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INCREASING PRODUCTIVITY OF PROCESSING THE MORTAR BODY COMPONENT

Within the study, the increase in processing productivity of the mortar body part of the aerosol system AEK-902 "Tucha", is studied, which is actively used for camouflage and enhancing combat capability of military equipment and vehicles, serves as an auxiliary means for evacuation, and as a defense method against drones. Using the automated selection method, cutting tools and efficient cutting parameters were chosen for mechanical turning operations, utilizing software, including Sandvik ToolGuide, Walter GPS, and Iscar Tool Advisor. The obtained parameters were compared, the productivity was calculated using the material removal rate (MRR) method, and comparative productivity charts were created. Based on the data, recommendations for selecting cutting tools and processing parameters for specific turning operations were developed. The results are based on software recommendations and require further experimental verification in real production conditions. Verification through practical experiments will allow comparison of calculated parameters to actual processing indicators, refining the parameters and considering possible deviations. This is relevant direction for future research in automated tool selection and optimizing mechanical processing.

Keywords: turning, machining, cutting parameters, processing productivity, automated selection, cutting tool, boring.
Fig.: 4. Tables: 5. References: 12.

Relevance of the research. The use of smoke screen devices is relevant method that can be employed for camouflage. Smoke screens are widely used on various types of equipment, including Ukrainian military vehicles. Aerosols used in smoke screens provide opacity in visible, infrared, and radar (millimeter wave) ranges and absorb laser radiation to counter detection systems. Application of smoke screens helps protect personnel and equipment from enemy fire, thereby preventing losses. Expanding smoke mortars could be equipped off-road vehicles widely used for troop movement or evacuation.

Target setting. Special attention is given to reliability and durability of the mortar body, as its failure could prevent deployment of the smoke screen at the critical moment. Ensuring the high quality of this part will contribute to maintaining functionality of smoke masking systems and enhancing combat capability of armored vehicles or transport. The mortar body in the launching system plays an important role, as it holds and stores the grenade before firing and directs the grenade's launch trajectory for modifications that involve firing the ammunition. Other mortar body modifications are designed for stationary launching of the smoke grenade, which can be useful in creating the smoke screen for vehicles against drones.

Actual scientific researches and issues analysis. The most widely used camouflage system in the Ukrainian Armed Forces (UAF) is the Soviet aerosol system AEK-902 "Tucha" (Ukr. "Khmara"). The system includes several launching devices (mortars), each of which is a smoothbore grenade launcher of 81 mm caliber, with a barrel length of 270 mm and a weight of 1.35 kg.

They are mounted on the hull or turret of the armored vehicle and equipped with electric trigger for remote grenade launch. The ammunition includes smoke grenades of types 3D6, 3D6M, or 3D17, which, after being launched, create a dense smoke screen at a distance of up to 300 meters [1]. Formation of the screen takes 10–20 seconds, and its duration is about 2.5 minutes, providing effective camouflage for armored vehicles on the battlefield [2-4]. It is used both on Soviet-era vehicles in service with the Ukrainian Armed Forces (T-62, T-64, T-72, T-80 tanks, BMP-1P and BMP-2 infantry fighting vehicles), as well as on new models such as the T-84 "Oplot" tank and BTR-3 and BTR-4 "Bucephalus" armored personnel carriers. In addition, the system is installed on modernized Ukrainian BTR-80UP and BMP-1U vehicles. The use of aerosols ensures: artificial deterioration of atmospheric transparency, reduction or complete elimination of visibility, screening of thermal and visible radiation from an object, or dispersion of electromagnetic radiation [4, 6-8]. Given the widespread use of the "Tucha" system in defense forces on many types of armored vehicles, maintaining its operational effectiveness is critical for the success of combat operations [5, 9-10].

