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# TESTING AN INFLUENCE OF THE PISTON MASS AND HEIGHT ON THE VIBRATIONS DYNAMICS IN THE CYLINDER LINER OF AN AGRICULTURAL TRACTOR IN PROECOLOGICAL ASPECT

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**Summary**. The paper presents tests results concerning an influence of size modifications in a piston of a tractor engine on the cylinder liner's vibrations level. The result showed a significant reduction of the liner's linear vibrations level in the range of mechanical activities of the piston. This can have an ecological and exploitation significance for both the staff and the working environment.

**Key words:** size modifications, piston, cylinder liner, vibrations dynamics

## INTRODUCTION

In a tractor's engine the piston with piston rings and cylinder liner is one of the basic systems in which mass and size  for many years have been traditionally adjusted, apart from the new developments in materials engineering [Niewiarowski 1983, Serdecki 1997]. The work of this system significantly affects the vibrations of an engine's body, especially in its transverse plane [Leyko and Sygniewicz 1986, Burski and Tarasińska 2003]. A significant influence on the cooperation dynamics between the p-r-c unit elements is exerted by such factors as: changeable and high temperatures, pressure of the working factor in a cylinder, transverse and vertical piston's movements in a cylinder's liner [Smoczyński and Sygniewicz 2004], lubricating conditions [Iskra 1998] as well as the influence of the tractor's working environment (e.g. dust, etc.)[Burski *et al.* 2003].

The complexity of the problem enforces an assumption of certain simplifying premises in the applied model and simulation research [Leyko and Sygniewicz 1986, Iskra 1998, Burski and Tarasińska 2003]. This concerns particularly an influence of pressure and combustion temperature as well as the combustion process itself, which is of a heterogeneous character.  This factor 'conceals' the mechanical forces (friction, strokes, etc.) of the p-r-c unit elements in the case of the  vibroacoustic diagnostics symptoms use [Burski *et al.* 2003].

An inspiration for experimental research on the system piston-piston rings-liner on a model stand in proecological aspect were the works conducted in the Vehicles Institute of the Lódż University of Technology on the physical and mathematical models of this system's dynamics [Leyko and Sygniewicz 1986, Smoczyński and Sygniewicz 2004], as well as the works concerning a multidirectional detection and selection of VA signals at the Poznań University of Technology [Cempel 1989].

## AIM OF THE PAPER

The aim of the present paper is an attempt at using a model of a piston's transverse movements in a cylinder liner as well as the directional detection of the VA signals in a tractor's engine for an evaluation of an influence of a piston's mass and height on the vibrations in a cylinder liner of a p-r-c unit at the initial (technological) clearance.

## ESSENCE OF THE PROBLEM

The basis for the assumed research methodology was a model of the transverse piston's movements in a cylinder liner worked out in the Vehicles Institute of the Lódz University of Technology (Fig. 1). There were determined four basic positions and four basic movements (rotations) of a piston in a cylinder liner, which were the main source of its mechanical vibrations.

Positions (I) and (II) are equivalent to the diagonal piston's location in a cylinder liner. For each of these positions in the work [Smoczyński and Sygniewicz 2004] there were stated three balance states characterized by an occurrence of one or both normal reactions. Positions (III) and (IV) are equivalent to a piston's adherence to one of a cylinder liner's walls. For each of these positions also three balance states were stated, characterized by the normal reaction's exact location. It was assumed that the movements (rotations) of the piston (V) and (VIII) are possible only in relation to the points equivalent to the tips of the piston's leading part at its both sides. For each of these movements two states were found out, varying as to their rotation's direction (hence varying as to the direction and turn of the rings friction forces).

## METHODS AND CONDITIONS OF RESEARCH

The tests were carried out by the method of experimental simulation on a model stand in which a single t-p-c system of a crankshaft unit in a S-4002/3 engine was driven by an electric engine. The research stand as well as the applied measuring equipment type SVAN 912 AE of the SVANTEK firm were described in detail in the items [Burski *et al.* 2003, Burski and Tarasińska 2003].

