UDC 004.67: 681.518.5

S. Shantyr, A. Shantyr

INCREMENT IN INFORMATION AND ALGORITHMIZATION OF CURRENT SPECTRUM TOLERANCE CONTROL FOR ROTARY MACHINE

Introduction

Existing systems for vibration control perform estimation of machinery technical state via method of current spectrum tolerance control of vibration signal [1–4] using tolerance windows.

Author's study of spectrum of rotary machine vibration signal [5, 6] shows occurrence of three well-recognized components in its composition:

– comb spectrum of synchronous component of vibration signal $\{G_i = G(f_i = i \cdot F_{rotor})\}_N$;

– concentrated (lobed) spectrum of asynchronous component of vibration signal $G_{aSC}(f)$, $f \in \Phi_{aSC} = (F_{lobe} \pm \Delta F_{aSC})$;

– nonuniform spectrum of noise component of vibration signal $G_{NC}(f)$, $f \in (F_{NC}^{low}, F_{NC}^{high})$.

Split usage of structural components spectrums enables increasing of amount of rotary machine technical state information pumped from vibration signal.

Problem definition

Article purpose – to design method and algorithm for processing current spectrum of vibration signal to provide increment in information of its tolerance control via usage of structural components spectrums.

Structure chart of system for current spectrum tolerance control for rotary machine

Structure chart of system for current spectrum tolerance control for rotary machine realizing developed method (fig. 1) includes linear measuring transducer L (amplifier, former of amplitude-frequency characteristic, integrator, stc.) of input measuring signal; analog-digital converter (ADC); selectors of synchronous (Selector SC) and asynchronous (Selector aSC) structural components of vibration signal; channels for separate tolerance control of generic numerical parameters of spectrums of synchronous, asynchronous and noise structural components. In each channel numerical value of generic parameter enters threshold device (TD) and decision-making device (DMD) about technical state of rotary machine (S).

