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DESIGN OF THE NEW TECHNOLOGICAL PROCEDURE OF PRODUCING GROOVE OF SPIRAL BITS

Abstract: *One of the most commonly used and at the same time the most complicated cutting tools in terms of body geometry is the spiral drill bit. In the process of their production, the key operation is the production of spiral grooves. Until now, the grooves on the drill bits have been mainly produced by milling, grinding, rolling and extrusion processes. All these procedures have their advantages and disadvantages as well.*

Based on the experimental measurements of the dimensions of the grooves of the drill bits produced by the rolling and grinding technology, the paper defines the basic parameters and a new technological procedure for the production of grooves of the drill bits has been designed. For the suggested technological procedure of making of grooves of the drill bits, the advantages and disadvantages of the conventional production of the grooves of the drill bits by rolling or grinding technology have been analysed.

Keywords: *Spiral bits; Technological procedure; Grinding; Rolling*

1. Introduction

The cutting tools are in a direct contact with the material of the workpiece and create its final appearance by machining by particle separation or deformation. During machining, the cutting tool blade destroys the connection of the material particles, causing it to be exposed to mechanical, thermal and chemical action, or wear (Trupković & Botak, 2014; Đorđević et al., 2019).

A spiral bit (SB) is one of the most complicated cutting tools with regard to the geometry of the body, the difficulty in controlling the occurrences during the hole - making process and the problems in determining the relative importance of a number of influencing factors on the durability, accuracy of the dimensions and shapes of the hole, quality of the machined surface and productivity.

The geometry of the SB body consists of a set of geometric elements (surfaces, angles, and cutting blades) with appropriate interrelationships and represents a key factor in the drilling process (Xavier & Elangovan, 2013). Complex geometry in comparison with other cutting tools involves numerous conflicts of design goals such as low cutting forces, abrasion resistance, torsional and axial stability, the ability to remove chips from the cutting zone, etc. (Abele & Fujara, 2010). Due to the complex geometry, it takes a lot of time and engineering research and knowledge to construct and produce new SB geometry (Meral et al., 2019). The basic geometry of the SB body consists of a conical work tip and two spiral grooves for removing the chips out of the cutting zone and supplying of the coolant and lubricant. The spiral groove is formed by two curved surfaces: profile and back. The profile side of the groove

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represents the front surface, and the conical surface of the tip represents the back surface of the cutter. The intersection of these two surfaces forms the main cutting edge. The shape and orientation of the cutting edge in relation to the SB axis influences the design of the drill bit. Most analyses of SB groove contour have been performed assuming that the main cutting edge is a straight line (Ren & Ni, 1999; Galloway, 1957; Fujii et al., 1970; Tsai & Wu, 1979; Huang et al., 1994).

As it can be noticed, the construction and making of grooves of spiral drill bits, that is, the construction and making of tools for making SB grooves, is a complex problem due to its complex geometry and other conflicting production goals. Due to the complexity of defining the profile of the tool for making SB groove while operating (Jovanović et al., 2014), the software has been developed for generating the profile of the tool for making SB groove depending on the diameter nominal of the SB, the core diameter, the angle of climb and the tip angle, provided that the main cutting edge is a straight line and keeping the width of key and the groove in the ratio 1:1. The tool for the automatic generating of the 3D model of SB, in SolidWorks, has been developed during the work process (Vijayaraghavan, 2006). Based on the production parameters entered by the user via the GUI, the software automatically generates a 3D model of a drill bit. The paper (Beju et al., 2016) describes a mathematical approach for modelling, simulation and making of SB groove profiles of different shapes, vertical in the cross section to the longitudinal axis, by applying standard forms of grinding wheels.

In the process of designing the technology for making the spiral drill bits, the key operation is indeed the production of the grooves, because their production gives the basic shape of the cutting part of the drill bit. Other operations are identical for all technologies, but the order, each operation is performed, is different. For that reason, the technology of production of spiral bits is named after the method of making spiral grooves and the following technologies have been in use so far:

- production of spiral drill bits by milling technology,
- production of spiral drill bits by grinding technology,
- production of spiral drill bits by rolling technology and
- production of spiral drill bits by extrusion technology.

In this research, the focus is on introducing innovation in the production process of a SB groove with diameter nominal of Ø10 - Ø20 mm. The new technological process for making of SB grooves is a combination of rolling and grinding operations, with the rolling process preceding the grinding process, which is the final operation. Based on the results of experimental measurements of SB grooves produced by rolling and grinding technologies, the paper is analysing the possibility of making SB grooves by a new technological procedure and the value of input parameters for designing the technological manufacturing process has been calculated.

The new technological process of making SB grooves with diameters Ø10 - Ø20 mm designed in this way enables the retention of positive properties of rolling technology (good mechanical properties of SB due to continuous flow of fibres, considerable raw material savings and reduced main time for production) and grinding technology (significantly improved quality of the machined surface and lower cutting resistance) and at the same time eliminates shortcomings of rolling technology (discrepancy of dimensions, i.e. deviation of the groove profile from the nominal dimensions) and grinding technology (frequent sharpening i.e. profiling of the wheels, reduced visibility of work due to extensive cooling, etc.). In addition, due to the small grinding attachment, this technological process also provides a saving in grinding wheels compared to the production of SB by grinding technology.