The basic research conditions of the p-r-c unit at the technological (initial) clearance concerning the present paper are presented in Table 1.

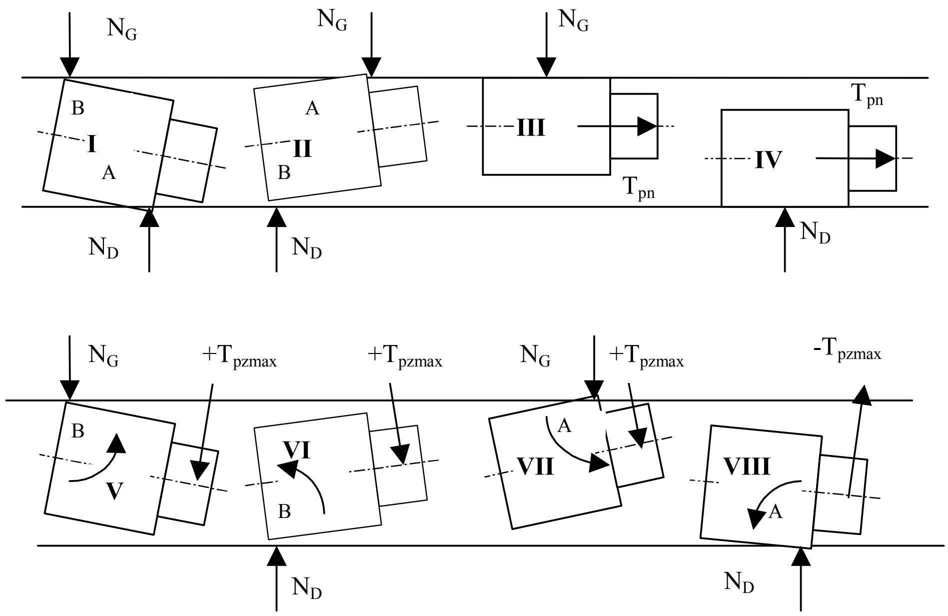


Fig. 1. Positions and movements of the piston in a cylinder liner for the assumed research conditions (after [Smoczyński and Sygniewicz 2004]). $N_D$, $N_G$ – normal reactions of a cylinder liner, $T_{pn}$, $T_{pz}$ – friction forces rings-cylinder liner and rings-piston's grooves

Table.1 The basic research conditions of the p-r-c unit at the technological clearance

| Specification | The piston modifications | | | | | | |
|---|---|---|---|---|---|---|---|
| | Chamber | 0 | 1c | 2c | 3c | 4c | 5c |
| Compression pressure (ps) [MPa] | I | 0.309 | 0.285 | 0.282 | 0.282 | 0.150 | 0.145 |
| | II | 0.145 | 0.135 | 0.106 | 0.106 | 0.096 | 0.096 |
| rotational speed of a shaft (n)[r/min] | I | 445 | 445 | 445 | 445 | 450 | 450 |
| | II | 445 | 450 | 450 | 450 | 450 | 455 |
| Coefficient of piston's modification $\gamma_{M/L}$ [g/mm] | | 9.4 | 9.6 | 9.8 | 9.9 | 10 | 10.1 |

In the applied research methodology the conclusions were taken into consideration resulting from the theoretical bases of the model of a piston's transverse movements pointing at the main direction of the generated vibrations and reactions of a cylinder liner (Fig. 1), as well as from the theoretical bases of the directional localization and selection of the VA signal of a piston's strokes at a cylinder's wall (Fig. 2, 3).