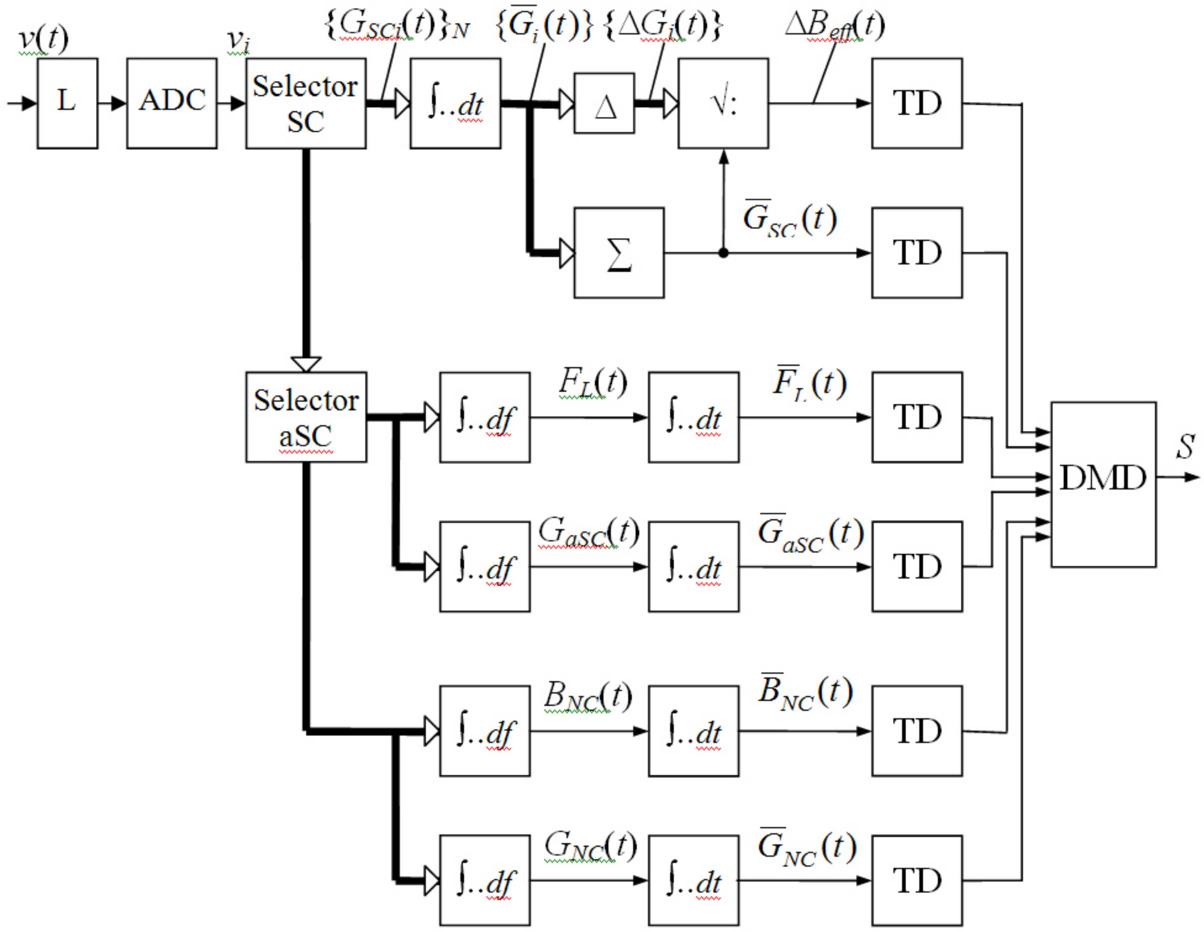


Fig. 1. Structure chart of system for current spectrum tolerance control for rotary machine

Vibration signal $v(t)$ enters the system and contain synchronous $v_{SC}(t)$, asynchronous $v_{aSC}(t)$ and noise $v_{NC}(t)$ components

$$v(t) = v_{SC}(t) + v_{aSC}(t) + v_{NC}(t). \quad (1)$$

Vibration signal $v(t)$ spectrum is on fig. 2.

Control purpose is detection and estimation of variation energy spectrum of vibration signal structural components during operation of rotary machine.

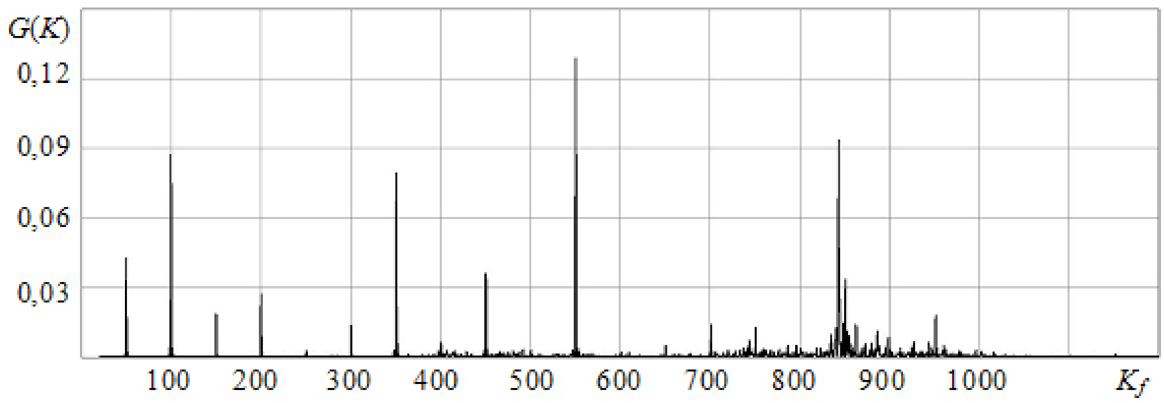


Fig. 2. Spectrum of rotary machine vibration signal $v(t)$

Control of spectrum of vibration signal synchronous component

Tolerance control of vibration signal synchronous component executed using its current energy spectrum $\{G_i(t)\}_N$ (fig. 3). Position dispersion on frequencies axis and oscillations power variance of spectral lines are indicators of variance of synchronous component energy spectrum.