2. Technology of making of spiral drill bits

Quality workmanship of SB should provide a reliable and stable cutting process with high productivity and maximum tool life (Denkena, 2011). Designing technologies for manufacturing of high performance SBs is a very complex process, primarily because of the complex relationships between the geometry of the tool itself and other conflicting design process goals. For this reason, the modelling and construction of SB grooves is the subject of numerous analyses.

The SB production technology is based on the manufacturing of grooves by material separation and plastic deformation processes, Figure 1.

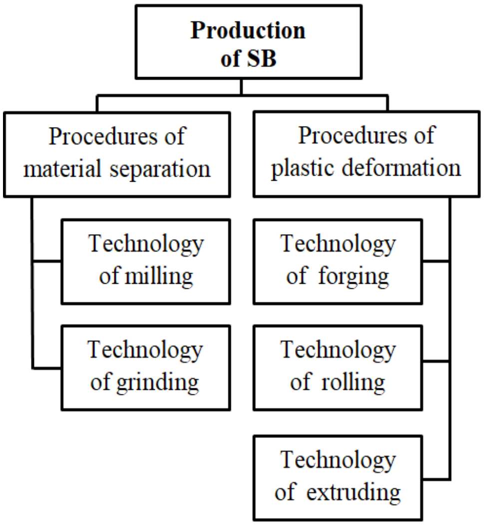

Figure 1. Procedures of the SB making

By the procedures of material separation SB grooves were initially manufactured by milling technology, which has sustained up until today although other technologies have been developed as well. The milling technology shape spiral grooves by profiled side and face milling cutters, Figure 2.

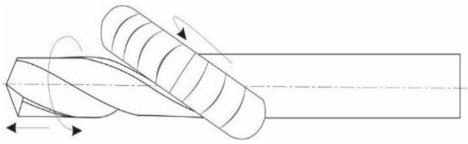

Figure 2. Making of a drill bit groove by milling technology

Basic features of spiral grooves making by milling technology are: less time needed for preparation and more time for main production process compared to other technologies, accuracy of shapes and dimensions, once the milling machine is adjusted there is no need for its readjustments until it is blunt or broken, poor quality of machined surface, usage of expensive tools (profiled side and face mill cutters), complicated design and regeneration of tools, etc.

The development of the deep grinding procedure has enabled the production of spiral grooves on bits by grinding technology by the abrasive which is profiled by respective diamond tools, Figure 3.

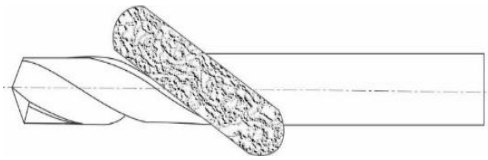

Figure 3. Making of a drill bit groove by grinding technology

By profiling the abrasive from its work surface, a layer of abrasive grains and binders is removed, the thickness of which should be as small as possible, due to less usage of abrasive, but large enough to remove the blunt abrasive grains and the layer of adhesive material which is being processed. This operation corresponds to the sharpening operation of cutting tools of defined geometry and is sometimes referred to as "sharpening of the abrasive". Recently, in addition to profiling the abrasive after performing the grinding operation, high-performance grinding is applied with continuous profiling of the abrasive during the process. This accomplishes profile maintenance and avoids the appearance of grinding defects when performing operations of profile grinding of grooves. In addition, processing time is shortened due to the loss of time for subsequent abrasive profiling (Jović et al., 1986). The basic characteristics of making the spiral drill bits grooves by grinding technology are: reduction of the main processing time, significantly improved surface quality and accuracy of shapes and dimensions in comparison to other technologies, frequent sharpening (profiling) and considerable consumption of the abrasive, reduced visibility of work due to extensive cooling, etc.

Making SB grooves by the material removal procedures provide high accuracy, but at the same time these procedures spend a large amount of the material because the usage rate of weight of the rod, used to make a bit, is often only 50-60% (Bulzak et al., 2014). The constant aspiration for finding better methods of shaping the grooves of the drill bits has led to the applying of plastic deformations, i.e. technologies of forging, rolling and extrusion, in the production of grooves on the drill bits. Forging, being the oldest method of drilling bits production, is no longer applied because of low productivity and the need to apply metal twisting once forging is completed. Techniques for making grooves of spiral drill bits by metal shaping are characterised by high productivity and efficiency, as they result in expensive tool steel savings of 30 to 40%, resulting in a significant reduction in the prices of final products. The SBs with grooves produced by plastic deformations have advantageous internal structures that provide high strength and wear resistance.

