RADIAL COMPRESSOR FAULT IDENTIFICATION USING DYNAMIC MEASUREMENT DATA

N. Aretakis, Research Assistant
K.Mathioudakis, Assistant Professor

Laboratory of Thermal Turbomachines
National Technical University of Athens

CONDITION MONITORING OF RADIAL COMPRESSORS

F Techniques usually employed for axial compressors.

Based on:

- **Aerothermodynamic measurements.**

  -Overall condition assessment
  -Identification of faults affecting performance.

- **Fast response measurements.**

  -Faults either related only to mechanical parts or to small faults of the gas path components.

THE PRESENT WORK

F Monitoring techniques based on fast response measurements.

F Purposes:

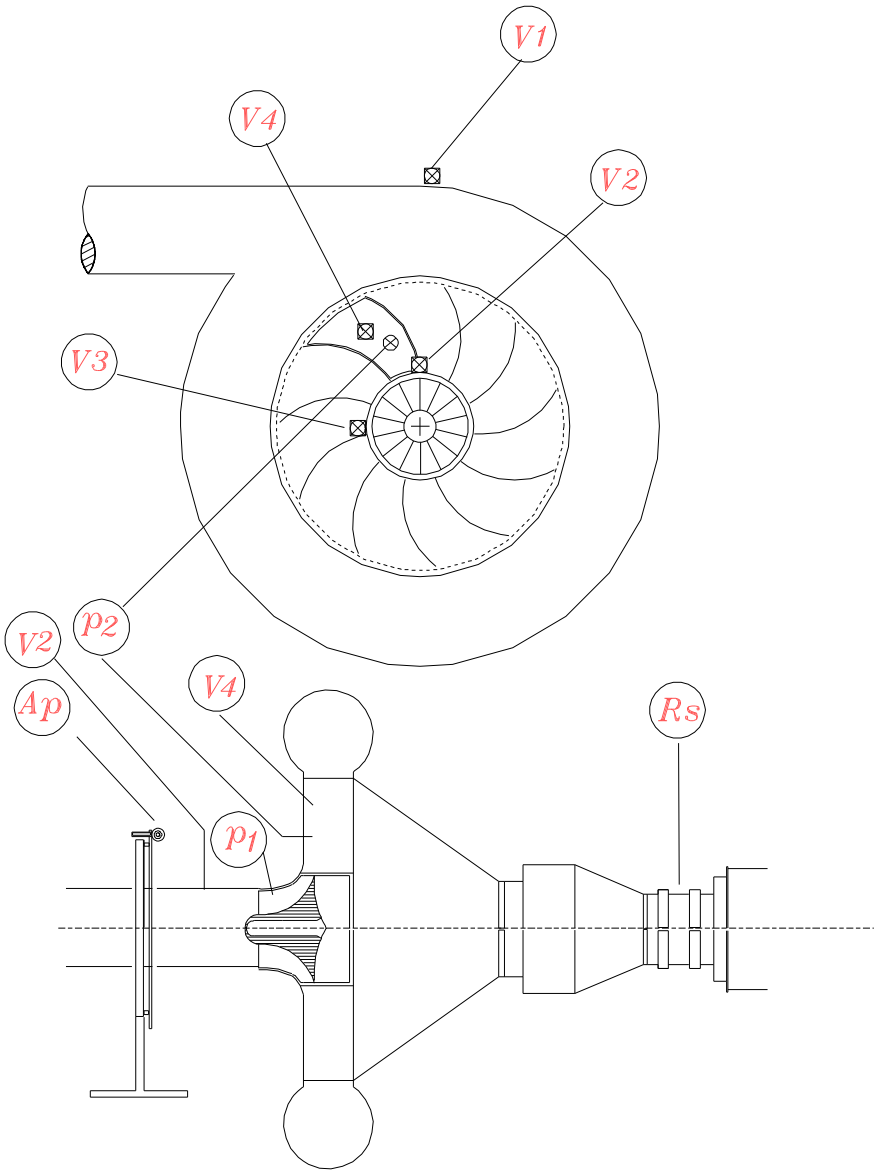
-To improve the understanding of the behaviour of dynamic quantities in relation to operating conditions of a radial compressor.

-To examine possibilities of fault diagnosis and establish related baseline information.

RADIAL COMPRESSOR FAULT IDENTIFICATION USING DYNAMIC MEASUREMENT DATA

- Compressor Layout, measurements.
- Experimental procedure.
- Power spectra calculation.
  - -Dependence on operating conditions.
- Spectral differences and fault signatures.
  - -Dependence on operating conditions.
  - -Specific measurements sensitivity to particular faults.
- Transfer function calculation.
- Fault signatures in transfer function.
- Discussion and Conclusions.

TEST COMPRESSOR INSTRUMENTS LOCATION



14 Vanes impeller, 11 vanes diffuser

V1: Scroll vibration.
V2: Compressor inlet casing vertical vibration.
V3: Compressor inlet casing horizontal vibration.
V4: Diffuser vibration.
P1: Impeller unsteady pressure.
P2: Diffuser unsteady pressure.
Ap: Acoustic pressure.

EXPERIMENTAL PROCEDURE

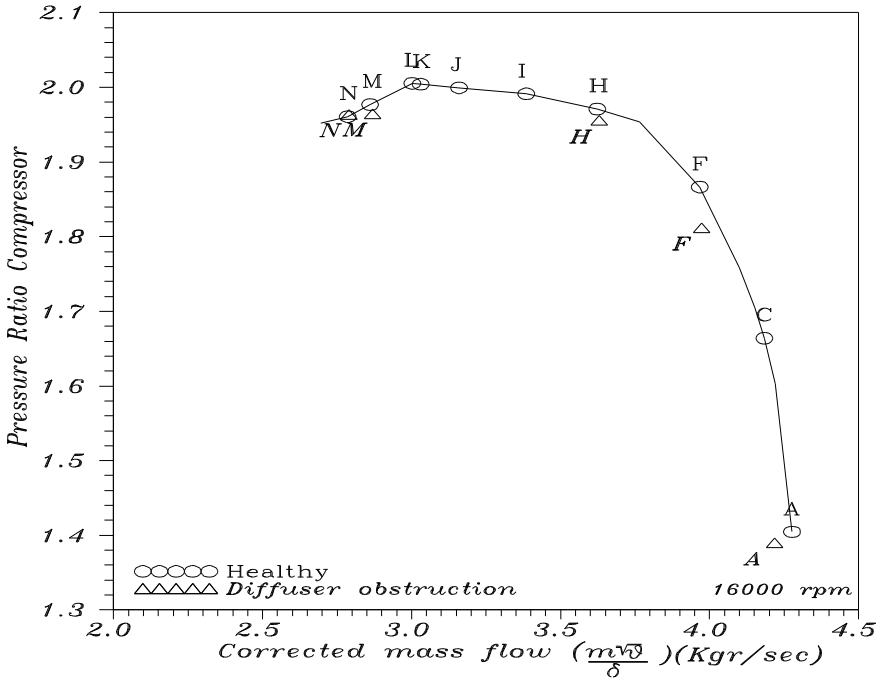
- **Measurements in initial intact condition.**

