The effect of the grinding wheel type and helix angle on flute profile and values on the cutting force

Wpływ typu ściernicy i kąta pochylenia spirali na kształt rowka wiórowego i siłę szlifowania

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In the paper the influence of the helix angle *λ* and grinding wheel type on flute profile and values on the cutting force during 5-axis flute grinding has been presented.
KEYWORDS: flute profile, force measurement, helix angle, grinding wheel type

The grinding of flute profile takes about 70% of the production time and is one of the critical process in end-mill manufacturing [1, 2]. The profile flute surfaces has a large effect on many properties of the finished tool, since the Flute profile is one of the geometric elements defining the cutting edge and the rake angle. In addition, the shape of the flute affects chip removal and machining stability [3, 4].

Simulation model

The tests were performed for two diamond wheels, whose geometrical parameters are shown in fig. 1:

- 1A1-100-10-5 20 D64K + 1421R C100 H,
- 12V9-100-2-6 20 D64K + 1421R C100 H.

Simulation tests were carried out on the ISOG 5-axis tool grinder manufactured by MTS AG (Mathematisch Technische Software) v. 10.0 Release 13 3D Rev 3163.

To ensure the transparency of the research and analysis performed, the simulations were divided into four stage: two variable parameters were adopted:

wheel type: **1A1** and **12V9**,

helix angle of the flute: λ = 15°÷45°.

For fixed parameters that define the flute on: the rake angle γ = 5, a core diameter *d* = 5 mm, blank diameter *D* = 10 mm, number of teeth *z* = 4.

In the first stage of the study, the flute shape obtained by means of a 1A1 grinding wheel for different helix angle λ (fig. 2) were compared. It can be seen that with increasing the value of λ is increased cross sectional area of the flute and reduces the land width w which is further illustrated in fig. 3.

In the second stage, the shape of the flute was made using a 12V9 grinding wheel depending on the helix angle λ (fig. 4).

The results show that in the assumed range of helix angle λ = 20°÷40°, the correct shape of the flute was not achieved with a 12V9 grinding wheel. This is because the resulting land width w in the case being analyzed is too large.

	D	U	X	T	H	E	K	Y
1A1	10	10	5	-	20	-	-	0,2
12V9	10	6	2	15	20	10	62	1

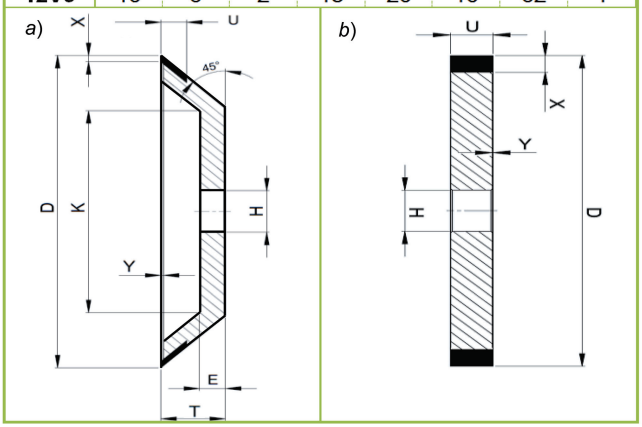

Fig. 1. Geometrical parameters of the wheel of type: a) 12V9, b) 1A1

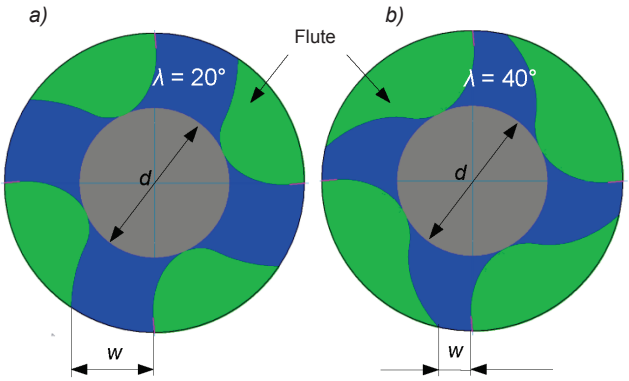

Fig. 2. Simulation of flute process using grinding wheel type 1A1 for a variable helix angle: a) λ = 20°, b) λ = 40°

