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Router performance characteristics at different air pressure levels

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Abstract: *Router performance characteristics at different air pressure levels.* The aim of this study was to determine influence of the air pressure on the performance characteristics of wood plunge router. Temperature increase, amplitude of vibrations and power consumption at different air pressure levels were examined in this paper. The advantageous results obtained indicate the need for further research.

INTRODUCTION

Both tool and spindle system must overcome aerodynamic resistances during work movement. Depending on their geometry and their rotation speed, these resistances may be negligibly small, but they may also influence the nature of the movement substantially. In case of wood processing, rotation speeds of the spindle reaching several tens of thousands rotations per minute are commonly applied, thus aerodynamic resistances play a significant role.

The subject of reducing air pressure in order to improve performance characteristics with less energy input was vividly discussed within „Hyperloop" project which assumes super-fast travelling capsule-like vehicle inside a tube over or under the ground with nearly no air inside (Taylor et al. 2016). Application of reduced air pressure in machining could lead to decreased air resistances, decreased electrical consumption, decreased vibrations and decreased sound level. Temperature increase, due to lack of the cooling medium, was expected to be much larger under conditions of reduced pressure. The main limitation of the idea is necessity of providing airtight autoclave in which the machine could be automatically operated. Modern wood industry plants look for high technology solutions in order to diminish labor costs and increase work efficiency. Machining consumes large amounts of energy (i.a. material removal, spindle rotation), hence optimization of machining processes is of utmost concern (Li et al. 2013). As of late, energy-saving technological solutions are very welcome and increasingly implemented.

METHODS

Because of the restricted free space available in the vacuum chamber, the plunge router has been chosen due to its relatively small dimensions and high rotation speed. Referring to technical data given by the producer, rated power of the plunge router was 1,3 kW. As far as no load rotation speed was concerned, it was in the range of 6 000 – 27 000 min^{-1}, however, the research was conducted in the top range of the rotation speed. The profile cutter has been fixed in the plunge router's socket.

The plunge router with all necessary sensors has been placed in the vacuum chamber. The sensors included in the research were: thermistor, vibration sensor, differential pressure sensor, wattmeter (fig. 1). The points of chamber exposed to leaks were tightly insulated with silicone. Moreover, a key element was vacuum pump which made it able to reduce air pressure inside the chamber. To acquire the data, the LabJack module and the Arduino microcontroller were used because of their low cost in relation to sufficient accuracy. Arduino

UNO can be used to design a simple DAQ system which can achieve sampling frequencies up to several kHz (Barański et al. 2019).

The investigations were carried out at four different pressure levels: atmospheric pressure and pressure reduced, respectively, to: -25 kPa, -50 kPa and -75 kPa. The test cycle included:

1. Reducing pressure inside the vacuum chamber.
2. Starting the motor for 3 minutes and data collecting.
3. Turning off the plunge router.
4. Equalizing pressure inside the vacuum chamber.
5. Cooling the plunge router's motor to a constant level.

The 1st and the 4th step were skipped in case of atmospheric pressure level.

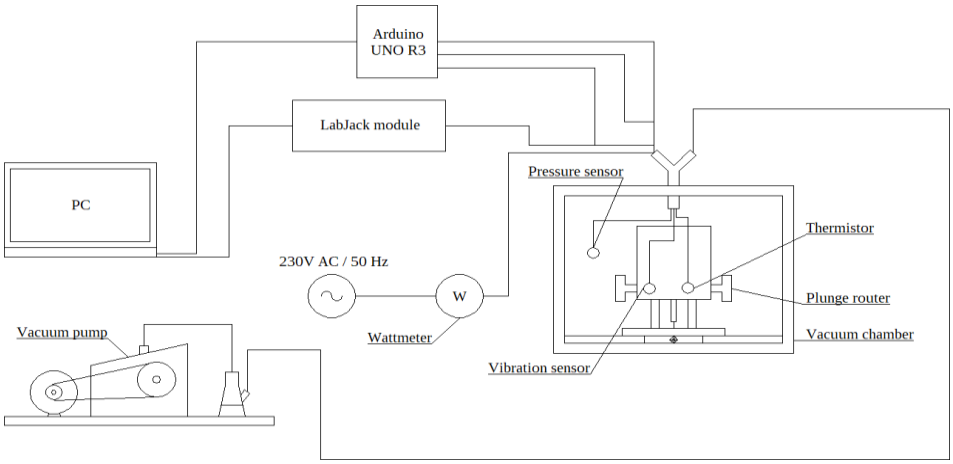

Figure 1. Scheme of the measuring apparatus.

