THE ROLE OF LOCAL CLOCKS IN MACHINE DIAGNOSTICS & MONITORING

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Summary

The paper aims to present & compare the usefulness of local clocks when machine run becomes non-stationary due to variable working cycle. Three methods of time scale conversion called PLL, OT 1and OT2 are discussed in relation to PM demodulation of machine VA signal. Local clocks has been synchronized respectively witch linear approximation of reference cycle trend, instantaneous cycle and carrier cycle. The results seems to confirm quantitatively TSC utility in practice of diagnostic oriented signal processing.. Since involved real PM signal components (carrier $\boldsymbol{y}_C$ and message $\boldsymbol{x}$) are generally unknown, tested procedures has been tested using simulated PM signals.

Keywords: diagnostics, PLD, synchronism, order analysis, PM demodulation.

ROLA ZEGARÓW LOKALNYCH W DIAGNOZOWANIU I MONITOROWANIU MASZYN

Streszczenie

Autor stawia sobie za cel wskazanie użyteczności opisu sygnału drganiowego w skalach czasu synchronizowanych pewną funkcją cyklu roboczego maszyn. Opis zmienności staje się prostszy umożliwiając stosowanie procedur właściwym sygnałom stacjonarnym, tu ważnej w diagnozowaniu demodulacji kąta. Dla synchronizacji zegarów lokalnych wykorzystano: liniowo odcinkową aproksymację cyklu chwilowego, referencyjny cykl chwilowy oraz cykl nośny – ten ostatni niestety w praktyce bezpośrednio niedostępny, stad weryfikacja eksperymentalna eksperymencie symulacyjnym. Wyniki potwierdziły skuteczność synchronizacji funkcja przybliżającą cykl nośny

Słowa kluczowe: diagnostyka, PLD, synchronizm, analiza rzędów, demodulacja.

1. THE NOTION OF LOCAL CLOCK

Time scale in which:

– variability description becomes simpler,
– essential characteristics of informational variability are preserved,

non-informational variability is reduced, could make diagnosing in variable operational conditions more efficient and easy at least in the case of cyclical machine. Furthermore Author refers this idea to the systems in which:

- dynamic influence of the elements (also media) is repetitive
- realisation of the primary objective includes repetition of event sequences;
- the motion is associated with vibroacoustic emission or other emission measurable outside the object.

Local time scales are synchronized with reference event sequences
synchronized with some characteristics $\psi(\Theta)$ of selected kinematics cycle here by:

2. – instantaneous cycle (case of OT1) [7]

Θ_T – short-term linear approximation of Θ growth in observation frame T (case of PLD) [4]

Θ_C – carrier cycle, generally unknown (case of modified OT2) [5,8]

The principle of conversion is presented on Fig. 1 (see also [2,5,8] for more details)

Realization of TSC in the case of spectral analysis and PPM demodulation was arranged according to the diagram on Fig.2