The production of grooves of the spiral bits by rolling technology, Figure 4, takes place by longitudinal rolling in the warm state by profiled rollers (segments) made of hard metal. The productivity of making the grooves by rolling technology is increased by 15 - 20 times compared to milling technology. Raw material savings are up to 30% in comparison to milling or grinding technology (Bulzak et al., 2014) Namely, with this technology there is no loss of material during the process of making the grooves and the rear parts, because it is transformed into a body of a drill bit by the rolling process. The making of grooves of the drill bits by rolling technology starts from the end of the groove, unlike the milling and grinding technology where the groove making starts from the tip of the drill bit. Rolling technology is characterized by a significant reduction of the main machining time, an increase in raw material savings compared to milling and grinding technologies, good mechanical properties of the drill due to the continuous flow of fibres, simpler operation of machines, deviation of the shape and dimensions of the groove profile from nominal measures, longer preparation time compared to other production technologies, the use of expensive rolling tools (segments), unprofitability in small batches, etc.

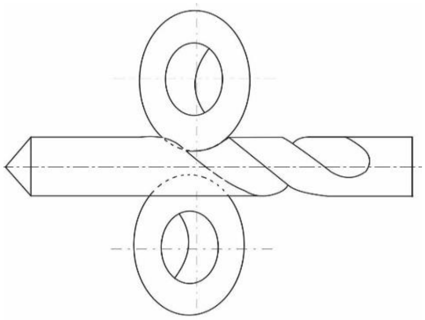

Figure 4. Making of a drill bit groove by rolling technology

Of the metal forming processes, in addition to the rolling process, extrusion methods are also used for making grooves of spiral drill bits, most commonly direct or forward extrusion.

Recently, screw extrusion has been increasingly used to make spiral bits grooves, Figure 5. This is a process of a material brought to the forging temperature being forced through a spiral hole made in a mould. The material leaving the mould performs a curved motion combined with a straight and rotational motion (Bulzak et al., 2017; Bulzak & Pater, 2013; Hwang & Chang, 2014).

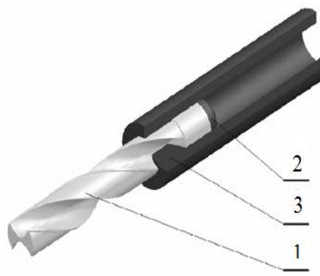

Figure 5. Making of SB groove by extrusion: 1 – SB, 2 –material, 3 – matrix (Bulzak & Pater, 2013)

The paper (Bulzak et al., 2014) presents a new procedure of making spiral bits by extrusion in separate moulds, Figure 6.

Unlike other methods, only the operational part of a drill bit can be made by extrusion methods, which later, usually by welding, is connected to the matching handle. The extrusion process can also be used to produce three-groove drill bits, concrete drill bits and larger drill bits (Bulzak et al., 2014).

The main disadvantage of the production of SB by extrusion processes is the inability to provide core thickening.

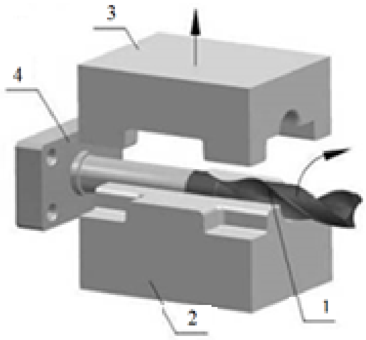

Figure 6. Making of a SB groove by extrusion in a two – part mould: 1 – SB, 2 – lower part of the mould, 3 – upper part of the mould, 4 – extruder (Bulzak et al., 2014)

3. Basic features of the new technological procedure of making spiral bit grooves

Conventional groove making technologies of SBs do not meet equally the criteria regarding quality and cost, Figure 7. For example, rolling technology achieves raw material savings, thus lowering the cost, but the quality is much lower than drills made by grinding technology whose price is much higher (Bulzak et al., 2016).