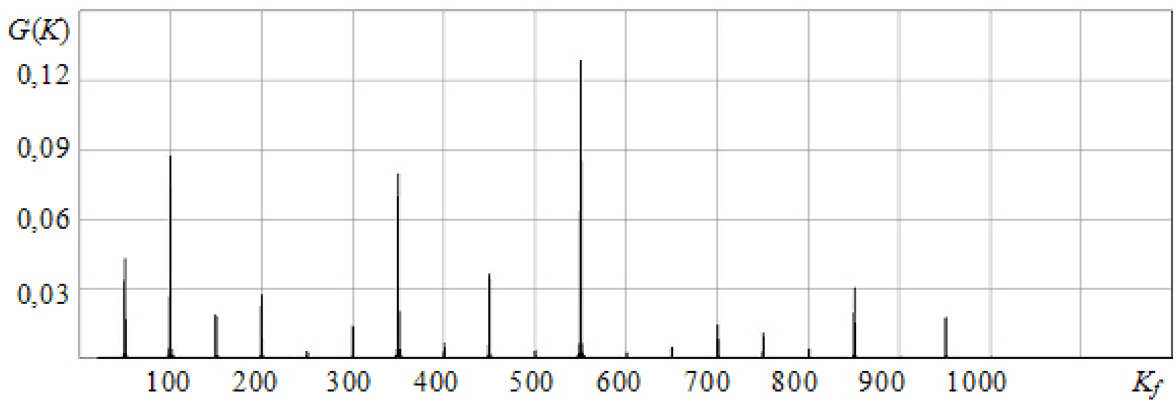


Fig. 3. Spectrum of synchronous component of rotary machine vibration signal

Experimentally detected that main reason of spectral lines position dispersion on frequencies axis is deviation of rotor speed. To eliminate that dispersion way of registration of spectral lines position changed: on horizontal axis marked not frequency but frequency multiplicity of rotor speed

$$K_f = f / F_{rotor} .$$

As the result every spectral line stands on fixed position suitable to its number

$$K_f^{line} = 1, 2, ..., i, ..., N .$$

Carried out studies show that process $\{G_i(t)\}_N$ on sufficiently great, but limited intervals of observation time T_{obs} has quasistationary nature, and it enables to use sample mean of process for tolerance control: sample mean power of every i spectral line

$$\bar{G}_i(t) = \frac{1}{T_{obs}} \int_{t}^{t+T_{obs}} G_i(t) \cdot dt , \quad i = 1,2,...,N .$$

It's known [2, 7] that redistribution of spectral lines power is sign of changing of technical state of machinery during operation. To account quantitatively change of energy of every separate line measuring of average power level shift of every i spectral line relatively to reference value $\{\Delta G_i(t) = \bar{G}_i(t) - G_i^{ref}\}_N$ included in scheme (fig. 1).

Following parameters of energy spectrum of vibration signal synchronous component defined as generic indicators of changing of technical state of machinery:

– average power of vibration signal synchronous component

$$\bar{G}_{SC}(t) = \sum_{i=1}^{N} \bar{G}_i(t) ;$$

– variance of spectrum effective bandwidth

$$\Delta B_{eff}(t) = \sqrt{\frac{\sum f_i^2 \Delta G_i(t)}{\bar{G}_{SC}(t)}} .$$

As opposed to operating systems for vibration control [3], where for each i spectral line set tolerance window determining two reference indicators (bandwidth (horizontal size of window Δf_i^{ref}) and power (vertical size of window G_i^{ref})), scheme (fig. 1) uses two-dimensional tolerance window for generic parameters of energy spectrum of vibration signal synchronous component:

– for power – tolerance for power of vibration signal synchronous component

$$\left| \bar{G}_{SC}(t) - G_{ref} \right| \le G_{tol} ;$$

– for frequency - maximum permissible value of spectrum effective bandwidth shift

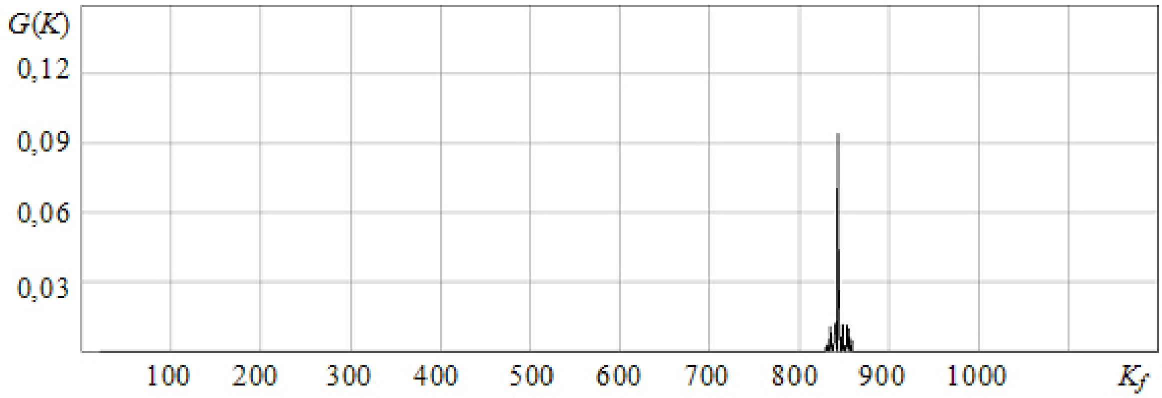
$$\left| \Delta B_{eff}(t) \right| \le \Delta B_{tol} .$$

Generic numerical parameters of spectrum of vibration signal synchronous component applied as indicators of technical state of rotary machine rotor element.

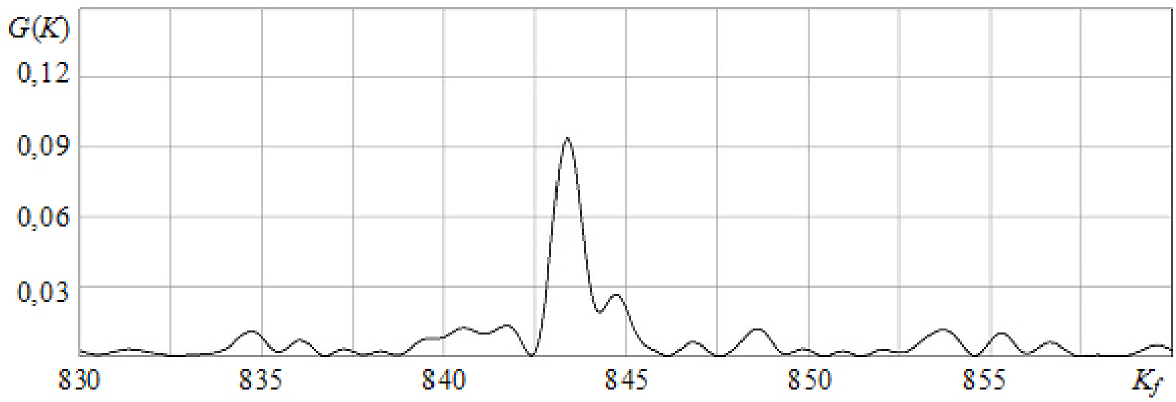
Control of spectrum of vibration signal asynchronous component

Tolerance control of vibration signal asynchronous component executed using its current energy spectrum $G_{aSC}(f,t)$. Position shift on frequencies axis and power variance of oscillations are indicators of variance of asynchronous component energy spectrum.