- **Introduction of mechanical alterations.**
  - **Inlet obstruction.**
  - **Diffuser obstruction.**
  - **Tip clearance variation.**
  - **Impeller fouling.**

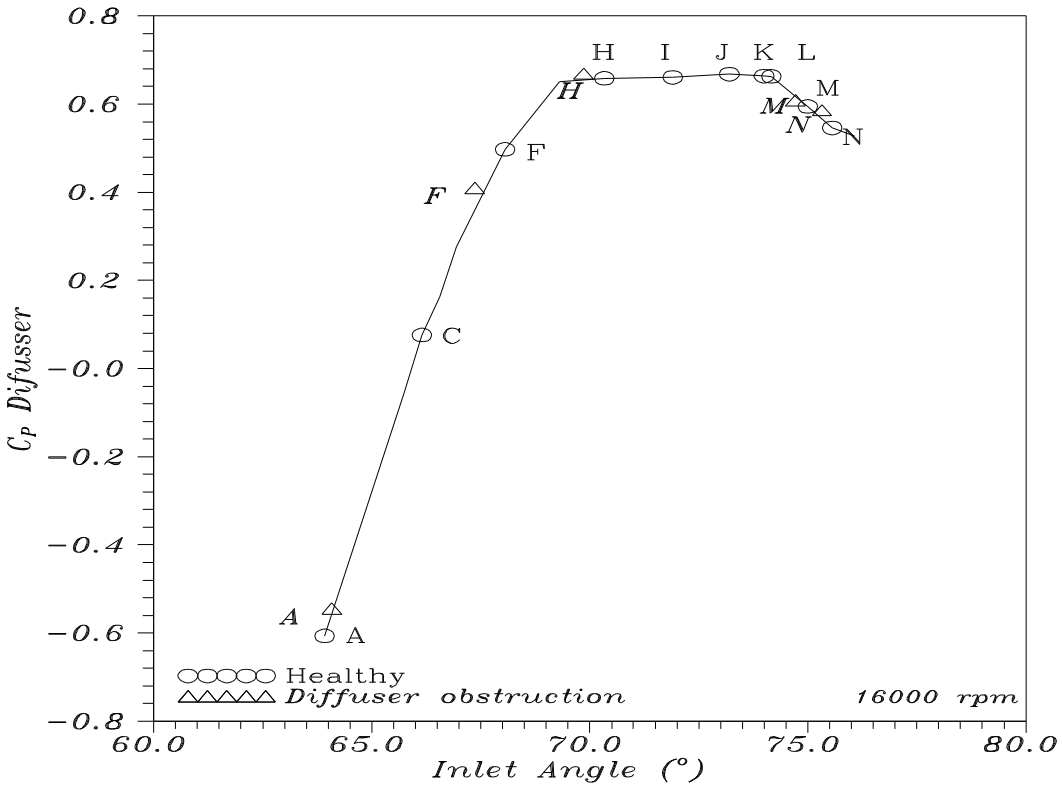
- **Measurements in new altered condition.**

- **Measurements for verification of restoration of initial condition.**

OPERATING POINTS FOR THE EXPERIMENTS



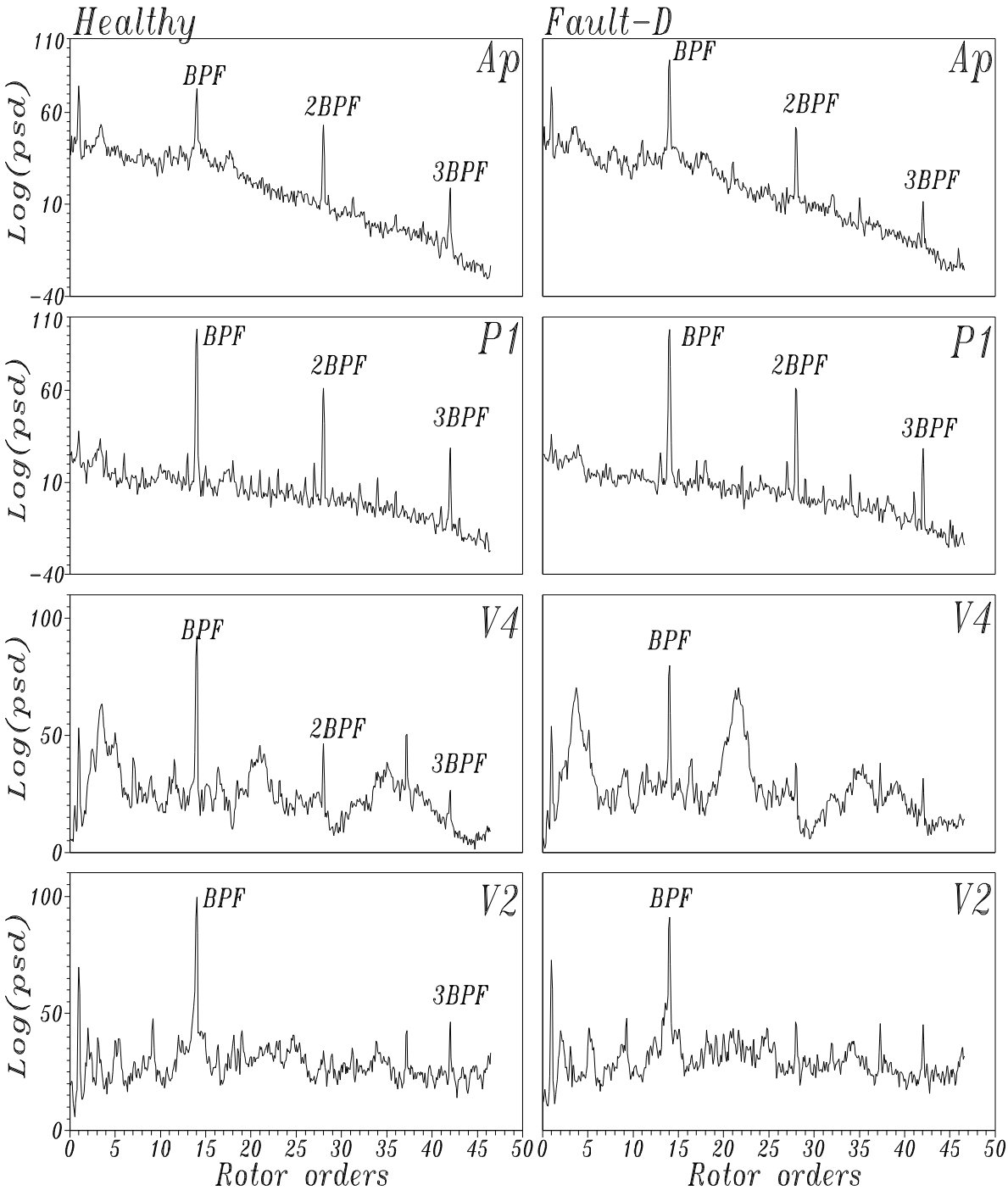
Compressor map (Healthy, Diffuser fault).