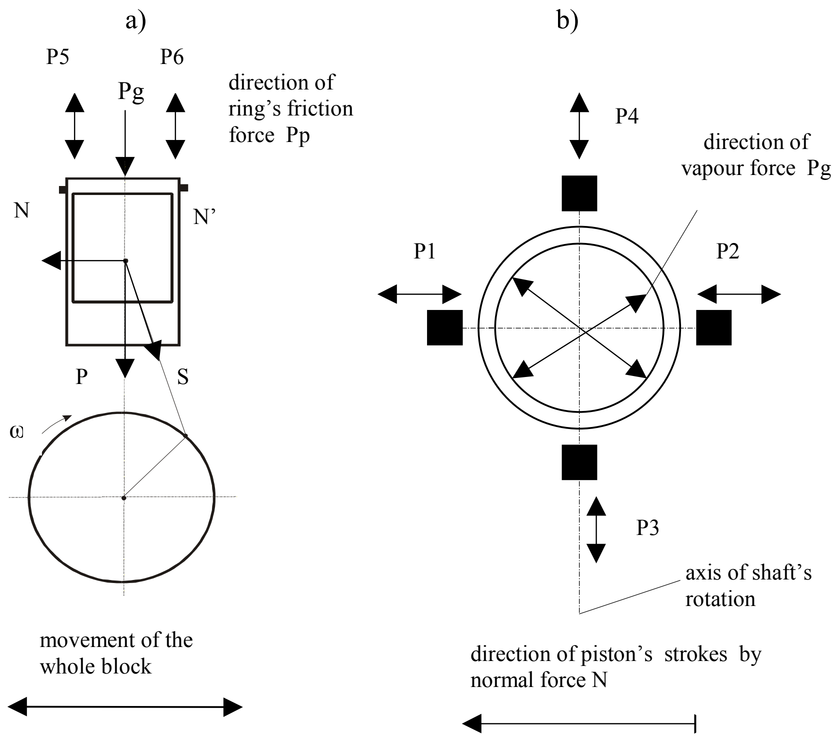


Fig. 2. Localization for vibrations measurements of a cylinder liner (a) and the model for acting of basic forces in unit p-r-c (b)

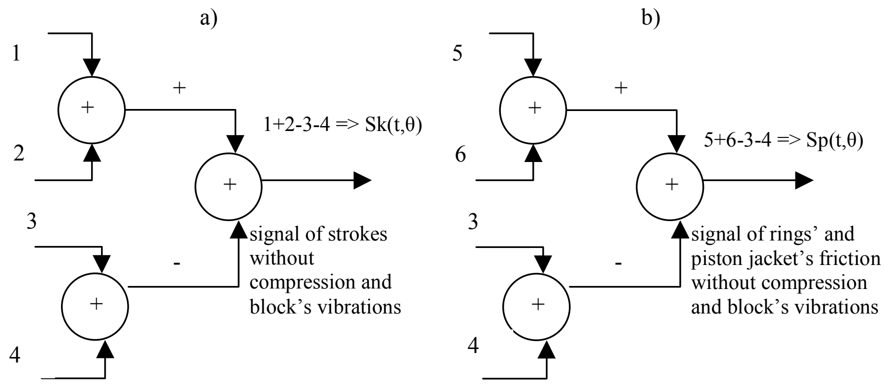


Fig. 3. The use of directional selection of the vibrations of a cylinder liner for the signal strokes (a) and rings and piston jacket's friction (b)

According to the accepted methodology and research conditions (Tab.1), four cuts were made (1c, 2c, 3c, 5c) on the length of the piston's leading part under the pivot and one cut (4c) above the pivot, ordered respectively to the symbols (1c – 5c). Consequently, there were achieved:

– change of the piston's jacket surface,
– change of the piston's rotational angle in the cylinder liner and a possibility to assess the influence
– the piston's gravitational forces,
– the piston's inertia forces, resulting from its transverse movements.

Besides, the application of experimental compression chambers (I and II) enabled to determine an influence of the vapour force on the strength of the liner's reaction to the strokes and on the friction of rings and the piston's jacket. The obtained tests results were compared to the working conditions of the conventional system (item O, Tab. 1)

## RESULTS OF TESTS

An influence of the consecutive piston's modifications on its height (L) and mass (M) was presented as the coefficient $\gamma_{M/L}$ (Table 1) and as the linear vibrations level (LIN) for the particular points and measurement planes in Fig. 4, 5 and 6.

