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# METHODS OF DIAGNOSING AN ACWW 1000 SUGAR CENTRIFUGE WITH THE USE OF VIBRATION PROCESSES*

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K e y w o r d s: sugar centrifuge, diagnosing, diagnostic algorithms.

A b s t r a c t

This paper presents a method of diagnosing a sugar centrifuge ACWW 1000, which employs vibration processes. The condition assessment was based on the RMS value for vibration speed amplitude. Shewhart's control charts were used to determine the warning and critical values. Campaign and inter-campaign period diagnosis algorithms were developed.

## METODA DIAGNOZOWANIA WIRÓWKI CUKROWNICZEJ ACWW 1000 Z WYKORZYSTANIEM PROCESÓW DRGANIOWYCH

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S ł o w a k l u c z o w e: wirówka cukrownicza, diagnozowanie, algorytmy diagnozowania.

A b s t r a k t

W pracy przedstawiono metodę diagnozowania wirówki cukrowniczej ACWW 1000 z wykorzystaniem procesów drganiowych. Jako podstawę oceny stanu przyjęto wartość RMS amplitudy prędkości drgań. Do określenia wartości ostrzegawczych i krytycznych wykorzystano metodę kart kontrolnych Shewhardta. Opracowano algorytmy diagnozowania kampanijnego i międzykampanijnego.

*Aim of the study: developing a diagnostic method for an ACWW 1000 sugar centrifuge to be employed by maintenance services.

## Introduction

In terms of effectiveness, a dynamic strategy (according to the technical condition) is the most beneficial of maintenance strategies. However, it requires appropriate diagnostic methods to assess the facility momentary condition and foresee its changes in future. The requirements concern machines in continuous operation, whose role is critical to the technological process. One of such machines is a sugar centrifuge ACWW 1000.

## Study object

A group of 12 ACWW1000-type sugar centrifuges was examined. An ACWW 1000 sugar centrifuge is a continuous centrifuge used in sugar production. The working speed of the centrifuge basket is 1800 rpm. Torque is transferred from the engine to the basket shaft directly through a permanent flexible coupling.

A centrifuge diagram is shown in Figure 1. Massecuite is fed through a feeding pipe (4) into the basket (3) and spread evenly on sieve surfaces by centrifugal force. In the course of centrifuging, powdered sugar is separated on sieves from the so-called “run-off” syrup. The products are carried off from the centrifuge by draining pipes (5).

The ACWW 1000 centrifuge power transmission system is shown in Figure 2. It consists of an electric engine (1) connected through a flexible coupling (2) with a shaft (3), on which a basket (4) with sieves is placed. The shaft with

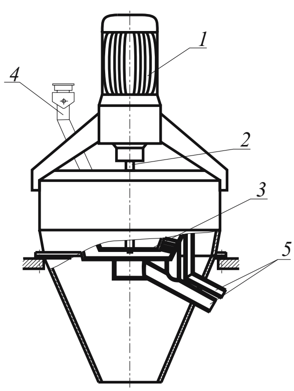


Fig. 1. A diagram of an ACWW1000 centrifuge: *1* – engine, *2* – drive shaft, *3*– basket with sieves, *4* – feeding pipe, *5* – draining pipes

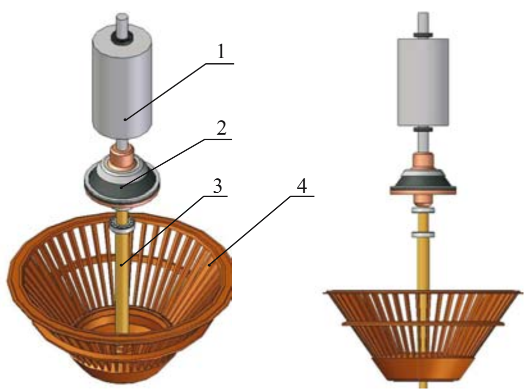


Fig. 2. View of the power transmission system of an ACWW1000 sugar centrifuge: *1* – engine, *2* – flexible coupling, *3* – shaft, *4* – basket

a basket is bearing supported on one side with two rolling bearings, placed in a gyro-socket cradle. A detailed structure of the rotating system of an ACWW 1000 centrifuge and its mathematical model were presented in another paper (WOROSZYŁ et al. 2005).