Diffuser map (Healthy, Diffuser fault).

FORM OF SPECTRA FROM DIFFERENT INSTRUMENTS AND CONDITIONS

Healthy **Diffuser fault**

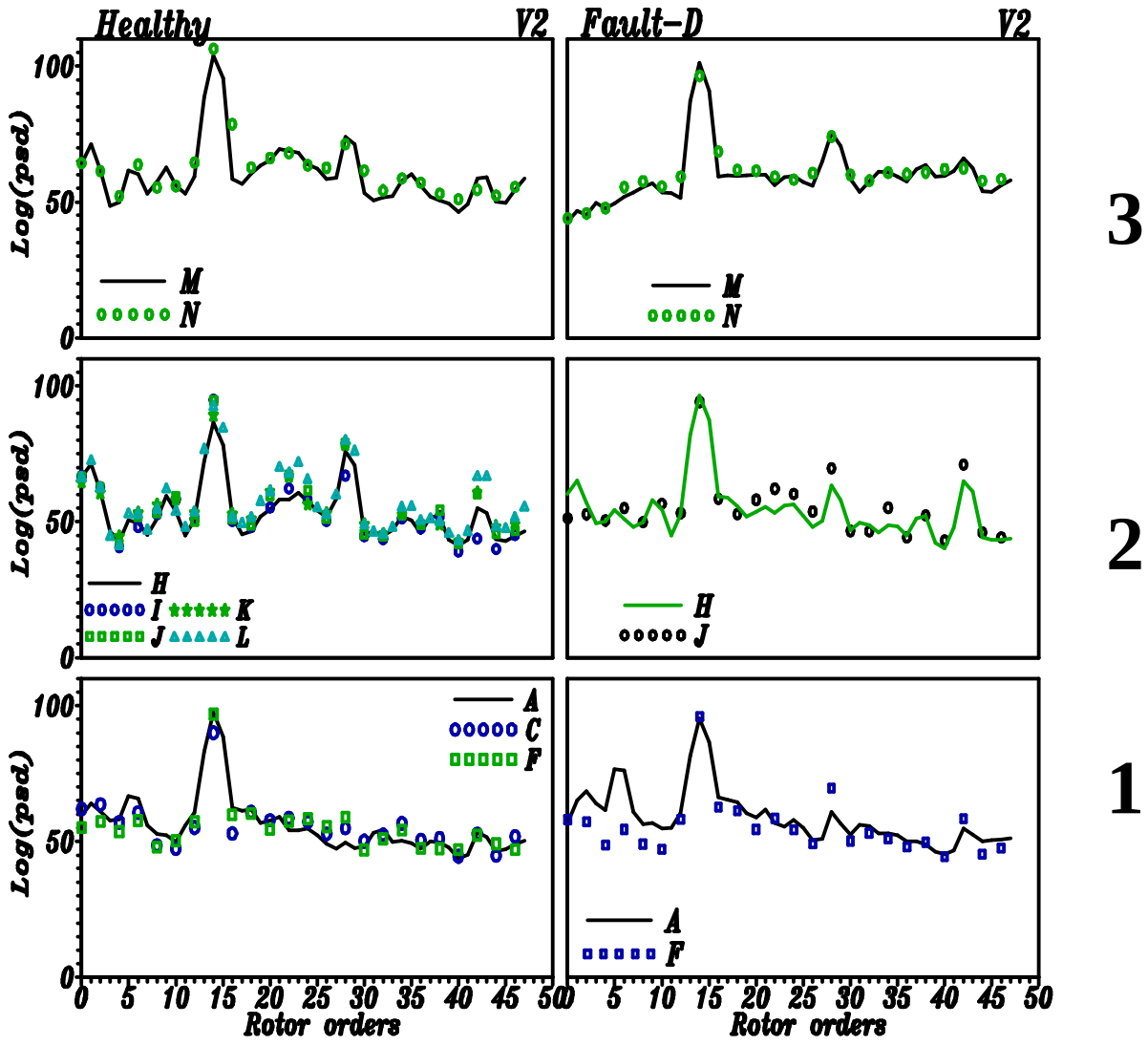


Rotor orders: multiples of shaft rotational frequency.

DEPENDENCE ON OPERATING CONDITION

Spectra from impeller accelerometer

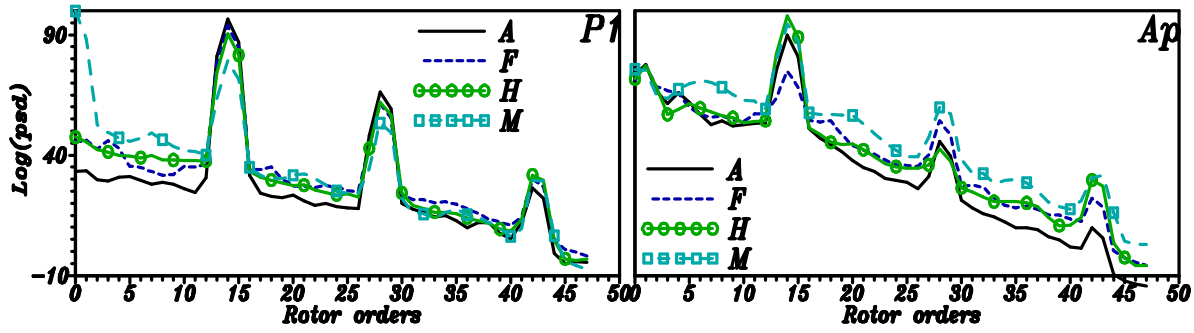
Healthy **Diffuser fault**



- Form of spectra preserved over parts of the performance characteristic.
- Difference in the form of spectra between the first and second region.
- Entering the third region leads to a reduction of the second harmonic and an increase of the first one.

