ID #47

Evaluation on the operational state of turboexpanders in a helium refrigerator for nuclear fusion experimental devices using principal component analysis

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1. Introduction

■ The stable operation of a helium refrigerator is required in a nuclear fusion experimental device using superconducting magnets during plasma experiments.

■ Turboexpanders, which are core equipment of the helium refrigerator, contain many parameters to be monitored constantly.

■ We propose the application of a machine learning technique to an operational state evaluation of the turboexpanders.

■ To develop the evaluation model of the turboexpanders, the operational data of the cryogenic system in the Large Helical Device (LHD) were used.

■ This paper describes the details of the model and the evaluation results of the helium refrigerator in the LHD cryogenic system.

2. Helium turboexpanders of the LHD cryogenics system

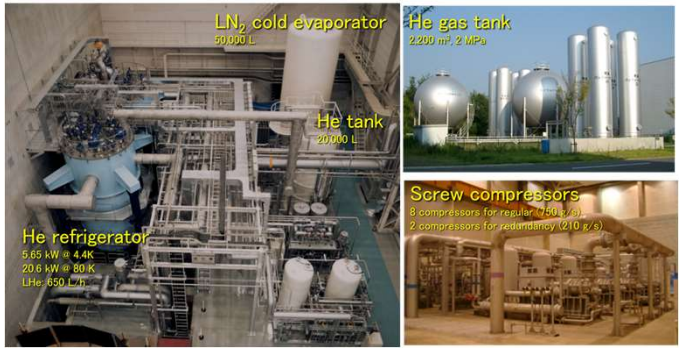

Fig.1 LHD cryogenics system.

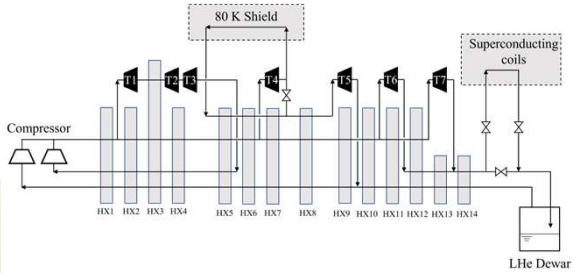

Fig. 2 Flowsheet of the He refrigerator in the LHD cryogenic system.

Table 1 Specification of the helium turboexpanders.

Turboexpander	T1	T2	T3	T4	T5	T6	T7
Journal bearing dia. [mm]	45	45	45	32	45	32	32
Expander wheel [mm]	45	45	45	32	40	18	18
Max. efficiency [%]	73.6	73.7	76.8	77.3	79.3	77.6	69.1
Rated speed [rps]	1650	1650	1650	2450	1650	1800	1500

3. Modeling

■ Principal component analysis (PCA) was applied for modeling to evaluate the operational state of the turboexpanders. PCA is a method for representing multidimensional data with fewer dimensions.

■ Two types of models were used to evaluate the turboexpanders using PCA.
- One is the **single model** for a single (T7) turboexpander.
- The other is the **multiple model** for seven (T1～T7) turboexpanders.

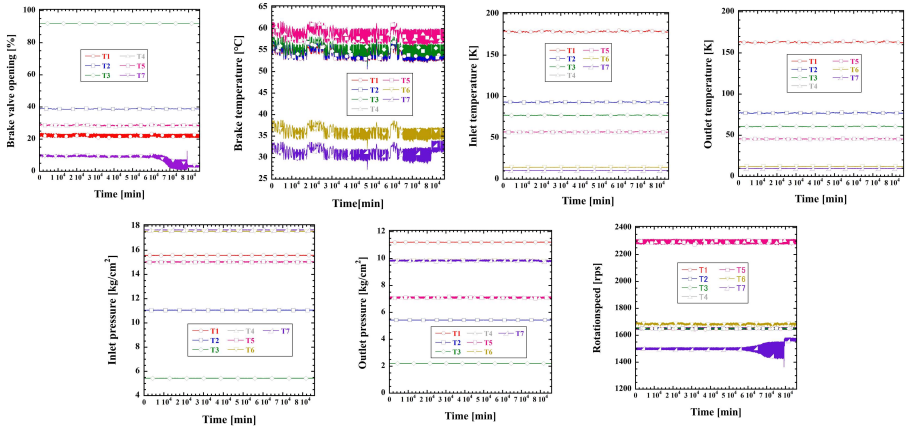

Fig. 3 Measurement data of the seven (T1～T7) turboexpanders.

■ Regarding the measurement data for modeling, the data of the turboexpanders in the 20th cycle of the LHD experimental campaign were utilized.

4. Results

■ Before and after the turboexpander T7 trouble, the clusters shifted in the **single model**, while the cluster distribution changed in the **multiple model**. Therefore, both models make it possible to detect the change of the state condition in turboexpanders.

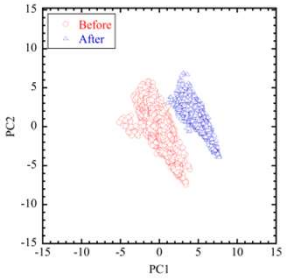

Fig. 4 Result of the single model.

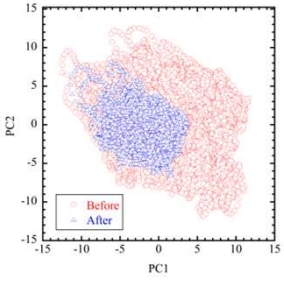

Fig. 5 Result of the multiple model.

5. Conclusion and further plan

■ The operational state of the turboexpanders in a helium refrigerator for the LHD was evaluated with PCA.

■ The evaluation models were successful in detecting the trouble with the turboexpanders. Compared to the **multiple model**, the **single one** is more practical because it allows for easier detection of abnormalities in the turboexpander.

■ As a further plan, we intend to develop an anomaly detection system using the single model for all turboexpanders mounted in the LHD cryogenic system, and operate the system in real time.