## Selecting the diagnostic signals

The best way to identify most faults of the rotating system elements (rolling bearings, coupling) is spectral analysis, owing to its universality and the abundant literature which describes it (CEMPEL 1989, ŻÓŁTOWSKI 1996). A specification of faults identified with spectral analysis and the corresponding frequencies are presented in Table 1.

Table 1

Fault states identified by spectral analysis of centrifuges

| Fault state | Typical (dominant) frequency and measuring points | Notes |
|---|---|---|
| Lack of balance of the rotating system | First harmonic (30 Hz) – measurement on the bearing support | If the values of vibration amplitude for the harmonic frequency change during a measurement, it indicates a technological lack of balance – interference caused by a working medium. |
| Loss of elasticity by the flexible coupling | Second harmonic (60 Hz) – measurement on the coupling casing | Increased amplitudes of vibrations are possible for the 1, 3, 4 harmonic frequency. |
| Lack of balance of the engine cooling fan or the engine rotor | First harmonic (30 Hz) – measurement on the engine | The vibration speed amplitude for the $1^{st}$ harmonic frequency at point 1 is higher than at points 2 and 3. |
| Defect of the centrifuge shaft bearings | Frequencies above 100Hz usually yield an image of grouped peaks – measurement on bearing support | It has been noted that in order to identify defects of a centrifuge shaft bearings it is enough to conduct a spectral analysis of the vibration speed of up to 1200 Hz. |
| Defect of the engine bearings | Frequencies above 100Hz usually yield an image of grouped peaks – measurement on the engine | |

## Selection of the measuring points

The measuring point selection was based on the diagram of interactions between centrifuge elements, shown in Figure 3 (LIGIER 2005).

The illustration indicates that the following structural points should be chosen for reception of signals informing about the state of critical elements (Fig. 4):

– to assess the condition of the engine bearings and the engine fan – the engine (point 1, close to the bearing support points);

– to assess the condition of the coupling – the coupling cover (point 2);

– to assess the condition of the centrifuge shaft bearings and the dynamic state of the rotary system – bearing support casing (point 3);

– to assess the precession of the rotating system – the centrifuge shaft (point 4).

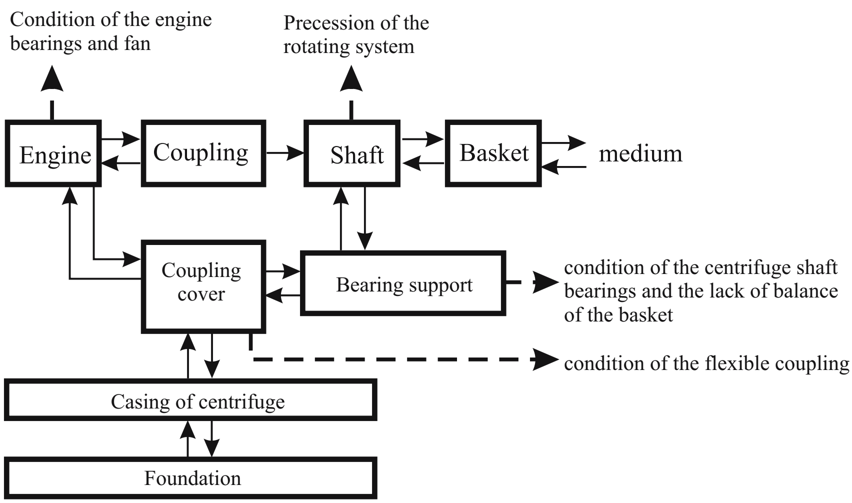


Fig. 3. A diagram of interactions of an ACWW 1000 centrifuge and possible sites of reception of diagnostic signals

The position of selected measuring points on a centrifuge is shown in Figure 4.

Figures 5-8 show example vibration spectra which identify centrifuge faults (LIGIER 2005).

In the spectrum of the vibration speed shown in Figure 5 there are two groups of "peaks" for the frequencies from 600 to 800 Hz and from 1150 to 1350 Hz, which indicate a defect of the shaft 3 rolling bearings, Figure 2. In the acceleration spectrum an increase in amplitude is visible in the range from 1000 to 2500 Hz, which also indicates a defect of bearings.