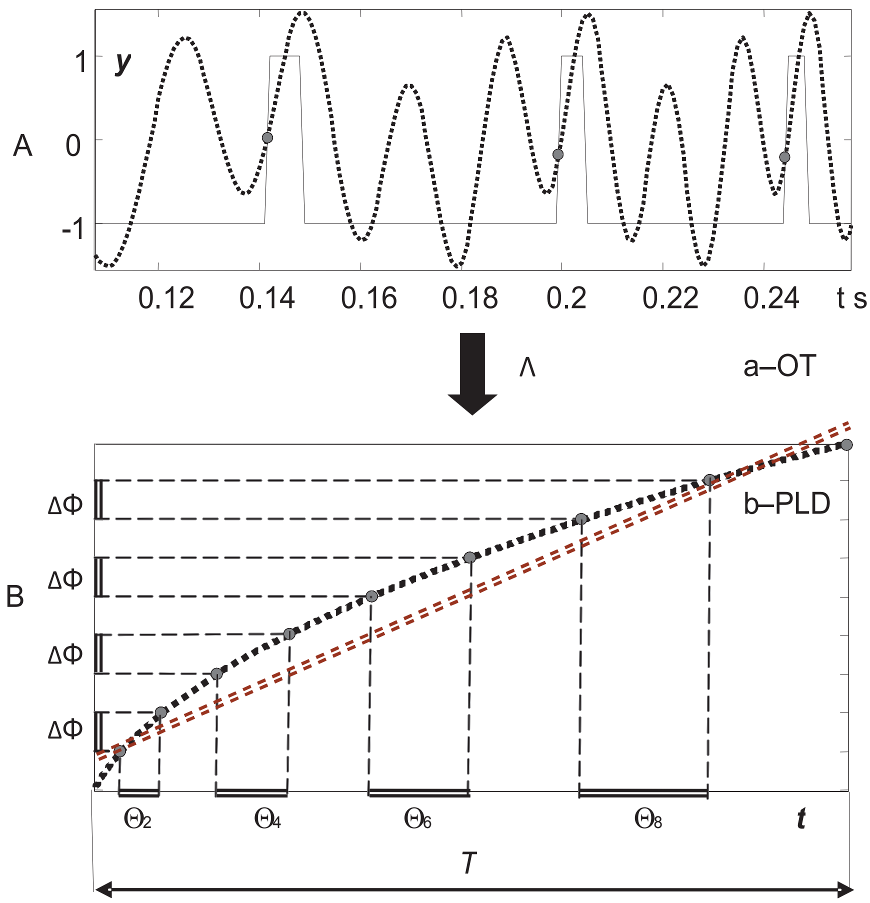

Fig. 1. Principle of time scale conversion TSC –
A) measurement of referential markers
B) TSC curve Λ – local time 'η' versus dynamic time 't'

Order transform OT

Impulses synchronized with Θ enable set of TSC clock markers (Fig. 1A.).

Missing OT_c translation curve since (generally unknown). As a result of TSC (see Fig 1A) using formula [4]:

$$\frac{d\eta}{dt} = \frac{1}{\Psi[\Theta(t)]} \qquad 1)$$

synchronizing cycle should be equalized – That means:

in case of OT – $[\Theta_1,\ldots\Theta_k] \rightarrow [\varphi]_k$, (Fig. 1a.)

In case of OT2 – $[\Theta_{C1},\ldots\Theta_{Ck}] \rightarrow [\Phi_C]_k$

In the above (OT2 synchronization with carrier cycle) Θ_C should replace Θ on axe '*t*'

PLD split instantaneous Λ(Θ) into several line segments S with constant growth rate in each fame which leads to 1[rd] order approximation of Θ change(Fig. 1a.) [5]:

$$\Theta_T(t) = \Theta_{ref}\left(1 + \frac{\Delta_\Theta}{\Theta_{ref}} t\right) \qquad 2)$$