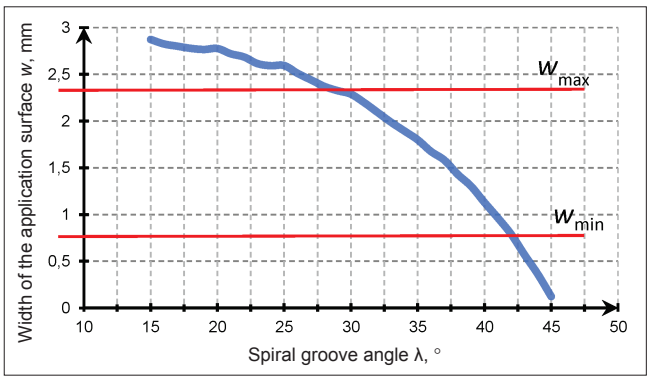

Fig. 3. Influence of the helix angle on the land width *w* (helix angle λ was analyzed every 1°)

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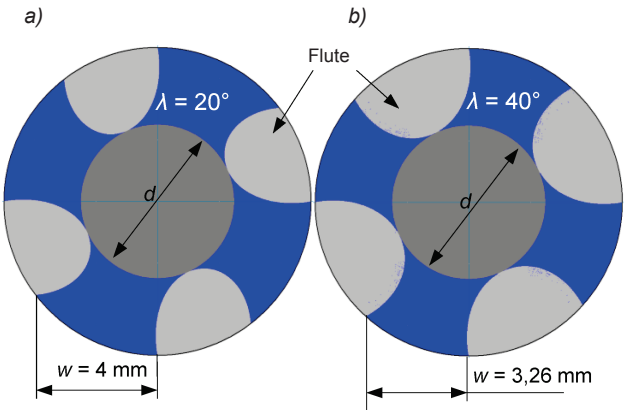

Fig. 4. Simulation of flute process using grinding wheel type 12V9 for variable helix angle: a) λ = 20°, b) λ = 40°

In the third step, the constant value of the parameter w = const. is assumed. The purpose of the study was to determine the maximum helix angle λ for grinding wheels type 1A1 and type 12V9 (fig. 5).

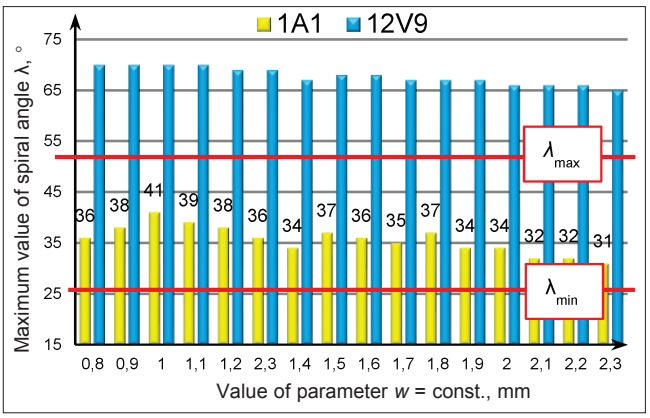

Fig. 5. Effect of constant land width w on the value of the spiral flute angle

As can be seen, in the case of the 1A1 type wheel there is a limited range of helix angle λ ≈ 15÷35°, in which a flute can be made. It was also noted that the fixed value of the land witdth w = const. in the range of w = 0.8÷2.3 mm, affects the helix angle λ, in which the flute can be made. For wheel type 1A1 the maximum value of the helix angle depends on the value of the parameter w varies in the range λ = 31÷41°.

For a 12V9 grinding wheel, a much larger range of helix angle values λ ≈ 15÷66° was observed in which a flute could be produced.

In industrial practice, the value of the helix angle is usually in the range of λ_{min} = 25° to λ_{max} = 50° [5]. Grinding wheel type 12V9 is therefore more versatile compared to 1A1 grinding wheel.

In the fourth stage, the profile flute – made by 1A1 and 12V9 grinding wheels – was investigated, depending on the helix angle λ, for a fixed: land width w = 1 mm (fig. 6).

