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Development of Mechanical-fault Diagnosis Using Spectrum Analysis (MEDUSA) for Condition Monitoring of Components and Equipments

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Development of Mechanical-fault Diagnosis Using Spectrum Analysis (MEDUSA) for Condition Monitoring of Components and Equipments

Masashi Ueda[1], Hitoshi Kondo[1]

Abstract

The MEDUSA (MEchanical-fault Diagnosis Using Spectrum Analysis) condition monitoring system was developed for the detection of anomalies, the diagnosis of their causes and to understand anomalies in major components and equipment, such as the main pumps or main blowers in the experimental fast breeder reactor "Joyo" at early stage.

This system cannot only measure the vibrational states of components and equipment at set times but also judges whether the states are normal or not, whenever we need. Moreover, some auxiliary functions of this system make possible for operators to understand the machine condition in detail without special knowledge and experience with vibration analyses.

This report describes the following.

(1) Hardware configuration of MEDUSA system

(2) Functions of MEDUSA system

(3) Example of vibration analyses in "Joyo"

The effects of this development are as follows.

(1) A useful condition monitoring method for the main components and equipment was provided on the basis of operation and maintenance experience.

(2) This system has been used in "Joyo" since September 1990, and it has been confirmed that there has been no serious change of the vibrational condition in any components and equipment.

(3) The applicapability to the following reactor was obtained, because this system was originally designed after due consideration for flexibility and expansibility.

From now on, analysis of the vibration data will be continued, and the improvement of this system will be performed by means of AI (Artificial Intelligence), neural networks and so on.

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[1] Maintenance Section, Experimental Reactor Division, OEC

公　開　資　料
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機器異常監視システム（ＭＥＤＵＳＡ）の開発

上田　雅司[1]、近藤　等士[1]

要　　旨

振動計測による機器異常監視システム”ＭＥＤＵＳＡ (MEchanical-fault Diagnosis Using Spectrum Analysis) ”は、高速実験炉「常陽」の１次系・２次系の主循環ポンプや主送風機等合計１３台のプラント重要機器を対象に、その振動状態をオンラインで常時監視することにより、異常の早期検出・原因の想定、進行程度の把握を行うものである。

本システムは決められた時間ごとに自動的に各機器の振動状態を監視するだけでなく、必要なときに簡単な操作で現在の振動状態の監視・解析を行うことができ、また、振動解析に関する知識を必要とせずに詳細な診断を行えるよう、いくつかの特徴的な機能を有する。

本レポートでは以下の内容について述べている。

(1) 本システムを構成する機器の概要
(2) 本システムの機能
(3) 「常陽」における振動データ解析の一例

本システムを使用することで、以下の成果を得た。

(1) プラントの重要機器に対して、実務で得られた経験を基に、現場のニーズに合致した異常監視手段を提供した。
(2) 1990年 9月に本システムの稼働を開始して以来、各機器の振動状態に有意な変化のないことを確認できた。
(3) 汎用性、拡張性を持った設計を内部のエンジニアリングで行ったことにより、後続炉に対しても容易に移植することが可能となった。

今後は、各機器の振動データの解析作業を継続すると共に、人工知能やニューラルネットワークといった手法を応用し、システムの高度化を図る。

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[1] 実験炉部　原子炉第二課

Development of Mechanical-fault Diagnosis Using Spectrum Analysis (MEDUSA) for Condition Monitoring of Components and Equipments

1. INTRODUCTION

In nuclear power plants, high security and reliability of components and equipment are required to reduce the chance of great loss and damage. Proper safety design, well-arranged maintenance and condition monitoring are necessary to keep a reactor safe during operation. Condition monitoring solves problems like anomalies that could not be foreseen in design, scattering of operating condition, overmaintenance, and so on.

The effects of condition monitoring are early detection of anomalies, identification of their causes and prolongation of plant life. These effects make a better operation and maintenance plan possible.