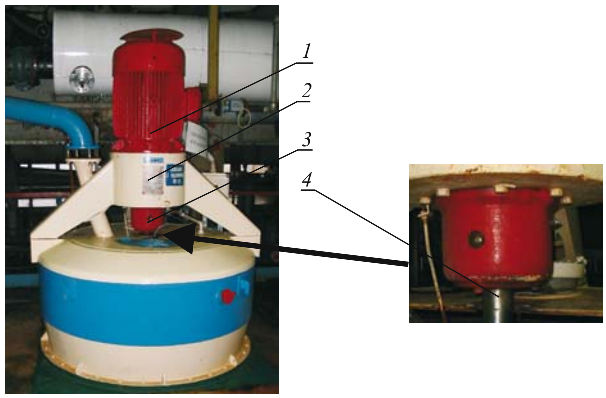


Fig. 4. The position of the measuring points 1, 2, 3 and 4 on an AWW 1000 centrifuge*1* – engine, *2* – coupling cover, *3* – bearing support case, *4* – centrifuge shaft

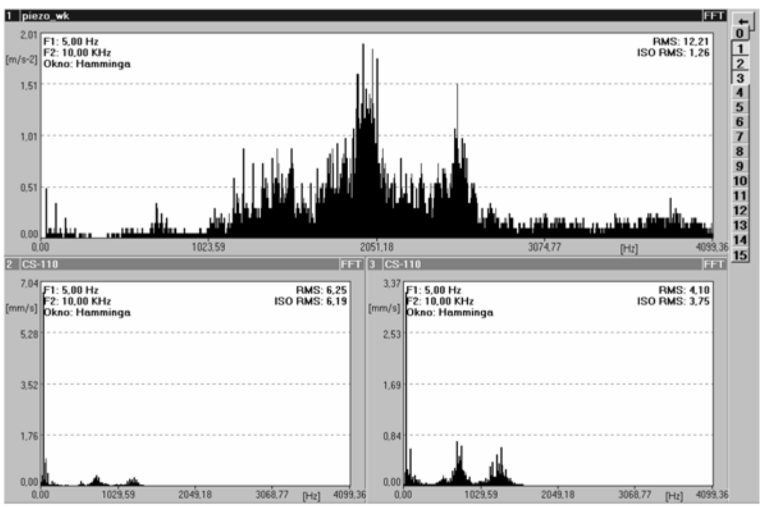


Fig. 5. A spectrum of centrifuge vibrations, measuring point 3

The spectrum shown in Figure 6 shows a considerable increase in the vibration speed amplitude (20 mm/s) for the first harmonic frequency of the centrifuge shaft (30 Hz). This indicates a lack of balance of the rotating system of the sugar centrifuge.

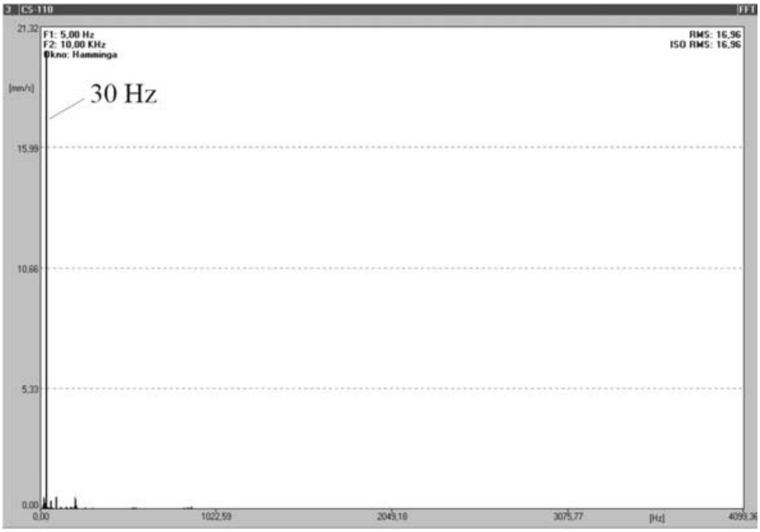


Fig. 6. A vibration speed spectrum for a centrifuge no. 1, measuring point no. 3

Figure 7 shows a spectrum of vibrations of a centrifuge with the defective flexible coupling. This is indicated by an increase in the vibration speed amplitude for the second harmonic frequency, which is higher than that for the first harmonic.

