**Krzysztof ZEMBROWSKI, Łukasz WOJNIŁOWICZ**
Przemysłowy Instytut Maszyn Rolniczych
ul. Starołęcka 31, 60-963 Poznań
e-mail: zembrowski@pimr.poznan.pl

# USE OF AMPLITUDE MEASURES AND THEIR DISCRIMINANTS IN LUBRICANTS COMPARATIVE STUDY FOR CHAIN SAW'S SAWING SYSTEMS

*Summary*

*The article presents analysis of results of lubricants comparative study on SBM-PIMR stand [6]. The tests were aimed to determine an amplitude measure values and their discriminants of the vibration speed signals and torque variations, according to a lubricant used in the test. Analyzes showed that the root amplitude and impulsiveness coefficient are the most important distinctive coefficients of the tested lubricants.*
***Key words**: chain saw, oil, acquisition, data processing, vibratory analysis*

# WYKORZYSTANIE MIAR AMPLITUDOWYCH I ICH DYSKRYMINANT DO BADAŃ PORÓWNAWCZYCH ŚRODKÓW SMARNYCH W UKŁADACH TNĄCYCH PILAREK ŁAŃCUCHOWYCH

*Streszczenie*

*Przedstawiono analizę wyników badań porównawczych środków smarnych na stanowisku do badań porównawczych SBM-PIMR [6]. Badania dotyczyły określenia wartości miar amplitudowych i ich dyskryminant bezwymiarowych sygnałów prędkości drgań i zmian momentu obrotowego, w zależności od zastosowanego środka smarnego. Na podstawie przeprowadzonych analiz wyników określono, że cechami wyróżniającymi są amplituda pierwiastkowa oraz współczynnik impulsowości.*
***Słowa kluczowe**: pilarka, olej, akwizycja, przetwarzanie danych, analiza drganiowa*

## 1. Introduction

In the outcome of conducted lubricants comparative stud, it has been found out that a type of lubricant has essential influence on functioning of the sawing system, therein on its durability [4, 6]. Elements that influence durability of the sawing system, among others, are: lubricant properties, system overload and inappropriate maintenance. The application of vibrational analysis in effect evaluation of applying lubricants has been encompassed in research works [3, 6], in which vibrational analysis method, in diagnostics of the chain saw's driving-sawing system, has been proposed. Utilization of the vibrational signal analysis gave impulse to search for measures beside effective value of vibration speed [1, 2], namely amplitude measures and their dimensionless discriminants for evaluation of lubricity in comparative study [6]. The application, in vibration signal analysis, of new quantities, therein mainly dimensionless discriminants, allowed elimination of negative attributes of amplitude measures i.e. mainly their low sensitivity to changeable work conditions [1] in dependence of applied lubricant. The applied research method also allows to diagnose possible malfunctions of the driving-sawing system and determine its worn out grade. Thereby it can influence lubricants selection for the chain saw's sawing system [5] in process of wood acquiring.

In the article, results of the research has been presented with the use of new methodology, specifically utilization usefulness of additional amplitude measures and their dimensionless discriminants to evaluate biodegradable lubricants by comparison of their lubricity.

## 2. Research method

Out of measured data, gathered on the test stand SBM-PIMR, for lubricants comparative studies, for comparative analysis, following courses of changes have been chosen: torque and vibration speed of the guide. Mount location of torque transducer DATAFLEX 22/20 and manner of laser vibrometer setup POLYTEC 353 has been presented in Fig. 1. Researches have been conducted in one hour work cycle of the test stand SBM-PIMR.

