IDENTIFYING FAULTS
IN THE VARIABLE GEOMETRY SYSTEM
OF A GAS TURBINE COMPRESSOR

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Identifying Faults in the Variable Geometry System of a Gas Turbine Compressor

- Variable guide vane (VGV) system and related malfunctions
- A test program for VGV fault effects
- VGV faults impact on engine performance
- Analysis of fault effects with adaptive modelling
- Effect on EGT profiles
- Discussion-Conclusions
Variable Guide Vane (VGV) System
Variable Guide Vane (VGV) System
Controlling Mechanism on Compressor Casing

Schematic of a linkage of a variable geometry vane
Schematic Representation Of Individual Vane Mistuning
A Test Program for VGV Fault Effects

Test Engine: TORNADO
Implanted fault cases

- Different magnitude (severity: size, number of vanes)
- Different locations
Implanting Vane Mistuning
**VGV Fault Effects On Engine Performance**

(a) Stage-1, one-vane faults, b) Stage-1, three vane faults, c) Stage-4 faults and d) IGV faults
Setting-Up An Adaptive Model For Fault Diagnosis

**Compressor:**
\[ f_1 = \frac{q_c}{q_{c,\text{ref}}} \quad f_2 = \frac{\eta_{pc}}{\eta_{pc,\text{ref}}} \]

**Burner:**
\[ f_3 = \frac{BPL}{BPL_{\text{ref}}} \quad f_4 = \frac{\eta_b}{\eta_{b,\text{ref}}} \]

**Turbine:**
\[ f_5 = \frac{q_T}{q_{T,\text{ref}}} \quad f_6 = \frac{\eta_{isT}}{\eta_{isT,\text{ref}}} \]
**Modification Factors Percentage Deviations**

(a) Stage-1, one-vane faults, b) Stage-1, three vane faults, c) Stage-4 faults and d) IGV faults
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Turbine Diagnostic Plane

Healthy Engine Area

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**Exhaust Temperature Distributions**

\[
dT_i = T_i - T_{i,\text{ref}}
\]

\[
dT_i^r = dT_i \left| \frac{dT_i}{dT_s} \right| \frac{1}{dT_{av}}
\]

\[
dT_{av} = \frac{\sum_{i=1}^{N} |dT_i|}{N}
\]
Temperature Pattern At Core Turbine Outlet For Two Cases
Reduced Temperature Deviations

Three vanes of stage-1 mistuned

![Graph showing temperature deviations](image-url)
Reduced Temperature Deviations

One vane of first stage mistuned

![Graph showing temperature deviations for different thermocouples at 5, 10, and 15 degrees, with healthy limits indicated.](image)
Reduced Temperature Deviations

Different cases of mistuned vanes

![Graph showing temperature deviations](image)

- One IGV 10 degrees
- Stage 4 vanes 10 degrees
- Stage 4, two vanes 10 degrees
- Healthy Limits
Reduced Temperature Deviations For Burner Faults (Tsalavoutas Et Al, 1996)
Comparison Of Reduced Temperature Patterns

Burner Faults

VGV faults

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Temperature Spread for the Examined Cases

![Graph showing temperature spread for different cases. The x-axis represents different stages and the y-axis represents the spread/SPread,ref ratio. The stages include Stage-1, one vane, Stage-1, three vanes, One IGV, and Stage-4.]
**Diagnostic Observations**

Particular features of VGV faults

- Mainly $f_1$ reduction
- Effect on EGT profile
- Mis-rigging no effect on EGT

![Diagram showing IGV +6 Degrees misrigging]

VGV faults also produce acoustic signatures
Conclusions

- Individual VGV faults have an effect on performance
- Adaptive modelling provides component oriented (localized) information
- EGT patterns are influenced by individual VGV faults (distinguishable on reduced temperature patterns)