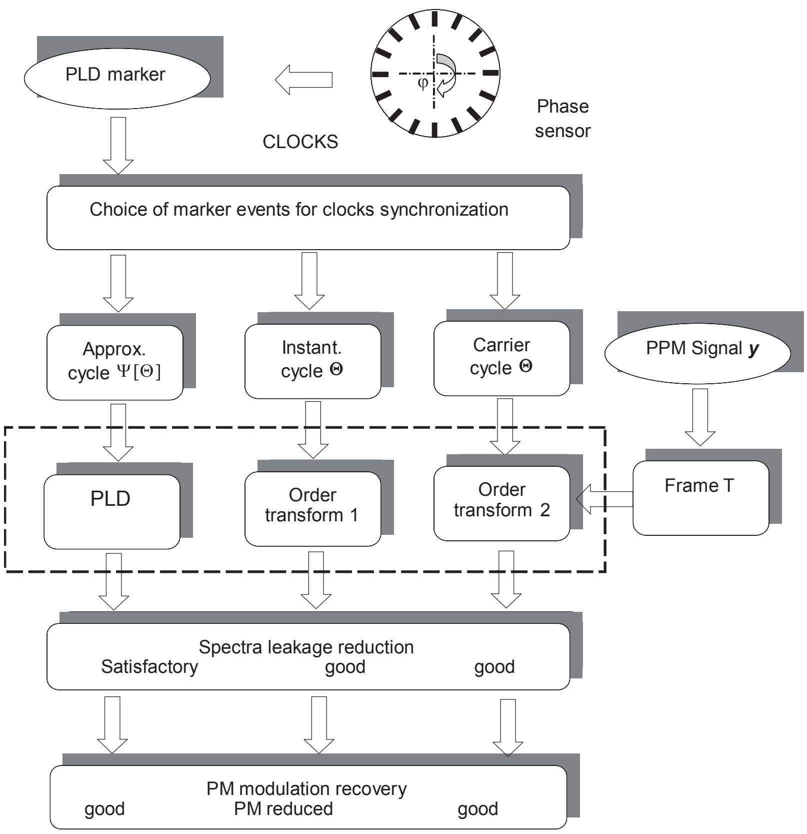

Fig. 2. Synchronization of clocks in relation witch applied TSC procedure:
a) procedure of linear decimation PLD;
b) order transform, standard version OT1;
c) order transform synchronized with carrier cycle OT2

2. TSC AIDED PM DEMODULATION

A number of detailed researches [1, 4, 6] indicate the occurrence of angle modulation and its pulse version PPM as early as in the first stages of damage evolution [6].

However, if the rotational speed, therefore also carrier frequency are not constant, the methods of angle demodulation, created and optimized for carrier signals of a specified form and constant frequency, turn out to be inefficient.

Could PLD/AD or OA/AD? Be helpful ? The matter of TSC has to be an elimination of carrier phase Φ_C nonlinear trend. Thus TSC should be synchronized with carrier cycle Θ_C (see also [4, 5]).

3. SIMULATIONS

To verify how TSC might aid PM demodulation, asynchronic PDP aided or not, was the object of simulation experiment, whose stages are put together in fig. 2, in accordance with (1.a,b,c)

Comparison concerned RMS spectra of PM signals of both dynamic and cycle time, as well as recovered signals spectra in the range of expected importance for diagnostics.(Fig. 5. B). Some of results are presented on Fig. 3, 4 and 5. Leakage of original PM spectra as well as efficiency of PM side-lobes recovery degree are there evident

4. CONCLUSIONS

The results seems to confirm certain conclusions issued from the model of machine signal PM modulation proposed once by author [4], Therefore:

Order transform synchronized by signals with cycle closed to instantaneous cycle reduces PM effect (see Fig 4. A.. b and Fig. 5. A.. b) [3]

Order transform recover well PM spectral side-lobes, but only when synchronized with carrier cycle Θ_C, generally unknown in the case of real machine signal PM(see Fig 4. B.b)

Contrary to the above PLL (see Fig. 3 b)

- does not require the precise carrier cycle approximation;
- does not require complex calculations
- is simple in on-line implementation

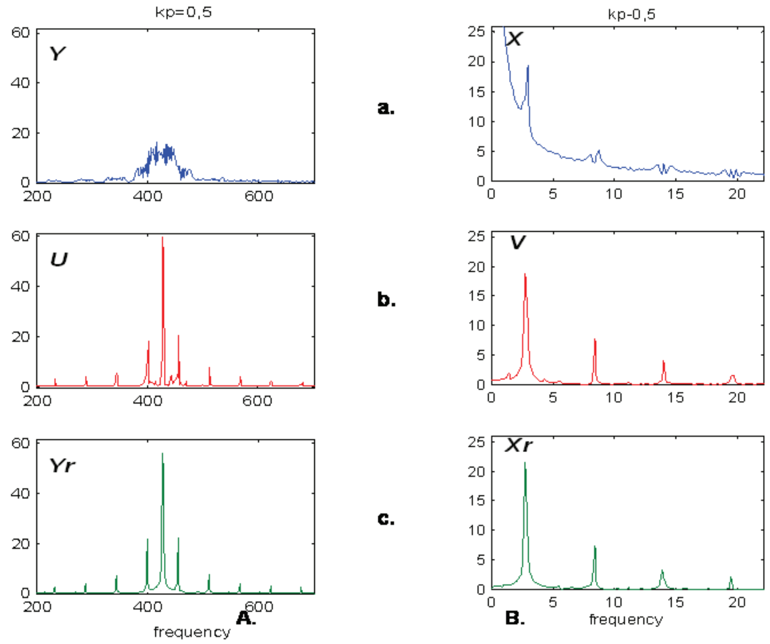

Fig. 3. PLD case, spectra of PM signal (A), and demodulation results (B).
a) real time signal; b) after PLD transform;
c) real time reference signal, constant carrier frequency;