Operating machines are damaged by mechanical, thermal, or chemical stress. These stresses makes degradation and failures like fatigue, wear and tear, or corrosion depending on the machines' operating conditions. In most cases, degradation and failures appear as condition changes of vibration or acoustic noise. Therefore, monitoring these conditions is used as an anomaly detection method in general.

Specially, vibration monitoring is a popular method for anomaly detection of rotating machines like motors and pumps, because detectors and instruments for vibration measurement can be operated easily, and because there is a clear correlation between the anomaly cause and the vibration frequency which appears in that anomaly condition.

Vibration and acoustic noise monitoring of main components and equipment has been continued since JOYO's start-up test. The MEDUSA (MEchanical-fault Diagnosis Using Spectrum Analysis) vibration monitoring system was developed on the basis of plant operation, maintenance, and condition monitoring experience to provide the early detection of anomaly in components and equipment.

MEDUSA monitors the vibration conditions at fixed periods automatically, and monitors and analyzes the conditions in response to operator request whenever needed. Operators can analyze the current condition in detail without any experience of vibration analysis, because MEDUSA supplies many powerful tools for vibration analysis.

This report describes the system configuration and functions of the MEDUSA system, and experience of vibration analysis in JOYO.

2. SYSTEM CONFIGURATION

Fig.1 shows the system configuration of the MEDUSA system. MEDUSA is an on-line vibration monitoring system of main components and equipment. Vibration signals measured by accelerometers are sent to the central control room through coaxial cables. The signals are conditioned by amplifiers and filters, converted from analog to digital, and sent to the computer system. The computer system calculates the root mean square, the power spectrum density, and the probability density function of vibration signals.

Finally, vibration signals are compared with alarm levels to judge whether the condition is normal or not. If anomaly condition is detected, MEDUSA shows the current condition on a CRT, beeps a warning and starts to monitor more frequently. Operators can watch the vibration condition on the CRT as required.

MEDUSA monitors fifteen components and equipment (42 monitoring spots), primary and secondary main pumps, air blast coolers, shielding concrete cooling blowers and so on. They were selected for the requirement of importance and maintainability. Application to other components and equipment is now under investigation .

2.1 Accelerometer

The accelerometers are of the piezoelectric type. The characteristics of this device are compact size, light weight, wide input range and wide frequency range.

2.2 Pre-Amplifier

The output signal of piezoelectric accelerometer is extremely small. When the distance between the accelerometer and charge amplifier is long, a pre-amplifier is necessary.

2.3 Filter

A low-pass filter is used to improve the S/N ratio and as anti-aliasing filter for A/D conversion.

A band eliminating filter is used to improve the S/N ratio by eliminating AC power noise (50Hz).

2.4 Charge Amplifier

Because the output signal of the piezoelectric accelerometer is a voltage, a charge amplifier should be used. The charge amplifier supplies the power supply of pre-amplifier.

2.5 A/D converter

The A/D converter is used to deal with analog voltage signals in the computer. Through the GP-IB interface, instrumentation control and data transmission can be done. And multi-channel high speed measurement (Max. sampling speed : 100KHz) is available.

2.6 Computer System

An engineering work station (EWS) type computer is used to conduct instrumentation control, data acquisition, data analysis and data management. MEDUSA had wide applicability because the software of the MEDUSA system was written in C-language for the UNIX operating system, which is very widely used and flexible.

3. FUNCTIONS OF MEDUSA

MEDUSA monitors the vibration condition at fixed periods automatically, and monitors and analyzes the condition in response to the requests of operators whenever needed.

In automatic monitoring, MEDUSA's computer system calculates the root mean square, the power spectrum density, and the probability density function of the vibration signals. It then compares the signal with alarm levels to judge whether the condition is normal or not. If an anomaly condition is detected, MEDUSA shows the current condition on a CRT, beeps a warning, records the condition, and starts to monitor the anomalous component more frequently. All these tasks are performed automatically as required.

In manual monitoring, operators can watch the vibration condition on a CRT. Referring to pop-up menu, by easy operation, operators can analyze the current condition in detail without any experience of vibration analysis, because MEDUSA supplies many powerful tools for vibration analysis.