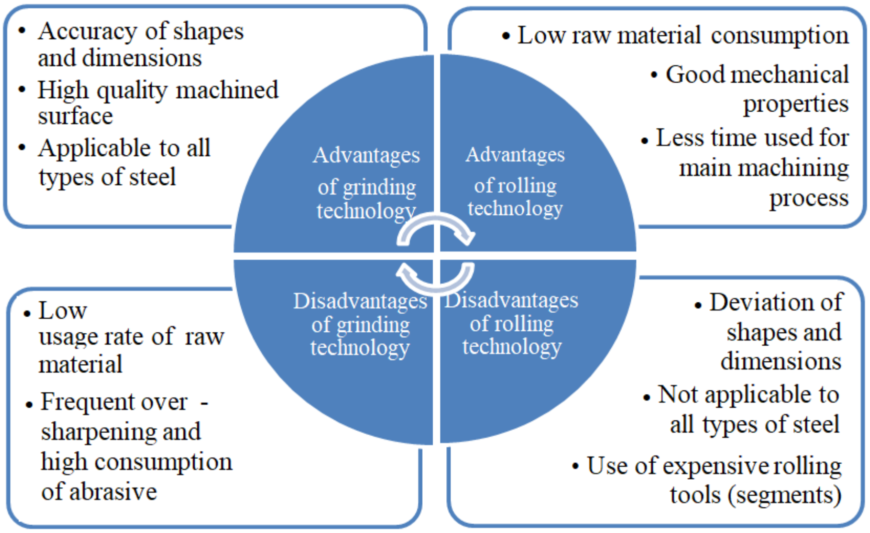

Figure 7. Basic features of SB grooves making technologies

The basic characteristics of the SB quality are cutting ability and rigidity, which, in addition to the material used, depend primarily on the geometric accuracy of the shape and dimensions and the surface roughness of the grooves. These are two colliding requirements that are difficult to optimize. Consequently, increasing the diameter and thickening of the core automatically increases the rigidity of the SB, but decreases the cutting capacity, while decreasing the diameter and thickening of the core increases the cutting capacity and decreases the rigidity. One of the requirements of cutting ability is a straight cutting edge, which can be achieved by SB sharpening only if the profile side of the groove is in the matching shape and geometric dimensions. The removal of chips from the cutting zone depends largely on the quality of the machined surface and the key - groove ratio. The optimum cross-sectional shape of the SB body is at the 1:1 ratio between the key and the grooves. However, the majority of SB manufacturers that use grinding technology, due to the less material removed and the consumption of the abrasive produces a larger diameter SB with a key - groove ratio of up to 1: 0.80. This ratio leads to an increase in the rigidity of the SB, but also to the difficult removal of the chips from the cutting zone and a decrease in cutting ability.

The new technological method of making grooves of spiral drill bits predicts production of grooves by combining two known technologies: rolling and grinding. In the first operation, the spiral grooves are made by rolling technology, with the grinding attachment. Thus, the SBs have all the positive features of rolling technology (raw material savings and good mechanical properties due to the continuous flow of fibres). After thermic treatment, the grooves are grinded until final dimensions are reached, Figure 8. The grinding operation eliminates the basic disadvantage of SB with groove made by rolling technology - deviation from the shape and dimension of the groove profile, and achieves the advantages of SB produced by grinding technology: good machined surface quality and accuracy of shape and dimension of the groove profile.

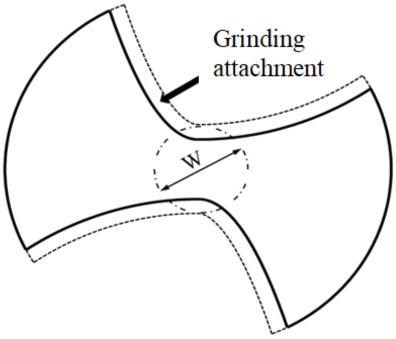

Figure 8. The scheme of SB groove making by a new technological procedure

As a result, the application of the new SB groove production process ensures that the SB owns the positive features of the SB groove production by both, grinding and rolling technology, Figure 9.

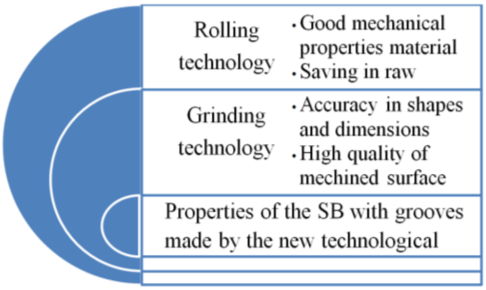

Figure 9. Properties of a groove with a groove produced by a new technological process

In addition, the grinding technology eliminates a small amount of material, so the consumption of the abrasive is negligible compared to the production of grooves by grinding technology. Thus, the application of the new SB groove manufacturing process ensures that the SBs possess the positive properties of the SB groove produced by grinding technology and rolling technology, as well as material and abrasive savings over grinding technology.

4. The analysis of potential application of the new technological procedure of making spiral bit grooves

In order to confirm the basic hypothesis in the paper, from the technological point of view, that there is a possibility of making SB grooves with a new technological procedure, as well as auxiliary hypothesis: that SBs with a groove made by the new technological procedure possess positive characteristics of SBs with groove made by both rolling and grinding technology, the basic dimensions measurements of SBs have been conducted (groove width, key width, core diameter and thickness and angle of climb for the spiral), of nominal diameter Ø12.0 mm, Ø15.0 mm and Ø20.0 mm, Figure 10, produced by rolling technology (Table 1) and grinding technology (Table 2).

