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VIBRATION DIAGNOSTICS OF ROTATING CENTRIFUGAL MILK

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ABSTRACT
In the paper work is examine the opportunities the vibration insulation mechanisms of the diagnostic which refers to the measurement of the mechanical vibration. Systems of the vibration insulation distort the diagnostic signal. In the paperwork is examine the influence of the vibration insulation systems to the diagnostic mechanisms, and also are establish what kind of the parameters this influence depends on.
Keywords: vibration insulation systems, diagnostic, monitoring.

1. INTRODUCTION
In purpose to achieve data about the functioning of milk separator vibro- transducers are used. They are located at outside of the separator distantly from vibration sources and researched element of the separator [1. 2]. The procedure of evaluation and treatment must be well-balanced in purpose to define the sources of vibration, localize their place and to receive information necessary for detection of defect. The methodical is necessary to create for the purpose to evaluate reliability of results. Diagnostic of such mechanisms is not enough developed. For this reason it is necessary to foresee such placement of transducers which would enable to distinguish excitation sources simultaneously acting, but situated in different places of the separator. The authors think that at contemporary development level of technique it is possible to create the diagnostic system being able to clear up characteristics of excitation sources in a milk separator and to foresee the up-rise of the defects. Such a system would not require interference into the work of a separator and can be used at design and creation of new separators for evaluation of their quality, checking in production stage, for diagnosis of different aggregates and equipment in milk processing enterprises and at their exploitation.

2. MATHEMATICAL STUDY
Statistic evaluation of vibration properties of a multidimensional linear system is based on the following correlation:

$$S_{jj}(f) = [\Phi_1(f), \Phi_2(f), ..., \Phi_q(f)] * \quad (1)$$

$$* \begin{vmatrix} S_{11}(f) & S_{12}(f) & \dots & S_{1q}(f) \\ S_{21}(f) & S_{22}(f) & \dots & S_{2q}(f) \\ \vdots & \vdots & & \vdots \\ S_{q1}(f) & S_{q2}(f) & \dots & S_{qq}(f) \end{vmatrix} \begin{vmatrix} \Phi_1^*(f) \\ \Phi_2^*(f) \\ \vdots \\ \Phi_q^*(f) \end{vmatrix}$$

$$\begin{vmatrix} S_1(f) \\ S_2(f) \\ \vdots \\ S_q(f) \end{vmatrix} = \begin{vmatrix} S_{11}(f) & S_{12}(f) & \dots & S_{1q}(f) \\ S_{21}(f) & S_{22}(f) & \dots & S_{2q}(f) \\ \vdots & \vdots & & \vdots \\ S_{q1}(f) & S_{q2}(f) & \dots & S_{qq}(f) \end{vmatrix} \begin{vmatrix} \Phi_1^*(f) \\ \Phi_2^*(f) \\ \vdots \\ \Phi_q^*(f) \end{vmatrix} \quad (2)$$

Here a vector-column in the right part (1) is a vector collectively conjugated with transposed vector Φ(f) while vectors-columns in the right part (2) are transposed vectors-lines $S_{ij}(f)$ and Φ(f). In this case correlation (1) and (2) serves as a basis for forecasting tolerances for mechanical vibration of the centrifugal separator the milk. For this purpose adequate correlative functions and spectrum density characteristics of vibration properties are needed.
Autocorrelati0n function of vibration analysis system has been evaluated according to the following expression [4]:

$$K_{jj}(k\Delta h) = \frac{1}{N-k}\sum_{n=1}^{N-k}\left(P_{jn} - \frac{1}{N}\sum_{n=1}^{N} P_{jn}\right)\left(P_{jn+k} - \frac{1}{N}\sum_{n=1}^{N} P_{jn}\right) \quad (3)$$

where n = 1, 2, ..., N; k = 0, 1, 2, ..., m – number of step, m – maximum number of steps. Cross-correlation function

$$K_{ij}(k\Delta h) = \frac{1}{N-k}\sum_{n=1}^{N-k}\left(P_{in} - \frac{1}{N}\sum_{n=1}^{N} P_{in}\right)\left(P_{jn+k} - \frac{1}{N}\sum_{n=1}^{N} P_{jn}\right) \quad (4)$$

$$K_{ji}(k\Delta h) = \frac{1}{N-k}\sum_{n=1}^{N-k}\left(P_{jn} - \frac{1}{N}\sum_{n=1}^{N} P_{in}\right)\left(P_{in+k} - \frac{1}{N}\sum_{n=1}^{N} P_{in}\right). \quad (5)$$

