# Analysis of the design development of the sliding table saw spindles

## Analiza rozwoju konstrukcji wrzecion pilarek formatowych

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**Producers of sliding table saws constantly strive for improvement in sawing accuracy. One of the method is an upswing in a spindle behavior, since, it affects to a large degree sawing effects. The design development of sliding table saw spindles during the last quarter-century is presented. The spindle system of the modernized spindle of the sawing machine Fx550 is described.**
**KEYWORDS: sliding table saw, spindle design, critical rotational speed, static stiffness**

Cutting the wood with circular saws is a popular machining operation in the woodworking and furniture industries. Its popularity is mainly due to the fact that in this method of cutting relatively simple and cheap tools are used – saws and disc cutters with small dimensions. In addition, circular saws used in the sawmill industry can achieve high feed rates $v_f$ up to 200 m min$^{-1}$.

There are 2 ways to attach saws to spindles. A system with saw blades having a spline in the inner hole working with a spindle saw having an external spline is common to circular saws for primary wood processing, especially in North America. The transverse position of the saw is determined by special guides (fig. 1*a*) [2, 10]. They can also be hydrostatic guides, where water is supplied to hydrostatic chambers [2]. This type of solution allows working at speeds greater than the critical speed of the saw [3, 4] and is therefore considered to be superior [10].

The second way of embedding the saws on the spindles of saws, common in Europe, is by fixing them with the fastening flanges (fig. 1*b*) [5–7]. In this case the operation of the saw must be at a rotational speed lower than their critical speed, guaranteeing the stable operation of the tool [7]. However, the clamping of the saw with the help of flanges allows for multi-saws to place saws on the spindles with little distances between them. Figure 1*b* shows the type of spindle used in format saws where the cutting torque is most often transmitted by friction between the mounting flanges and the saw blade (fig. 3, fig. 4).
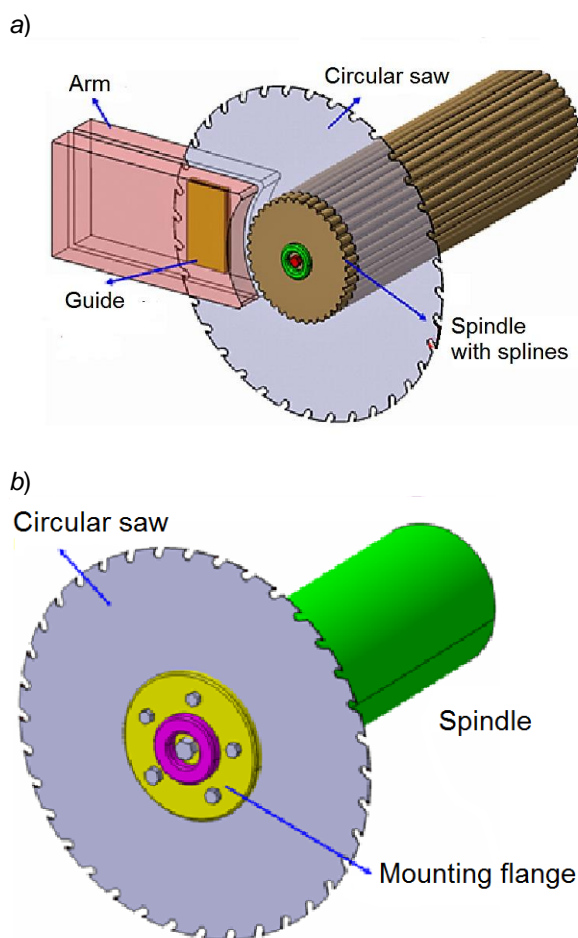
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a)



b)



Fig. 1. Construction variants of circular saw spindles: *a*) free saw on the spindle fixed in the guide, *b*) circular saw mounted with flange

The aim of this paper is to analyze the development of the main spindles of the sliding table saws for the last quarter century.

## Theoretical basics

The theoretical model of cutting on a circular saw is shown in fig. 2. It is oriented in a rectangular coordinate system *X, Y, Z*, where the *Z* axis coincides with the axis

of rotation of the spindle and $X$ axis is parallel to the assumed direction of travel ($X$ II $v_f$). The axes of the $XYZ$ system along with the $P_{XY}$, $P_{XZ}$ and $P_{YZ}$ planes defined by these axes are the reference system for determining the geometrical and movement geometry of the circular saw. In the circular saw of the circular sawing system model, it is assumed that the saw plane $P_p$ rotates in a plane perpendicular to the spindle axis $Z$, and the geometric center and center of gravity of the saw lie on the spindle geometry axis. In addition, the cut material moves in the $P_{pm}$ parallel plane to the $P_{XZ}$ plane ($P_{pm} \parallel P_{XZ}$) and is guided in a $P_{kp}$ direction perpendicular to the $P_{YZ}$ plane.

