CHIP AND CHIPLESS WOODWORKING PROCESSES, 11(1): 31–37, 2018
Zvolen, Technical University in Zvolen, ISSN 1339-8350 (online), ISSN 2453-904X (print)

NUMERICAL ANALYSIS OF CHIP REMOVING SYSTEM OPERATION IN CIRCULAR SAWING MACHINE USING CFD SOFTWARE

Jacek Barański[1] – Marcin Jewartowski[1] – Jan Wajs[1] – Kazimierz A. Orłowski[2]

Abstract

Paper presents the analysis of the results of numerical simulations of the air flow process of wood chips removing system in the circular sawing machine. The attention is focused on the upper cover and bottom shelter of the chip removing system. Within the framework of the work a systematic numerical modeling of the air flow distribution in the cover and shelter during operation of the selected rotational speed of saw blade with a diameter of ∅300 mm and ∅ 450 mm was carried out. The analysis of the results obtained from the numerical simulations and from the experimental measurements allowed to predict the areas with improper air movement hindering the organized transport of chips. Also, those results from the numerical modeling were used in the process of optimizing the shape of the casing and the shelter. As a result, a new design of chip removing system was obtained, vastly improving the chips extraction from the tool operation space.

Key words: *numerical simulations, CFD, chip removing system, sliding table saw*

INTRODUCTION

The development of woodworking machines design, the introduction of new technologies, and above of all the machining and feed speed result in the need to provide more effective wood wastes (chips) removing systems. A modern machine, which operates without connection to a properly designed extraction installation loses immediately its performance and service life.

Woodworking machines and cutting parameters as well as wood material properties determine the particle size distribution of chipped wood. In the technological processes of machine wood chipping, a by-product is also formed besides the main product.

Particles of wood substance formed in individual processes of chipping and machining are called “bulk wood substance”. Workers’ exposure to airborne wood dust particles in the surrounding air of the workplace may cause different occupational health problems in wood industry workers. The nature of the present production and conditions of chips require its continual removal from the place where they are formed. As far as sanding dust is concerned, it is removed by means of an air-technical device - suction. To develop an appropriate suction system, it is important to know the size and shape of bulk substance particles, which are the basic data for characterizing bulk material. The above characteristics affect physical and mechanical properties of bulk substance (bulk density,

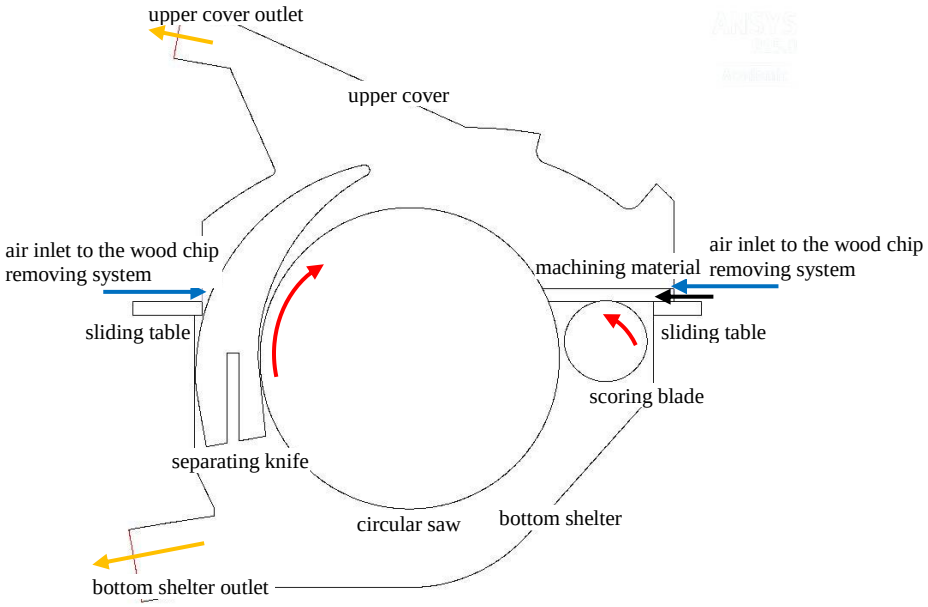
Gdansk University of Technology, [1]Department of Energy and Industrial Apparatus, [2]Department of Manufacturing Engineering and Automation, Narutowicza 11/12, 80-233 Gdansk, Poland
e-mail: jbaransk@pg.edu.pl