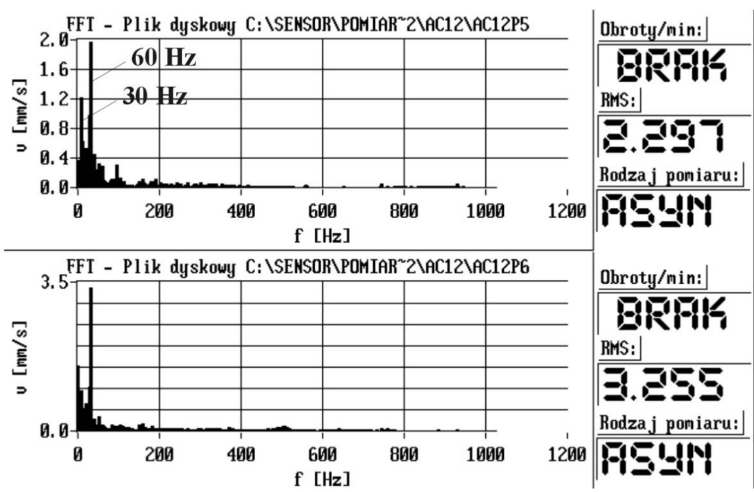


Fig. 7. Vibration spectrum for a centrifuge no. 12, measuring point no. 3 – defective coupling

Figure 8 shows a vibration speed spectrum for measurement point 1 (on the engine) and no. 3 (on the bearing support). A comparison of the registered spectra reveals that that the vibration amplitude for the first harmonic frequency is higher than for point 3. This provides grounds for the conclusion that the source of vibrations is situated closer to point no. 1, which indicates that the lack of balance of the engine fan is the cause.

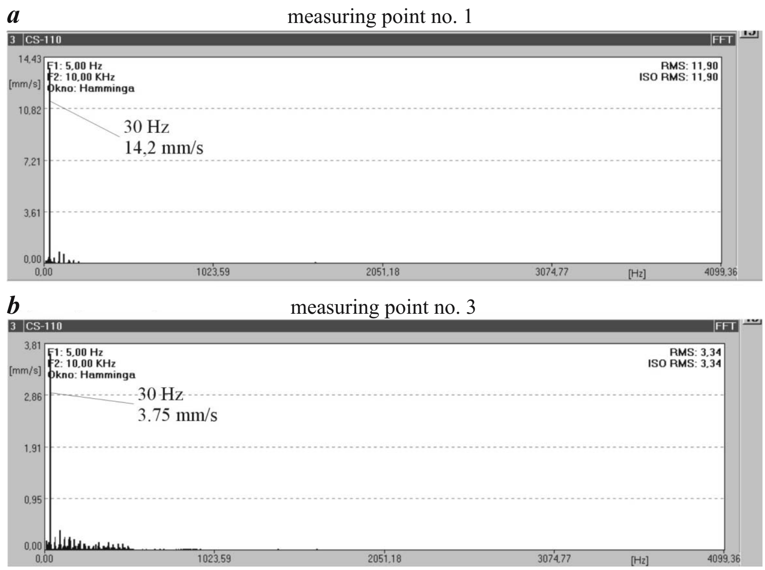


Fig. 8. Vibration spectra for centrifuge no. 2 – lack of balance of the engine rotor

## Determination of the limiting values

According to PN-90/N-01358 (Methods of measurement and assessment of machine vibrations), for an assessment of a general condition of a machine, based on vibration analysis, application of vibration speed amplitude RMS values is recommended. According to the standard, ACWW 1000 centrifuges are classed as group II machines. It should be assumed that the acceptable value of vibrations for the machines is 7.1 mm/s, and the warning value – 4.5 mm/s. Due to the interfering effect of the centrifuged medium, the values can only be applied in the inter-campaign centrifuge diagnostics. They had to be corrected for the diagnostics in the campaign period. To this end, Shewhart's control charts were used (MIKOŁAJCZAK et al. 2002).

The warning and critical values were determined, defined in the following manner:

– the upper warning line – $UWL = \bar{X} + 2\sigma$;
– the upper control (limiting) line – $UCL = \bar{X} + 3\sigma$.

where:
$\bar{X}$ – signal mean value;
$\sigma$ – standard deviation.