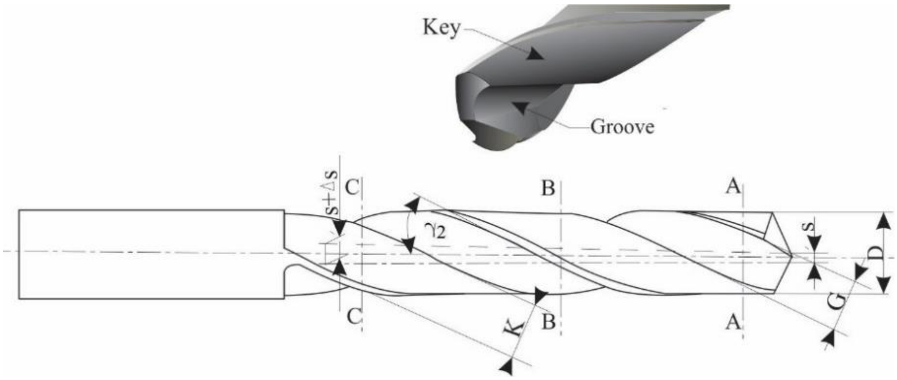

Figure 10. Geometric elements of the SB groove

For all spiral bits (SB) listed in the Tables 1 and 2, the measurements have been conducted on 3 samples of spiral bits on both spiral groove/key at three locations: tip of the spiral groove (location A), the middle of the spiral groove (location B) and the end of the spiral groove (location C).

From the measurement results (Tables 1 and 2) it is evident that there is a slight discrepancy of the dimensions of the grooves (groove and key width, diameter and thickness of the core and angle of climb), and that due to the thickness of the core, the width of the groove decreases evenly in both technologies, from the tip towards the end of the grooves, whereas the width of the key increases. It can also be seen that the width of the grooves produced by grinding technology is smaller than the width of the grooves produced by the rolling technology by 3 to 10%, depending on the diameter nominal of SB, whereas the core diameter is up to 30% larger. Thus, for SB Ø12 mm, the groove width is in the ratio 0.94:1 in relation to the width of the key; this ratio is 0.96:1 for SB Ø15, and even 0.84:1 for SB Ø20, instead of the required ratio of 1:1.

This deviation in the dimensions of the grooves produced by grinding technology reduces the amount of material removed, the consumption of the abrasive agent and the grinding resistance. On the other hand, the decrease of the groove width in relation to the width of the key has a negative effect on the drilling resistance (due to the increase in the transverse blade) and the removal of the chips from the cutting zone, which is a significant disadvantage of the spiral drill bits. However, according to the SB manufacturers' technological roadmap who provided the sample SBs for the analysis, a SB of nominal diameter > Ø13.0 mm produced by grinding technology up to 10% smaller core diameter is projected, and for all SBs produced by grinding technology a smaller core thickness ≈ 25 - 45% compared to SB produced by rolling technology is also anticipated. This way of designing core diameter and core thickening for SB produced by grinding technology provides a groove width of 1: 1 or marginally larger groove width, as well as a smaller increase in groove width due to core thickening, compared to SB produced by rolling technology.

Based on the previous analysis, the conclusion that can be drawn is as follows: from the technological point of view there is indeed a possibility to make spiral drill bits grooves by combining the operations of rolling and grinding, where the rolling operation comes earlier and grooves are produced by the grinding attachment, and the grinding operation shapes the grooves until final dimensions are reached, which proves the basic hypothesis of this paper.

Table 1. Dimensions of the SB groove produced by the rolling technology

Diameter nominal of the bit	Data from the technological roadmap			Data gained my measurements									
	Diameter of the core	Core thickness	Angle of climb for the spiral	Sample	Diameter of the core	Core thickness	Angle of climb for the spiral	Width of the groove			Width of the key		
								Location of measurement			Location of measurement		
								A	B	C	A	B	C
Ø12.0	1.9	1.29 - 1.72	25 – 30	1	1.88	1.45	28.5	7.95	7.93	7.90	7.82	7.85	7.87
								7.92	7.90	7.88	7.84	7.86	7.88
				2	1.90	1.50	27.5	7.90	7.87	7.84	7.85	7.88	7.91
								7.92	7.90	7.87	7.83	7.85	7.88
				3	1.89	1.55	28	7.88	7.85	7.81	7.85	7.88	7.90
								7.92	7.88	7.84	7.83	7.87	7.89
Mean value								7.92	7.89	7.86	7.84	7.87	7.89
Ø15.0	2.5	1.485 - 1.98	25 – 30	1	2.54	1.78	27	9.94	9.87	9.85	9.75	9.87	9.92
								9.90	9.86	9.83	9.77	9.91	9.95
				2	2.48	1.75	27	9.98	9.94	9.90	9.72	9.85	9.87
								9.94	9.90	9.86	9.71	9.84	9.86
				3	2.50	1.72	27.5	9.94	9.91	9.87	9.73	9.85	9.87
								9.92	9.87	9.85	9.74	9.85	9.88
Mean value								9.94	9.89	9.86	9.74	9.86	9.89
Ø20.0	3.3	1.865 - 2.5	25 – 30	1	3.25	2.24	30	13.24	13.21	13.16	13.10	13.15	13.18
								13.21	13.17	13.14	13.08	13.14	13.17
				2	3.30	2.20	29.5	13.19	13.15	13.12	13.12	13.16	13.18
								13.20	13.17	13.14	13.11	13.15	13.19
				3	3.28	2.30	30	13.23	13.18	13.12	13.11	13.14	13.22
								13.18	13.14	13.08	13.09	13.12	13.18
Mean value								13.21	13.17	13.13	13.10	13.14	13.19