DEPENDENCE ON OPERATING CONDITION

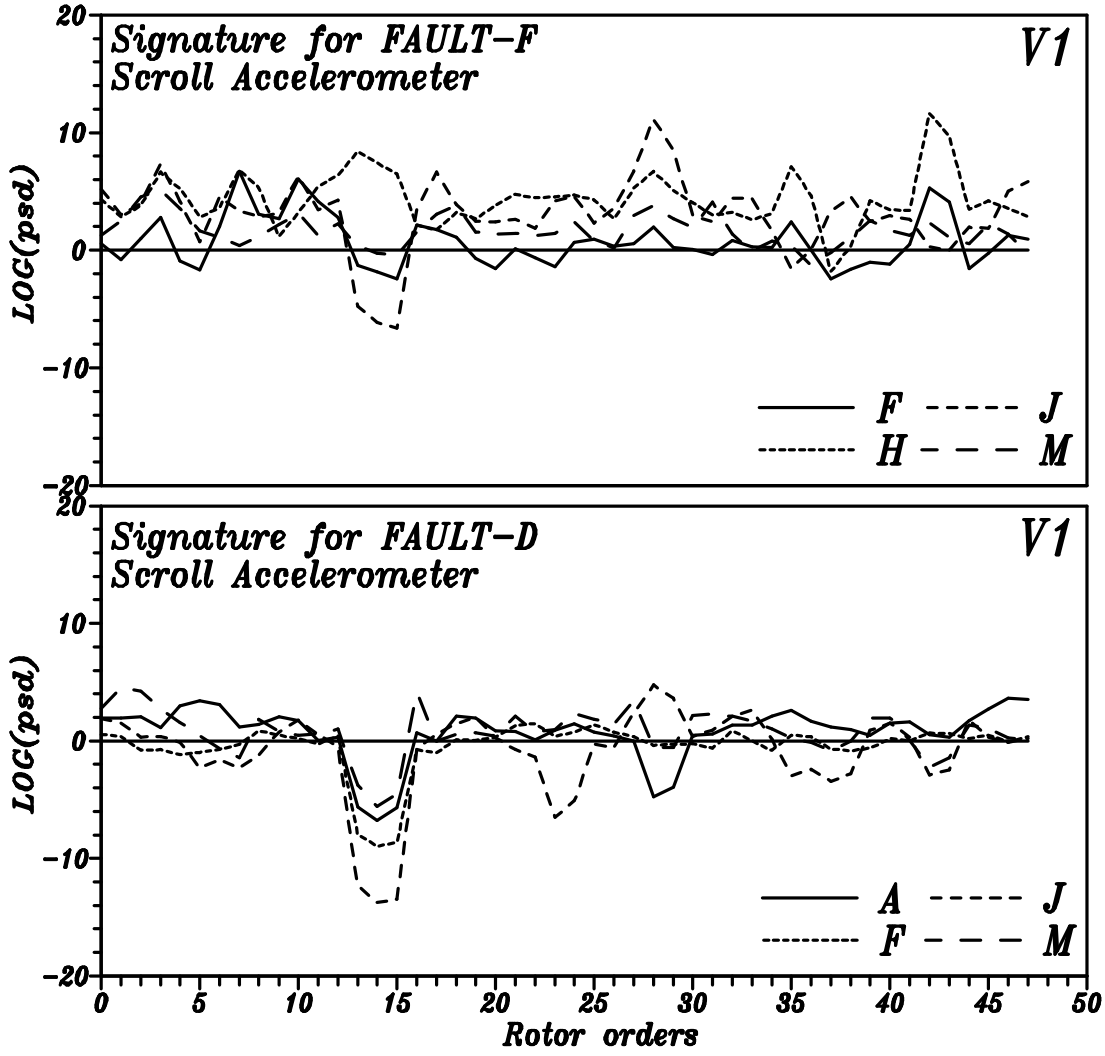
Different behaviour from Unsteady pressure - microphone



F Spectra keep the same shape but a change in the amplitude of the harmonics is observed.

FAULT SIGNATURES (Spectral differences)

Scroll accelerometer



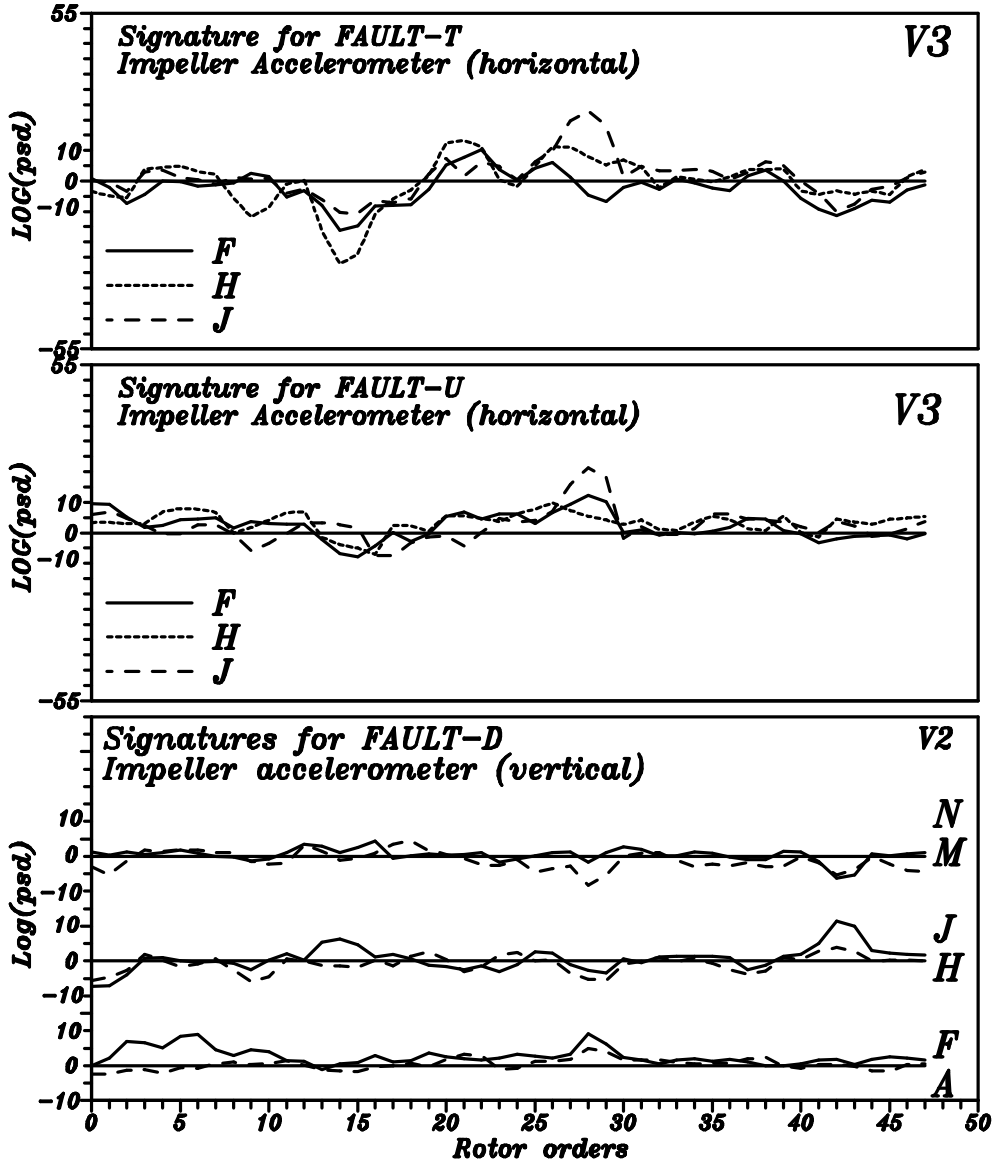
Impeller Fouling

Diffuser Fault

- **Fault-F: small changes in the form.**
- **Fault-D: Form preserved. small changes in the amplitudes of the harmonics.**