bulk angle, tilt angle, aerodynamic properties of particles in the piping of the suction system) and conditions of separation or filtration in the separating device [1, 5].
Removal of dust is difficult when working zone is large and when the tool moves during processing at relatively high velocities. The dispersion of chips in different directions in the space of the treatment zone is very unfavorable in this respect. When the movement direction of the chips created during machining does not coincide with that of the air suction created by an extraction system, many of the chips are still not removed and can become dispersed in the air surrounding the machine. This takes places during sawing when the whole tool goes into the work piece. For this reason, there are problems with the direct removal of chips from working zone and working tools. The dispersion of chips in all directions also occurs due to the high-speed rotation of those tools.
The authors carried out systematic experimental investigations in existing circular sawing machine, commercially available on the european market. The special attention was focused on upper casing and bottom shelter in its chips removing system.
During the experimental research, pressure distribution inside the casing was accurately recorded with the selected rotational speeds of 3500 1/min and 6000 1/min of saw blade with the diameter of ∅ 300 mm and ∅ 450 mm [2, 3]. The analysis of the results of these experiments helped to identify in the upper cover areas with insufficient vacuum (and even with small overpressure), which caused chip ejection from the casing.
In this paper the chosen numerical modeling results of the air flow process in the wood chips removing system for sliding table saw were presented. The aim of the full research was to optimize the chip extracting system. On the basis of the obtained results, a new design of the casing has been proposed [4].

METHODOLOGY

To create 2D numerical models of the sliding table saw complex geometry an unstructured mesh was used. Thus, it was possible to divide the flow region into finite elements of small size. This approach was very important to achieve convergence and accuracy of the solution. For these models, the number of unstructured elements (cells) was about 1 892 600. In selected cases, the air flow in the dust extraction system was analysed without taking into account the occurrence of the wood chips movement. In the Figure 1 the examples of the circular sawing machine numerical model with separation knife and without separating knife respectively are presented. The saw blade with the diameter of ∅ 450 mm shown.

a)



b)

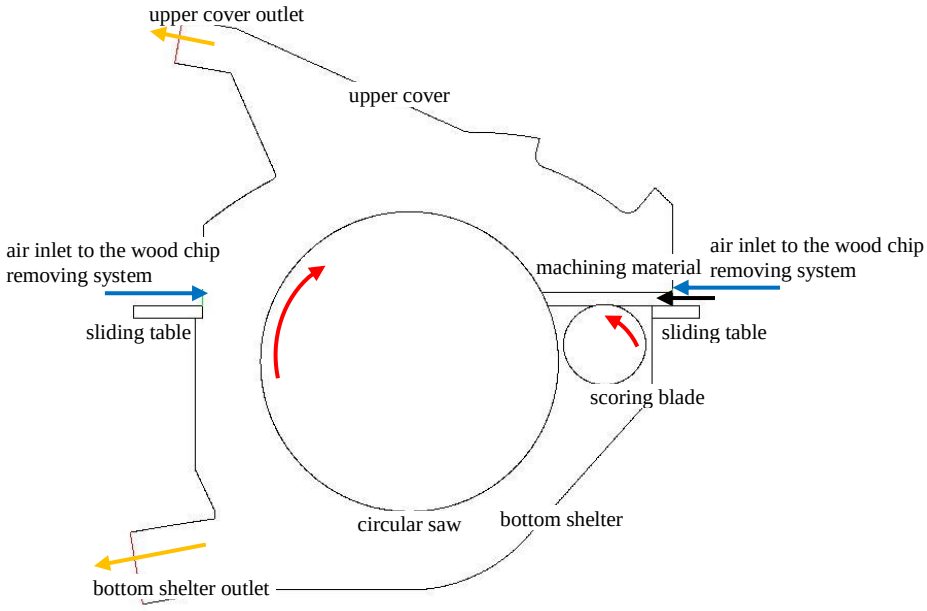


Figure 1. The cross section view of the circular sawing machine numerical model: a) with separation knife, b) without separating knife.

The numerical simulations were performed for different boundary conditions and circular saw diameter, as presented in Table 1.

Table 1. The boundary conditions assumed for numerical simulations of the chip removal system.