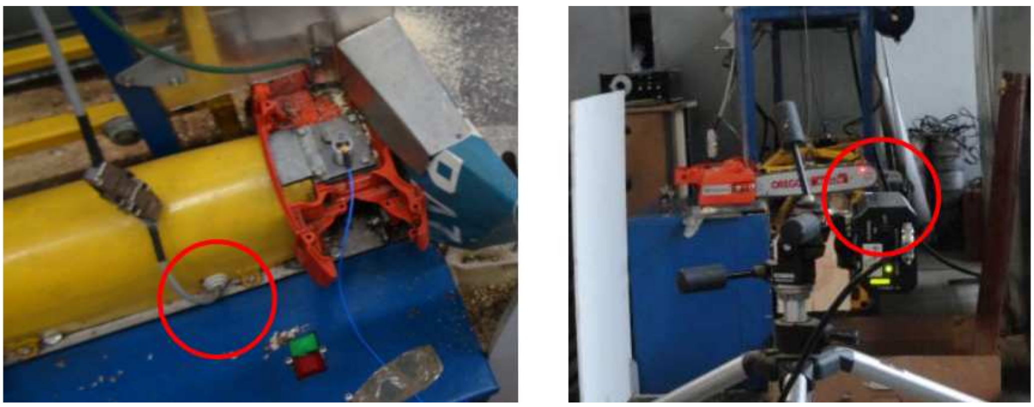

*Fig. 1. View of mounted torque transducer and laser vibrometer*

During the work mode, inverter pDRIVE MX eco4V7,5 maintained rotational speed of the driving motor in accordance to characteristic (Fig. 2) and settings (Table 1). The logging frequency of changes in vibration speed of the guide and changes in torque was 800 Hz [6]. Seven intervals has been determined. Each interval contained 2048 samples, evenly distributed in one hour trial. They served for carrying out calculation and determination of given measures and discriminants.

Calculation has been carried out with National Instruments (NI) software, namely DIAdem. In turn, acquisition and processing of data from trials has been implemented with the use of NI controllers [7].

Trials has been conducted on the test stand SBM-PIMR, in one hour work mode, for three different lubricants, which were designated with letters: "A", "B", "C", with preservation of equal work conditions for each lubricant.

## 3. Analysis results

Frequency analysis of signal encompassed determination of, most frequently used in the vibrational diagnostic, amplitude measures and their discriminants (Table 2) [1].

Below, results of vibrational analysis have been presented i.e. changes in vibration speed of the guide and changes in torque of the drive shaft in dependence of applied lubricant. Most differentiating measures and discriminants have been shown for lubricants under consideration.

The shape coefficient K has been skipped in analysis, because it was too insensitive to state changes in the driving-sawing system [1]. It was assumed that the rest of the measures, embraced in Table 2, are satisfyingly sensitive to determine state changes of the driving-sawing system in dependence of applied lubricant.

In article [1] author, concluding research results, found out that peek values of vibration amplitude have the most influence on momentarily stress and from difference of their peek value and average value was able to evaluate content of impact impulses in the analyzed process.

Taking above into account, in the considered process, for determining lubricant compliance with damping of impact impulses, such measures and discriminants have been determined, which mirror the best the difference in process course in dependence of trialed sample of a lubricant.

Values of different amplitude measures and discriminants of vibration speed, for trialed oils "A", "B" and "C" on the stand SBM-PIMR have been put together in the Fig. 3.

Ratio of maximal to minimal value of amplitude measure of vibration speed of the guide, for trialed lubricants, is the most differentiated by coefficients in that order: root amplitude measure $W_{SQRT}$ = 1,69, effective value amplitude measure $W_{RMS}$ = 1,58 and peek value amplitude measure $W_{PAEK}$ = 1,37.

In turn, for dimensionless discriminants, is differentiated the most by coefficients in that order: impulsiveness coefficient $W_I$ = 9,76, play coefficient $W_L$ = 1,79 and peak coefficient $W_C$ = 1,59.

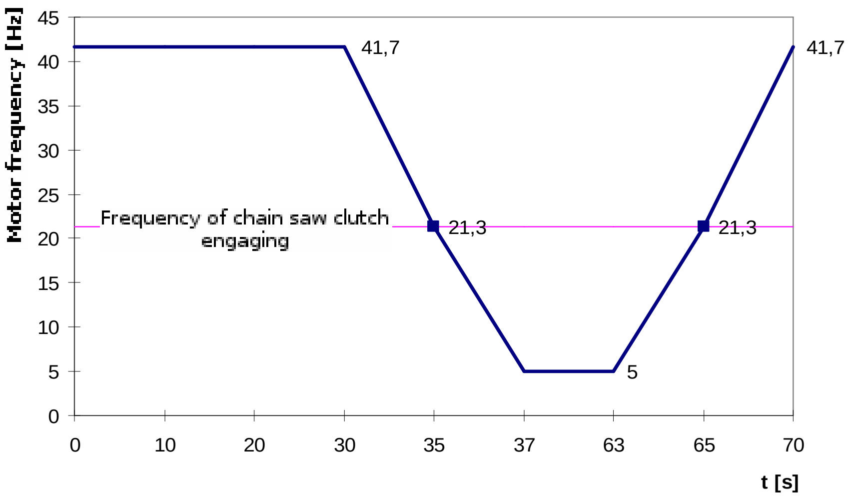


*Fig. 2. Course of one cycle of researched chain saw functioning [6]*

*Table 1. Inverter settings for one hour work mode on the test stand SBM-PIMR [6]*

