

IMPROVEMENTS OF WOOD MILLING MACHINES

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Abstract:

The paper presents a serie of experimental researches performed in order to improve the construction of a vertical spindle moulder MNF10. The experiments involved determinations of the vibrations of different sub-assemblies with important role in obtaining a proper processing accuracy: machine-table, fence-bars, working shaft. The measurements showed that the changes made to the machine really reduced the vibration amplitude of the machine subassemblies. The results lead to some important conclusions for the industrial practice of wood processing, as well as for wood machines builders.

Key words: milling machines; vibrations; improvement.

INTRODUCTION

Obtaining quality surfaces is the aim of any wood processing operation, including the milling of wood. This is usually the penultimate or even the final operation within the technology of mechanical wood processing. For this reason, the quality of the final surface has to ensure all the design requirements.

The surface quality obtained by rotary milling is determined by the specific kinematic undulations and the vibrations generated in the Machine-Tool-Wood Piece (Radu & Curtu 1981). It is known also that these vibrations have a negative influence on the surface quality during cylindrical (Chivens et al. 1975, Effner 1992). Vibrations of the whole elastic Machine-Tool-Wood Piece system always accompany the milling of wood.

The machine-tools vibrations are due to imperfections in the design, fabrication, assembling, defects occurred during exploitation and the working process itself, which is a vibration generator. The main causes, which generate vibrations, forced ones, as well as self-induced ones, during the cutting process are:

- disequilibrium of rotating parts;
- inadequate assembling (wrong alignments, weak mechanical joints);
- bearing defects (wear, inadequate assembling etc.);
- drive defects;
- the cutting process (self-induced vibrations);
- anisotropy of wood;
- vibrations produced by other machines and transmitted through the foundation.

Several authors have previously studied the influence of the vibrations on the machining accuracy. Most have avoided the pure theoretical approach, which is very difficult and leads only to approximate results, and have focused on experimental studies.

For example, Vitchev et al. (2020) studied the influence of several factors on the vibrations of the working shaft of a vertical milling machine and observed higher vibration velocity at the upper bearing housing of the main shaft of the machine, and they are less intense in certain ranges of cutting speed, feed rate and working depth.

Melekhov et al. (2018) investigated the influence of some parameters of woodcutting tools on the vibration degree and obtained surface roughness. They determined that there is a steady relationship between the vibration level and surface roughness. Such parameters as cutting edge inclination, teeth number, chip holding grooves at the tool edges lessen the processing vibration and enhance the surface quality.

Cherepanov et al. (2015) investigated the dependence of vibration level of a tool and surface roughness on the cutting conditions, the number of cutter teeth, timber species and feed direction with respect to the fibers. The experiments showed that with increase of spindle speed and the cutting depth the vibration level increased. The analysis of vibrational spectra showed that the spectrum was dominated by harmonics of spindle rotation frequency and frequency of teeth incision.

Jackson et al. (2007) established that the primary cause of surface waviness defects in rotary milling is forced vibration.

Szwajka and Górski (2006) use the monitoring of vibrations generated by the tool in the machining process to determine the degree of wear and the moment when this tool needs to be replaced. Gasparetto et al. (1999) studied a phenomenon of self-excited vibrations that was observed in a wood cutting machine during milling with a negative influence on the quality of the obtained surface.

Therefore, in order to obtain high quality surfaces, it is very important that the vibrations of the milling machines (but not only) be as low as possible.

In this context, a careful analysis from the constructive point of view of the MNF10 type vertical axis wood milling machines, reveals a series of “details” that can be improved:

- the structure of the cutting mechanism comprises a wide belt transmission that additionally stress the main shaft at bending and generates vibrations and noise;
- the working shaft subassembly is insufficiently rigid due to the support on only two ball bearings;
- the working shaft itself is insufficiently rigid, especially the milling cutter mandrel;
- the system for fixing the tool on the working shaft - cylindrical shaft and hole (mandrel and bore in the cutter body), adjustment with clearance fit - is a system that introduces errors of centering of the tool, and leads to the generation of vibrations.