In order to determine the value of the examined diagnostic signal, which is registered in the operational conditions, a passive and active-passive diagnostic experiment was conducted. Table 2 shows a specification of the UWL and UCL values calculated for $V_{RMS}$, based on the data collected during the sugar production campaigns of 2001-2002.

Table 2
Specification of results of calculation of UWL and UCL values for $V_{RMS}$, for three measuring points (to be applied during the campaign period)

| Statistical parameter | $V_{RMS}$ at measuring point no. 3 [mm/s] | $V_{RMS}$ at measuring point no. 2 [mm/s] | $V_{RMS}$ at measuring point no. 1 [mm/s] |
|---|---|---|---|
| UWL | 12.36 | 7.60 | 7.69 |
| UCL | 15.55 | 9.41 | 9.58 |

It is noteworthy that the warning and control values are different for measuring point 3 than for measuring points 1 and 2. This is associated with the considerable effect of the load of the centrifuged mass on the vibrations of the lower bearing.

Shewhart's control charts can be related only to a selected machine, by marking the values of the measured signal for consecutive measurements (values of $V_{RMS}$ vs. time). An example of such a chart is given in Figure 9; it indicates the possibility of using such charts to analyse changes of the value of the examined signal and taking corrective actions at an appropriate time.

The frequency of diagnosis is determined based on the practical knowledge of the defect development rate and on the observation of changes of the analysed signal.

During an inter-campaign period, it is beneficial to measure vibrations vs. rotation for the centrifuge start run. This makes it possible to estimate the rotation speeds which trigger resonance. An example vibration speed amplitude vs. rotation for a centrifuge start run is shown in Figure 10.

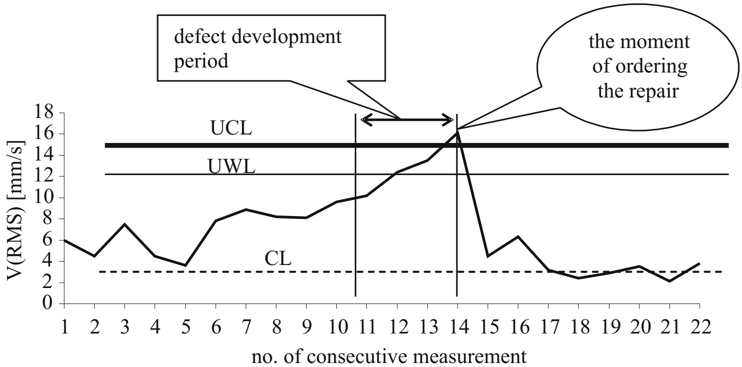


Fig. 9. Vibration speed amplitude RMS values for 22 consecutive measurements of centrifuge no. 6 – measuring point no. 3

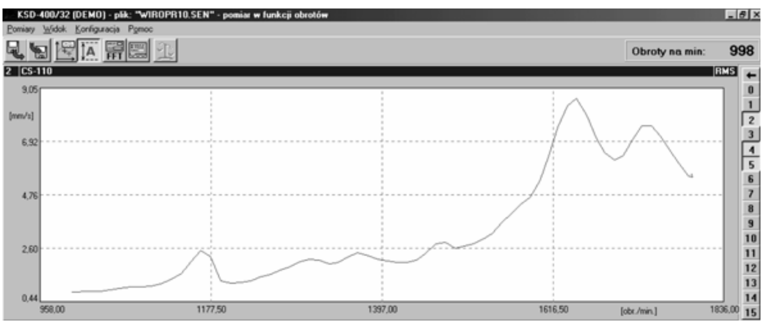


Fig. 10. Vibration speed amplitude vs. rotation for a centrifuge start run

An analysis of diagrams shows that a vibration amplitude increases for the rotational speeds of 1163, 1644 and 1735 rpm, which corresponds to the frequencies of 13, 27 and 29 Hz. This can be employed in determination of the maximum speed of a centrifuge which does not cause the resonance and applying the speed during the campaign period as the working speed.

## Diagnostic algorithms

Due to the use of centrifuges in campaigns, different diagnostic algorithms have been proposed for the campaign and inter-campaign periods; they are shown in Figure 11 and 12.