	Ambient pressure	Vacuum pressure at bottom shelter outlet	Vacuum pressure at upper cover outlet	Circular saw rotational speed	Scoring blade rotational speed
	[Pa]	[Pa]	[Pa]	[1/min]	[1/min]
circular saw ∅ 300 mm					
1.	101 130	- 400	- 200	3 500	8 500
2.	101 130	- 400	- 400	3 500	8 500
3.	101 130	- 1 500	- 1 500	3 500	8 500
4.	101 130	- 400	- 200	6 000	8 500
5.	101 130	- 400	- 400	6 000	8 500
6.	101 130	- 1 500	- 1 500	6 000	8 500
circular saw ∅ 450 mm					
7.	101 130	- 400	- 200	3 500	8 500
8.	101 130	- 400	- 400	3 500	8 500
9.	101 130	- 1 500	- 1 500	3 500	8 500

A series of computer simulations were performed. Each simulation was performed at various boundary conditions. The differences concerned the rotational speed of the saw, the vacuum pressure in the both outlet and the diameter of the saw, which were presented earlier.
The vacuum pressure values at the outlets from the upper cover and lower shelter were assumed on the base of the results of experimental measurements (200 Pa in the upper cover outlet and 400 Pa in the lower shelter outlet). The maximum value of the vacuum pressure in both outlets, i.e. 1500 Pa, was adopted in accordance with the information provided by the Panel saw manufacturer and the data available in the literature. Simulations of air flow process for vacuum pressure in both outlets with value of 400 Pa were also performed.

For the turbulent flow modeling, a standard model of turbulence k-ε (k-ε standard) and a mesh of the entire dust extraction system with machining material and with or without a separating knife were used.

The calculations for each case were carried out until the values of the solutions of the equations of behavior (the so-called residuals) were stabilized in a narrow range of variation at the level of 10^{-4}.

For each modeling case, which was carried out, the chosen simulation results in the ANSYS Fluent software will be presented graphically for the velocity vector field and possibly the flow line field.

RESULTS OF EXPERIMENTS

Below, the chosen results from numerical simulations of the circular sawing machine will be presented. Figures 2 and 3 present examples of the numerical calculations results of the

velocity field of the sawing system of the table sawing machine for the following boundary conditions:
- vacuum pressure at the upper cover outlet - 200 Pa,
- vacuum pressure in the lower shelter outlet - 400 Pa,
- circular saw diameter ∅ 450 mm,
- circular saw speed of 3 500 1/min,
- rotational speed of the scoring blade 8 500 1/min.

Fig. 2 presents the results of numerical calculations of the air flow process through the wood chip removal system for the material cutting for a case where a separating knife is present in the sawing machine system.

The occurrence of the knife affects the less favorable distribution of air flow in the rear part of the dust extraction system, Fig. 2a. In addition, in the front part of the upper cover, it can be seen that the air is pushed into the environment with greater intensity compared to the further case (marked with a blue circle). The speed value is higher here, Fig. 2b. There is no air turbulence zone in the upper part of the upper cover, near the handle. This is the effect of the smaller impact of the rotating saw on the flowing medium. The separating knife is an obstacle to the air flow process at the outlet of the lower shelter.

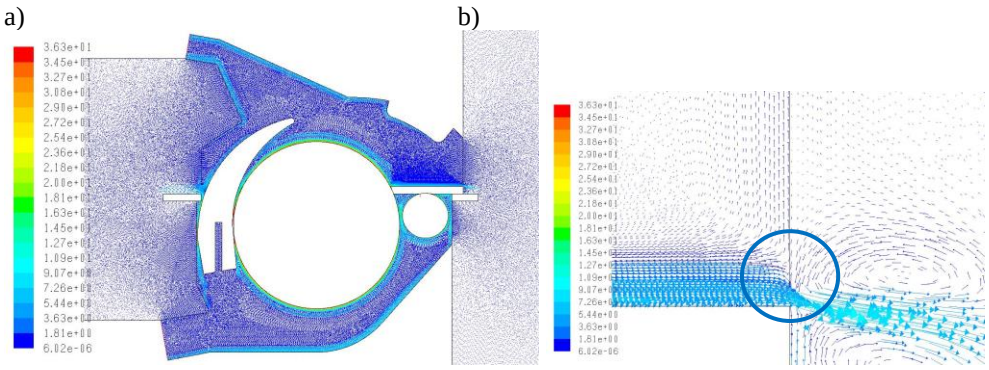


Figure 2. The air flow velocity vectors through the saw and chip removal system with a saw diameter ∅ 450 mm: a) in the sliding table saw, b) in the front of the upper cover.