Since the part "mortar body" is made of steel 30ХГСА (30KhGSA), it is essential correctly select the cutting tool and cutting modes for mechanical operations. The advantages of using this material to manufacture the mortar body are high strength, wear resistance, and the ability to withstand significant dynamic loads. Key properties of steel 30ХГСА include high strength after heat treatment and good wear resistance, especially under cyclic loads, which is particularly important for the launcher guide. Steel 30ХГСА is resistant to fatigue failure [11]. The disadvantages are as folows: low machinability of this steel since steel 30ХГСА is prone to build-up on the cutting edge of the cutting tool and low thermal conductivity, which can lead to overheating in the cutting zone [12-13]. It has also been established that during processing of long or thin-walled parts, vibrations may occur, leading to the occurence of traces of beating, the decrease in surface quality, and dimensional errors during the manufacture of the part or its deformation [12]. Given that the mortar body component has thin walls and, as a result, low rigidity, solving the machining problems by selecting rational cutting modes and cutting tools, taking into account processing features, is a relevant issue.

Uninvestigated parts of general matters defining. Methods for solving the above problems that arise during the machining of the "mortar body" component include using additional support devices during processing, effective cooling, special fastening methods, and rationalization of cutting modes. Given active hostilities, particularly the widespread use of military equipment equipped with this system, increasing the productivity and economic efficiency of processing is a relevant task. Cutting parameters can be rationalized by selecting the appropriate cutting tool and conditions, such as feed, depth, and cutting speed. Rational selection of modes and cutting tools, considering characteristics of the part material and its characteristics, reduces formation of growth and the risk of part deformation during machining. In addition, it contributes to increasing machining productivity, reducing the cost of the part, and improving the accuracy of the manufactured components.

The article aims to determine productive cutting conditions for machining the mortar body component through automated tool selection.

The statement of basic materials. The material used for the mortar body is steel 30ХГСА, a high-strength alloy steel used in aviation (landing gear components, aircraft structural elements), mechanical engineering (axles, shafts, gears, rods, studs), and military industries (armor elements, load-bearing structures). Advantages of this steel include high strength, wear resistance, and ability to withstand significant dynamic loads. Key properties of steel 30ХГСА include high strength after heat treatment, good wear resistance, especially under cyclic loads, which is particularly important for the launcher guide. The steel is sensitive to overheating and prone to temper brittleness, which is a negative factor for its use in stationary smoke grenades due to high temperature of the smoke-forming chemical reaction, which can reach 450-500°C. Steel 30ХГСА is resistant to fatigue failure [11].

Alternative materials that can be used in production include steels such as 30ХГТ, 40Х, 35ХГС, 40ХГС, and 15ХМ. Suitable analogs are steels like AISI 4340 and AISI 4140. Among these materials, the most appropriate substitutes for the mortar body are AISI 4340 and 40X steel, as they have similar wear resistance, which is crucial for operational conditions of the mortar body.

As a blank for the part, considering conditions of single or small-scale production, it is advisable to use standardized rolled products that are as close as possible to the shape of the part. This is best achieved with hot-deformed rolled products in a seamless steel pipe, according to DSTU 8938:2019 [12]. Dimensions of the blank are as follows: outer diameter Ø102 mm, inner diameter Ø70 mm, and length 214 mm. The sketch of the blank is shown in Figure 1.