FAULT SIGNATURES (Spectral differences)

Impeller accelerometers



Large Tip clearance increase

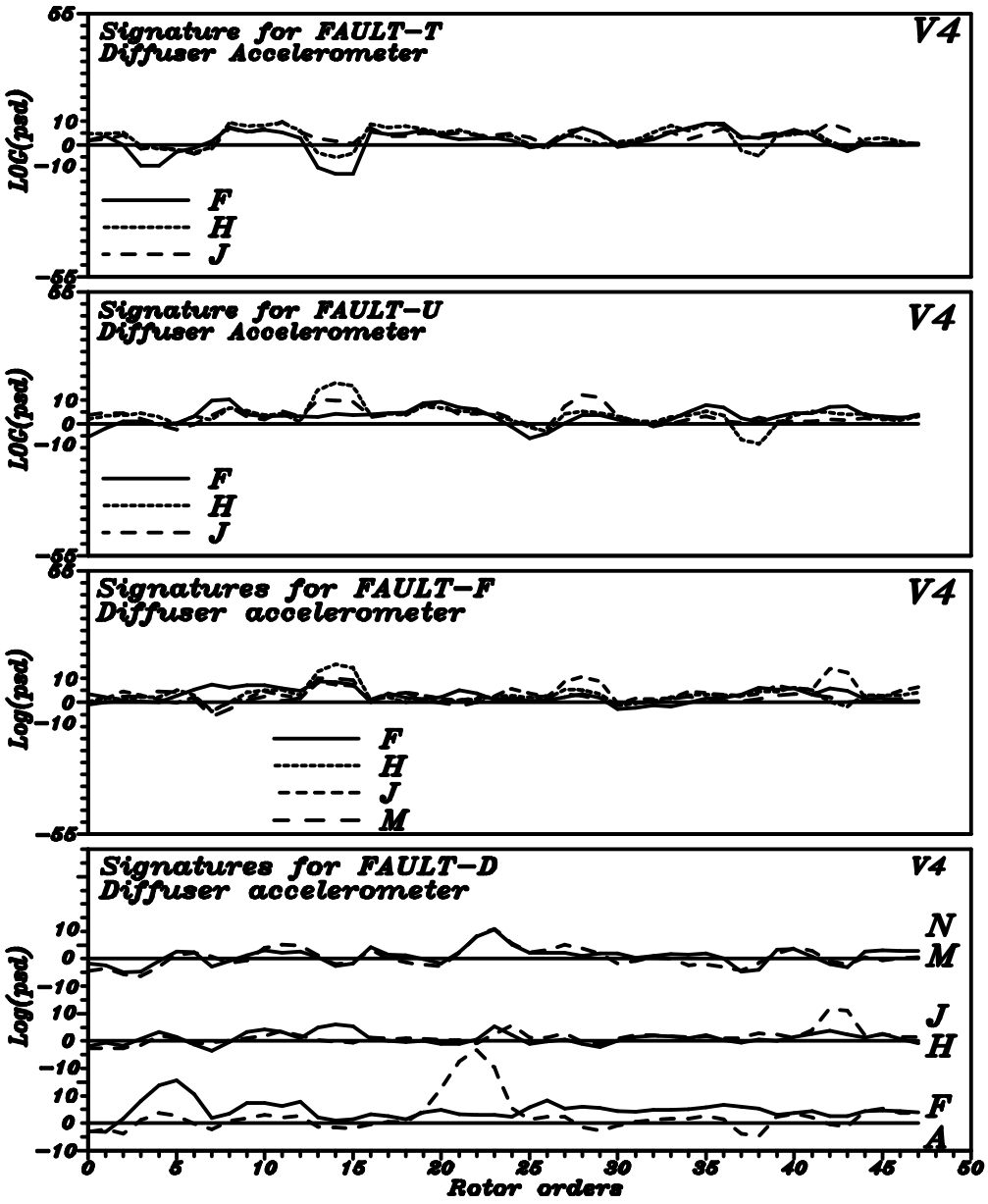
Small Tip clearance increase

Diffuser fault

- **Fault T,U: Produce the same difference pattern (smaller magnitude for the smaller clearance).**
- **Fault D: A unique signature for each region.**

FAULT SIGNATURES (Spectral differences)

