

## Study of accuracy and surface roughness of holes in comparative testing of small diameters gun drills

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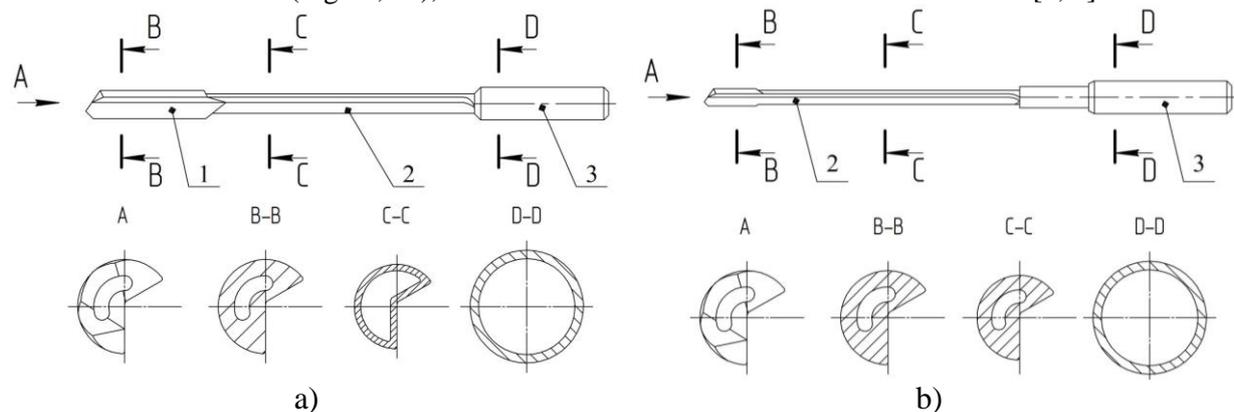
**Abstract.** The results of industrial tests of gun drills with the diameter of 2.05 mm with carbide and with steel stems are given. It is shown that the gun drills with cemented carbide stem and especially AlTiN coating have a greater resistance and greater accuracy diametrical holes sizes in comparison to gun drill with steel stem.

### Introduction

In the process of manufacturing fuel injection equipment for diesel engines there is a need for deep holes drilling of small ( $\leq 5$  mm) diameters. The mentioned above holes have high demands of accuracy (IT 6-9), surface roughness ( $R_a$  0,08 ... 1,25) and drill runoff (0,01 ... 0,03 mm/100 mm). Such small diameters of holes and the specified requirements for them are achieved by the use of tools with certainty based - gun drills. Gun drills with steel (GDSS) or cemented carbide (GDCCS) stems and deposited on the working parts of the wear-resistant coatings are mostly used for this purpose nowadays [4-7].

### THEORETICAL BACKGROUND

GDSS consists of carbide cutting tip 1, the steel stem 2 (steel 30HGSA) and the shank 3 (Figure, 1a). GDCCS tip and stem are a single cemented carbide rod 2 (produced by extruding) soldered to the shank 3 (Figure, 1b), or carbide rod that is both the stem and the shank [1, 3].



**Figure 1.** Gun drills with steel a) and cemented carbide b) stems.

Thanks to the use of cemented carbide ( $E = 6,20 \dots 6,45 \cdot 10^5$  MPa) [2] having the modulus of elasticity of more than 3 times higher than the modulus of elasticity of steel 30HGSA (Table 1) ( $E = 1,98 \dots 2,04 \cdot 10^5$  MPa) GDCCS as compared with GDSS possess greater strength under torsion and bending as well as greater rigidity and resistance in the transverse direction. These advantages have made the company «Botek» (Germany) produce GDCCS the smallest diameter of 0.47 mm (GDSS from it is 2.0 mm), while the drill diameter  $> 1$  mm - significantly improve the processing performance by increasing drilling regimes [3]. Cylindrical cemented carbide rods with eccentrically located kidney-shaped direct channel, which serves to supply cooling (Figure, 1b) are used for manufacturing GDCCS [1].



**Table 1.** Alloy compositions in the stem of GDSS.

C, %	Si, %	Mn, %	Ni, %	S, %	P, %	Cr, %	Cu, %	Fe, %
0,28...0,34	0,9...1,2	0,8...1,1	<0,3	<0,025	<0,025	0,8...1,1	<0,3	~96

## EXPERIMENTAL DETAILS

A special study was made to assess the technological capabilities of the drill resistance and accuracy of diametrical sizes. It was conducted in a production environment by drilling in automatic calcium steel brand AC41Cr4 of holes  $2^{+0,1}$  mm with the length 40 mm on the quadruple machine brand ML 250-4-850 Tiefbohrtechnik (Germany). Gun drills with 2,05h5 mm in diameter with steel and cemented carbide stems produced by «Botek» and Transet (Russia, Saint-Petersburg) were used as cutting tools. The drawings and technical requirements of the mentioned instruments have been developed in Tomsk Polytechnic University. Working parts of 9 GDCCS were deposited with wear-resistant coatings *TiN*, *AlTiN*, *TiCN* (Table 2).