Table 2. Dimensions of the SB groove produced by the grinding technology

Diameter nominal of the bit	Data from the technological roadmap			Data gained my measurements									
	Diameter of the core	Core thickness	Angle of climb for the spiral	Sample	Diameter of the core	Core thickness	Angle of climb for the spiral	Width of the groove			Width of the key		
								Location of measurement			Location of measurement		
								A	B	C	A	B	C
Ø12.0	2.0	0.96 – 1.20	$30^{+/-5}$	1	2.42	1.45	30	7.52	7.31	7.28	8.12	8.29	8.47
								7.58	7.28	7.22	8.05	8.15	8.33
				2	2.35	1.55	29.5	7.64	7.47	7.26	8.00	8.22	8.42
								7.58	7.45	7.30	8.02	8.15	8.28
				3	2.46	1.50	31	7.56	7.45	7.32	8.08	8.22	8.46
								7.64	7.48	7.24	8.04	8.20	8.38
Mean value								7.59	7.41	7.27	8.05	8.21	8.39
Ø15.0	2.38	1.20 – 1.50	$30^{+/-5}$	1	2.82	1.38	27	9.59	9.28	9.22	9.73	9.92	10.37
								9.67	9.48	9.35	9.83	10.12	10.49
				2	2.78	1.25	27	9.62	9.44	9.30	9.92	10.17	10.35
								9.58	9.40	9.26	9.88	10.04	10.22
				3	2.70	1.42	27.5	9.64	9.46	9.26	9.96	10.25	10.54
								9.66	9.46	9.28	10.04	10.28	10.60
Mean value								9.63	9.42	9.28	9.89	10.13	10.43
Ø20.0	3.0	1.40 – 1.75	$30^{+/-5}$	1	3.30	2.24	30	12.18	11.94	11.66	14.54	14.72	14.98
								12.12	11.83	11.61	14.46	14.65	14.94
				2	3.36	2.20	29.5	12.16	11.88	11.72	14.48	14.66	14.92
								12.08	11.82	11.68	14.36	14.65	14.84
				3	3.22	2.30	30	12.23	12.04	11.72	14.41	14.74	14.92
								12.28	12.00	11.68	14.59	14.62	14.96
Mean value								12.18	11.92	11.68	14.47	14.67	14.93

The analysis clearly shows that this process of making SB grooves would preserve all the positive properties of SB with grooves produced by rolling technology: high productivity, saving raw material compared to SB with grooves produced by grinding technology, advantageous internal structure that provides high hardness and resistance to wear, as well as all the positive features of the groove making of the drill bits by grinding technology: improved machined surface quality and lower cutting resistance. While keeping positive features, this process eliminates the basic disadvantage of SB with grooves produced by rolling technology: deviation from the defined profile of spiral grooves, as well as the basic disadvantages of groove making by SB grinding technology: substantial consumption of grinding wheels, frequent sharpening (profiling) of grinding wheels and reduced visibility of operation due to extensive cooling. Accordingly, the auxiliary hypothesis of the paper has been proven by this as well.

5. Designing the new technological procedure for making the spiral bits grooves

In order to create a new technological process for the design of the SB groove, it is necessary to provide suitable input parameters. Thus, for the grinding operation, the diameter and the thickness of the core have been adopted according to the technological roadmaps of the SB manufacturer and for the rolling operation adopted values provide a grinding attachment of 0.5 mm for SB Ø12, 0.55 for SB Ø15 and 0.75 mm for SB Ø20 mm. For both operations, a 27+/- 2 angle of climb of the grooves has been adopted.

Based on the above SB dimensions, provided that the groove and key widths are in the ratio 1:1, and after the cutting operation at an angle of the tip of 118˚ with the straight line cutting edge, by generating the SB geometric model using the AutoCAD application program, it all resulted in groove and key widths, as well as grinding attachment area and the groove area measured in cross section vertical to the angle of climb of the groove, for rolling and grinding operations, Figures 11 and 12. The values gained are shown in Table 3.

The adopted dimensions of the SB groove of diameter nominal Ø12 mm, Ø15 mm and Ø20 mm for operations of rolling and grinding of the new technological procedure are shown in Table 4.