| Settings of inverter<br>pDRIVE MX eco4V7,5 for hour work mode on test stand SBM-PIMR |
|---|
| <u>I. Settings concerning velocity of sawing chain under research:</u><br>- max rotational speed 8000 rpm,<br>- max angular velocity 837,758 rad·min$^{-1}$,<br>- max linear velocity 22,619 m·min$^{-1}$,<br>- speed of clutch disconnecting - 4086 rpm.<br><u>II. Inverter settings</u>:<br>- 41,7 Hz corresponds to max rotational speed,<br>- 21,3 Hz corresponds to speed of clutch engage (20,85 – 1,3) Hz ie. ca. 4000 rpm<br>- 5,0 Hz corresponds to min rotational speed (light running)<br><u>III. Settings concerning duration of research</u>:<br>- 60 minutes,<br>- full cycle count: 51 |

*Table 2. Amplitude measures and dimensionless discriminants used in the vibration diagnostics*

| **Amplitude measures** | **Definition** |
|---|---|
| Absolute average value [AVER]: | $x_{AVE} = \frac{1}{T}\int_0^T \lvert x(t)\rvert dt$ , |
| Effective value [RMS]: | $x_{RMS} = \sqrt{\left(\frac{1}{T}\int_0^T x^2(t)dt\right)}$ , |
| Positive peek value [PAEK]: | $x_{PEAK+} = \max_{0<t\leq T} x(t)$ , |
| Root amplitude [SQRT]: | $x_p = \left[\frac{1}{T}\int_0^T \lvert x(t)\rvert^{\frac{1}{2}} dt\right]^2$ , |
| **Discriminants** | **Definition** |
| Peak coefficient [C]: | $C = \frac{X_{PEAK}}{x_{RMS}}$ , |
| Impulsiveness coefficient [I]: | $I = \frac{X_{PEAK}}{x_{AVE}}$ , |
| Shape coefficient [K]: | $K = \frac{X_{RMS}}{x_{AVE}}$ , |
| Play coefficient [L]: | $L = \frac{X_{PEAK}}{x_p}$ . |

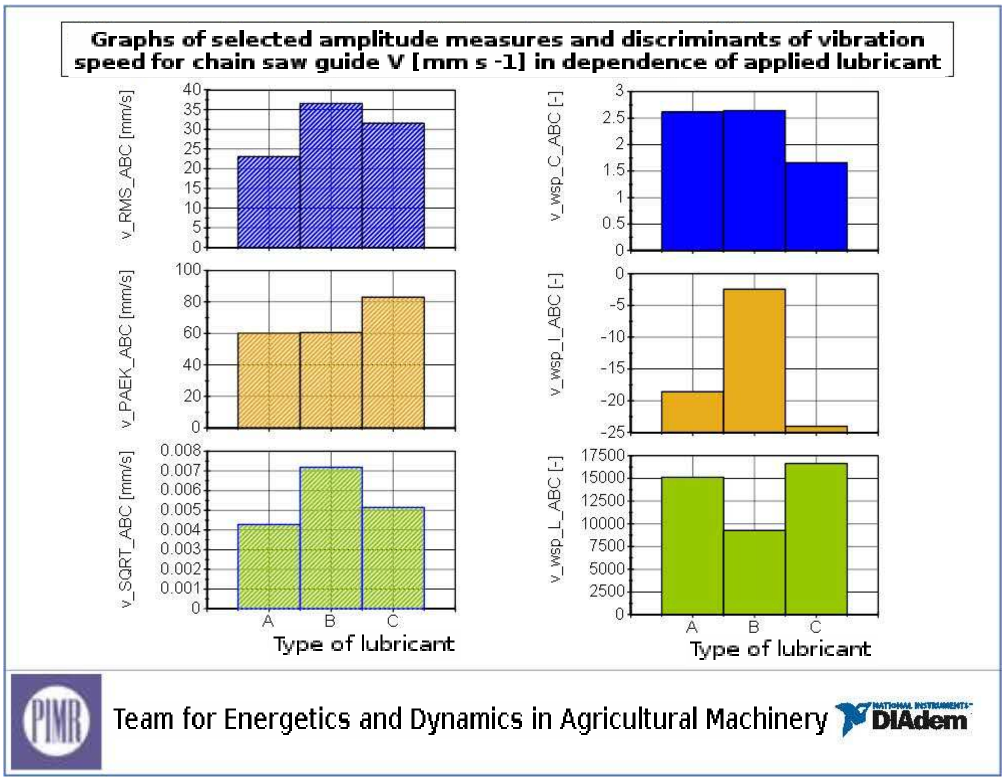


*Fig. 3. Graphs of selected amplitude measures and discriminants of vibration speed for chain saw guide V [mm s $^{-1}$] in dependence of applied lubricant*