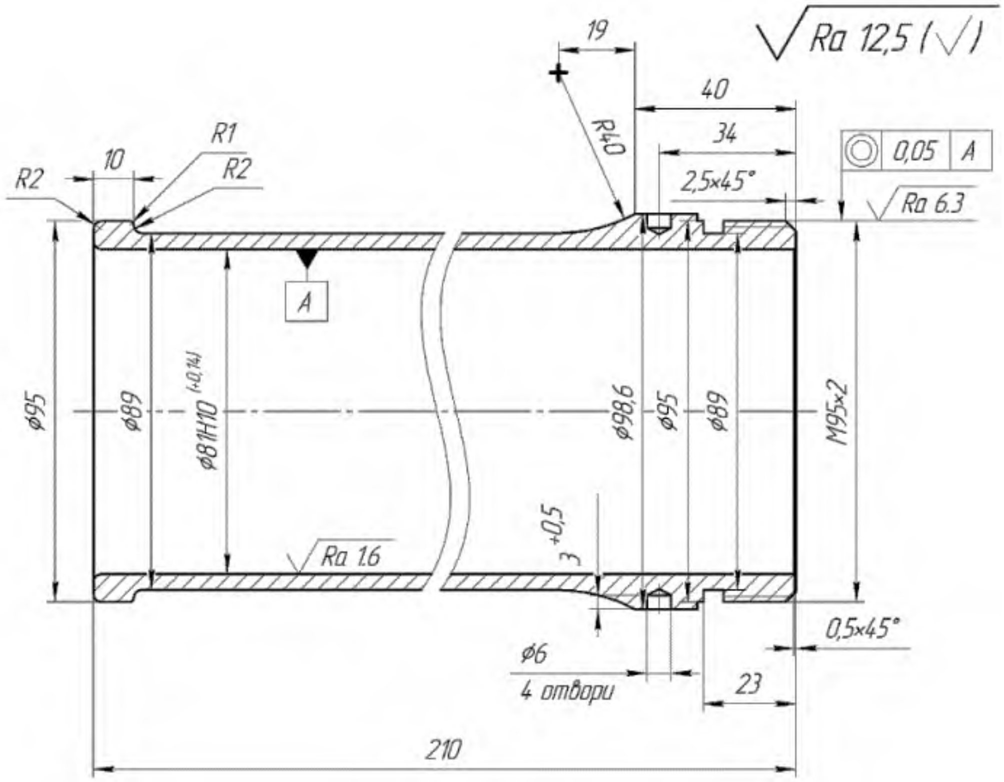

Fig. 1. Sketch of the mortar body part

The following machine specifications will be used for calculations, namely: the turning-milling machine Mazak Quick Turn 15MS, featuring a spindle speed of up to 5000 rpm, a maximum turning diameter of 300 mm, a power output of 18.5 kW, and the machining length of 508 mm. Machining conditions include the use of cutting fluids (coolants). In the respective software tools, the machine is configured according to specifications provided in the manufacturer's documentation.

Automated selection of cutting tools and machining parameters will be carried out using software products from Sandvik Coromant (ToolGuide), Walter (GPS), and Iscar (Tool Advisor) for each turning operation. The workflow of the selection process in the mentioned programs is shown in Figure 2.

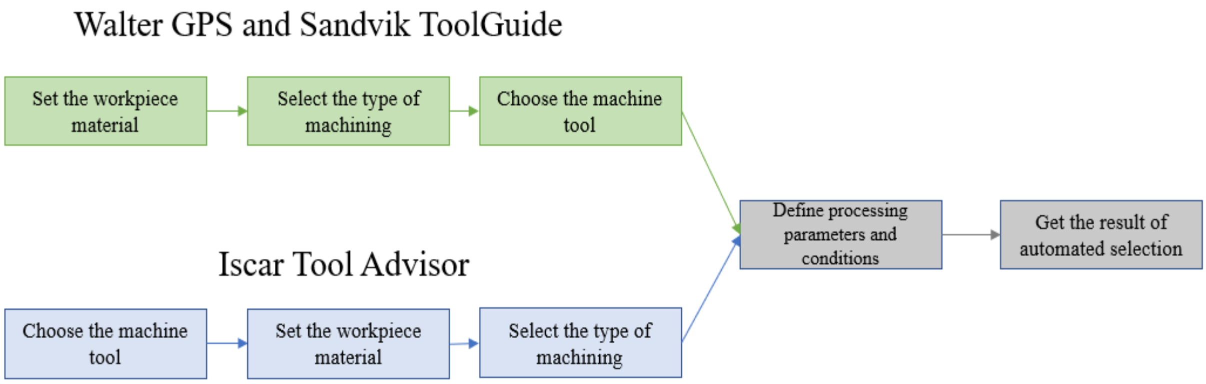

Fig. 2. Block diagram of the algorithm used in the specified programs

As shown in the block diagram in Figure 2, the algorithms used in Walter and Sandvik follow similar sequence: first, the workpiece material is selected, followed by the type of machining operation, the machine tool, and then the machining parameters and conditions are specified. The result is presented as a recommended cutting tool and cutting parameters.