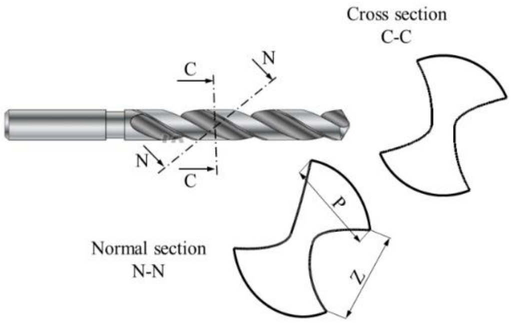

Figure 11. Cross section and the normal section of the SB

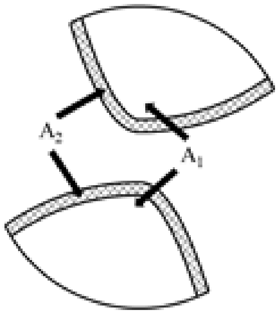

Figure 12. Areas in the cross section of the SB

Table 3. Dimensions of the grove and the key for the operations of rolling and grinding

Diameter Nominal D [mm]	Rolling operation			Grinding operation			
	Width of the key K [mm]	Width of the groove G [mm]	Area of the groove A_1 [mm^2]	Width of the key K [mm]	Width of the groove G [mm]	Area of the groove A_1+A_2 [mm^2]	Area of the grinding attachment A_2 [mm^2]
Ø12	8.90	6.96	45.26	7.90	7.96	55.94	10.68
Ø15	10.97	8.85	73.24	9.87	9.95	88.05	14.81
Ø20	14.67	11.76	130.72	13.17	13.26	157.78	27.06

Table 4. Dimensions of the SB groove in accordance with the new technological procedure

Diameter Nominal of the drill bit	Rolling operation					Grinding operation				
	Diameter of the core	Thickness of the core	Angle of the climb of the spiral	Width of the groove	Width of the key	Diameter of the core	Thickness of the core	Angle of the climb of the spiral	Width of the groove	Width of the key
Ø12	3.0	0.96 – 1.20	27°	6.95	8.90	2.0	0.96 – 1.20	27°	7.95	7.90
Ø15	3.5	1.20 – 1.50		8.85	11.00	2.38	1.20 – 1.50		9.95	9.90
Ø20	4.5	1.40 – 1.75		11.75	14.65	3.0	1.40 – 1.75		13.25	13.15

Having in mind that, in the new technological process of making the SB groove, the rolling operation is performed by the grinding attachment, Fig. 12, a smaller volume of material is extruded from the spiral grooves into the body of the SB. Consequently, the length of the formed spiral body will be smaller, so that the length of the raw part (material) must be larger than the length of the raw part (material) for making the SB groove by the rolling technology.

The difference between the length of the raw parts for the new technological process of for making the SB groove and the length of the raw part for making the SB groove by the rolling process can be obtained from the equation of the volume of the grinding attachment and the volume of the SB body made by the grinding attachment, according to the pattern:

$$V_{ga} = V_{ba} \qquad (1),$$

this is as follows:

V_{ga} – volume of the grinding attachment and

V_{ba} – volume of the SB body made by the grinding attachment.

Acknowledging that:

$$V_{ga} = A_2 \cdot l_s \text{ and}$$
$$V_{ba} = A_t \cdot x \qquad (2),$$

with the following:

A_2 - area of the cross section of the grinding attachment,

l_s- length of the raw part where groove rolling is performed,

$A_t = A - A_1$ – area of the cross section of the SB body,

A - area of the cross section of the raw part and

A_1- area of the cross section of 2 grooves with the grinding attachment,

x - length of the SB body made by the grinding attachment.

Thus, subsequent to the pattern (2):

$$x = \frac{V_{ga}}{A_t} = \frac{A_2 \cdot l_s}{A - A_1} \qquad (3).$$

The calculation of the difference between the length of the raw part for the new technological process of making SB grooves and the length of the raw part for making SB grooves by rolling, according to the form (3), for SB of diameter nominal Ø12 mm, Ø15 mm and Ø20 mm is shown in Table 5.

Table 5. The calculation of the difference between the lengths of raw parts

Diameter nominal of SB	Ø12	Ø15	Ø20
The length of the raw part for groove rolling ls [mm]	55	60	79
The area of the cross section of the grinding attachment A_2 [mm^2]	10.68	14.81	27.06
Area of the section of the raw part A [mm^2]	113.04	176.63	314.00
Area of the section of 2 grooves A_1 [mm^2]	45.26	73.24	130.72
Difference in the length of the raw parts x [mm]	**8.67**	**8.60**	**11.66**

The difference in the length of the raw part for making the SB grooves by the new technological procedure compared to the making of the SB grooves by the rolling process and the length of the raw part for making the SB grooves by the rolling process represents the length of the raw part for making the SB grooves by the new technological process. Calculated in that way, the dimensions of the raw parts for the production of SB of diameter nominal Ø12 mm, Ø15 mm and Ø20 mm are shown in Table 6.

The suggested technological process for making the SB grooves does not require additional funds for providing the tools, as the rolling operation of the grooves can be performed by the variation of the input parameters with already existing tools, and the final grinding with the tools projected for making the SB grooves by the grinding technology.

