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The evolution of generalized fault symptoms and fault intensities as indicators of observation redundancy and coming system breakdown

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ABSTRACT

Application of SVD to fault extraction from the machine symptom observation matrix (**SOM**) seems to be validated enough, especially by data taken from many real diagnostic cases. However, decomposition has two sets of components, singular vectors, and singular vales. The first component we obtain directly as the lifetime discrete function and it has direct diagnostic meaning in condition monitoring. The second component has not so direct interpretation but with some software update one can see how singular value evolves along the system lifetime. Strangely, it is a good indicator of observation redundancy, and it is the measure of generalized fault intensity. More importantly, this measure is not sensitive to the changing condition of machine work, like working load, and we do not need to filter our observation or generalized symptoms in any way. This seems to be the most important conclusion of this paper, but needs more validation.

1. Introduction

The idea of symptom observation matrix (**SOM**) in multidimensional condition monitoring of machines is well established and brings several advantages [15,17–19]. It is based on $p > r$ rectangular observation matrix, with (r) symptoms $\boldsymbol{S_r}$ in columns, measured along the system life $\boldsymbol{\theta}$, what gives p symptom readings in our passive experiment [15]. This observation technique allows placing all physically different symptoms[1] measured in a phenomenal field of the machine in one **SOM**, and to process them in order to obtain projection of designed **observation space** to the **fault space** of machine, which we are looking for. Of course, at the beginning we usually observe more symptoms (*columns of* **SOM**), than the expected number of essential faults[2] in a machine.

The preprocessing of **SOM** may be different (*see for example* [1,2,13]), but for condition monitoring it was found that normalization and extraction of symptom initial value is the best solution, bringing all symptoms to their dimensionless form. Then, the application of SVD to the dimensionless form of **SOM** gives needed projection of observation space to the fault space. The resultant three matrices of SVD decomposition allow calculation of two diagnostically important matrices. The first is $\boldsymbol{SD}$ matrix, which gives us generalized fault symptoms $\boldsymbol{SD_i}$, and in theory they are independent of each other. From this matrix we can calculate the so called total damage (*generalized*) symptom, as the sum of all $\boldsymbol{SD_i}$ generalized fault

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[1] Symptom, measurable quantity covariable (*or assumed to be*) with the system condition.

[2] Essential fault can lead to machine breakdown, or terminal damage, if not interrupted by machine renewal.

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