SOLUTIONS AND PRACTICAL IMPLEMENTATION

Following the above considerations, for the constructive improvement of the MNF10 milling machine, the subassembly of the cutting mechanism was redesigned, namely:

- additional bearing of the working shaft: the radial upper bearing has been replaced with two radial-axial bearings of high precision, with “O” mounting, with the possibility of compensation the clearances and pre-loading;
- partial unloading of the working shaft by bending moments due to the wide belt drive; the wide belt drive has been replaced with a V-belt;
- the use of a system for mounting the tool on the working shaft to allow the elimination of the clearances.

Thus, the structure of the cutting mechanism, in the classic version, shows according to Fig. 1a, and in the modified version according to Fig. 1b. The subassembly of the working shaft in the usual version is presented in Fig. 2a, and in the improved version in Fig. 2b.

The elimination of the clearances when mounting the cutters on the cutter-holder mandrel was achieved by using a conical mandrel and an elastic bush as an intermediate element (see Fig. 3).

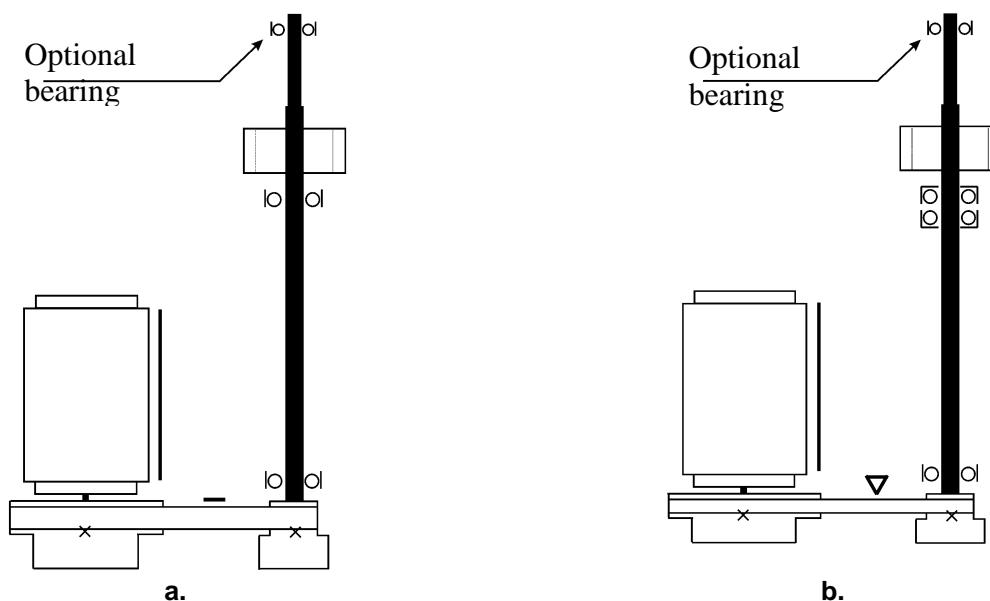


Fig. 1.

**The structure of the MNF10 milling machine cutting mechanism:
a. the classic variant; b. the modified version.**





Fig. 2.
The working shaft of the MNF10 milling machine:
a. the classic variant, before the modification; b. the improved variant, after the modification.



Fig. 3.
Tool clamping system with conical mandrel for the MNF10 milling machine.

ORGANIZATION AND CONDUCT OF EXPERIMENTS

The performed experiments aimed at verifying the technical solutions put into practice. Thus, determinations of the vibrations of the different subassemblies of the machine with important role in obtaining a corresponding processing precision were made: the machine table, the guide rails, the working shaft.

Methodology and equipment

The experiments were performed both on an ordinary construction machine (MNF10) and on the same machine modified according to those shown above. Measurements of the vibration amplitude were made for: the working shaft (perpendicular and parallel to the feed movement), the front and rear guide rails (perpendicular to the feed movement) and for the machine table (vertical direction). The positioning of the piezoelectric sensors is shown in Fig. 4.

The measurements were performed both in idle mode and under load, for different cutting regimes. Beech wood with a humidity of 10% was processed.