Iscar follows different sequence but ultimately provides the same outcome. The step-by-step implementation of the block diagram using the Walter GPS software is illustrated in Figure 3.

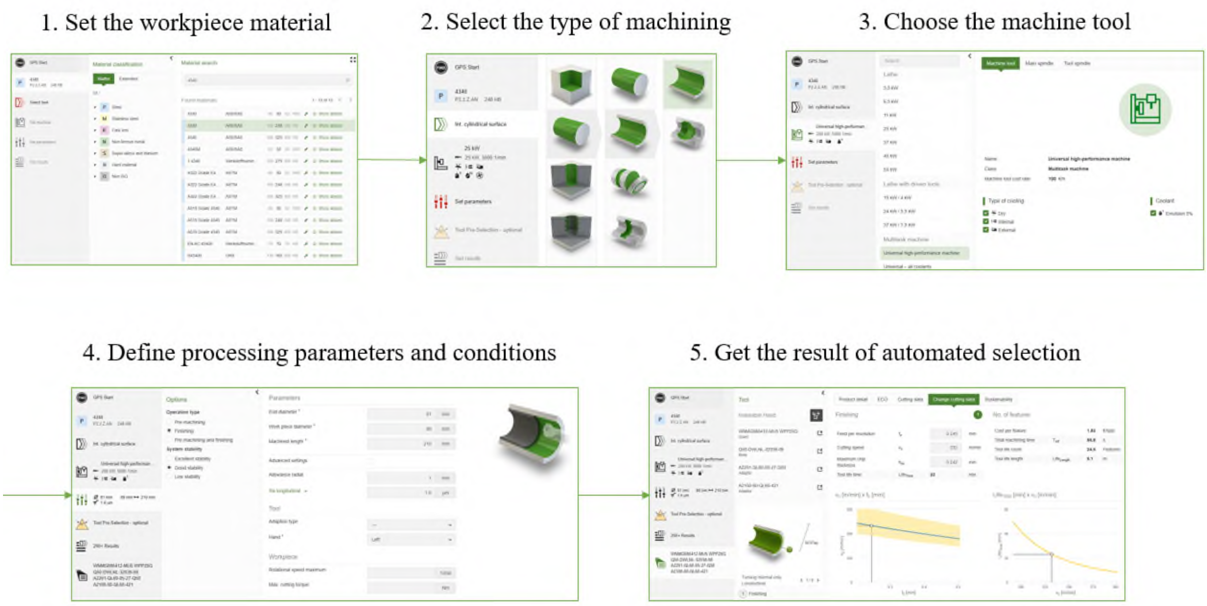

Fig. 3. Sequence of the tool selection for finish boring in the Walter GPS program

Comparing the results is carried out based on factors such as cutting speed, feed rate, depth of cut, tool life, machining time, and material removal rate (MRR). Since not all software tools calculate tool productivity in terms of the volume of material removed per minute, where necessary, the MRR is determined using the formula:

$$MRR = v_c \cdot f \cdot a_p \,, \tag{1}$$

were v_c – cutting speed (m/min), f – feed rate (mm/rev), a_p – depth of cut (mm).

To solve the problem of low rigidity, we use appropriate settings in the software selection, for Sandvik ToolGuide we set “Poor stability”, for Walter GPS “Low stability” and for Iscar Tool Advisor “Unstable”. This will allow us to take into account the conditions of low rigidity during automated selection.

