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Study of the impact of the lubricant-cooling agent with the diamond graphite submicropowder additive on the durability of AISI M2 steel drill bits

E A Petrovsky[1], **K A Bashmur**[1], **N A Smirnov**[2], **V S Tynchenko**[1,2], **V V Bukhtoyarov**[1,2], **A A Gorodov**[1,2], **V E Petrenko**[1,2] **and V V Kukartsev**[1,2]

[1]Siberian Federal University, 79, Svobodny Av., Krasnoyarsk, 660041, Russia
[2]Reshetnev Siberian State University of Science and Technology, 31, Krasnoyarsky Rabochy Av., Krasnoyarsk, 660037, Russia

E-mail: petrovsky_quality@mail.ru, bashmur@bk.ru

Abstract. The present study analyzes the impact of various lubricant-cooling process agents on the durability of drill bits made of AISI M2 (DIN 1.3343) high-speed steel. The research was conducted for a wide range of steels and alloys, namely: 1045, 321H, Mo-PM (molybdenum powder alloy), and W-Ni pseudo-alloy. New lubricant-cooling process agents with diamond graphite submicropowder additive are studied. The optimal composition of diamond graphite additive is revealed when drilling these steels and alloys. Experimental studies established a positive effect of lubricant-cooling process agents with the diamond graphite submicropowder additive on the durability of the drill bits made of AISI M2 steel.

1. Introduction

The main methods of increasing the tool durability, in particular drill bits, can be identified: improvement of processing parameters; improvement of the geometric parameters of the tool; use of new materials for the tool; use of new coatings for the tool; design of effective tool geometry and design parameters; synthesis of efficient lubricating-cooling process agents (LCPA) during processing [1, 2].

It is likely that the largest reserves of drill bits durability lie in the field of synthesis of new LCPA which is the focus of this article. This is due to the high durability of the tool. In doing so, the cooling effect of LCPA on different cutting operations is manifested differently due to the high specificity of heat exchange conditions when they are performed [3, 4].

The immediate result of the cooling action of LCPA is to change the temperature field of the solid system (tool, workpiece, and chips) interacting during cutting. The consequence of this is to improve the accuracy of processing due to the reduction of temperature deformations and durability of cutting tools due to lower temperature and favorable change in the distribution of it on contact surfaces [5].

Efficiency of LCPA cooling action is determined by its cooling properties and ability of tool-chip-part system to provide additional heat removal due to heat exchange at boundaries with LCPA [6].

Heat can be removed from cutting zone through cutting tool, chips and/or workpiece. LCPA heat exchange with cutting tool surfaces has the greatest effect on temperature reduction of contact surfaces during cutting. Heat removal from processed parts is of independent importance during processing of small-size or thin-walled workpieces (reduction of workpiece temperature), high-precision parts (reduction of temperature deformations) and in other cases [7, 8].

The study of the new LCPA is of particular interest in terms of increasing the resource of conventional high-speed drill bits for the processing of hard-face alloys. These studies are also relevant in terms of increasing the economic effect. Savings are achieved through the use of conventional high-speed materials for the tool and available LCPA which can be attributed to LCPA with the diamond graphite submicropowder additive. Experimental studies of this type of LCPA should be conducted to determine its effect on the durability of the tool.

2. Methods and Materials

LCPA feed scheme used in the experiments is shown in Figure 1.

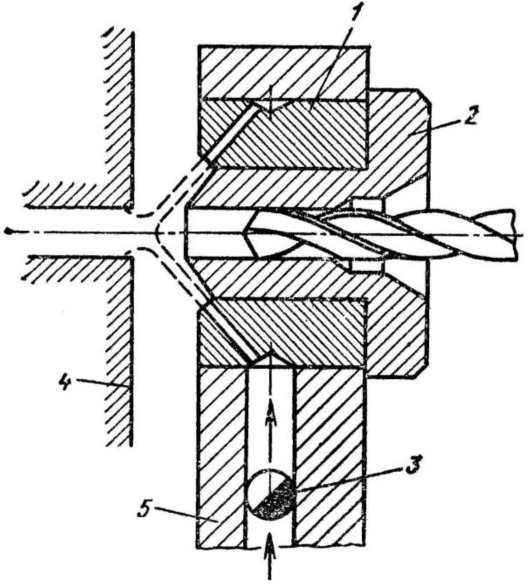

Figure 1. Schematic diagram of the lubrication drilling process: 1 – base stand; 2 – screw nut; 3 – retaining screw; 4 – workpiece; 5 – bushing.

The choice of such a lubricant supply system is due to the fact that it allows several jets of liquid to be supplied uniformly along the cone. The axis of the cone coincides with the axis of the tool, and the vertex is located in the gap between the bushing 5 and the workpiece 4 (Figure 1). This helps prevent spraying and loss of LCPA when drilling deep holes.

There are also known more effective lubrication supply systems, such as through an axial hole in the tool [9]. However, these systems are not yet common and do not have a significant impact on the study of processes of LCPA impact on the durability of the tool.

Water which has the highest relative productivity ratio was chosen as the basis for LCPA [10].

During the experiments the following components were added to the lubricant-cooling fluid (LCF) composition:

1. Fatty acid potassium and sodium salts - binder stabilizer, substances with good lubricating, emulsifying and washing properties.
2. Trietanolamine - hydrophilic lubricant, stabilizer, dispersant.
3. Potassium chromium and sodium nitrate are surfactants that soften the oxide film.
4. Glycerin is a stabilizer with good dispersing properties.