Diffuser accelerometer



Large Tip clearance increase

Small Tip clearance increase

Impeller fouling

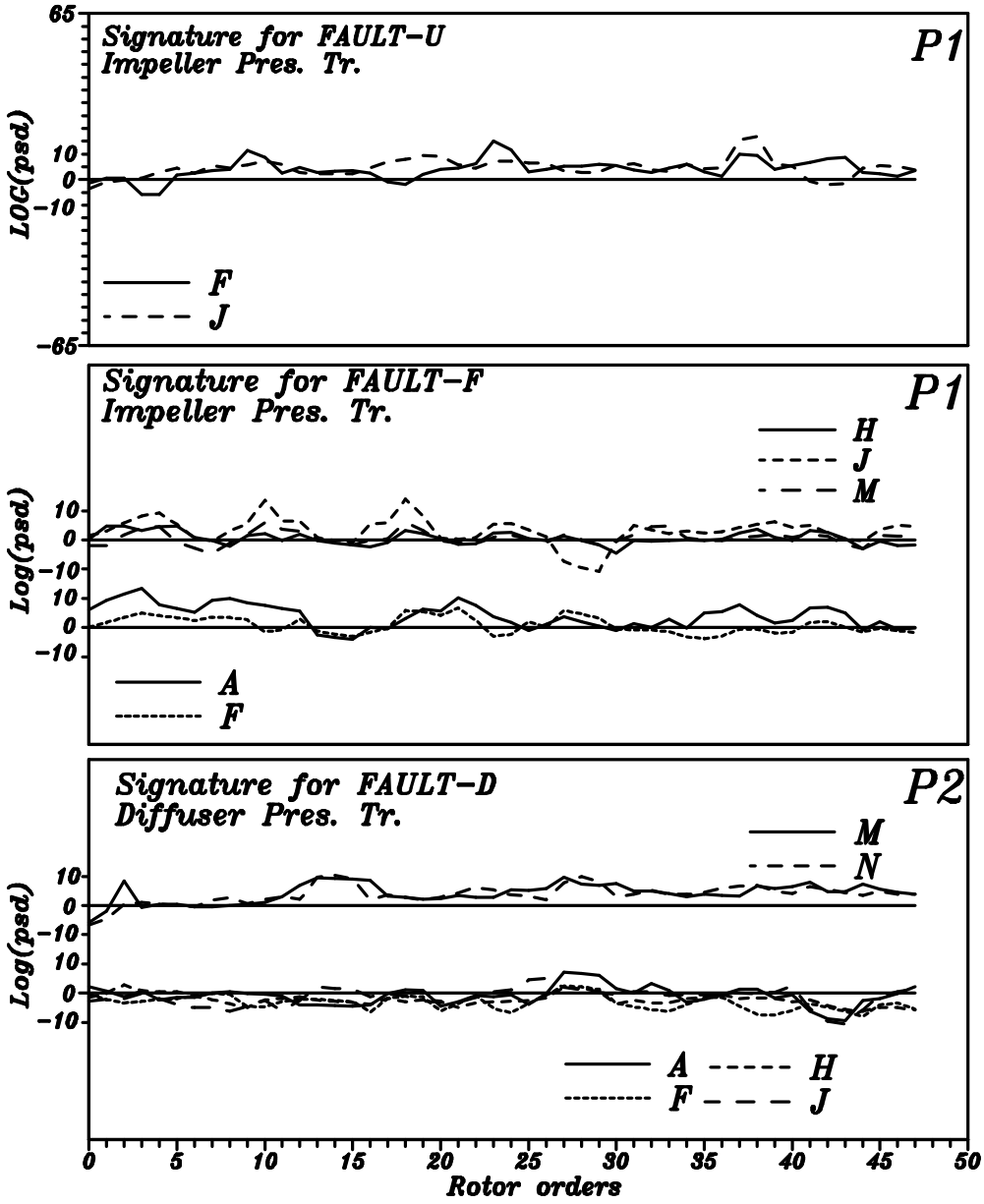
Diffuser fault

F Fault T,U,F: signatures independent from operating point.

F Fault D: A unique signature for each region.

FAULT SIGNATURES (Spectral differences)

Impeller and Diffuser pressure transducer



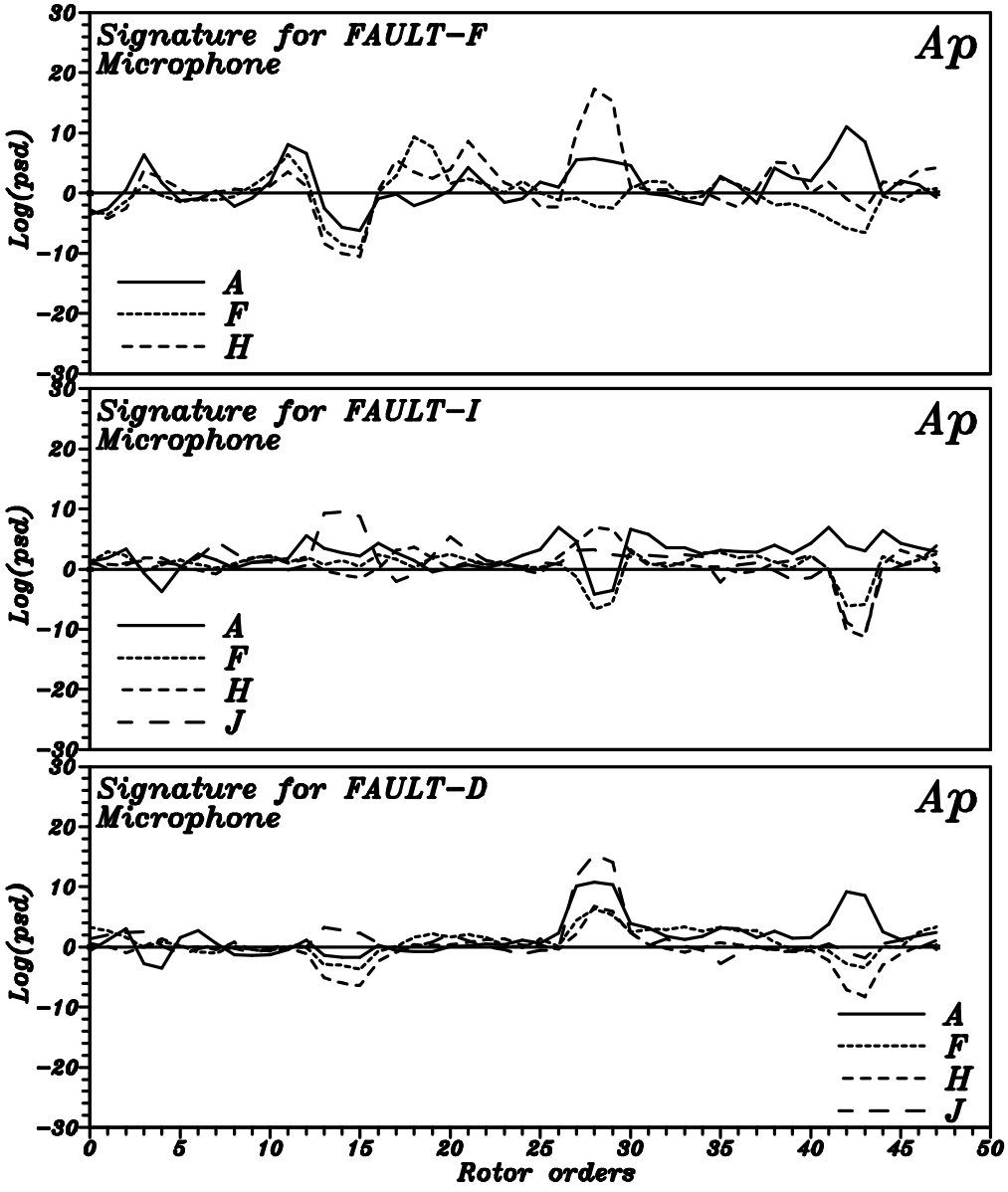
Tip clearance increase

Impeller Fouling

Diffuser fault

FAULT SIGNATURES (Spectral differences)