Since most of the sawing solutions have a material guide plane rigidly connected to the guide plane, both of these planes define the plane of motion of the $P_{rm}$ material. From the simplified assumptions it follows that the plane of motion of the $P_{rm}$ material coincides with the plane of the $P_p$, creating a jointly assumed plane of motion $P_f$, that is, the plane in which both the cutting velocity vector $v_c$ and the velocity vector $v_f$ lie.
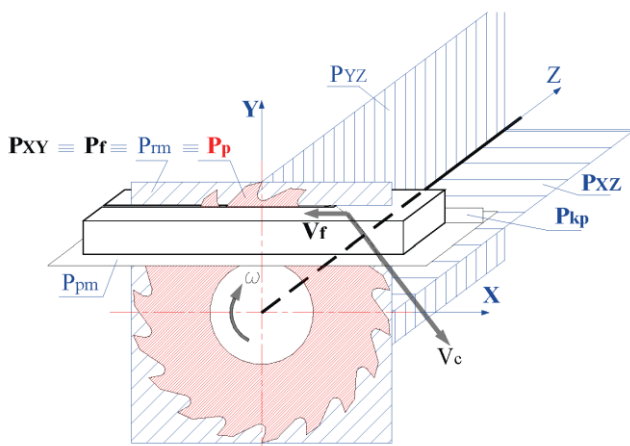


Fig. 2. Theoretical model of cutting using a circular saw [14]

Under machining conditions, the displacement and deformation of the cutting system always occurs. Therefore, the saw plane does not coincide with the plane of the cut material ($P_p \neq P_{rm}$), and thus the actual plane of motion $P_{fe}$, where the velocity vectors $v_c$ and the velocity $v_f$ lie, is virtually nonexistent with the assumed plane of motion ($P_{fe} \neq P_f$). This phenomenon is, among others, the effect of:

- low static rigidity of the spindle and its support, which causes the cross-cutting of the total saw blades with a diameter of Ø400 mm determined below the chip grooves, taking into account the sawmill flaws and the geometric accuracy of the flanges can reach up to 0.42 mm [5, 6, 14, 15];
- the main spindle drive method – for example: for an unloaded spindle with a pulley located on the rear spindle end, axial drive saws with a diameter of Ø400 mm can reach up to 0.42 mm [14]; however, the use of a spindle-loaded power design gives a very positive effect in minimizing spindle deformation and the beating is significantly reduced and can reach values up to 0.14 mm [16, 17];
- low static rigidity of circular saw [15];
- low critical speed values of circular saws [4, 7];
- saw blade operation under conditions during washboarding [12, 13].

## Construction variants of main spindles

In the last decade of the twentieth century, the long spindles with ratio of the supports spacing $L$ to the inner diameter of the front bearing $d$ of about 12.7, were mounted in the format saws [5, 17, 20, 21] (fig. 3a, fig. 3b). This type of solution is still found in the DMMS-40 Classic (REMA S.A., fig. 3b), in which the traditional V-belt has been displaced by the PK belt. In 2006, Altendorf showed at the Drema Fair in Poznan a new generation F45 Elmo, with a short main spindle with a $L/d$ span of about 3 [9]. Since then, the market has been supplying mainly short-wheeled spindle-driven mains with a rear-wheel transmission, such as UNICA 400 (Griggio) [22], K 700S (Felder) [23] and PF 400S (Rojek) [24].

In most cases, the spindle of a format saw can develop one of three working speeds $n_{rob}$ of 3500, 4500 or 6000 min$^{-1}$ during operation [6, 20]. Altendorf, in one version of the F45, offers a drive in which the spindle speeds can be varied continuously between $2000 \div 6000$ min$^{-1}$. In turn, the UNICA 500 is equipped with a 4-speed belt pulley located between the supports [22]. In the CONCEPT 350 [25] hybrid saw, in which the main spindle also functions as a sub-cutting spindle, a single pulley is placed between the front support and the saw mounting flange. The spindle has one rotational speed – 4000 min$^{-1}$. A similar solution can be found in the K 700S (Felder) saw chain aggregator [23].

