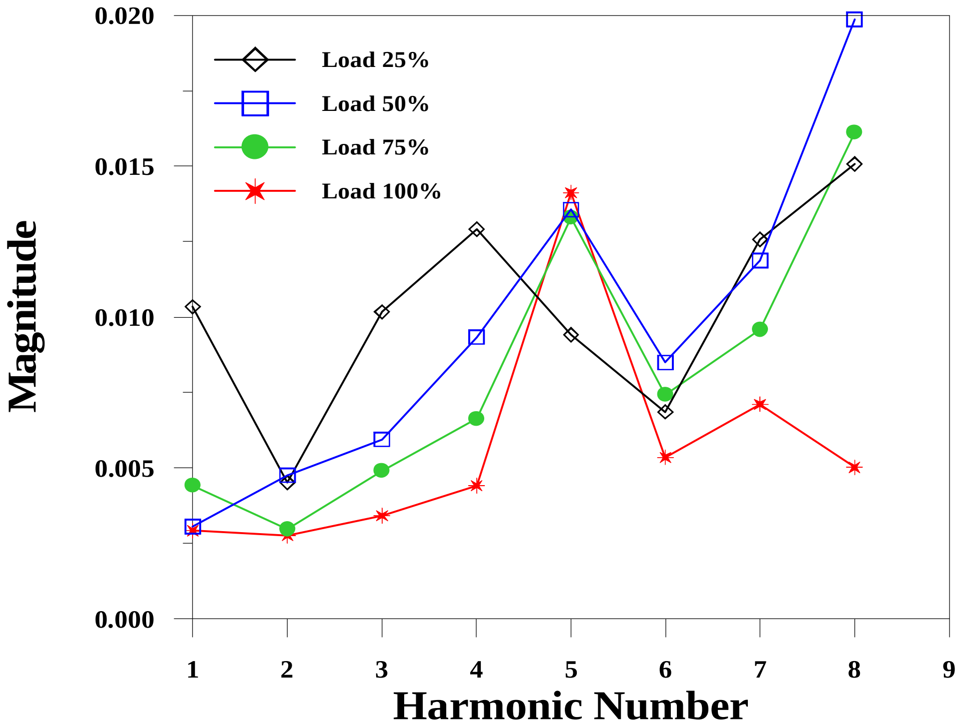
  (b) Pattern classification can be established with modern methods.

Reduced Temperature Deviations

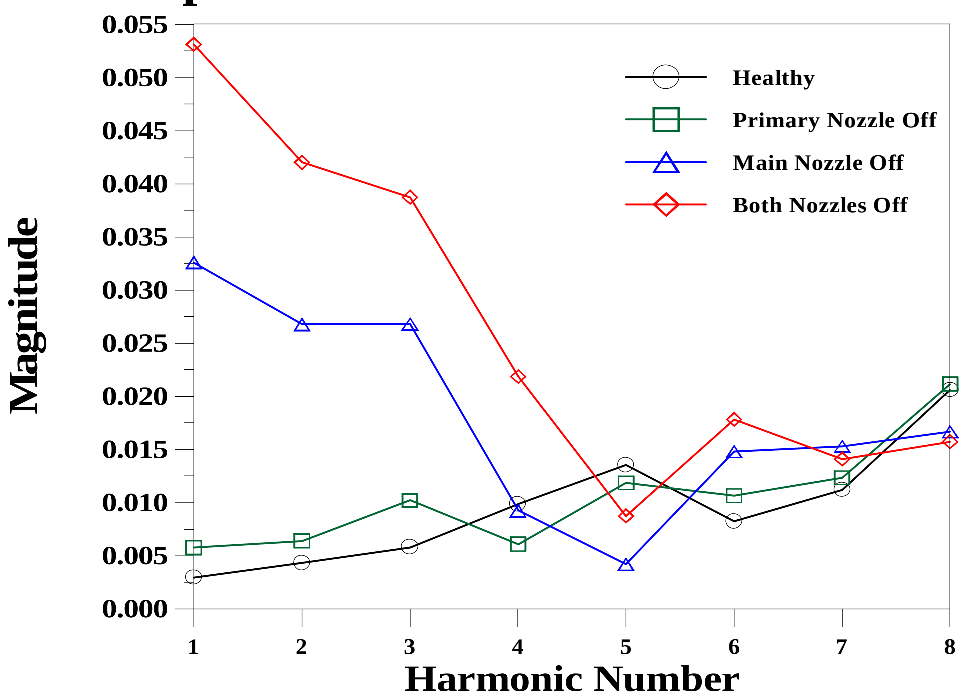
Distorted Burner (Dundas et al, 1992)



Magnitude of Fourier Coefficients of healthy condition temperature patterns



Magnitude of Fourier Coefficients of temperature patterns with burner faults



Conclusions

* A method of processing circumferential temperature patterns for identifying gas turbine burner faults has been presented.

* Application to experimental data has revealed its ability to identify even small burner faults.

* Applicability issues have been discussed, and issues establishing datum information and recognizing kind of fault have been addressed.

* A new way of investigating temperature profile, based on Fourier transformation, has been introduced.