Fig. 4.
Piezoelectric sensors
(accelerometers type KD35)
for measuring the amplitude of
vibrations.

The used cutting regimes had the following parameters:

- tool diameter, $D_s = 80$ mm;
- number of cutting edges, $z = 4$;
- working shaft rotating speed, $n_{arb.} = 3282, 4810, 6557, 9604$ rpm.;
- cutting depth, $h = 1, 2, 4, 8$ mm;
- cutting width, $b = 40$ mm;
- feed speed, $u = 4, 6, 8, 12$ m/min;
- the beech specimens dimensions: 400 x 40 x 40mm.

The measurements were performed using a National Instruments DAQ system, the block diagram of the experimental installation being presented in Fig. 5. The software used was the LabVIEW package.

The vibration amplitude measurement was done on 5 channels simultaneously, for all 5 points taken into account:

1. working shaft - in the direction perpendicular to the feed movement (channel 0);
2. working shaft - in the direction parallel to the feed movement (channel 1);
3. anterior guide ruler - in a direction perpendicular to the feed movement (channel 2);
4. rear guide ruler - in a direction perpendicular to the feed movement (channel 3);
5. machine table - in the vertical direction (channel 4).

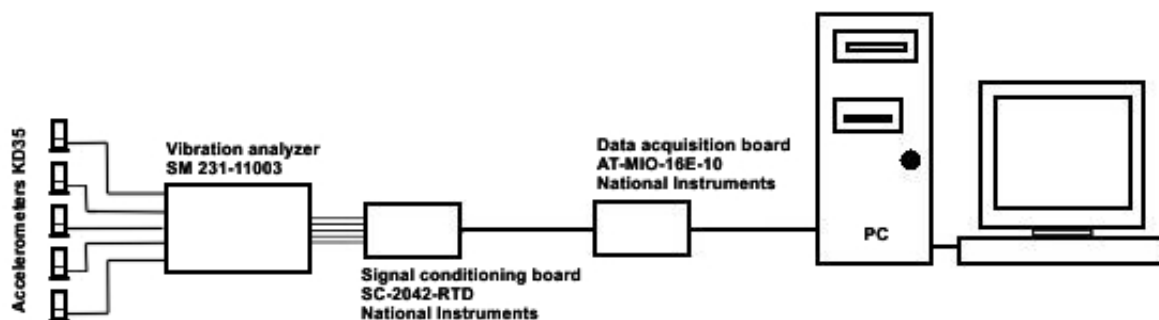
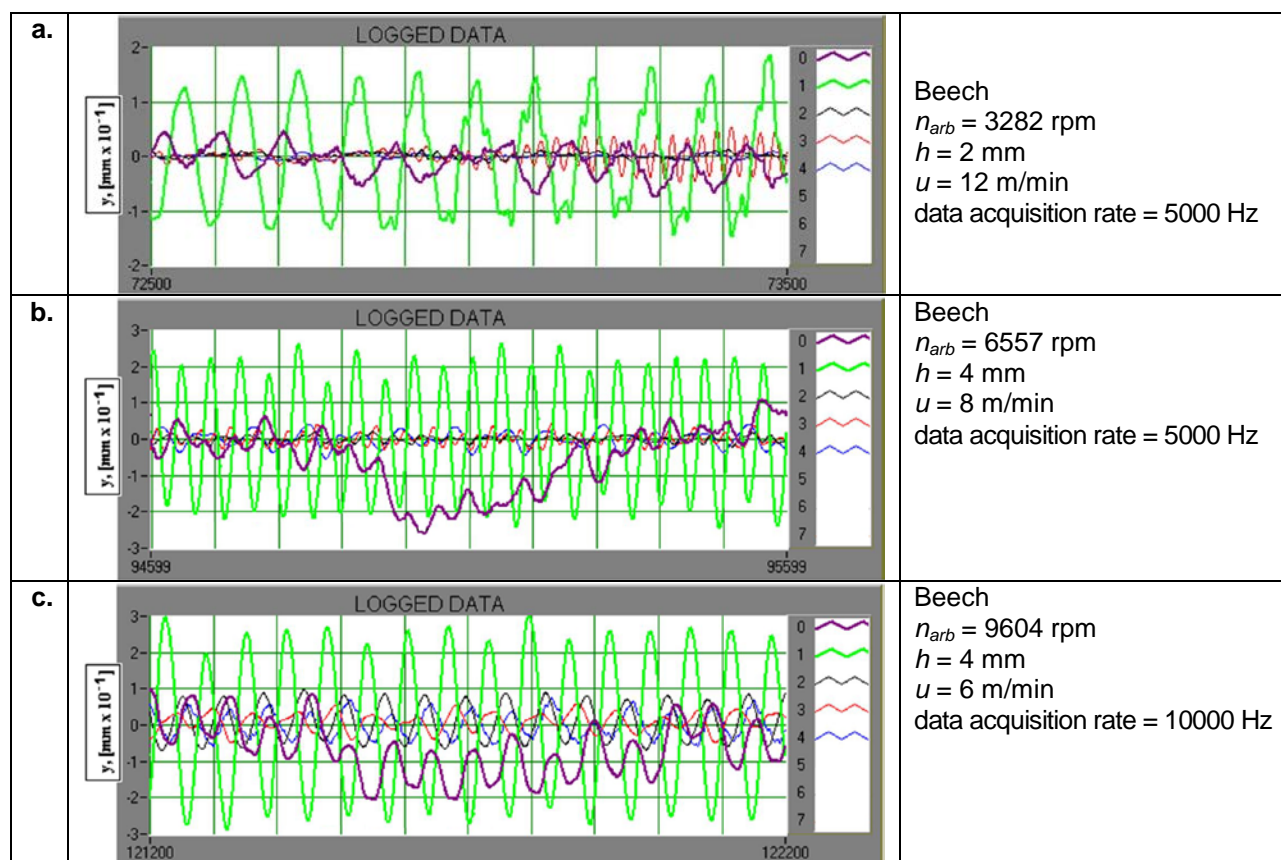