3.1 Comparison with reference data

MEDUSA collects the characteristic vibration data in normal conditions and anomalous conditions as reference data. The reference data can be shown on a CRT with current vibration data. Therefore, it is possible to understand the current condition and the cause of the anomaly easily.

3.2 Trace back progress of condition changes

MEDUSA keeps the automatically collected data for 70 days. And these data can be shown on the CRT as reference data. Therefore, it is possible to understand when an anomaly symptom occurred and how it progressed.

3.3 Selectable alarm levels

Alarm levels can be changed in response to the operating conditions such as full-load, no-load and so on. Therefore, the optimum monitoring can be done in all operating conditions.

3.4 Continuous scanning

When anomalous symptom is detected in a certain component or operation under the special examination is being carried out, the vibration of that component can be monitored at the required periods with top priority.

Fig.2 shows a view of the CRT screen displaying the power spectrum density of the primary main pump. At first, the alarm level was the average value plus three times variance. The variance was calculated from 100 data samples stored just after the starting up of the component. Then the alarm level was corrected experientially to be optimized.

In this spectrum, multiples of 93Hz can be observed. The accelerometer was attached to the outer casing near the impeller and sodium bearing. The pump impeller makes 13.3 revolutions per second, and have 7 blades. Because the frequency of the sodium's pulse pressure are 93 Hz, it is considered that this vibration is caused by sodium's pulse pressure.

Fig.3 shows a view of the CRT screen displaying a trend of RMS and probability density function. The trend of RMS makes it easy to understand the rate of increase of the change in the vibration condition. The probability density function represents the statistical characteristics of the vibration waveform.

4. EXPERIENCE OF VIBRATION ANALYSIS IN JOYO

On September 20th 1990, anomalous sound was detected near by the bearing housing of the cooling fan of the primary system electromagnetic pump. To investigate the cause of the anomaly, the vibrations of the bearing housing were monitored before and after the replacement of the bearing.

Table1 shows the RMS value, the peak value and the crest factor of the vibrations before and after replacement of the bearing. These values and factors before replacement were obviously greater than those of after replacement. The crest factor is the ratio of the peak value and RMS value. The increase of the crest factor means that the vibrations became impulsive.

Fig.4 shows the power spectrum of the vibrations before and after replacement of the bearing. The power spectrum of the vibrations before replacement was greater than that of after replacement, and it was outstanding in the part of the spectrum more than

400Hz. A remarkable feature was the appearance of peaks at equal distances of 13.7Hz and 135 Hz before replacement.

13.7Hz is close to the frequency that one bearing ball touches one point on the surface of the inner race in a second. 135Hz is the twice the frequency that one point on the bearing ball touches the surface of inner or outer race.

These results suggested that the anomalous vibration had occurred at the moment when the shaft's load had been placed on a faulty bearing ball, and when the ball had touched the surface of inner or outer race.

After disassembling the bearing, one bearing ball showed the marks of flaking and there were many defects on the surface of the inner or outer race. This result agreed with the result of vibration analysis.

5. CONCLUSION AND FUTURE PLAN

(1) A useful condition monitoring method for the main components and equipment was provided on the basis of operation and maintenance experience.

(2) This system has been used in "JOYO" since September 1990, and it is confirmed that there have been no serious changes of vibrational conditions in any components and equipment.

(3) Applicability to the following reactor was obtained, because this system was designed originally after due consideration for flexibility and expansibility.

From now on, analysis of vibration data will be continued, and the improvement of this system will be performed by means of AI (Artificial Intelligence), neural networks and so on.

