**Incipient Fault Detection Based on Exergy Efficiency and Support Vector Data Description.**

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**Highlights**

* Exergy-data abstraction using mutual information.
* Reduce complexity of the SVDD model based on process exergy efficiency
* Detect incipient faults with different severity based on EESVDD

**1. Introduction**

In the paper, a novel fault detection method based on exergy efficiency and support vector data description (EESVDD) for incipient fault is proposed. The complexity of the SVDD model is reduced based on process exergy-data abstraction using mutual information (MI) method. Additionally, the proposed method presents great fault detectability and isolability and can detect incipient faults with different severity and indicate the evolution direction of faults. The effectiveness of the proposed method is illustrated by an industry distillation column system.

**2. Methods**

Exergy loss is the opposite of exergy efficiency, which represents the loss of process effective energy. Actually, the concept of performance degradation is intrinsically included by exergy, which can be used to explain the performance changes of incipient fault processes. In our work, MI is used to get the correlation between measured variables and exergy efficiency. Generally, MI can be composed of marginal entropy and joint entropy, it is possible to use K-nearest neighbor statistic to estimate entropy and then to obtain MI value. It is meaningful to compare which of the measured variables contain more information of exergy efficiency. After the MI values are obtained between each measured variable and the exergy efficiency, a set of measured variables that are most relevant to exergy efficiency is identified for improving the validity of datasets according to the cumulative percent mutual information (CPMI).

And then, the corresponding SVDD state models can be established with the feature sample sets of different fault states. The main idea of SVDD is to find a sphere region that contains most of the target samples with the smallest volume. Given a train set ，whereis the number of samples. The radius minimization problem of the sphere can be formulated as the following quadratic programming problem with inequality constraints.

 (1)

 (2)

where,  is a penalty factor and  are the slack variables. The sphere can be described by radius  and center . The fault can be detected according to the principle of minimum relative distance and identify qualitatively the severity of the fault.

The overall framework of the proposed method is shown in Figure 1.

**3. Results and discussion**

The proposed method has been illustrated by an industrial distillation process, which consists of two distillation columns which is used to separate propane and propylene, as shown in Figure 2. In this case, the faults are generated by stepping the fouling factor of the shell and tube side. And the different severities of fault can be also obtained. For the sake of convenience, the fault detection rate (FDR) is used to quantify the detection performance for different fault states. The FDRs of SVDD, principal component analysis and SVDD (PCA-SVDD), EESVDD in different incipient fault states have been compared in Table 1. From Table 1, it is obvious that the EESVDD method is better than the other two methods in the FDRs of three fault states. The exergy-data abstraction based method draws on the process physical and thermodynamic knowledge, and reveals the performance degradation information of process.

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| **Figure 2**. The flowchart of the industrial distillation columns | |  |  |  |  | | --- | --- | --- | --- | |  | Normal  condition | Moderate  degradation | Severe  degradation | | SVDD | 0.8654 | 0.9091 | 0.8830 | | PCA-SVDD | 0.9038 | 0.9394 | 0.9474 | | EESVDD | 0.9679 | 0.9848 | 0.9766 |   **Table 1.** The FDRs of SVDD, PCA-SVDD, EESVDD on different incipient fault states |

**4. Conclusions**

The key idea of the proposed method is that the relationship is constructed between the exergy efficiency and measured variables using MI method, and the SVDD detection model is established by replacing the principal component vectors with the exergy efficiency feature. Besides, the method can detect the severity of incipient faults and point out the evolution direction of faults. The method extends the application for incipient fault detection based on exergy-data abstraction. The case have been showed the effectiveness of the proposed method.