Fig. 5.
Block diagram of the experimental installation for measuring vibrations.

Data acquisition, processing and analysis of the obtained results

The LabView software package, which specializes in data acquisition and primary processing, was used. The final data processing was performed using the Microsoft Excel program under Windows.

A part of the diagrams obtained from the experiments are presented in Fig. 6, and a part of the diagrams regarding the variation of the machine vibration amplitude in the considered 5 points is represented in Fig. 7.



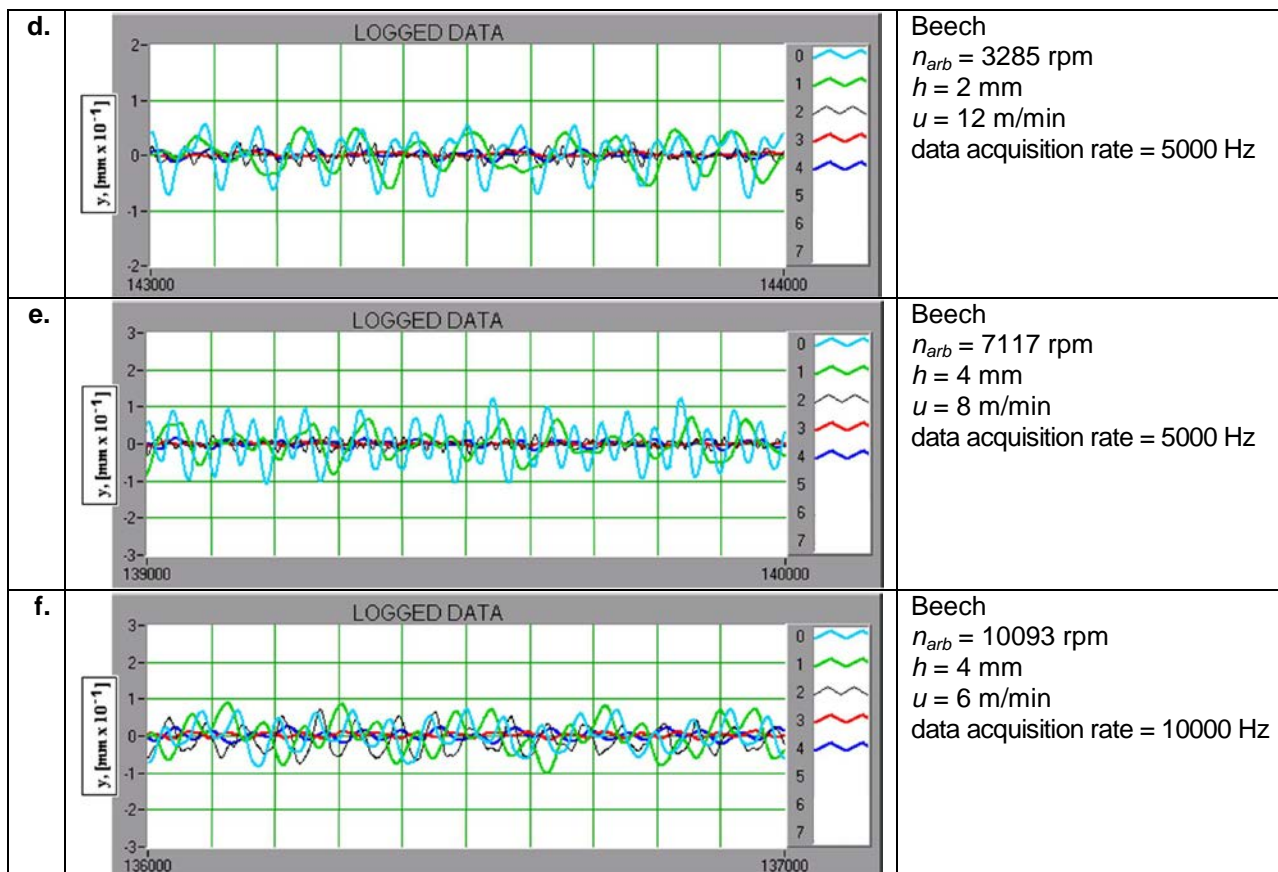


Fig. 6.

Diagrams of the measured vibrations when processing beech wood on the MNF10 milling machine: a, b, c - in the classic constructive variant; d, e, f - in the modified constructive variant.

CONCLUSIONS

Following the analysis of the obtained results, the following conclusions could be formulated:

- the highest amplitude has the vibrations of the working shaft (measured at the upper end) in a direction parallel to the feed movement, followed by those of the same organ, but in a direction perpendicular to the feed movement, then those of the guide bars and of the machine table;
- the forces generated by the cutting process have a relatively small influence on the amplitude of the measured vibrations; a more important influence is exerted, however, in the moments immediately following the one in which the actual cutting begins (respectively in which the first cutting edge comes into contact with the wooden part) when the amplitude of vibrations increases suddenly, returning to normal after a short time, the elastic system Machine - Tool - Wooden Part regaining its state of equilibrium after the appearance of a disturbing element; this is the explanation of a phenomenon quite common in milling, namely the large unevenness of the milled surfaces on the first processed centimeters;
- the main cause of vibrations are mass imbalances (mainly those of the tools) followed by the incorrect centering of some subassemblies (the milling cutter mandrel and the upper support bearing) as well as the use of the wide belt transmission (due to the joint area and on-wheel instability);
- the most "sensitive" element of the Machine - Tool - Wooden Part system is the working shaft (see channels 0 and 1 on the diagrams in Fig. 6).

After modifying the machine, the performed measurements - respecting the same working conditions - showed the following (see the diagrams in Fig. 6):

- the amplitude of the main shaft vibrations measured at the upper end (channels 0 and 1 in Fig. 6) decreased two to three times depending on its rotating speed, less at low speeds and more at high speeds. This is normal if we take into account that the shaft works in the self-centering zone and with the increase of the speed a removal from the critical speed is achieved;
- the amplitude of the vibrations of the other considered organs (guide rails and machine table - channels 2, 3 and 4 in Fig. 6) also decreased, but to a lesser extent, which is understandable if we take into account that on them were not made constructive modifications.