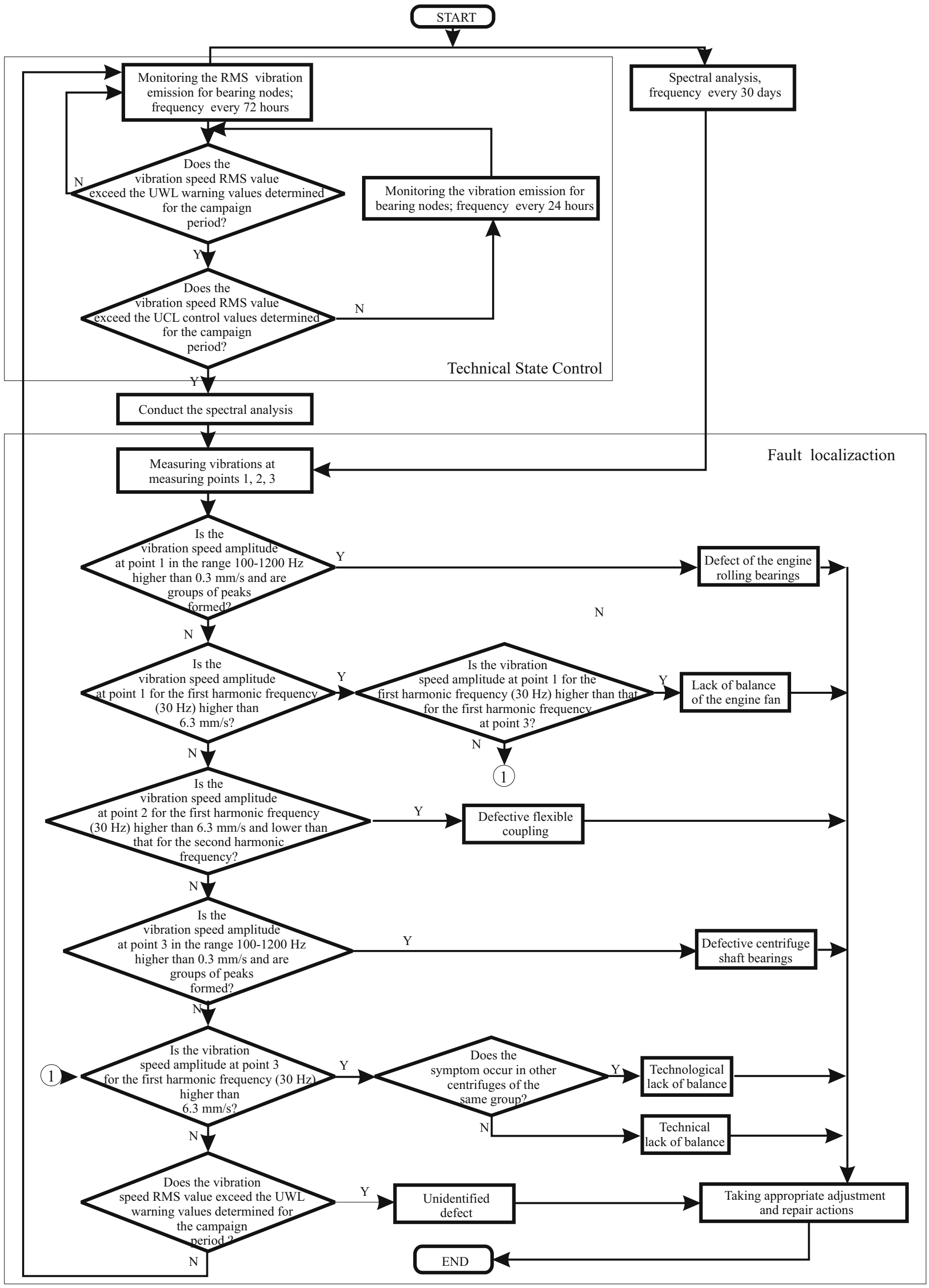


Fig. 11. Diagnostic algorithm for a campaign period for an ACWW 1000 sugar centrifuge