In addition, it reduces the impact of the saw on the air flow. In the rear part of the casing, the inflowing air is separated into two streams and flows to the outlets of the lower shelter and the upper cover. It can be seen that the air in the upper cover, in addition to pushing into the environment, is directed towards its upper wall. In addition, there is an area where the air flow values are small

Fig. 3 shows the air flow through the wood chip removal system for the material cutting event without taking into account the presence of a separating knife at the back of the saw. We can see the behavior of the air flow process, which after entering the dust collection system is directed to the outlets of the lower shelter and the upper cover.

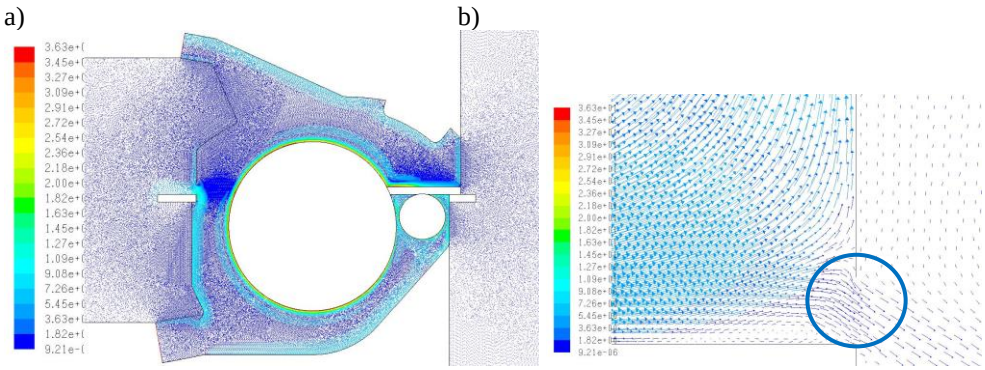


Figure 3. The air flow velocity vectors through the saw and chip removal system with a saw diameter ∅ 450 mm: a) in the sliding table saw b) in the front of the upper cover.

We can see here the large impact of the rotating saw on the flowing medium and the intensive mixing process with incoming air. This is due to the high value of the linear speed of the saw and the shape of the upper cover, which has got the so-called the dead space from which the air is unable to get out. In addition, we can clearly see the effect of the saw on pushing the air out of the upper cover in its front part (Fig.3b). This is the total effect of the linear speed of the saw and the occurrence of a small vacuum pressure (200 kPa) at the upper cover outlet (marked with a blue circle).

CONCLUSIONS

Existing chip removing system in the analyzed woodworking machine did not provide satisfactory chip extraction from the working area. After numerical simulations and experiments it was proved, that in the area around the tool the insufficient vacuum pressure can occur hindering the organized transport of wood wastes. After several changes in the system, especially in the upper casing, all parts of suction system were optimized and modified, except for the structure of the fan, which allowed to achieve efficient performance. Eventually, a new design of the chip removing system was obtained.

REFERENCES

1. Dzurenda, L. (2007) *Sypká drevná hmota, vzduchotechnická doprava a odlučovanie (Bulk wood mass, air transport and separation)*. 1st ed., 182 p. Technical University in Zvolen, Slovak Republic.
2. Barański J., Jewartowski M., Wajs J., Pikała T. (2016) *Experimental analysis of chip removing system in circular sawing machine*. Chip and Chipless Woodworking Processes (Trieskove a Beztrieskove Obrabanie Dreva), vol. 10, no. 1, pp. 25-29;
3. Barański J., Jewartowski M., Wajs J., Pikała T. (2018) *Experimental examination and modification of chip suction system in circular sawing machine*. Drvna Industria, Vol. 69 (2018), No. 3 (in print)
4. Wajs J., Barański J., Jewartowski M., Orłowski K., Pikała T., Dudek P. *Method of chips upper removal for working space of the circular sawing machine, particularly panel saw*

and upper cover of dust extraction system of circular sawing machine, particularly panel saw. (in Polish) Patent pending No. P.421584.
5. Kohler, B. (1995) *Wood dust and cancer*. National Report - Health, Safety and Environment, IARC, France.
6. ANSYS Fluent User's Guide, 2012.