Table 6. Dimensions of the raw parts for the new technological procedure for making of SB grooves

Diameter Nominal of SB	Dimensions of the raw parts for the new technological procedure		Dimensions of the raw parts for the grinding technology	Difference	
	Diameter nominal [mm]	Length [mm]		mm	%
Ø12	Ø12.3	113	151	38	25.2
Ø15	Ø15.3	123	169	46	27.2
Ø20	Ø20.3	155	205	50	24.4

Thus, the production price of the SB with a groove made by the new technological process will be slightly higher than the cost of the SB with the groove produced by the rolling technology, and the quality is better or equal to the SB with the groove produced by the grinding technology.

6. Conclusion

An analysis of the application of the new technological procedure for SB groove making has shown that, from a technological point of view, there is indeed a possibility of making SBs with a groove produced by the newly designed technological procedure which combines rolling and grinding operations. The grooves produced by the new technological process retain all the positive features of the grooves produced by the rolling and grinding technology and at the same time eliminate their disadvantages. In addition, the new SB groove making process provides significant savings in both material and abrasives over the SB groove produced by the grinding process as well as the highest quality SBs so far.

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References:

Abele, E., & Fujara, M. (2010). Simulation-based twist drill design and geometry optimization. *CIRP Annals Manufacturing Technology*, *59*, 145-150.

Beju, L. D., Brîndaşu D. P., Muţiu N. C., & Rothmund J. (2016). Modeling, simulation and manufacturing of drill flutes. *International Journal of Advanced Manufacturing Technology 83*(9-12), 2111-2127.

Bulzak, T, Tomczak, J., & Pater Z. (2014). Method for producing twist drills by extrusion using a three-slide forging press. *Key Engineering Materials*, *622-623*, 129-135

Bulzak, T., & Pater, Z. (2013). Numerical analysis of the extrusion process of twist drills. *Acta Metallurgica Slovaca*, *19*(2), 132-140.

Bulzak, T., Pater, Z., & Tomczak, J. (2016). Numerical modelling of screw rolling process of twist drills. *Advances in Science and Technology Research Journal*, *10*(32), 124-131.

Bulzak, T., Pater, Z., & Tomczak, J. (2017). New extrusion process for producing twist drills using split dies, *Applied Computer Science*, *13(3)*, 55-63.

Denkena, B., Lucas, A., & Bassett, E. (2011). Effects of the cutting edge microgeometry on tool wear and its thermomechanical load. *CIRP Annals - Manufacturing Technology, 60,* 73-76

Đorđević, A., Erić, M., Stefanović, M., Mitrović, S., Pantić, M., Kokić Arsić, A., & Džunić, D. (2019). Predicting cutting parameters by applying developed neural network and linear regression models. Paper presented at the 16th International Conference on Tribology - SERBIATRIB ’19. *Proceedings on engineering sciences*, *1*(1), 482-489.

Fujii, S., Devries M. F., & Wu, S. M. (1970). An analysis of drill geometry for optimum drill design by computer, Parts I and II, Drill geometry analysis; Computer-aided design, *Journal of Engineering for Industry, Transactions ASME*, Series B, 92, 647-666.

Galloway D. F. (1957). Some experiments on the influence of various factors on drill performance, *Transactions ASME 79*, 191-231.

Huang, H. T., Weng C. I., & Chen, C. K. (1994). Analysis of clearance and rake angles along cutting edge for multifacet drill, *Journal of Engineering for Industry, 116(1),* 8-16.

Hwang, Y. M., Chang C. N. (2014). Hot extrusion of hollow helical tubes of magnesium alloys. *Procedia Engineering*, *81*, 2249-2254.

Jovanović, J., Spaić, O., Tomović, R., & Ivanković, R. (2014). Computer Aided Design of Grinding Wheel for Drill Flute Production, *Journal of Mechanics Engineering and Automation*, *4*(9), 709-715.

Jović M., & associates (1986). Grinding process, Faculty for Mechanical Engineering of Belgrade University, *JUPITER community*, Beograd, 316-334.

Meral, G., Sarıkaya, M., Mia, M., Dilipak, H., Şeker, U., & Gupta, M. K. (2019). Multi-objective optimization of surface roughness, thrust force, and torque produced by novel drill geometries using Taguchi – based GRA. *The International Journal of Advanced Manufacturing Technology 101,* 1595-1610. doi: 10.1007/s00170-018-3061-z

Ren, K., & Ni, J. (1999). Analyses of drill flute and cutting angles. *International Journal of Advanced Manufacturing Technology*, *15*(8), 546-553.

Trupković, I., & Botak, Z. (2014). The influence of the geometry of the cutting edge to the duration of drill bits. *Tehnički glasnik*, *8*(1), 59-63.

Tsai W. D., & Wu, S. M. (1979). A mathematical model for drill point design and grinding, *Journal of Engineering for Industry*, *101*(3), 333-340.

Vijayaraghavan, A. (2006). Automated drill design software. Lab Manuf Sustain 1, 01-10.

Xavier, F. L., & Elangovan D. (2013). Effective Parameters for Improving Deep Hole Drilling Process by Conventional Method - A Review. *International Journal of Engineering Research & Technology (IJERT)*, *2*(3), 01-11.

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