Since material 30ХГСА is not available in the specified software, its equivalent, AISI 4340 steel, was used for the calculations. According to the material classification, AISI 4340 steel belongs to ISO group P7. This steel was used for all calculations across the selected software platforms.

Manufacturing the mortar body requires high precision, cutting stability, and effective tool wear management. Three leading manufacturers — Sandvik, Walter, and Iscar – were analyzed to evaluate the efficiency of different cutting tools in turning operations.

During the study, a cutting tool was selected for each mechanical turning operation using automated selection methods. The obtained results are presented in Tables 2–4. In these tables:

- i – number of passes per operation,
- a_p – depth of cut for the specified pass,
- f – feed rate (mm/rev),
- v – cutting speed (m/min),
- t – machining time per operation (seconds),
- t_{life} – tool life for the specified operation (minutes).

Table 2 summarizes the results of automated tool selection using Sandvik Coromant's "Tool Guide" software. Sandvik's tool demonstrated high efficiency in rough turning of the mortar body. The high cutting speed enables fast machining of the workpiece; however, the tool has a moderate tool life, which may require more frequent insert replacements. It proved especially effective in facing and rough turning operations.

Table 1 – Selection results in Sandvik ToolGuide software

№	Operation	i	a_p	f	v	t	t_{life}
005	Facing	1	2	0.707	279	4,86	20
010	Rough and finish turning	1	3,9	0.5	279	44,7	27,6
		2	2,55				
		3	2,55				
015	Rough boring	1	2,54	0,36	314	46,1	26,7
		2	1,96				
020	Facing	1	2	0,707	279	4,86	20
025	Rough and finish turning	1	3,5	0,518	173	8,16	20
		-	-	-	-	-	-
030	Rough boring	1	2,54	0,373	199	14	20
		2	1,96				
035	Milling	-	-	-	-	-	-
040	Drilling	-	-	-	-	-	-
045	Thread cutting	1	1	-	160	20,2	17,3
050	Finish boring	1	1	0,253	239	53,8	22,6

Table 3 presents the recommendations provided by Walter. The depth of cut values are similar to those recommended by Sandvik; however, the suggested cutting speeds and feed rates are lower. As a result, the machining productivity and material removal rate are reduced, negatively affecting the total machining time. On the other hand, these conditions contribute to increased tool life.

This option may be considered a compromise solution when machining time is not a critical factor in production. Still, there is a need for a more stable and consistent cutting process along with improved surface quality.

Table 2 – Selection results in Walter GPS software

№	Operation	i	a_p	*F*	*v*	*t*	t_{life}
005	Facing	1	2	0,44	153	14,3	23
010	Rough and finish turning	1	4	0,523	208	58	23
		2	2,5				
		3	2,5				
015	Rough boring	1	2,25	0,393	238	54	28
		2	2,25				
020	Facing	1	2	0,44	153	14,3	23
025	Rough and finish turning	1	1,8	0,564	198	14,2	23
		2	1,7	0,495	206		
030	Rough boring	1	2,25	0,393	199	13.4	23
		2	2,25				
035	Milling	-	-	-	-	-	-
040	Drilling	-	-	-	-	-	-
045	Thread cutting	1	1	-	127	15,3	19
050	Finish boring	1	1	0,245	232	56.3	23

Table 4 summarizes the results obtained from the automated selection using Iscar Tool Advisor software. It can be observed that, despite having similar depth of cut values, the cutting speeds and feed rates are the lowest among the manufacturers considered. Consequently, this has a negative impact on machining productivity and processing time. In this case, it can be concluded that the manufacturer places a greater emphasis on tool life, which is the highest compared to the other manufacturers.

Table 3 – Selection results in Iscar Tool Advisor software.