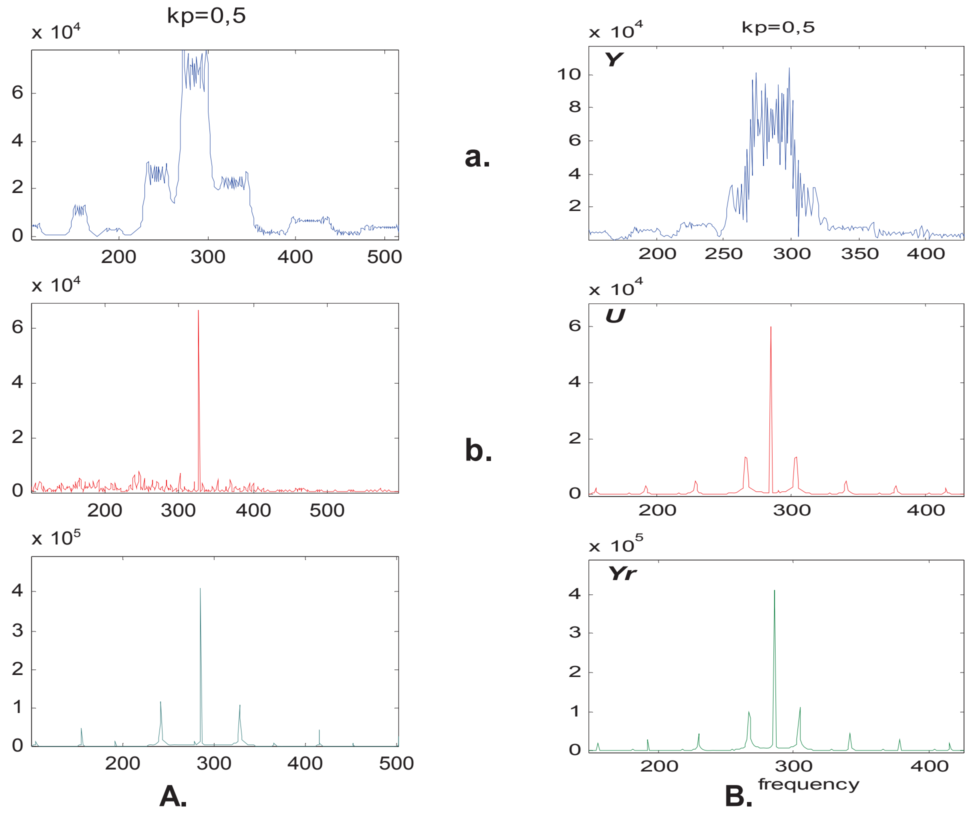

Fig. 4. PLD case, spectra of PM signal, side-lobes represent PM recovery:
A) order transform 1, standard version;
B) order transform 2 synchronized with carrier cycle
a) real time signal
b) after time scale transform
c) real time reference signal, constant carrier frequency