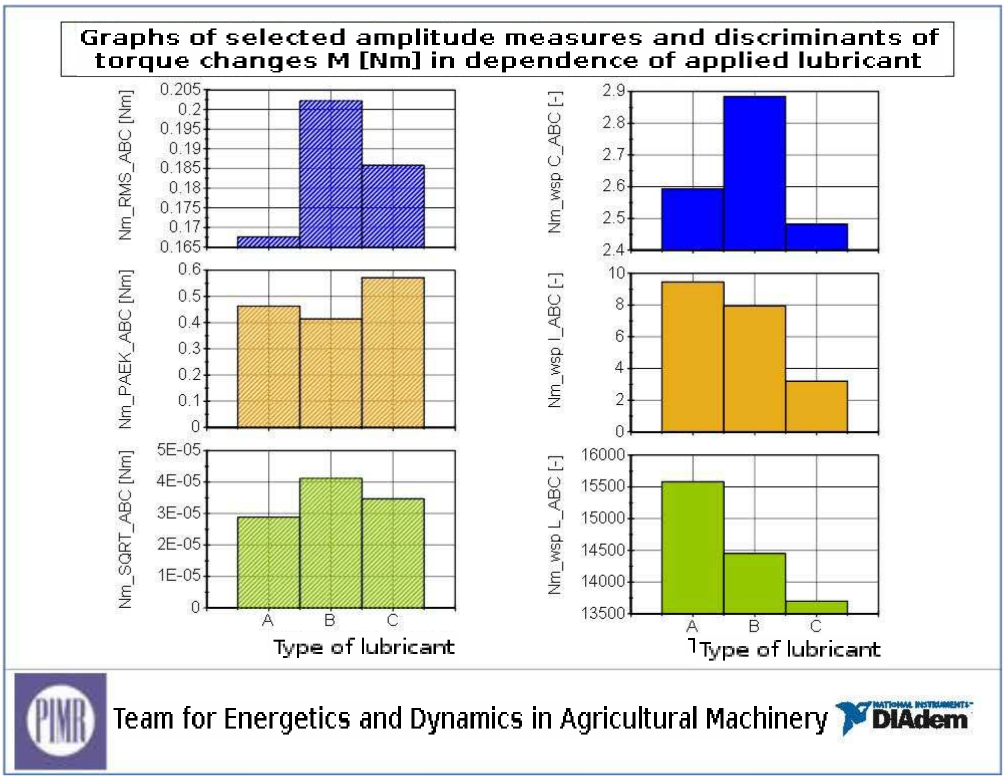


*Fig. 4. Graphs of selected amplitude measures and discriminants of torque changes M [Nm] in dependence of applied lubricant*

In the Fig. 4 different amplitude measures and discriminants of changes in torque, measured by torque transducer DATAFLEX 22/20, for biodegradable oil lubricants "A", "B" and "C", trialed on test stand for comparative study SBM-PIMR [1], have been presented.

For trialed lubricants, a ratio of maximal to minimal value of amplitude measure of torque is differentiated the most by coefficients in that order: root amplitude measure $W_{SQRT}$ = 1,43, peak amplitude measure $W_{PAEK}$ =1,37 and effective value amplitude measure $W_{RMS}$ = 1,21.

In turn, for dimensionless discriminants, are differentiated the most by coefficients in that order: impulsiveness coefficient $W_I$ = 2,95 peak coefficient $W_C$ = 1,16 and play coefficient $W_L$ =1,14.

## 4. Conclusions

Research and analysis based conclusion has been formulated:

- In case of both measured signals - vibration speed of the chain guide and torque changes, the root amplitude (SQRT) and dimensionless impulsiveness coefficient (I) differentiate the best trialed lubricants.
- The root amplitudes, as well as impulsiveness coefficients, showed essential change in value due to different lubricity properties of trialed lubricants.
- In case of the impulsiveness coefficient of vibration speed of the guide, the most difference has been obtained in case of coefficient ($W_I$ = 9,76) – which perfectly characterizes damping properties of trialed lubricants.
- Functioning of the driving-sawing system lubricated with lubricant "A" characterized itself by the lowest vibration level in the driving-sawing system and good properties pertaining to damping of impact impulses, generated by the system.

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