**Table 2.** Gun drills used in the tests.

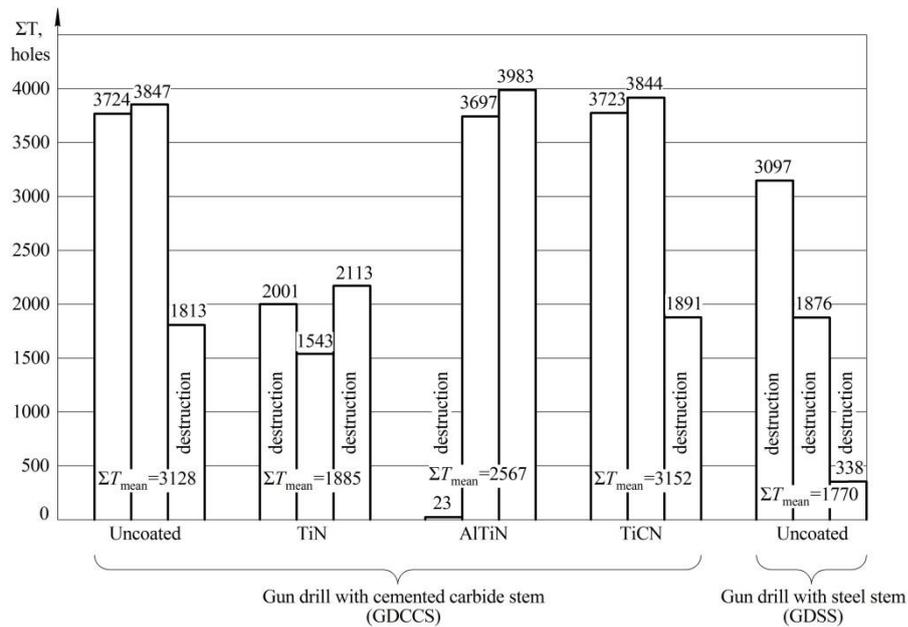
The type of a gun drill	Coating	The number of units
Gun drill with cemented carbide stem (GDCCS)	Uncoated	3
	TiN	3
	AlTiN	3
	TiCN	3
Gun drill with steel stem (GDSS)	Uncoated	3

Drilling regime: spindle speed  $n=14000 \text{ min}^{-1}$  (cutting speed  $V=90 \text{ m/min}$ ); feed  $S_m=64 \text{ mm/min}$ ; oil pressure coolant brand MP-3 with Technical Condition 0258-041-57518521-2011  $p=9...13 \text{ MPa}$ .

## RESULTS AND DISCUSSION

37552 holes were drilled by 15 drills during the test. It indicates the high quality of the testing instruments (Figure 2).

So, the average limit (until catastrophic wear) tool life of GDCCS without coating was 3128 holes, with TiN coating – 1885 holes, with AlTiN coatings – 2567 holes and TiCN coatings – 3152 holes, and uncoated GDSS – 1770 holes. Moreover, all the GDSS tests were withdrawn due to breakdown while only 5 drills (42%) with cemented carbide stem were destructed. The remaining 7 drills (58%) were not used in the test due to the appearance of burrs at the exit holes and could drill more.