№	Operation	i	a_p	*f*	*v*	*t*	t_{life}
005	Facing	1	2	0,35	264	17,3	34
010	Rough and finish turning	1	4	0,28	271	125	36
		2	2,5				
		3	2,5				
015	Rough boring	1	1,5	0,17	132	334	34
		2	1,5				
		3	1,5				
020	Facing	1	2	0,35	264	14,3	34
025	Rough and finish turning	1	1,8	0,28	278	19	36
		2	1,7				
030	Rough boring	1	2,25	0,16	185	33	34
		2	2,25				
035	Milling	-	-	-	-	-	-
040	Drilling	-	-	-	-	-	-
045	Thread cutting	1	1	-	110	-	-
050	Finish boring	1	1	0,16	195	99	40

Using Equation 1 from the research methodology, the Material Removal Rate (MRR) parameter was calculated in cm³/min. Based on the obtained calculated data, machining productivity graphs for mechanical operations were constructed (Figure 4).

The analysis of material removal volume graph emphasizes that Sandvik tool has the highest productivity in all the mentioned mechanical turning operations. The notably higher productivity is noticeable during facing operations. Walter's tool ranks second in terms of productivity. It occupies an intermediate position in terms of productivity in almost all cases, except for facing. The tool from Iscar ranks third. To systematize the obtained results, they were summarized in Table 5, which can serve as a guide when choosing a cutting tool manufacturer.

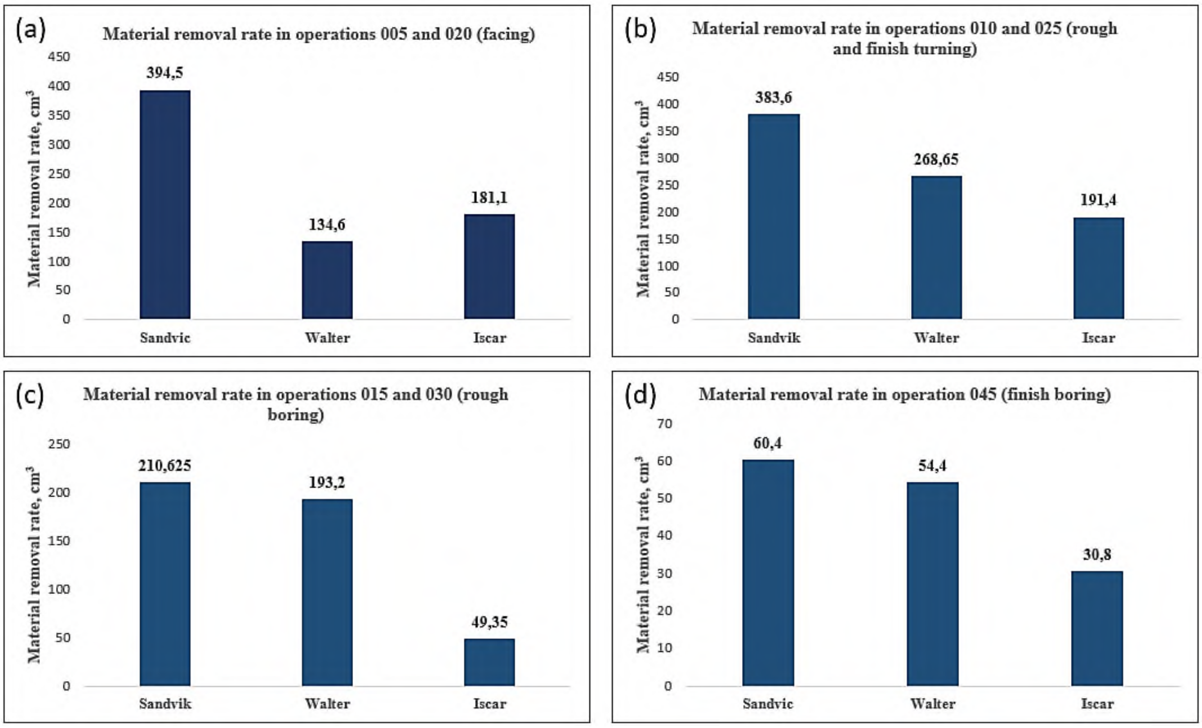

Fig. 4. Productivity charts (a) – for facing operation, (b) – for rough and finish turning, (c) – for rough boring, and (d) – for finish boring