Form of spectrum of vibration signal asynchronous component is on fig. 4. Figure shows that main sign of spectrum of vibration signal asynchronous component is well-recognized main lobe. Structure of spectrum side components has no readable elements.



a)



b)

Fig. 4. Spectrum of asynchronous component of rotary machine vibration signal: a) $K_f = 1, 2, ..., 1200$; b) $K_f = 830, 831, ..., 860$

Position parameter of spectrum of vibration signal asynchronous component on frequencies axis

$$F_{lobe}(t) = \frac{\int_{\Phi_{aSC}} f \cdot G_{aSC}(f,t) \cdot df}{\int_{\Phi_{aSC}} G_{aSC}(f,t) \cdot df}.$$

Power of vibration signal asynchronous component

$$G_{aSC}(t) = \int_{F_{lobe}-\Delta F_{aSC}}^{F_{lobe}+\Delta F_{aSC}} G_{aSC}(f,t) \cdot df \,.$$

Generic numerical parameters of spectrum of vibration signal asynchronous component defined as:

- sample mean

$$\bar{F}_{lobe}(t) = \frac{1}{T_{obs}} \int_{t}^{t+T_{obs}} F_{lobe}(t) \cdot dt \,;$$

- sample mean

$$\bar{G}_{aSC}(t) = \frac{1}{T_{obs}} \int_{t}^{t+T_{obs}} G_{aSC}(t) \cdot dt \,.$$

Tolerance window for generic parameters of energy spectrum of vibration signal asynchronous component includes:

- for power – tolerance for power of vibration signal asynchronous component

$$\left| \bar{G}_{aSC}(t) - G_{ref} \right| \le G_{tol} \,;$$

- for frequency - maximum permissible value of spectrum effective bandwidth shift

$$\left| \bar{F}_{lobe}(t) - F_{ref} \right| \le F_{tol} \,.$$

Generic numerical parameter of spectrum of vibration signal asynchronous component applied as indicators of technical state of rotary machine stator element.

Control of spectrum of vibration signal noise component

Tolerance control of vibration signal noise component executed using its current energy spectrum $G_{NC}(f,t)$. Power variance and its distribution in energy spectrum of vibration signal noise component are indicators of variance of noise component energy spectrum. Typical form of spectrum of vibration signal noise component is on fig. 5. Numerical parameters of spectrum of vibration signal noise component defined as:

- power of vibration signal noise component

$$G_{NC}(t) = \int_{F_{NC}^{low}}^{F_{NC}^{high}} G_{NC}(f,t) \cdot df \,;$$

- effective bandwidth of spectrum of vibration signal noise component

$$B_{NC\ eff}(t)=\sqrt{\frac{\int_{-\infty}^{\infty} f^2 G_{NC}(f,t)\cdot df}{G_{NC}(t)}}\,.$$

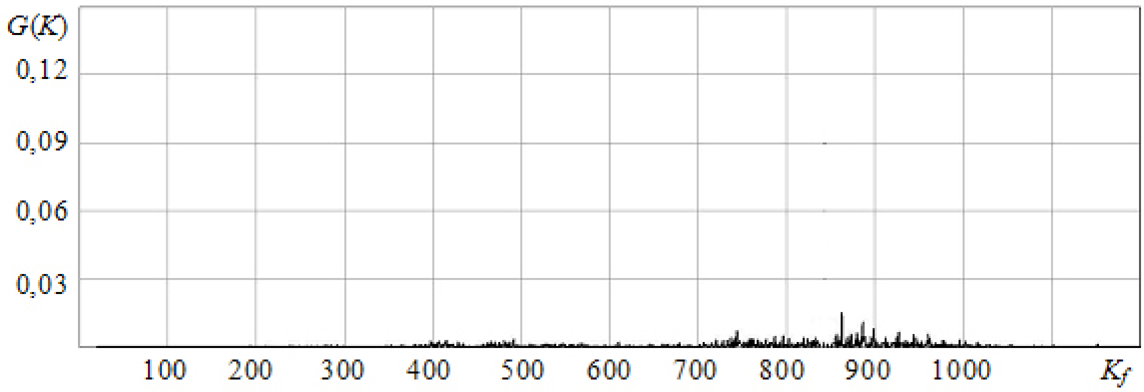


Fig. 5. Spectrum of noise component of rotary machine vibration signal

Generic numerical parameters of spectrum of vibration signal noise component defined as:

– sample mean

$$\bar{G}_{NC}(t)=\frac{1}{T_{obs}}\int_{t}^{t+T_{obs}} G_{NC}(t)\cdot dt\,;$$

– sample mean

$$\bar{B}_{NC\ eff}(t)=\frac{1}{T_{obs}}\int_{t}^{t+T_{obs}} B_{NC\ eff}(t)\cdot dt\,.$$

Tolerance window for generic parameters of energy spectrum of vibration signal noise component includes:

– for power – tolerance for power of vibration signal noise component

$$\left|\bar{G}_{NC}(t)-G_{ref}\right|\le G_{tol}\,;$$

– for frequency – maximum permissible value of spectrum effective bandwidth shift

$$\left|\bar{B}_{NC\ eff}(t)-B_{ref}\right|\le B_{tol}\,.$$

Generic numerical parameters of spectrum of vibration signal noise component applied as indicators of technical state of rotary machine energy element.

Findings

This research shows that while diagnostic estimation of shaft movement asynchronous and noise components of vibration signal acts like restrictions decreasing reliability of measuring information.

Proposed method of separate tolerance control of parameters of vibration signal synchronous, asynchronous and noise components spectrums that enables increasing of measuring information reliability via decreasing of disturbing components.

Generic parameters of distribution of energy spectrum for every component of vibration signal performed. That enables decreasing of number of controlled indicators of technical state of rotary machine.

Application of separate tolerance windows for generic indicators of energy spectrum of vibration signal synchronous, asynchronous and noise components enables to advance usage of informational capabilities of vibration signal. Performance of generic indicators enables algorithmization of process of detecting of changing's in technical state of rotor, stator and energy elements of rotary machine.

Father studies are planned to be directed on statistical synthesis and studying gauge realizing proposed method and algorithm of processing of current spectrum of rotary machine vibration signal.

References

1. *Генкин М. Д., Соколова А. Г.* Виброакустическая диагностика машин и механизмов. – М.: Машиностроение, 1987. - 288 с.
2. *Ольсен У.* Измерение, контроль, диагноз и устранение колебаний машин. – Дармштадт: Карл Шенк АГ, - 71 с.
3. Система для мониторизации состояния машинного оборудования типа 3542. Инструкция по эксплуатации. – Нэрум: Брюль и Къер. – 154 с.
4. Прогрессивные методы и приборы, обеспечивающие снижение расходов по техническому обслуживанию машин. – Дармштадт: Карл Шенк АГ, - 82 с.
5. *Шантырь С., Шантырь А.* Применение методов корреляционного анализа к спектральным характеристикам сигналов для исследования связи их свойств во временной и частотной областях//Техніка і технології АПК, -2009. - №3. – С. 28-30.
6. *Шантырь С., Шантырь А.* Оптимизация длительности реализации при структурном анализе виброизмерительного сигнала роторной машины//IX Міжнародна науково-технічна конференція «Приладобудування 2010: стан і перспективи». Тези доповідей. – К.: НТУУ «КПІ». 27-28 квітня 2010. – С. 245-247.
7. Мониторизация состояния машинного оборудования. – Нэрум: Брюль и Къер. 1991. – 48 с.
8. *Гоноровский И. С.* Радиотехнические цепи и сигналы: Учебник для вузов.-4-е изд., перераб. и доп. – М.: Радио и связь, 1986.-512с.
9. *Левин Б. Р.* Теоретические основы статистической радиотехники. -3-е изд. перераб. и доп. – М.: Радио и связь, 1989. – 656 с.