Microphone



Impeller Fouling

Inlet Obstruction

Diffuser fault

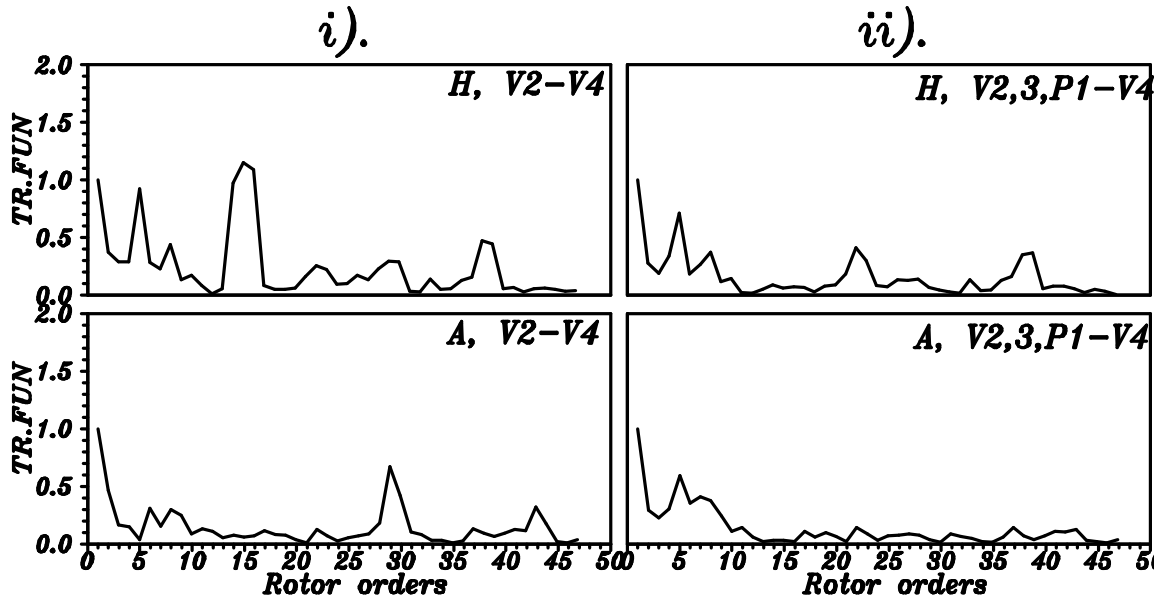
F Fault signatures with well defined patterns which have different forms (the ability to distinguish between the faults exists).

DEPENDENCE OF TRANSFER FUNCTION ON OPERATING CONDITION

F 1ST CASE

Single input V2
Single output V4

Multiple input V2,V3,P1
Single output V4



F There is a significant dependence on operating point. This situation still remains even if we use multiple input.

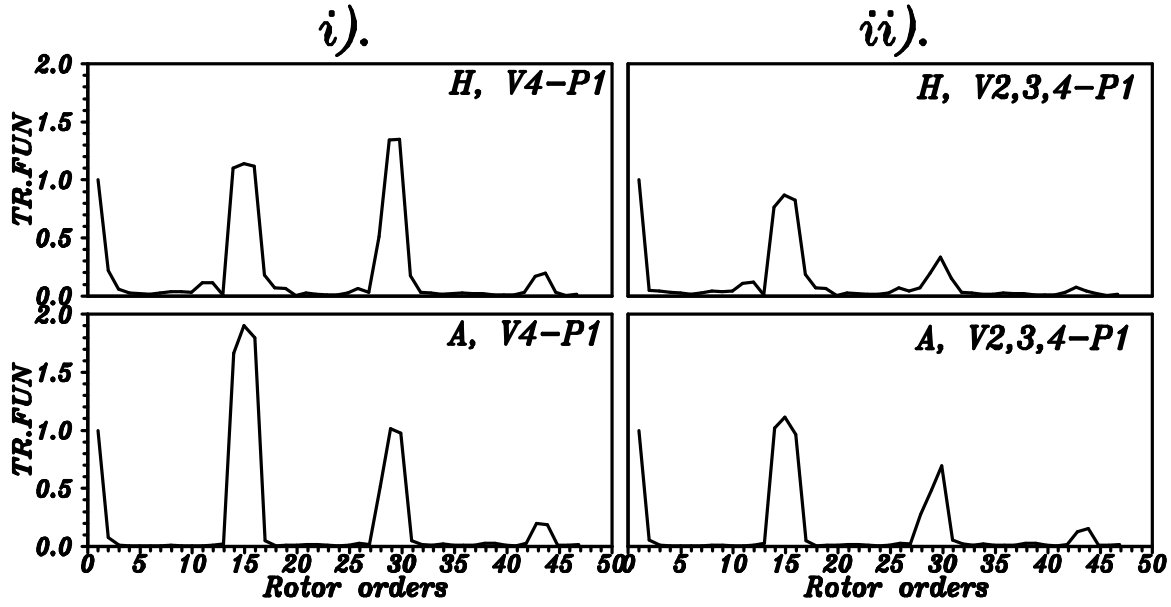
V2: Compressor inlet casing vertical vibration.
V3: Compressor inlet casing horizontal vibration.
V4: Diffuser vibration.
P1: Impeller unsteady pressure.