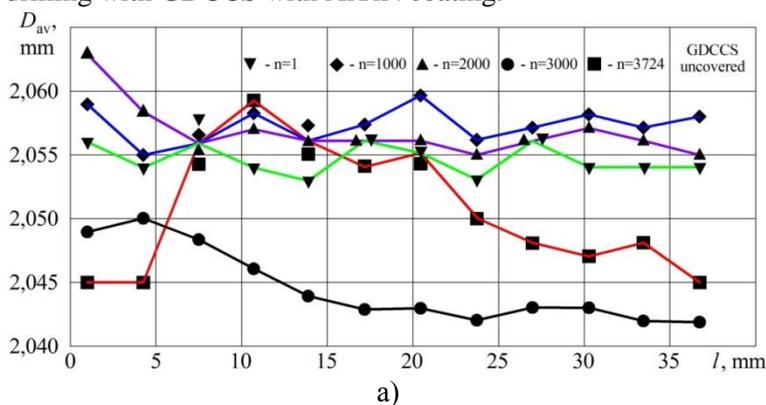


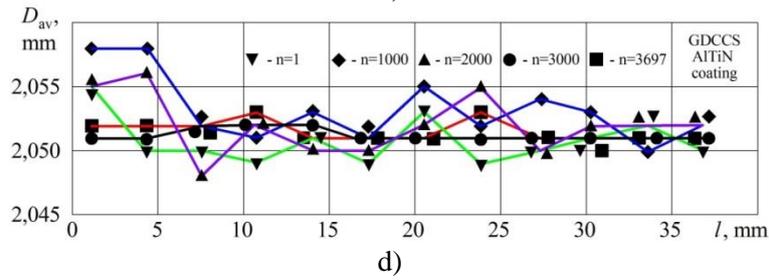
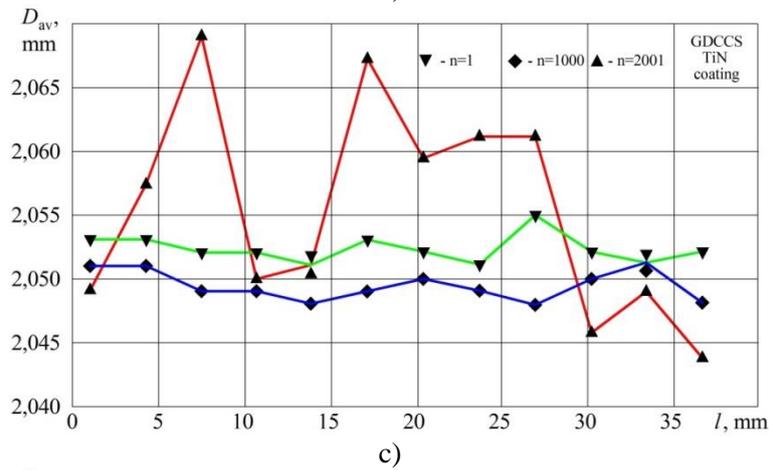
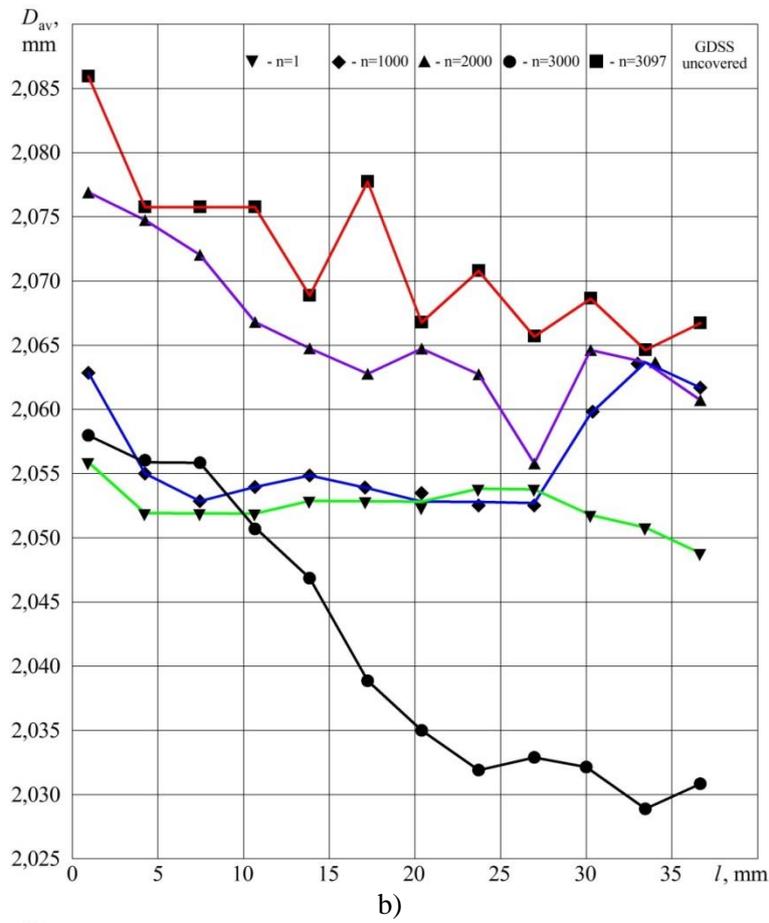
**Figure 2.** The influence of the gun drill type and the kind of wear-resistant coating on the total  $\Sigma T$  and the average  $\Sigma T_{\text{mean}}$  tool life.