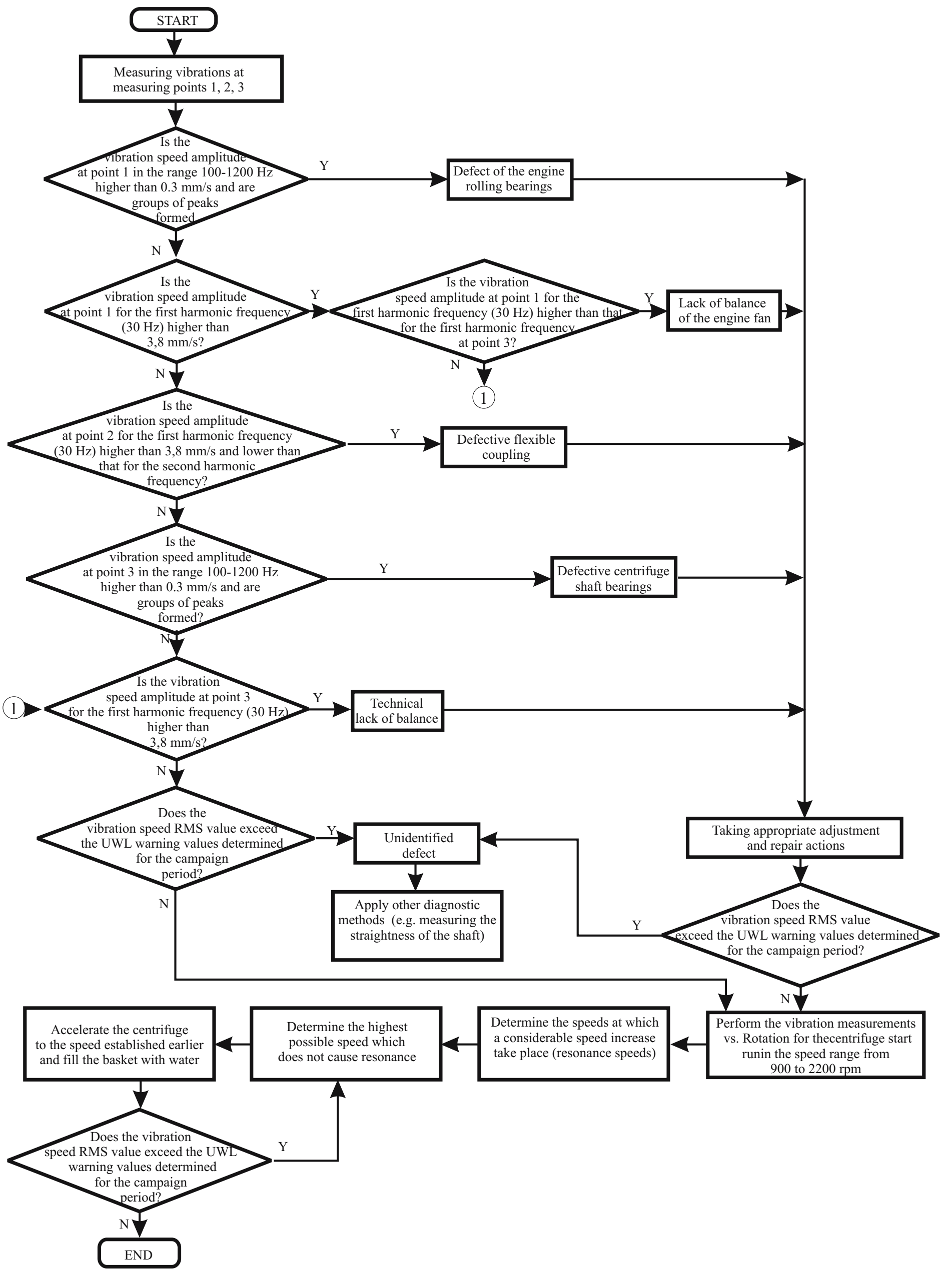


Fig. 12. Diagnostic algorithm for an inter-campaign period for an ACWW 1000 sugar centrifuge

## Summary

Vibration processes generated during a centrifuge operation provide information which helps diagnose the device technical condition and identify most faults which occur in the course of its operation, without switching it off.

The diagnostic algorithms proposed in this paper help to make assessment of the machine condition and preparation for a sugar production campaign as well as of its condition during the campaign.

The condition assessment in the algorithms is based on the vibration speed amplitude RMS value for which the warning and critical values for the campaign and inter-campaign periods have been determined. Spectral analysis has been applied to identify the device faults resulting from technical and technological defects. The measurement of vibrations vs. rotational speed for the centrifuge start run allows for easy identification of resonance speeds for particular centrifuges, which in turn helps determine the maximum safe operation speed for each device.

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