Analyzing the manufacturers in terms of the cutting depth parameter, it was determined that the cutting depth does not differ significantly across the manufacturers. In almost all cases, the manufacturers propose the same processing strategy, which includes the same number of passes, with the cutting depth parameter varying slightly depending on the manufacturer. The only exception is operation 025, where Sandvik proposed operating one pass, while Walter and Iscar suggested two passes. At the same time, Sandvik recommends using significantly higher feed rates during processing (closer to the recommendations of Walter) and higher cutting speeds, which significantly affect the operation's productivity, as seen in graphs *a, b, c*, and *d* in Figure 4. The high speed and productivity, in turn, negatively affect the tool life. As can be seen, the tool from Sandvik has the shortest tool life, while the tools from Iscar and Walter, which operate at lower speeds, have a longer tool life. It is important to note that using tools at high speeds may lead to formation of build-up edges and premature cutting edge chipping, which can negatively affect the accuracy of the machined surface. Additionally, using lower cutting speeds helps reduce the risk of vibrations. Considering that the goal of this study is to determine productive machining modes, the Sandvik tool is the most suitable for use, as the machining time of the part will be significantly shorter compared to the others.

Table 4 – Comparative Tool Table

Parameter	Sandvik	Walter	Iscar
Cutting Depth	***	***	***
Feed	***	***	*
Cutting Speed	***	*	**
Processing Time	***	**	*
Tool Durability	**	***	***
Productivity	***	**	*

Given the results obtained for all operations, the Sandvik tool is preferred. The tool (holder, insert, adapter) selected using the automated tool selection method through the Sandvik ToolGuide program is listed in Table 5.

Table 5 – Tool Selection Recommendations

№	Operation	Toolholder	Insert	Adapter
005	Facing	DSSNL 2525M 15	SNMG 15 06 16-PR 4425	-
010	Rough and finish turning	DCLNL 2525K 15	CNMG 15 04 16-PR 4425	-
015	Rough boring	C4-570-3C 40 173	CCMT 12 04 12-PR 4425	570-SCLCL-40-12
020	Facing	DSSNL 2525M 15	SNMG 15 06 16-PR 4425	-
025	Rough and finish turning	DCLNL 2525K 15	CNMG 15 04 16-PR 4425	-
030	Rough boring	A25T-SSKCL 12	SCMT 12 04 12-PR 4335	-
045	Thread cutting	266LFA-2020-16	266LG-16MM01A200M 1125	
050	Finish boring	HT30D-CY32 320-32	DCMT 11 T3 12-PM 4335	570-SDXCL-32-11

Conclusions. This article presents the search for productive cutting conditions for the mechanical processing of the mortar casing of the smoke screen system through automated selection and analysis of cutting tools from the manufacturers Sandvik, Walter, and Iscar. The corresponding software from the manufacturers, namely Sandvik "ToolGuide," Walter "GPS," and Iscar "Tool Advisor," were used for tool selection. As a result of the research, the following was determined:

- Cutting Depth – The tools from all manufacturers offer almost the same processing strategy in most cases, so the cutting depth values are similar across all manufacturers.
- Feed Rate – The tool from Sandvik suggests using higher feed rates, while Walter recommends slightly lower values. Much lower feed rates are proposed for the tool from Iscar.
- Cutting Speed – The tool from Sandvik suggests the highest values, the tool from Iscar shows intermediate cutting speed values, and Walter proposes the lowest cutting speeds.
- Processing Time – The shortest processing time is achieved with the Sandvik tool, intermediate time with Walter, and the longest machining time with Iscar.
- Tool Life – Iscar logically proposes the most extended tool life, which works with lower cutting conditions. The tool from Walter occupies the second place for tool life, and the third is Sandvik.
- Productivity – The most productive tool is from Sandvik, the second is Walter, and third is Iscar.