Based on the results of the simulation tests, it was found that, regardless of the grinding wheel used, the constant land width w = const. causes small changes in the shape and cross-sectional area of the flute profile in the assumed spiral angle range from λ_{min} to λ_{max}. Accepting the constant

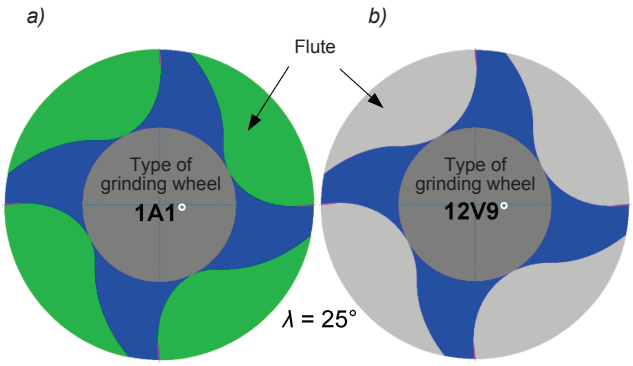

Fig. 6. Simulation of flute process using wheels type 1A1 (a) and 12V9 (b) with the constant land with w = 1 mm

land width w allows to obtain the same flute profile irrespective of the grinding wheel type used.

Experimental studies

Experimental studies were carried out on a five-axis FORTIS grinding center machine from ISOG (fig. 7). Kistler type 9123 rotary force gauges were used to measure the grinding force.

Test conditions are shown in the Table.

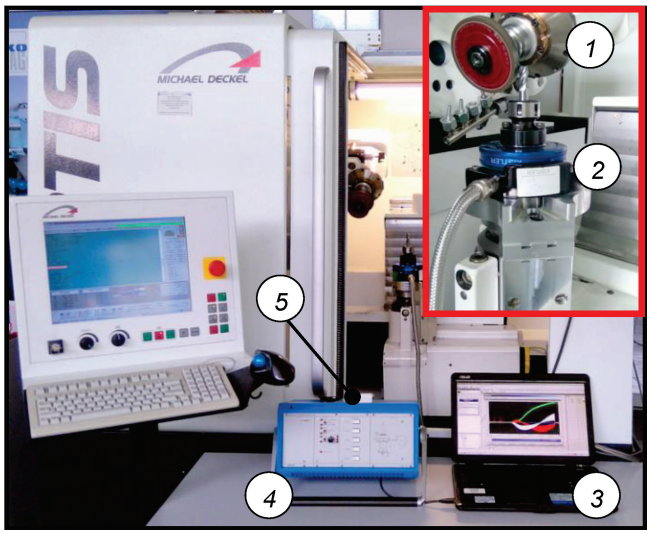

Fig. 7. Test stand for flute process grinding: 1 – wheel grinder, 2 – Kistler dynamometer, 3 – computer, 4 – signal transducer 5223B1, 5 – A/C converter 6009 [6]

TABLE. Grinding conditions

Workpiece	Sintered carbide K20F
Coolant	grinding oil
Cutting speed v_c, m/s	20
Feedrate v_t, mm/min	40
Grinding infeed a_p, mm	2,5
Tool length L, mm	10
Diameter of the blank D, mm	10
Core diameter d, mm	5
Rake angle γ, °	5
Width of the application surface w, mm	1
Spiral groove angle λ, °	25, 30, 35, 40

Test results

The maximum values of grinding force F for the examined grinding types 1A1 and 12V9 depending on the helix angle λ are shown in fig. 8.

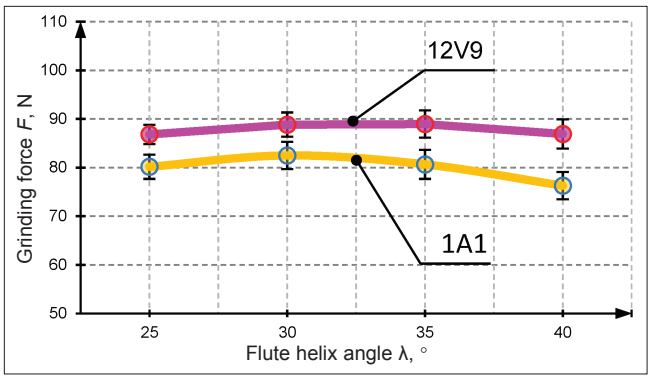

Fig. 8. The dependence of the grinding force F on the flute helix angle λ for both types of tested grinding wheels 1A1 and 12V9

The total grinding force F was determined as the square root of the grinding force components F_N, F_T and F_F. Obtained results show that the grinding force values of approx. 10% were obtained for 1A1 grinding wheel. There are slight variations in the value of the force F depending on the spiral angle λ – they are less than 4%.