RESULTS AND DISCUSSION

As previously mentioned, the temperature increase was expected to be much larger under conditions of reduced air pressure due to lack of the cooling medium. As it turned out, while the air pressure was reduced to -75 kPa, temperature increase after 3 minutes was smaller nearly by 10°C compared to the case of atmospheric pressure (fig. 2).

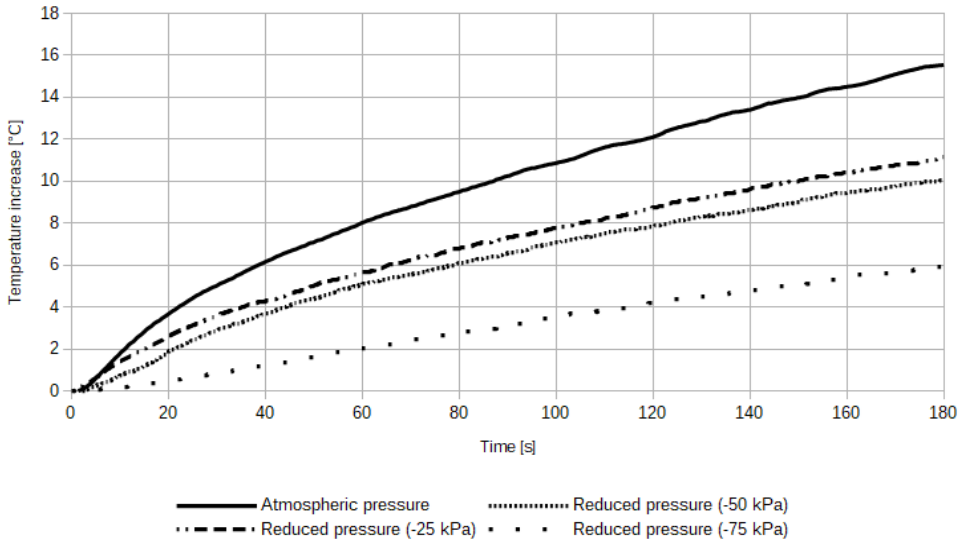

Figure 2. Values of temperature increase of the plunge router in the function of time.

The most likely reason of observed phenomenon is the decrease of air resistances which, in normal conditions, influence movement of the rotor significantly, thus the temperature increase is considerable. However, since lack of the air impedes a heat dissipation, providing alternative cooling system is obligatory.

Amplitudes of vibrations, relative to those in atmospheric pressure, are shown on the figure 3. The vibration sensor has been placed in the bearing axis in order to receive the most reliable data. As it emerged, the relative amplitude of vibrations has been also altered, however, not that significantly (3,6% and 9,7% for -25 kPa and -50 kPa, respectively), except for the last case. While the pressure has dropped to -75 kPa, the relative amplitude of vibrations has been diminished by 27,2%. Decrease in the amplitude of vibrations is an advantage which might be a possible way to extend the durability of components of the machine and reduce the sound level as well.

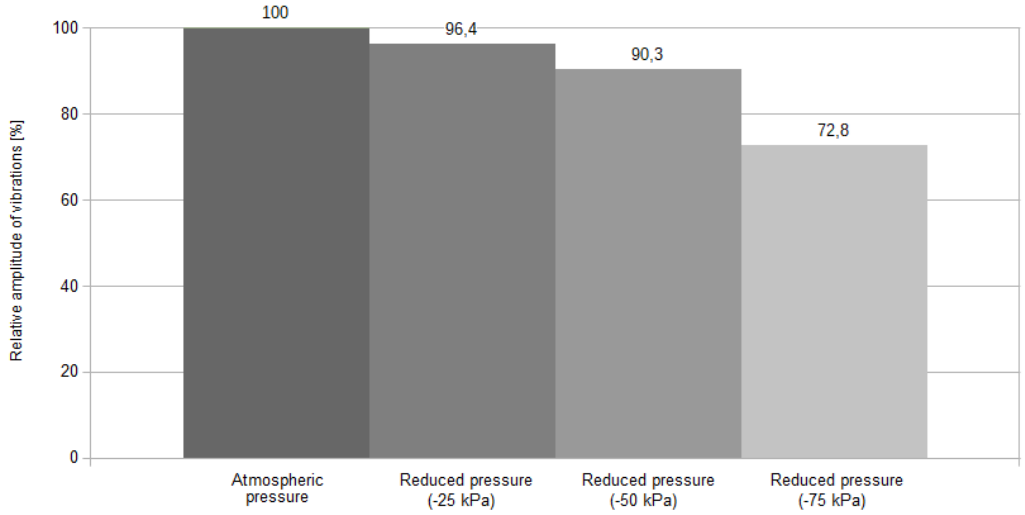

Figure 3. Values of relative amplitude of vibrations of the plunge router in the function of applied pressure.