LCPA compositions used in the experiments are shown in Table 1.

Mathematical treatment of the results was to determine the average values of durability of drill bits X and root-mean-square deviations σ. As an estimate of durability degree in the drilling of materials the coefficient of durability K_L equal to the ratio of arithmetic average values of durability of the current LCPA to durability without LCPA (dry drilling) was calculated. The coefficient of durability for dry processing is accepted as $K_L = 1.0$.

Table 1. LCPA compositions

Component	Agent content numbers and component content, %				
	1	2	3	4	5
Diamond graphite submicropowder	Dry cutting	-	2	-	5
Potassium chromate		-	-	0.028	0.025
Trietanolamine		-	2	0.25	0.2
Sodium nitrate		-	-	0.07	0.06
Fatty acid salts		-	-	0.015	0.01
Glycerin		-	-	0.8	0.7
Water		100	96	98.837	93.805

Studies were carried out for various types of steels and alloys, namely 1045, 321H, Mo-PM (molybdenum powder alloy), W-Ni pseudo-alloy. Some mechanical and physical properties of the mentioned steel and alloy grades are given in Table 2 (according to the data of the standards for these materials).

Table 2. Mechanical and physical properties of steels and alloys

Properties	Steel and alloy grades			
	1045	321H	Mo-PM	W-Ni
Hardness, Brinell	163	217	225	252
Tensile Strength, MPa	565	515	655	760
Density, g/cc	7.87	7.92	10.2	16.5

To avoid the impact of speed and tool delivery drilling modes, parameters, and drill bit material were assumed to be the same. Common drill bits of fast-cutting steel AISI M2 (DIN 1.3343) were chosen as a working body.

3. Results and discussion

The durability values of the drill bits in 1045 steel processing are given in Table 3, 321H steel processing is given in Table 4, Mo-PM molybdenum powder alloy processing is given in Table 5, and W-Ni pseudo-alloy processing is given in Table 6. In all cases the number of drill bit revs selected is 710 rpm, drill bit feed - 0.1 mm/rev.

Experiments found that compared to dry cutting (LCPA No. 1) water cooling (LCPA No. 2) can both increase and reduce the durability of the tool and is expressed by the influence which for each grade of material is individual. That is, for the researched processing conditions the use of water does not have a significant impact on the durability and therefore is ineffective. The same can be said about LCPA No. 4 without diamond graphite additives. The use of LCPA No. 3 and SOTS No. 5 with various contents of diamond graphite additives definitely increases the durability of the drill bit.

It has been found that the drilling operation is unstable in the case of LCPA using and dry cutting, the root-mean-square deviation of durability values from the average value reaches 60%. However, the analysis of average values reveals differences in durability.

Maximum durability increase (12 times) is found in W-Ni pseudo-alloy drilling using LCPA No. 3. LCPA No. 3 provides increase of tool durability 2-3 times compared to water cooling and dry cutting on all investigated materials. This agent shows itself most in the hard alloys processing. During drilling processing of examined steels and alloys LCPA No. 5 provides the average increase of tool durability by 280%; LCPA No. 3 provides the average durability is increased by 481%.

Table 3. Drill bit durability values for processing 1045 steel

Drill bit No. /parameter	Drill bit durability values, s				
	agent 1	LCPA 2	LCPA 3	LCPA 4	LCPA 5
1	53	22	67	41	5
2	43	16	50	40	90
3	47	64	197	10	69
X	47.7	34	104	30.3	54.7
σ	4.11	21.35	65.66	14.38	36.15
K_L	1.0	0.71	2.1	0.6	1.15

Table 4. Drill bit durability values for 321H steel processing

Drill bit No. /parameter	Drill bit durability values, s				
	agent 1	LCPA 2	LCPA 3	LCPA 4	LCPA 5
1	25	4	3	125	39
2	11	62	28	97	45
3	3	12	61	88	30
X	13	26	30.7	103.33	38
σ	9.09	25.67	23.75	15.76	2.5
K_L	1.0	2.0	2.36	7.95	2.92

Table 5. Drill bit durability values for Mo-PM steel processing

Drill bit No. /parameter	Drill bit durability values, s				
	agent 1	LCPA 2	LCPA 3	LCPA 4	LCPA 5
1	5	9	24	10	9
2	7	6	9	7	8
3	3	10	7	31	6
X	5	8.33	13.33	16	7.67
σ	1.63	1.7	7.59	10.68	1.25
K_L	1.0	1.67	2.67	3.2	1.53

Table 6. Drill bit durability values for W-Ni steel processing

Drill bit No. /parameter	Drill bit durability values, s				
	agent 1	LCPA 2	LCPA 3	LCPA 4	LCPA 5
1	13	10	93	5	9
2	3	9	165	10	190
3	21	14	188	3	8
X	12.3	11	148.7	6	69
σ	7.36	2.16	40.47	2.94	85.56
K_L	1.0	0.89	12.09	0.487	5.61

4. Conclusion

Drilling operation using lubricating-cooling process agents and dry cutting is very unstable, the root-mean-square deviation of durability values on average reaches 60%.

In the drilling processing of the steels and alloys studied, 5% diamond graphite-enhancing agent provides the average increase in tool durability by 280%; 2% diamond graphite-enhancing agent provides the average durability increase by 481%.

Maximum durability increase (12 times) is found in W-Ni pseudo-alloy drilling using LCPA with the 2% diamond graphite submicropowder additive.

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