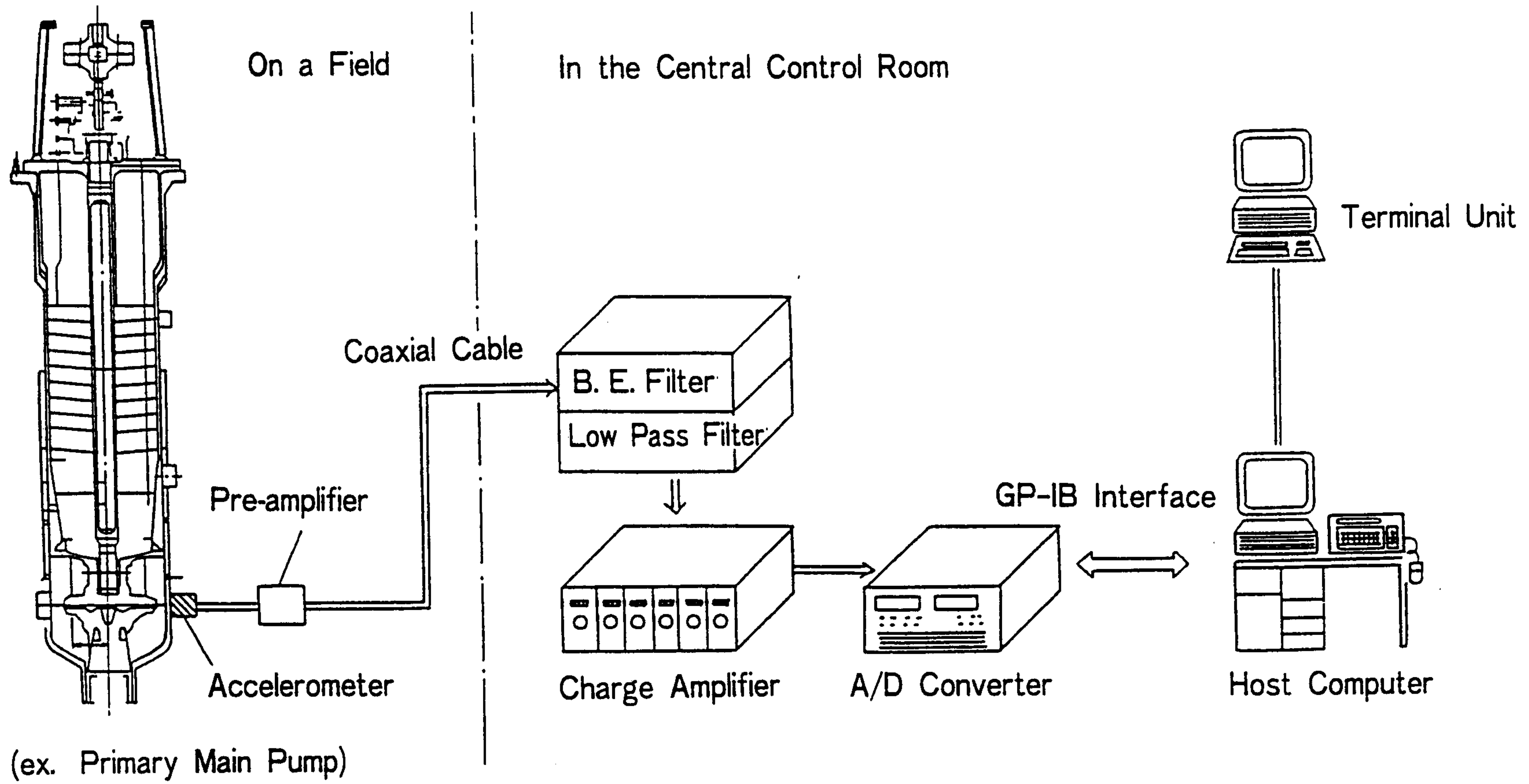

Fig. 1 System Configuration of the MEDUSA System

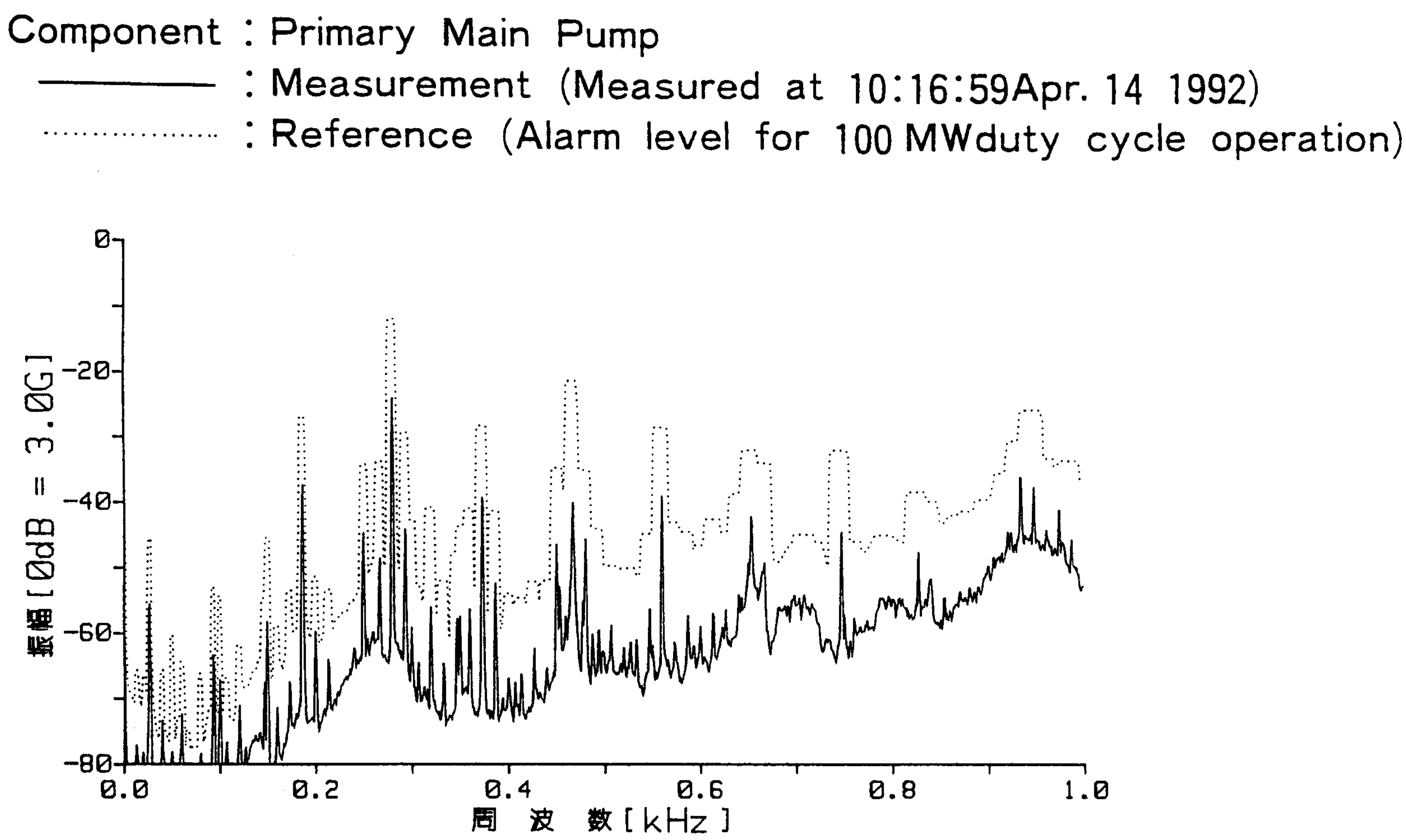

Fig. 2 A View of the CRT Screen Displaying a Power Spectrum Density