The maximum values of the grinding force components F_N, F_T and F_F for the examined grinding types 1A1 and 12V9 depending on the helix angle λ are shown in fig. 9.

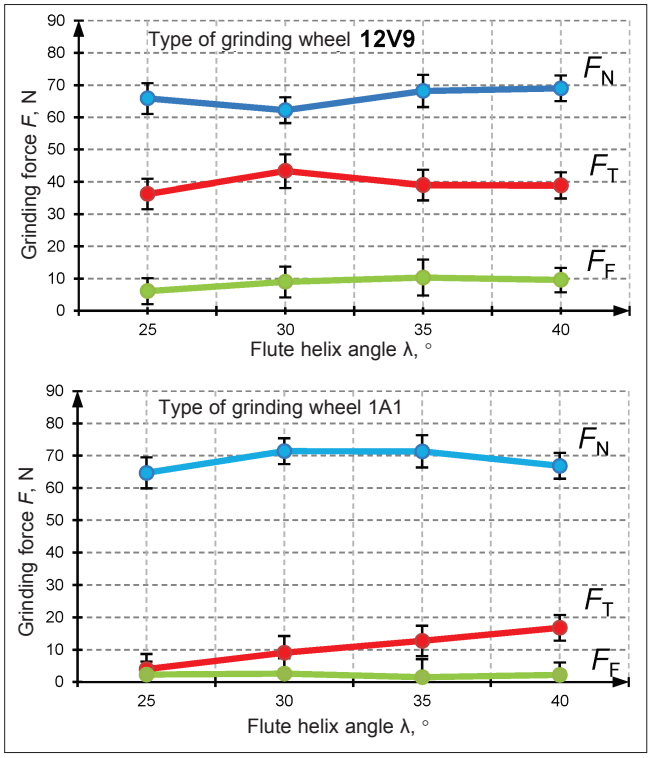

Fig. 9. The course of grinding force components F (F_N, F_T, F_F), depending on the helix angle λ for both tested grinding wheels 1A1 and 12V9

The graphs show that for the two abrasive wheels, the maximum value of the normal F_N was approximately the same and amounted to about 70 N. The smallest values reached the feedrate F_F – for the type 1A1 grinding wheel it was about 1.5 N, and for the wheel type 12V9 It was almost seven times larger and was about 10 N. The highest value difference was recorded for the tangential component F_T, which was approximately 10 N for the wheel 1A1 and for the grinding wheel 12V9 was four times higher and the average was 40 N. It was noted that with the increase in the value of the spiral angle λ, value of the tangent component F_T increases as well. A similar relationship did not occur with the 12V9 type wheel.

Conclusions

- In the first and second stages of the simulation, it was found that the change the flute helix angle caused a significant change in the profile flute due to the change land width value. It turned out that with the increase in the spiral angle, the land width value decreased. Obtaining the appropriate flute profile depends on the type of grinding wheel used – 1A1 or 12V9.
- At the third and fourth stage of the simulation study, it was proved that the adoption of a fixed value of the land width w = const. It is possible to obtain the same flute profile regardless of the value of the helix angle and the type of grinding wheel used. In addition, it has been observed that the use of a constant land width value limits the technological possibilities of the wheel. In the case of the 12V9 type grinding wheel, manufactrunig of the flute is the largest (λ ≈ 25÷50°), while for the 1A1 grinding wheel, this value is the smallest (λ ≈ 25÷35°). It has also been observed that changing the constant value of the parameter w in the range of 0.8 to 2.3 mm significantly influences the technological limitations of the 1A1 grinding wheel in the range λ = 31÷41°.
- Based on the simulations, it has been found that it is possible to obtain the same profile flute at different values of the helix angle and the use of different grinding wheels. The simulation was designed to determine the specific value of the cross-section profile during the five axis flute grinding irrespective of the helix angle value.
- During the experimental study, small changes in the resultant grinding force F were observed under the influence of change helix angle – this is due to the small change in the contact area of the grinding wheel with the workpiece. A greater reduction in grinding force F – by about 10% – was observed with the use of a 1A1 grinding wheel.

For the two grinding wheels, the largest differences were found in the grinding force components. Components force F_F and F_F have the highest values for the 12V9 grinding wheel.

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