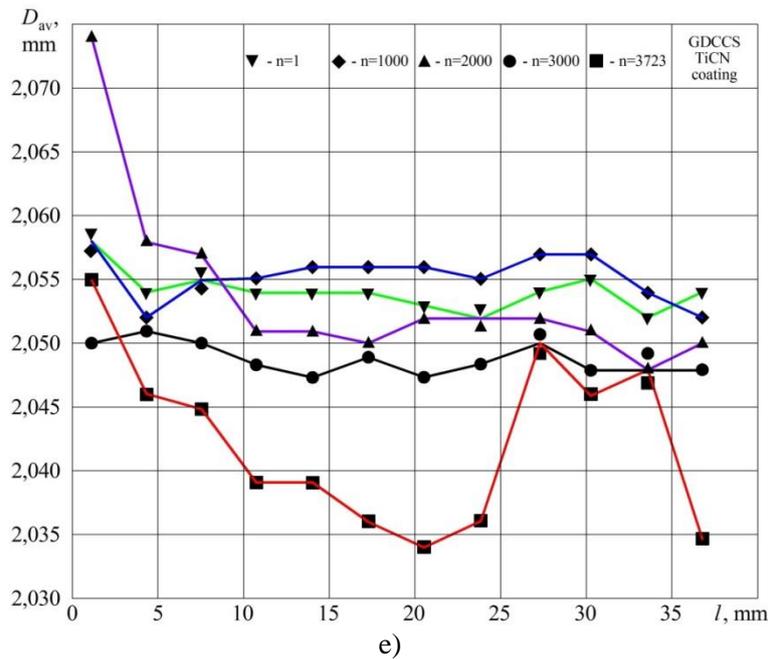
After the resistance test each first and the last one in a thousand of the drilled workpieces was selected to cutoff into the rings with the width of 7 mm. On the both sides and in the middle of each ring limit ( $D_{\text{max}}$  and  $D_{\text{min}}$ ) diameters of holes were measured by the high accuracy hole-gauge Mitutoyo with the precision of 1  $\mu\text{m}$ .

Measurements showed that as the number of drill holes (drill wear) increases the average diameter  $D_{\text{av}} = (D_{\text{max}} + D_{\text{min}}) / 2$  in each section of the holes also increases, and its fluctuations on length holes grow and as we approach the time of limit (catastrophic) wear the fluctuations reach the maximum (Figure 3).

In this case, the greatest diameter of the holes fluctuations occur during drilling with GDSS, and the lowest - in drilling with GDCCS with AlTiN coating.

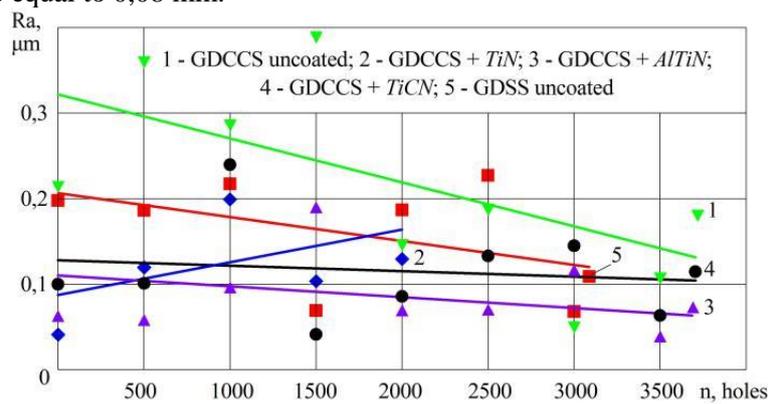






**Figure 3.** The fluctuations of average diameter holes  $D_{av}$  along its length  $l$  depending on the amount of the number of drilled preforms, gun drill design and the type of the wear-resistant coating.

After all of this milling workpiece for measuring arithmetic mean value  $R_a$  on non-contact profilometer Micro Measure 3D Station produced by STIL (Figure 4). All measurements of roughness were performed in CMPM in Tomsk Polytechnic University. For the analysis was used special program Surface Map 1.0.3. The resolving power of the laser was set at  $1 \mu\text{m}$ , the speed of movement of the laser beam is  $0,03 \text{ mm / sec}$ . Tracing length was  $2 \text{ mm}$  and was chosen from recommendations by ISO 4288-1996 and ISO 16610. In order to isolate the roughness used filtering Gaussian function with a cutoff value equal to  $0,08 \text{ mm}$ .



**Figure 4.** Fluctuations the surface roughness  $R_a$  of holes depending on the number  $n$  drilled holes, design of gun drills and the type of wear-resistant coating.

## SUMMARY

1. Tests showed the high quality of gun drills made by «Botek».
2. Tool life of GDCCS due to the greater stiffness and strength of 1,5 ... is 1,8 times higher than the tool life of GDSS.
3. GDCCS with AlTiN coating provide the greatest accuracy and stability of diametrical hole sizes.
4. Wear-resistant coatings are reduces holes roughness Ra of 1,5... is 3,0 than uncoated.

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