DEPENDENCE OF TRANSFER FUNCTION ON OPERATING CONDITION

F 2ND CASE

Single input V4
Single output P1

Multiple input V4,V2,V3
Single output P1

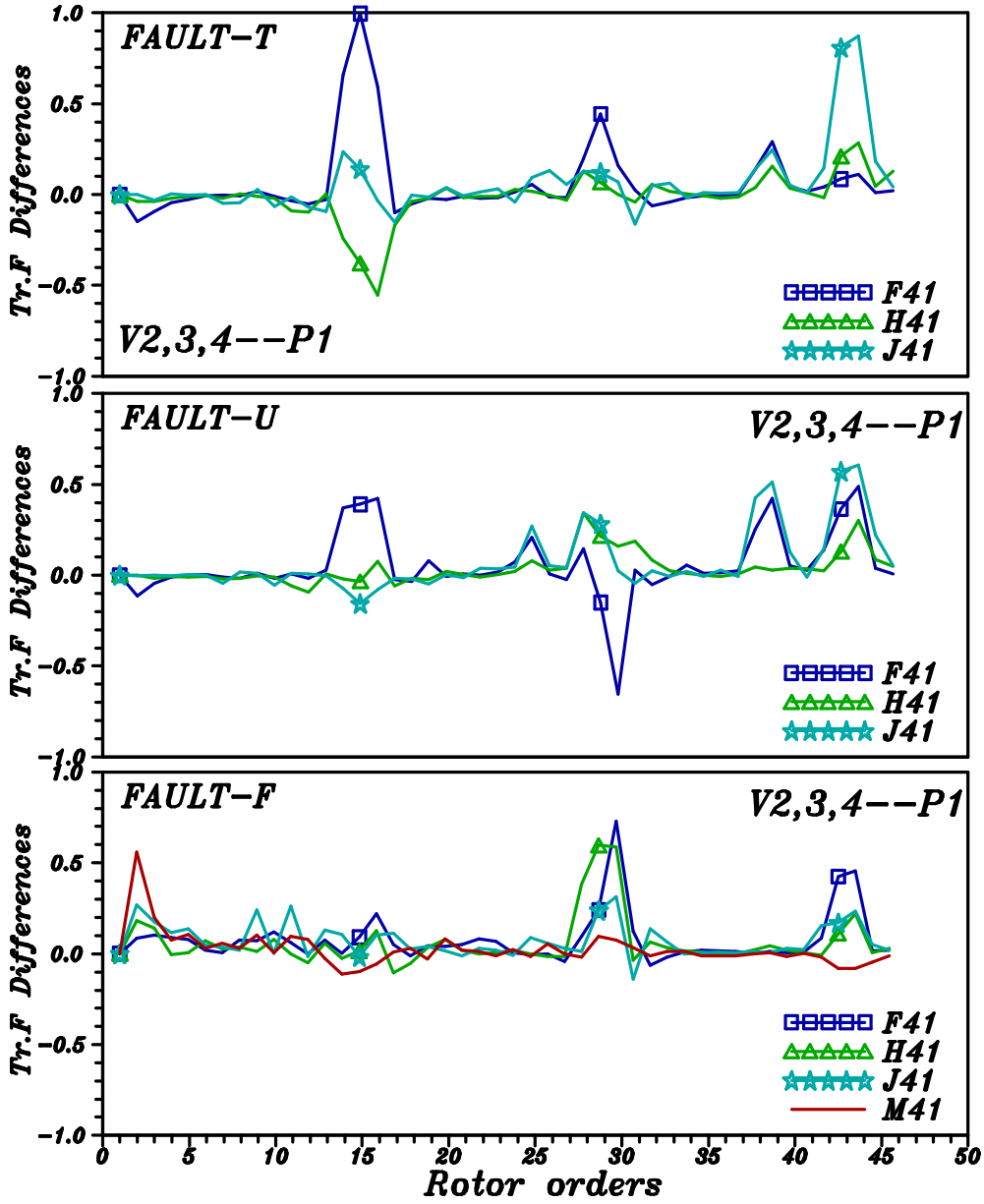


F The simple input case is stable with operating point, which further improves if we use multiple input.

V2: Compressor inlet casing vertical vibration.
V3: Compressor inlet casing horizontal vibration.
V4: Diffuser vibration.
P1: Impeller unsteady pressure.

FAULT SIGNATURES
(Transfer function differences)

Multiple input case V4,V2,V3--P1



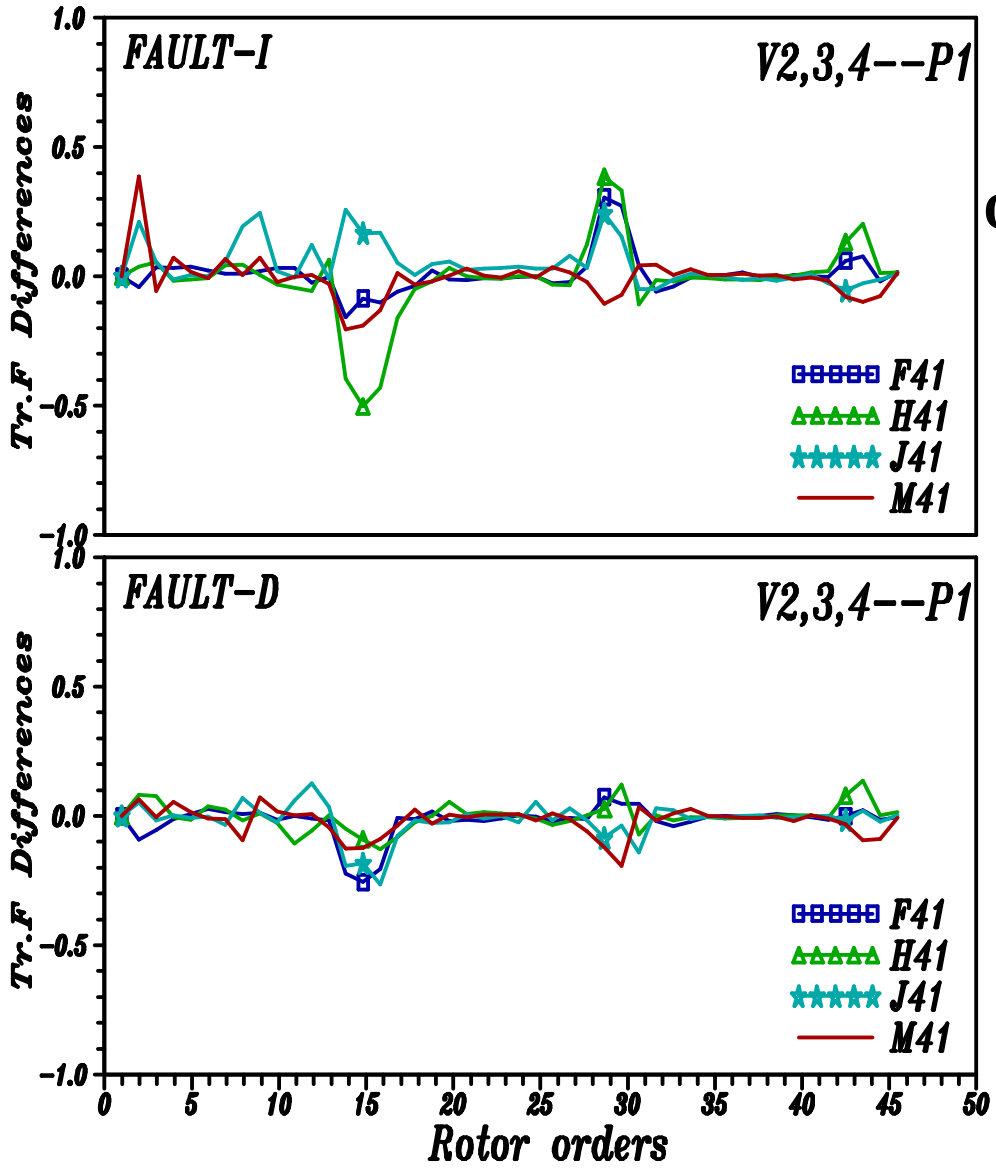
Large tip clearance increase

Small Tip clearance increase

Impeller fouling

FAULT SIGNATURES
(Transfer function differences)

Multiple input case V4,V2,V3--P1



Inlet Obstruction

Diffuser fault

F Fault signatures with well defined patterns which are distinguishable from one fault to another.

DISCUSSION AND CONCLUSIONS

F The spectral composition of signals depends on operating condition.

-Care must be taken to obtain data at corresponding points.

F The division of the performance curve into different ranges allows a grouping of the signatures.

-More than one reference signature should be used for fault identification.

F Accelerometers and microphones seem to provide more information than unsteady pressure transducers.

-Certain locations seem to be more suitable than others.

F Monitoring of a radial compressor seems to be more complicated than the same task for an axial one.

F By the choice of appropriate instruments, processing technique and way of organizing the information, fault signatures can be derived.

F Minor faults which do not disturb compressor operation significantly can be possibly detected by fast response measurements.