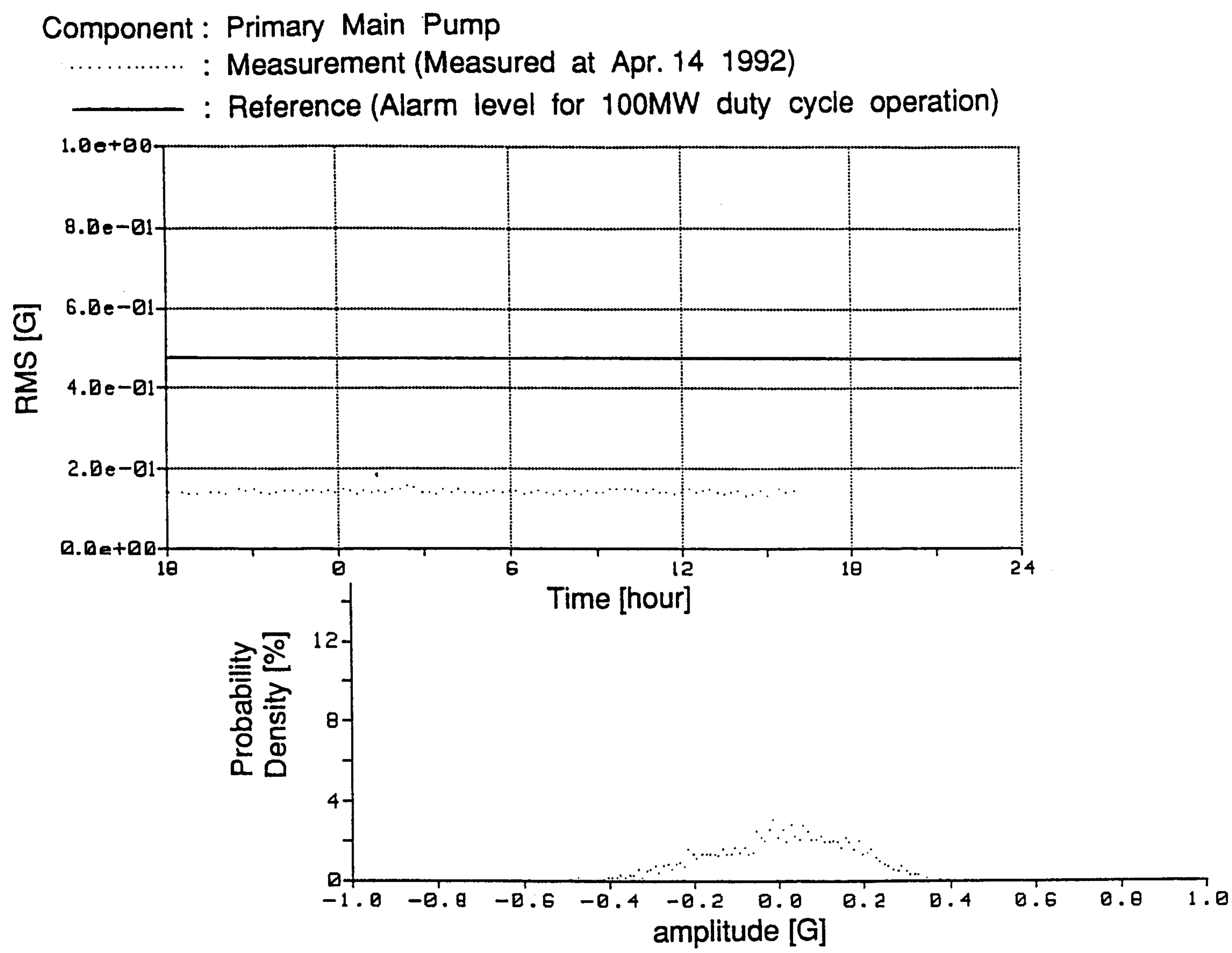

Fig. 3 Displaying a Trend of RMS and Probability Density Function

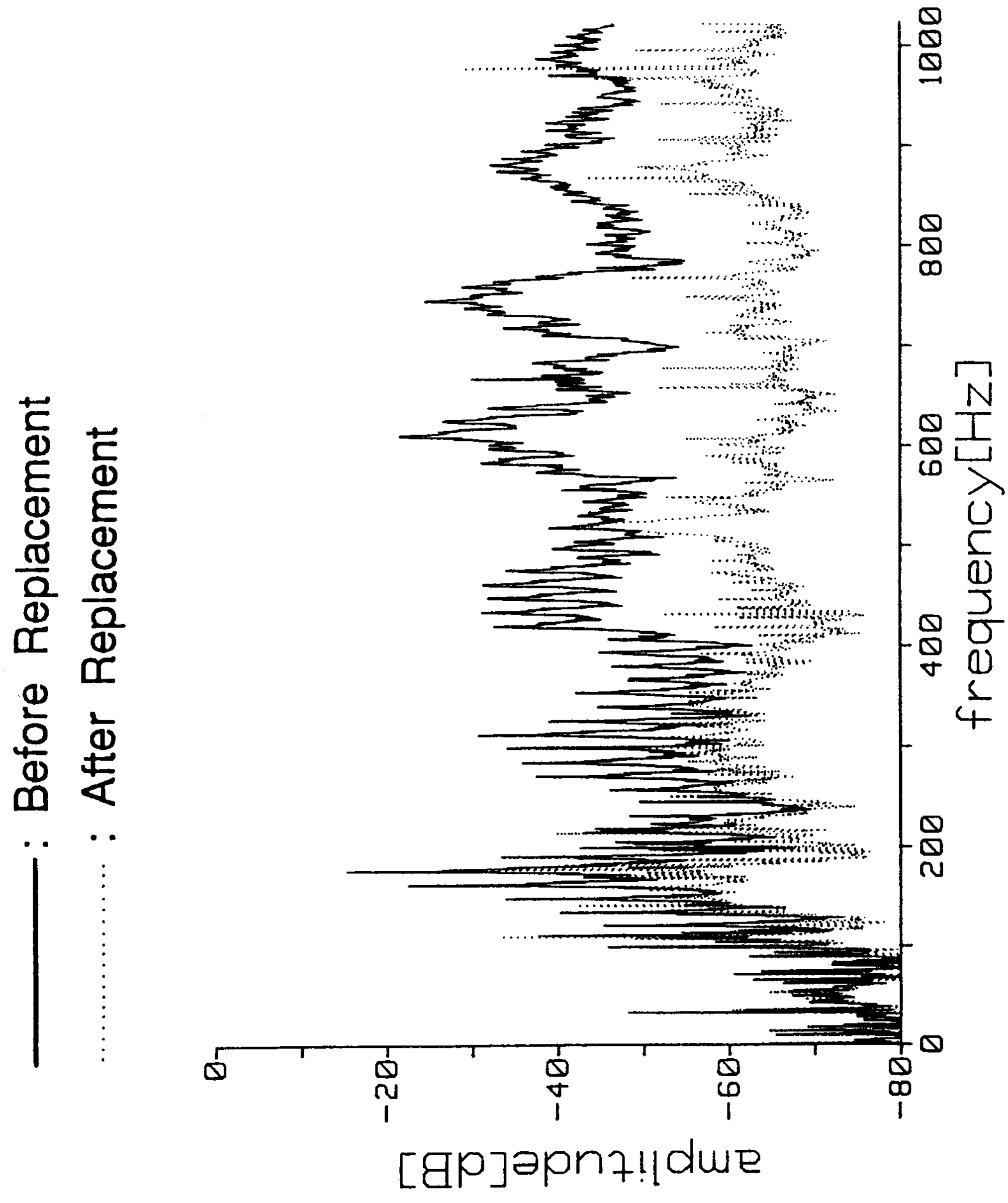

Fig. 4 The Power Spectrum of the Vibration Before and After Replacement of the Bearing

(G)

	Vertical Vibration			Horizontal Vibration		
	RMS value	peak value	crest factor	RMS value	peak value	crest factor
Before Replacement	0.72	3.88	5.36	0.67	5.10	7.60
After Replacement	0.07	0.29	4.16	0.11	0.48	4.26
ratio	10.5	13.5	1.29	5.99	10.7	1.78

Table 1 Characteristic of Vibration Before and After Replacement of the Bearing