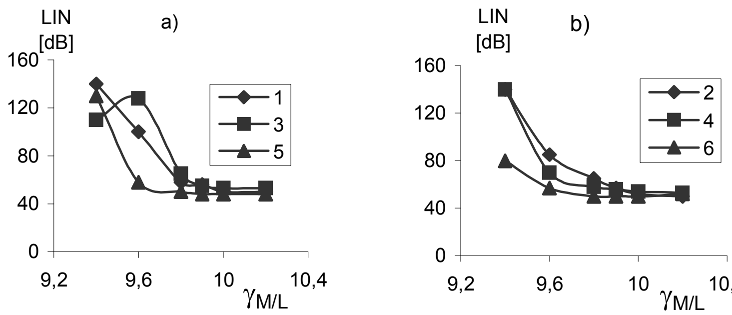


Fig. 4. The change of the linear vibrations level as a function of piston's modifications coefficient $\gamma_{M/L}$ in conditions of acting force $P_b$ (ps = 0). The measurement points 1-6 described in Fig. 2.

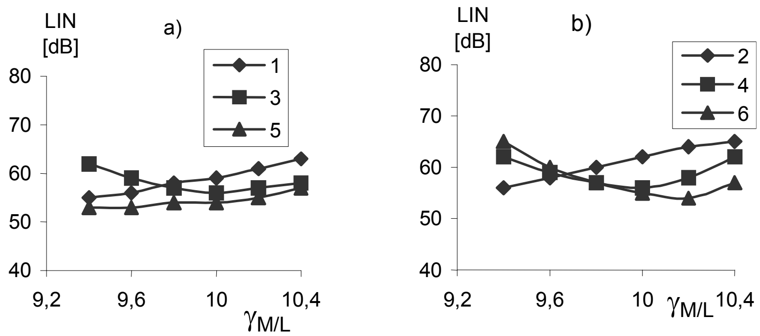


Fig. 5. The change of the cylinder liner's linear vibrations level as a function of modifications coefficient $\gamma_{M/L}$ in conditions of acting force Pmax (Pb+Pg); chamber I. The measurement points 1-6 described in Fig.2

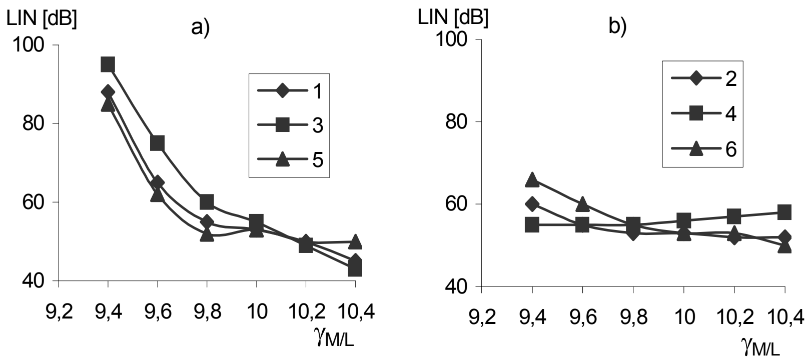


Fig. 6 The change of the cylinder liner's linear vibrations level as a function of the piston's modifications coefficient $\gamma_{M/L}$ in conditions of acting force Pmax (Pb+Pg); chamber II; measurement points 1-6 described in Fig. 2