The main object of the investigations was the power consumption of the plunge router under conditions of reduced air pressure as it has direct impact on labor costs. Decrease in power consumption was apparent as a consequence of reduced air resistances, however, the size of the phenomenon remained unknown. As it turned out (fig. 4), reducing air pressure by:

- 25 kPa diminished power consumption by 30%,
- 50 kPa diminished power consumption by 56%,
- 75 kPa diminished power consumption by 83%.

These values illustrate the impact of air resistances on the power consumption at idling. It is also worth mentioning that the pressure has been reduced only by 75% of its maximum value hence further research on this matter is necessary in even higher vacuum.

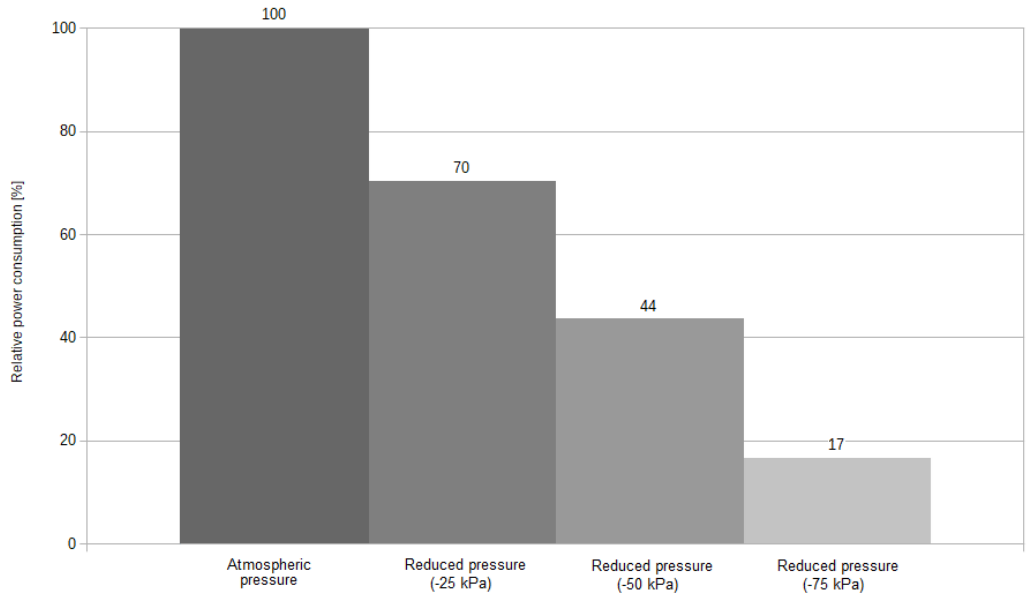

Figure 4. Values of relative power consumption of the plunge router in the function of applied pressure.

The survey and the received data indicate the possibility of direct reduction of labor costs due to less energy consumption. One may inquire about the costs related with reducing air pressure, but there is no clear answer to this question. Factors such as autoclave size and its air tightness, the efficiency of the pump and number of work cycles affect the final power balance. Although removing air from the autoclave might be expensive, it is worth to consider that it can be done only once for several machining operations.

Another essential aspect is the temperature increase of the plunge router in the conditions of reduced air pressure. Despite it has been shown that the increase of temperature is much slower when air pressure reduced, at one point it is going to reach the level at which cooling down would be necessary. Therefore, an alternative cooling system is required and liquid-cooled motor is going to be applied in the further study.

CONCLUSIONS

The performance characteristics of idling plunge router at different levels of air pressure was studied. Temperature increase was smaller in vacuum (-75 kPa), comparing to atmospheric pressure by 38%. Relative amplitude of vibrations and power consumption have been significantly reduced in pressure decreased by 75 kPa by 27% and 83% respectively

The further study on that matter is necessary. To define its practical utility in actual industrial conditions, it is obligatory to carry out a research on wood processing under conditions of reduced air pressure to examine its performance.

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Streszczenie: *Charakterystyka wydajności frezarki przy różnych poziomach ciśnienia powietrza*. Celem tego badania było określenie wpływu ciśnienia powietrza na charakterystyki pracy frezarki do drewna. W niniejszej pracy zbadano wzrost temperatury, amplitudę drgań i pobór mocy przy różnych poziomach ciśnienia powietrza. Uzyskane korzystne wyniki wskazują na potrzebę dalszych badań.

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