Where $N = T_p/\Delta h$ – length of realization; Δh – step of quantization. Spectrum and inter-spectral densities have been evaluated according to autocorrelation (7) and cross-correlation (8, 9) functions:

$$S_{jj}(f) = 2\Delta h\left[K_{jj}(0) + 2\sum_{k=1}^{m-1}\varphi(j)k_{jj}\cos\left(\frac{\pi f}{f_c}\right)\right], \quad (6)$$

where k = 0, 1, 2, ..., m, $m \le f_d/ 2\Delta f_N$.

$$S_{ij}(f) = \mathrm{Re}S_{ij}(f) - \mathrm{Im}_N S_{ij}(f), \quad (7)$$

where

$$\mathrm{Re}S_{ij}(f) = $$
$$= 2\Delta h\left\{k_{ij}(0) + 2\sum_{i=1}^{S-1}\varphi(i)\frac{1}{2}\left[k_{ij}(i\Delta h) + k_{ij}(-i\Delta h)\right]\cos\left[(2\pi k_i \Delta f_N)/f_d\right]\right\}$$

$$\mathrm{Im}_N\, S_{ij}(k\Delta f_N) =$$
$$= 4\Delta h\sum_{i=1}^{S-1}\varphi(i)\left[k_{ij}(i\Delta h) - k_{ij}(-i\Delta h)\right]\sin\left[(2\pi k_i \Delta f_N)/f_d\right]$$

whereΔf_N – step of quantization by frequency; $f_d = 1/\Delta h$ – frequency of quantization of continuous signals; φ(i) – weight function levelling down correlative functions. Spectrum density has been evaluated by means of Hann's weight functions

$$\varphi(i) = \begin{Bmatrix} 0{,}5\left(1 + \cos\dfrac{\pi r}{m}\right) \\ 0, \quad r > m \end{Bmatrix}, \qquad r = 0{,}1{,}2{,}..{,}m, \quad (8)$$

If $S_{ij}(f)$ and $S_{ij}(f)$ are known, equations (2) are resolved in the following way:

$$\begin{vmatrix}\Phi_1(f)\\ \Phi_2(f)\\ \vdots\\ \Phi_q(f)\end{vmatrix}=\begin{vmatrix}S_{11}(f) & S_{12}(f) & \ldots & S_{1q}(f)\\ S_{21}(f) & S_{22}(f) & \ldots & S_{2q}(f)\\ \vdots & \vdots & & \vdots\\ S_{q1}(f) & S_{q2}(f) & \ldots & S_{qq}(f)\end{vmatrix}\begin{vmatrix}S_{1j}(f)\\ S_{2j}(f)\\ \\ S_{qj}(f)\end{vmatrix} \tag{9}$$

3. DIAGNOSTIC SYSTEM

A diagnostic scheme with distribution of converters is presented in Fig. 1. The label of point generates the impulses establishing the rotation angle of the rotary and four accelerometers measure the vibro-accelerations of the frame. The digital discretisation of signals in the system depends on what kind of signal is analysed

At any stage of signal processing the data can be reviewed on the monitor of PC in order to be certain that the signals are processed correctly. The procedure of the signals processing is presented in software to equation (2-9).