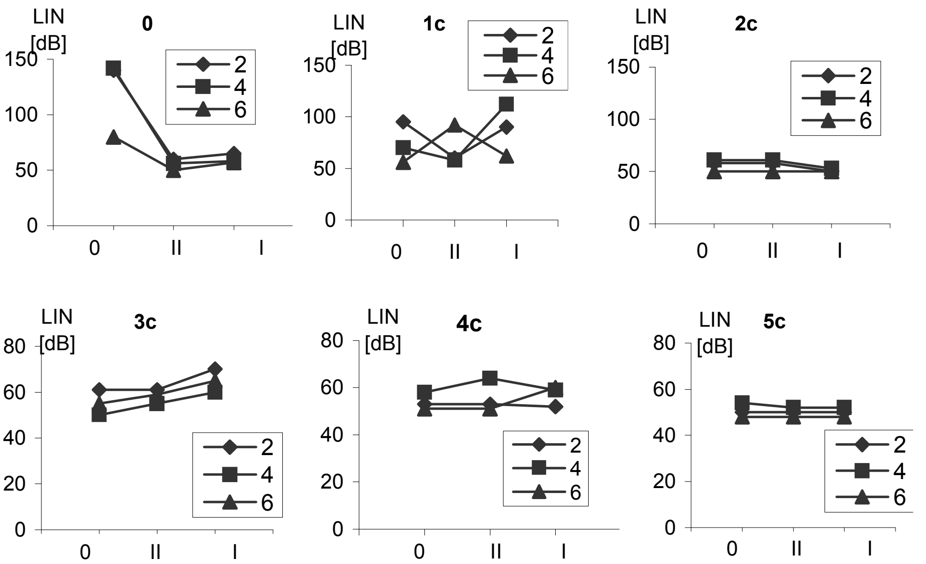


Fig.7 The influence of experimental compression chambers (I and II) on linear vibrations level c
cylinder liner; 0-5c -research conditions (piston's cuts); 2,4,6- measurement points described in

They point at a clear direction of the LIN values change. The influence of the vapour force on the linear vibrations level (LIN) of the cylinder liner, related to the use of experimental compression chambers (I and II) was presented in Fig. 7 and Fig. 8. From the coefficient's value $\gamma_{M/L}$ = 9.8 (2c), no significant influence of the compression pressure (ps) was found on the cylinder liner's vibrations intensity in the analyzed measurement planes.

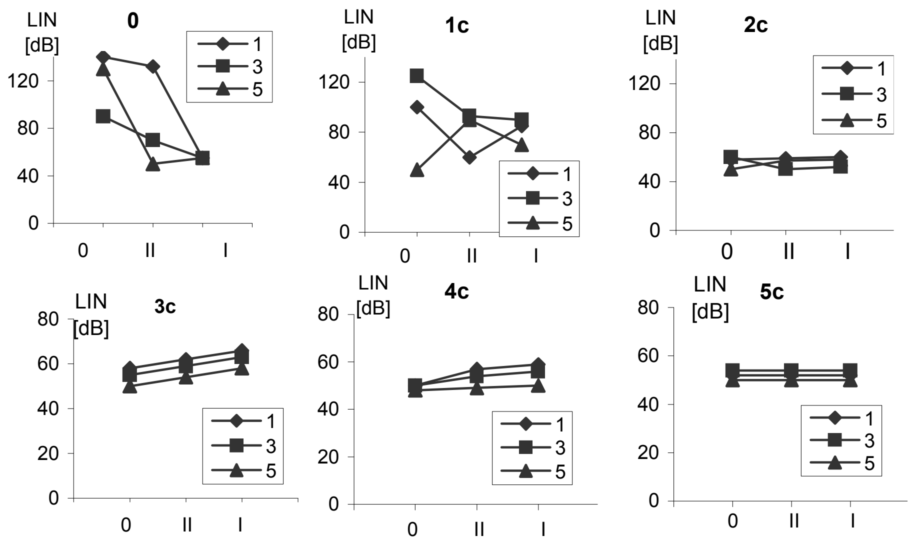


Fig. 8. The influence of experimental compression chambers (I and II) on the linear vibrations level of a cylinder liner; 0-5c – research conditions (piston's cuts); 1, 3, 5 – measurement points described in Fig. 2