Based on the observations, it can be assumed that most manufacturers in the design process use statistical and comparative methods [18], which rely on rational imitation of practically proven sawmill drives of similar design, similar size and similar kinematics, taking into account development trends in a given group of machine tools.
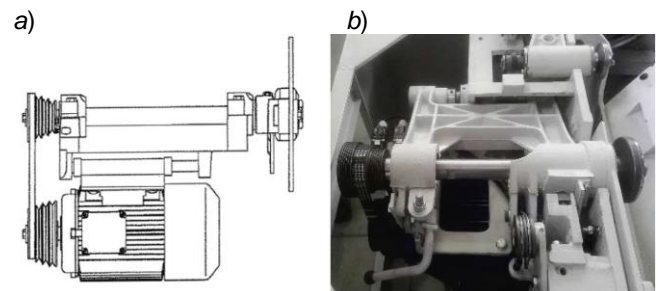
a)                                              b)



Fig. 3. Main long spindle in the format saw in: a) F45 (Altendorf) [21], b) DMMS-40 Classic (REMA S.A.)

The short spindle of the sliding table saw Fx3 (before modernization) presented at work [6] can develop working speeds of 3500, 4500 and 6000 min$^{-1}$ [20], depending on the location of the PK belt in belt pulley. This type of solution appeared in this saw in 2011 [9]. On the spindle, Ø450, Ø350 or Ø300 mm circular saw blades can be attached to the Ø125 mm diameter flanges, which determines the rotation speed. On both sides, the spindle is supported on 6206 2RS1 Explorer (SKF) bearings and $L/d$ = 2.6.

The spindle model was calculated, with the support diameters up to Ø35 mm (under 6207 2RS1 Explorer bearing), increasing the $L/d$ ratio to 3.0, according to SKF recommendations for optimum spacing of spindle supports [19]. Due to the predominant influence of the forces from the drive, the diameter of the rear end was also changed. The resulting deformation values for the changed spindle turned out to be smaller [6], which

resulted in the higher $n_{kryt}/n_{rob}$ ratios for each case of rotational speed [1, 11]. An improved spindle of the new type (fig. 4) was implemented in the Fx550 format saw [20].
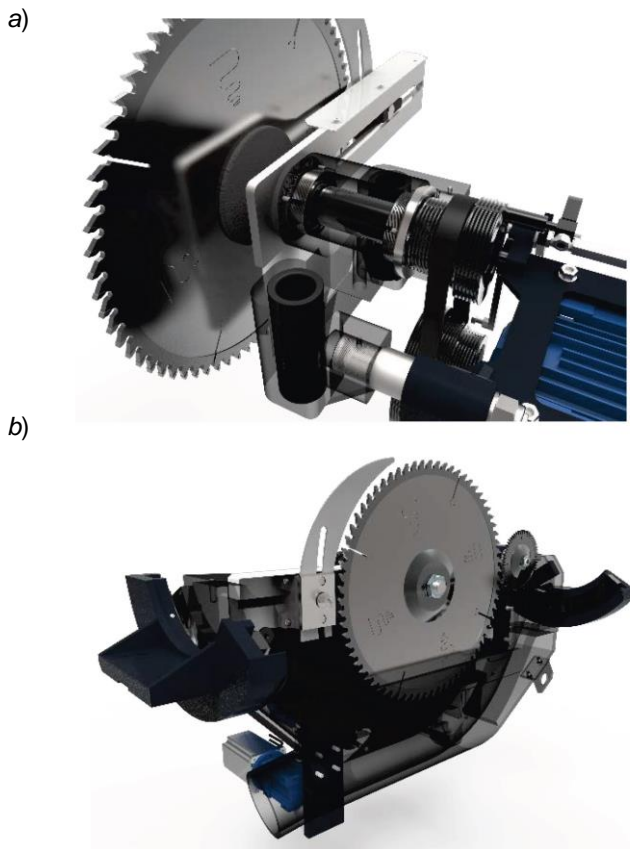
a)



b)



Fig. 4. Fx550 format saw milling machine (REMA S.A.) with main spindle of modernized structure: *a)* main spindle from motor side, *b)* view from circular saw side (main and minor undercut)

It should be noted that the Fx550 with a new saw aggregator significantly reduced the vibration and noise levels generated by the machine (on average 5 dB).

In addition, numerical calculations were performed to demonstrate the influence of the pulley position on the spindle with increased rigidity [8] at its critical speeds. The results of the calculations showed that for this type of rigid spindle in each of the analyzed cases the wheel position was approximately 14,400 min$^{-1}$ and the ratio of $n_{kryt}/n_{rob} \approx 2.4$.

## Conclusions

Based on the analyzes, it can be concluded that most manufacturers in the spindle design process use statistic-comparative methods, which rely on rational imitation of practically tested saws. In the case of the implemented short main spindle in the Fx550 saw, the ratio $n_{kryt}/n_{rob}$ meets the requirements specified for this type of spindle. This resulted in a reduction in the level of vibration and noise generated by the saw.

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