MARIE CURIE ACTIONS

Energy-SmartOps

Integrated Control and Operation of Process, Rotating Machinery and Electrical Equipment

Model-based Condition Monitoring Of Industrial Operated Centrifugal Compressors For Process Industry Applications

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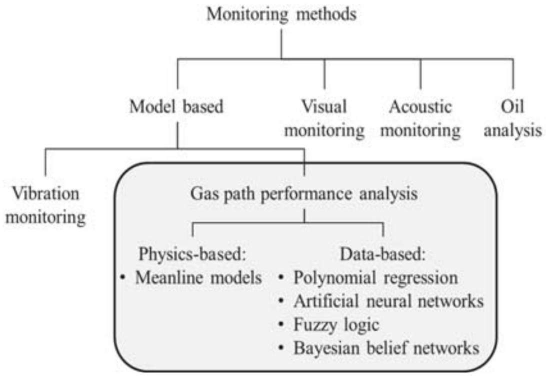
Project aim

Development of physics-model-based methods for on-line performance and gas path components condition monitoring with focus on slow dynamic mechanisms of performance degradation.



Problem statement

The gas path geometries are slowly modified by deteriorating external agents, and both the degree of modifications and a quantification of their impact on performance drops is unknown.

The component deterioration status although not directly measurable can be correlated to measurable variables using a physical or a data-driven model, such that a change in the former will induce changes in the latter [1].

Monitoring methodology

$z_{id} = h(x, u, \theta, v, b),$	(1)
$z_{act} = h(x, u, \theta + \lambda, v, b),$	(2)
$r = z_{id} - z_{act}.$	(3)

$z \in \mathbb{R}^M,\ z = (z_1, z_2, \dots, z_M)^T$	performance parameters
id	performance of the system in the design/un-degraded status
act	performance of the system in the actual status
$r \in \mathbb{R}^M,\ r = (r_1, r_2, \dots, r_M)^T$	performance deviations
$x \in \mathbb{R}^N, x = (x_1, x_2, \dots, x_N)^T$	measurable but non-controllable operating parameters
$u \in \mathbb{R}^P, u = (u_1, u_2, \dots, u_P)^T$	measurable and controllable operating parameters
$\theta \in \mathbb{R}^Q, \theta = (\theta_1, \theta_2, \dots \theta_Q)^T$	known geometrical parameters (i.e. design geometry)
$\lambda \in \mathbb{R}^Q, \lambda = (\lambda_1, \lambda_2, \dots, \lambda_Q)^T$	un-known geometrical parameters representing the modifications caused by external deteriorating agents
$v \in \mathbb{R}^{N+P}, v = (v_1, v_2, \dots, v_{(N+P)})^T$	measurements noise
$b \in \mathbb{R}^{N+P}, b = (b_1, b_2, \dots, b_{(N+P)})^T$	sensor biases
$h(\cdot), h \in \mathbb{R}^{N \times P \times Q \times (N+P) \times (N+P))} \to \mathbb{R}^M,\ (h_1, h_2, \dots, h_M)^T$	vector valued nonlinear continuous function (i.e. the physical or data-driven model).

Modelling methodology

»Description on a single zone basis:

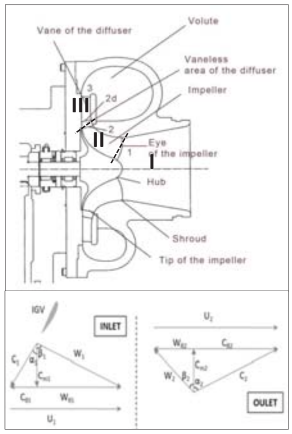
I. Inducer

II. Impeller

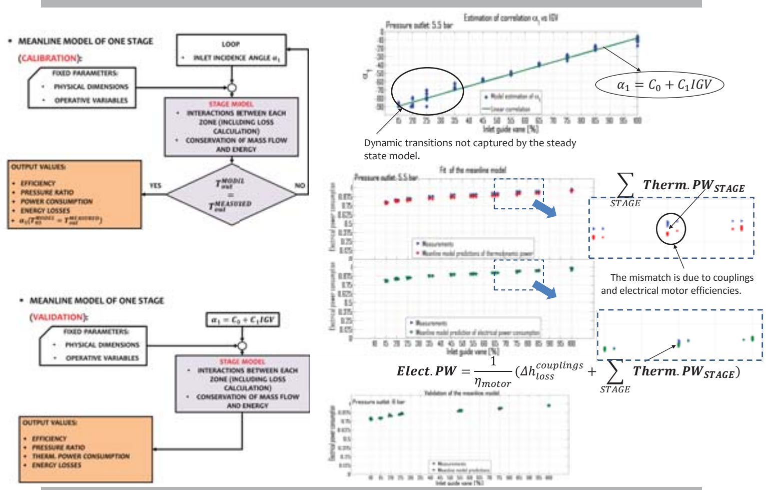
III. Diffuser

»Constitutive equations:

- Mass and energy balances
- Velocity triangles at inlet and outlet of the impeller
- Equations of state
- Loss correlations



Model calibration and validation[2]



Future works

I. Development of systematic approach to loss correlations selection.

II. Implementation of data pre-processing techniques.

III. Development and implementation of monitoring method.

IV. Proof of numerical stability for the developed algorithm.

V. Experimental investigation of fouling and humidity effects on performances.

[1] Urban, L.A. "Gas path analysis applied to turbine engine condition monitoring. Parameter selection for multiple fault diagnosis of gas turbine engines." J. Eng. Power Transaction ASME, 1975: 97 Ser A(2):225-230.
[2] Cicciotti, M., Martinez-Botas, R., Gozalbo, R., Geist, S., Schild A., Thornhill N. F., Khars O., Reiser W., 2012. "Assessment of meanline models for centrifugal compressors in the process plant industry". 5th International Symposium on Fluid Machinery and Fluids Engineering (ISFMFE), 24-27th of October, in Jeju, Korea.

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