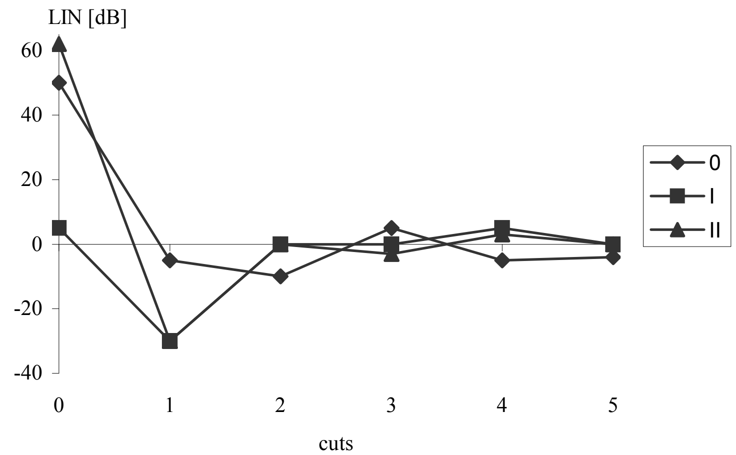


Fig. 9. The share of piston's mechanical strokes (+) and vapour force (-) for consecutive cuts; I and II – compression chambers, 0 – without compression

Results of calculations of the cylinder liner's reaction to the piston's strokes and friction under the action of the normal force N, in relation to the action of the vapour force Tg, by the method of directional selection of the vibrations plane (transverse and longitudinal) are presented in Fig. 9 and Fig. 10. Independently from the assumed coordinates, a change of the coefficient $\gamma_{M/L}$ ( in the conditions of air suction and compression processes going on) leads to the state of their balancing. This means a reduction in a liner's reaction to the mechanical activity of a piston, due to the introduced modifications.

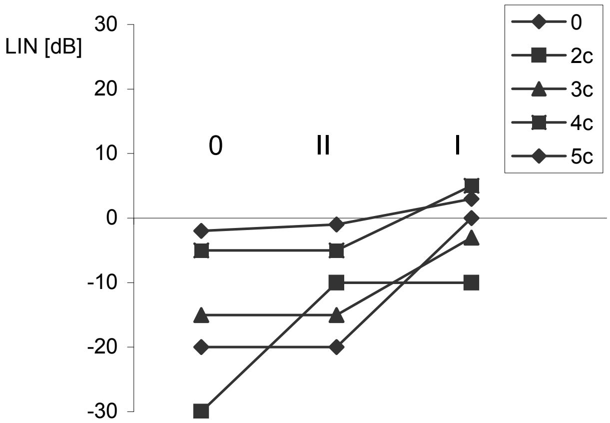


Fig. 10. The share of piston rings' and jacket's friction signal (+) and vapour force (-) as a function of chambers' compression pressure (I and II) and ps = 0 in conditions of consecutive modifications (2c-5c)

## CONCLUSION

The conducted research on a cylinder liner's reaction in a tractor engine were carried out in the conditions of the tribological processes happening during air suction and compression strokes. In both the working processes the occurring movements and rotations of the piston happen twice and last relatively long. Thus, the accompanying forces and moments, both the vapour and mass ones, exert a much lower influence than e.g. at the working stroke. Also, the layer of lubricating oil becomes more significant, separating the piston's surface from the cylinder's wall.

The applied modification of the piston's size and mass, already after the second shortening of its height and reduction in mass ($\gamma M/L = 9.8$), does not show any significant changes in the intensity of the cylinder liner's vibrations , despite the growth in its rotational and movement angle value. As expected, only for the conventional system and for the first applied experimental compression chamber , the direction of the changes is clear. A greater influence is in this case exerted by mechanical strokes and the piston jacket's friction in the transverse vibrations plane ( from the N force) than by the action of the vapour force Tg in a longitudinal plane.

The application of higher pressure to the compression chambers should, during further research, confirm the positive influence of the LIN changes in the exploitation-ecological aspect, as well as determine the scale of their occurrence.

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