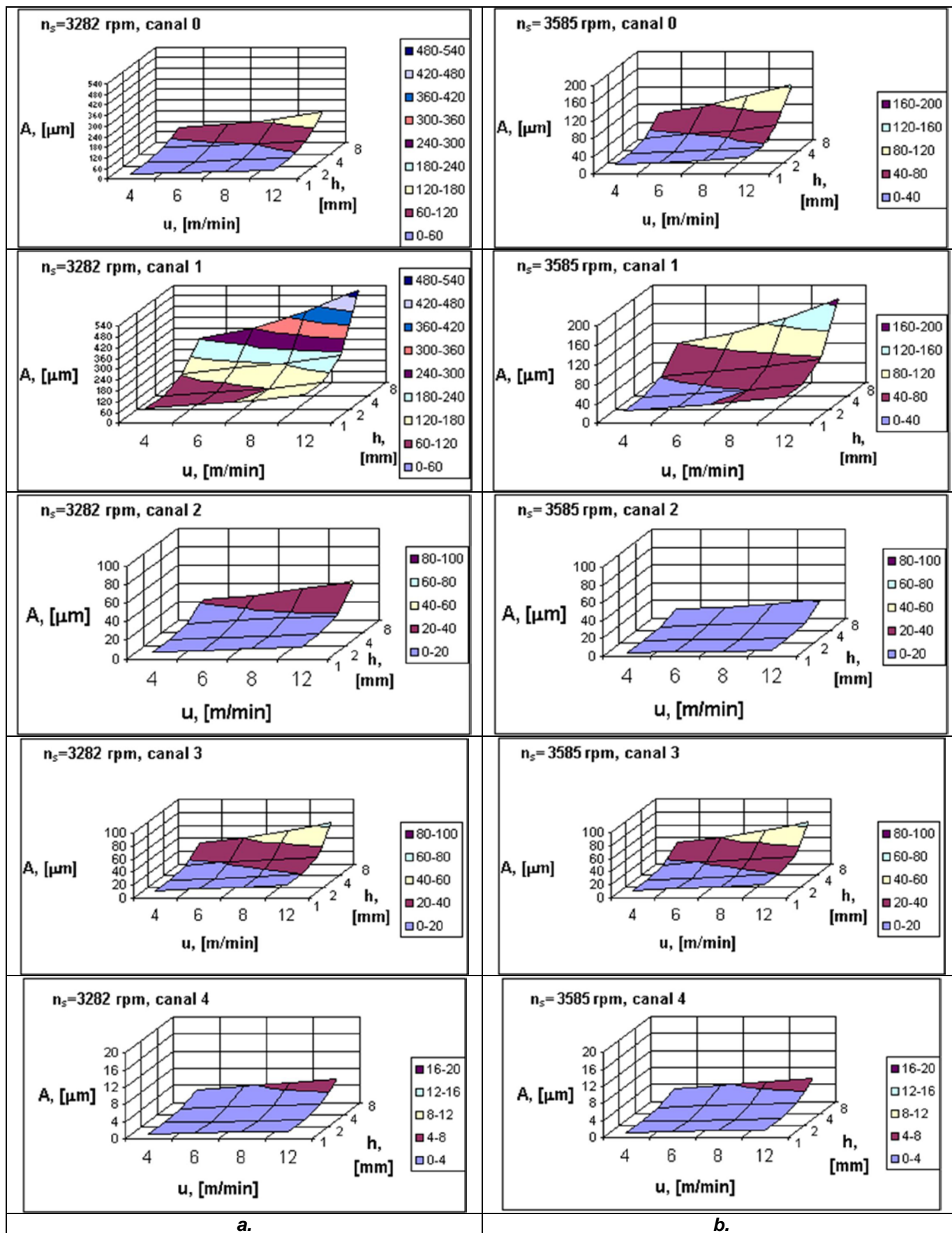


Fig. 7.

Variation of the vibration amplitude of the MNF 10 milling machine, when milling beech wood: a. in the classic constructive variant; b. in the modified constructive variant.

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