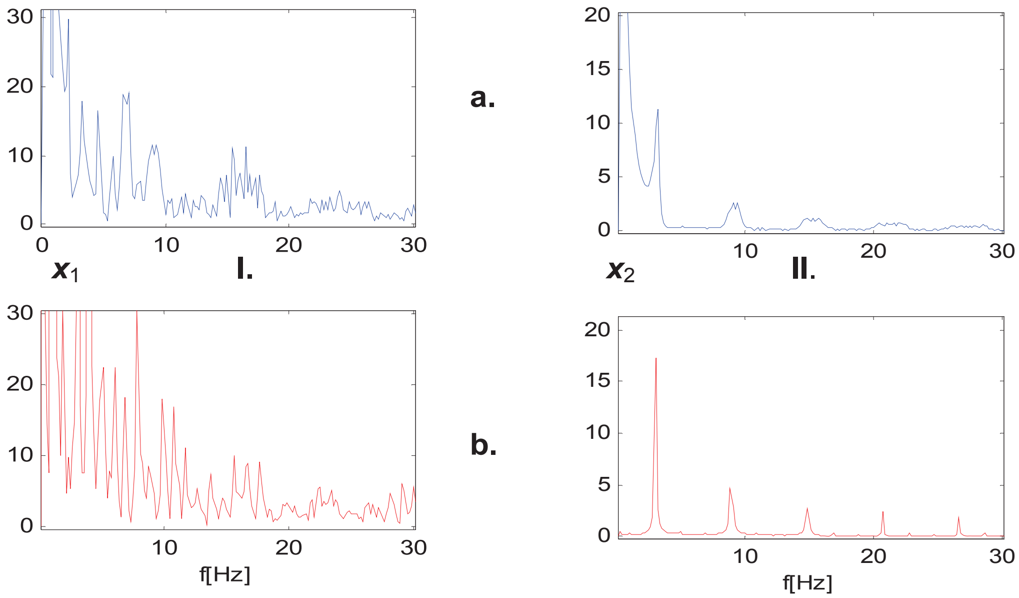

Fig. 5. Spectra of recovered message signal:
I) order transform 1, standard version;
II) order transform 2 synchronized with carrier cycle;
a) real time signal;
b) after time scale transform
real time reference – see Fig.4.c

The best reproduced are the modulations whose cause is synchronized by carrier cycle, unfortunately unknown in real conditions.

6. MAIN SYMBOLS & ABBREVIATIONS

AP – asynchronous procedure
CS – carrier signal
MS – message signal
OT – order transform
OT/AD – OT aided demodulation
PDP – phase demodulation procedure
PLD – procedure of linear decimation
PLD/AD – PLD aided demodulation
PM – phase modulation
TSC – time scale conversion
VSM – vibration signal modulation
$\psi(\Theta)$ – synchronizer of cycle time scale
Θ_C – carrier cycle
Θ_T – linear approx. of Θ growth
Θ – instantaneous cycle
$\boldsymbol{x}_O$ – reference message signal
$\boldsymbol{x}_h$ – recovered message signal
$\boldsymbol{y}$ – modulated vibration signal
$\boldsymbol{y}_C$ – carrier signal

5. REFERENCES

[1]. Cioch W , Krzyworzeka P.: *Modulacje niezamierzone w diagnozowaniu głośnika*. Diagnostyka, vol. 28, 2003, 29 – 36

[2]. Cioch W , Krzyworzeka P.: *PLD aide demodulationof starting vibratios In rotating machinery*. Diagnostyka, vol. 43, 2007, 105 – 110

[3]. Korbiel T.: *Order analysis in the diagnostic of nonstatinary VA process*: Diagnostyka, vol. 43, 2007, p. 99 – 104

[4]. Krzyworzeka P.: *Demodulacja drgań maszyn przy zmianach prędkości obrotowej*. Diagnostyka, vol. 31, 2004, 21 – 28.

[5]. Krzyworzeka P.: *Wspomaganie synchroniczne w diagnozowaniu maszyn*: Kraków-Radom. BPE, Wyd. ITE . 2004

[6]. Radkowski St.: *Wibroakustyczna diagnostyka uszkodzeń niskoenerge-tycznych*: W-wa, Radom, WITE, 2002

[7]. Piotrowski A., Stankiewicz A., Balunowski J., Solbut A.: *Diagnostics symptoms forming in the rotating machine monitoring based on the order tracking analysis*. II International Congress of Technical Diagnostics, Diagnostika'2000, Poland, Warsaw 19-22 September 2000

[8]. Korbiel T., Krzyworzeka P.: *An application of splines In synchronous analysis of nonstationary machine run*. Diagnostyka, vol. 43, 2007, 105 – 110