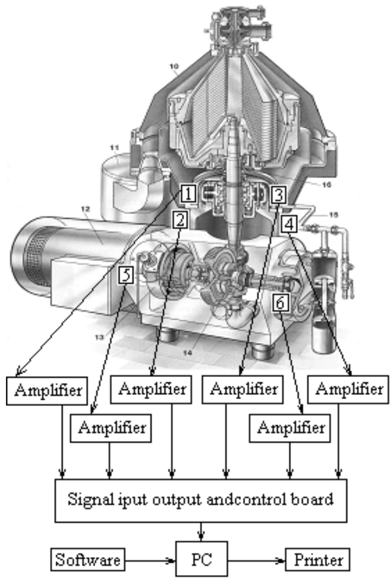
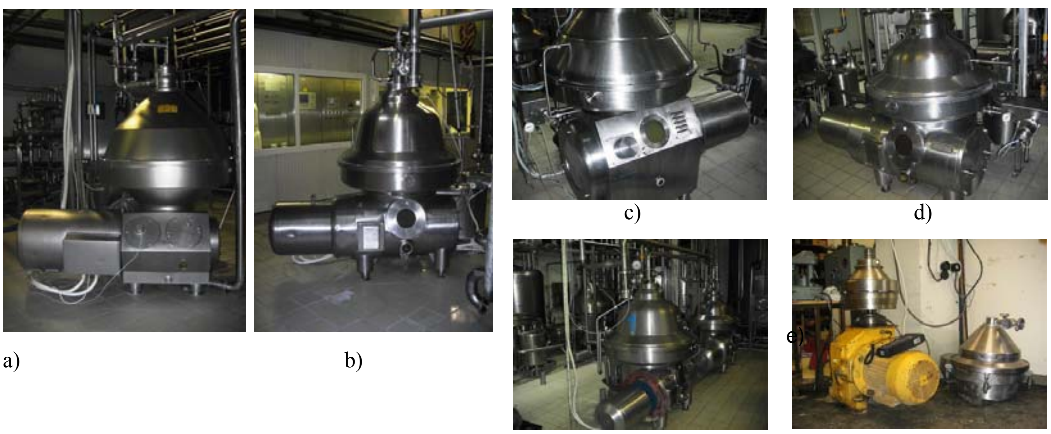


Figure 1. Diagnostic diagram



a) b) c) d) e) f)

Figure 2. Milk separator of different types:a – Milk separator (productivity 25t/h, 22kW);b – Milk bactofug (productivity 25t/h, 20kW);c – Milk cleaner (productivity 15t/h, 17kW);d – Milk cleaner (productivity 25t/h, 20kW);e – Milk cleaner (productivity 35t/, 26kW);f – Milk separator of stand type (Milk cleaner (productivity 5t/h, 7kW,).

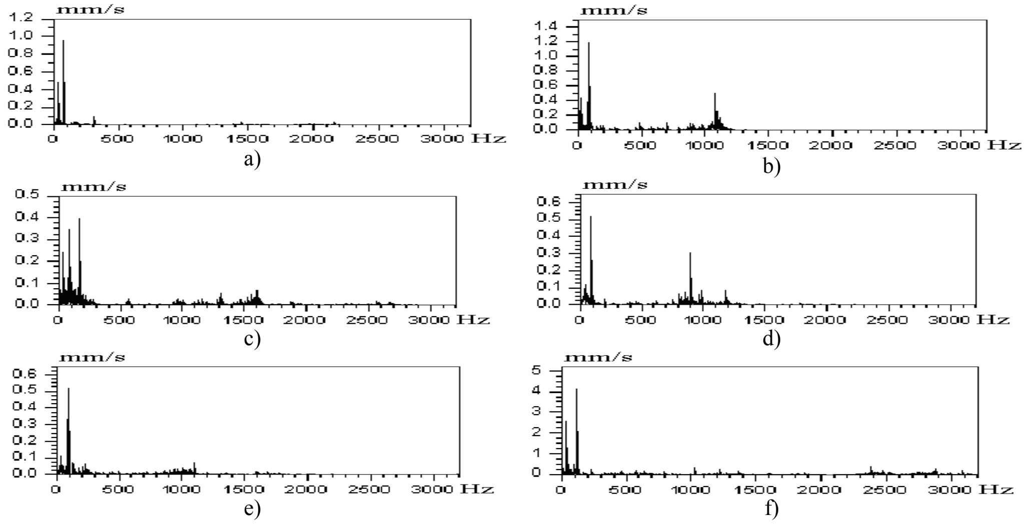


Figure 3. Spectrum of vibrospeeds of mechanisms a, b, c, d, e and f.

Vibro-speed values are recommended for evaluation of technical state of mechanisms [3].
The state of separators with power more than 15kW (a, b, c, d ir e) is kept right or satisfactory if vibro-speed of mechanisms is no bigger that 1,12 and 2,8 mm/s accordingly. Limits of right and satisfactory vibro-speed states for separators (f) of power lees than 15kW are 0,71 and 1,12 mm/s accordingly.

4. CONCLUSIONS

1. Values of vibro-speeds of tested milk separators powered from 17 to 26 kW does not exceed allowable by ISO standards.
2. Vibro-speed values of lower power (7kW) show according to ISO standards the necessity to change bearings of a mechanism.

5. REFERENCES

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