According to the obtained data, the recommended cutting conditions and cutting tools for turning operations are:

- 005 and 020 (Facing) – Holder DSSNL 2525M 15, insert SNMG 15 06 16-PR, cutting depth – 2 mm, feed rate – 0.707 mm/rev, cutting speed – 279 m/min.
- 010 and 025 (Rough and Finish Turning) – Holder DCLNL 2525K 15, insert CNMG 15 04 16-PR 4425, cutting depth – from 2.55 to 3.9 mm, feed rate – from 0.5 to 0.518 mm/rev, cutting speed – from 173 to 279 m/min.
- 015 and 030 (Rough Boring) – Holder C4-570-3C 40 173 (adapter 570-SCLCL-40-12) and A25T-SSKCL 12, insert CCMT 12 04 12-PR 4425 and SCMT 12 04 12-PR 4335, cutting depth – from 1.96 to 2.54 mm, feed rate – from 0.36 to 0.373 mm/rev, cutting speed – from 199 to 314 m/min.
- 045 (Finish Boring) – Holder HT30D-CY32 320-32 (adapter 570-SDXCL-32-11), insert DCMT 11 T3 12-PM 4335, cutting depth – 1 mm, feed rate – 0.16 mm/rev, cutting speed – from 195 m/min.

The data obtained from the automated selection open up the question of verifying the results through practical experiments, which may be an important topic for future research.

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ПІДВИЩЕННЯ ПРОДУКТИВНОСТІ ОБРОБКИ ДЕТАЛІ КОРПУС МОРТИРИ

У дослідженні розглянуто підвищення продуктивності обробки деталі корпус мортири аерозольної системи АЕК-902 «Туча», що активно застосовується для маскування та підвищення бойової спроможності техніки та автотранспорту, служить як допоміжний засіб для евакуації та як спосіб захисту від дронів. Методом автоматизованого підбору виконано підбір ріжучого інструменту та продуктивних режимів різання для механічних токарних операцій, з використанням програмного забезпечення Sandvik ToolGuide, Walter GPS та Iscar Tool Advisor. Виконано порівняння отриманих режимів, розраховано продуктивність обробки методом розрахунку об'єму знятого матеріалу (MMR) та побудовано порівняльні графіки продуктивності. На основі отриманих даних розроблено рекомендації щодо вибору ріжучого інструменту та режимів обробки для конкретних токарних операцій. Для торцювання рекомендовано використання державки DSSNL 2525M 15 із пластинкою SNMG 15 06 16-PR, що забезпечує глибину різання 2 мм, подачу 0,707 мм/об і швидкість різання 279 м/хв. Для чорнового та чистового точіння оптимальним вибором є державка DCLNL 2525K 15 із пластинкою CNMG 15 04 16-PR 4425, з глибиною різання від 2,55 до 3,9 мм, подачею від 0,5 до 0,518 мм/об і швидкістю різання 173–279 м/хв. Для чорнового розточування рекомендовано державки C4-570-3C 40 173, A25T-SSKCL 12 із пластинками CCMT 12 04 12-PR 4425 і SCMT 12 04 12-PR 4335, що працюють на глибинах різання 1,96–2,54 мм, подачі 0,36–0,373 мм/об і швидкості різання 199–314 м/хв. Чистове розточування найкраще виконувати державкою HT30D-CY32 320-32 із пластинкою DCMT 11 T3 12-PM 4335, що забезпечує глибину різання 1 мм, подачу 0,16 мм/об і швидкість різання 195 м/хв. Отримані дані базуються на рекомендаціях програмного забезпечення і потребують подальшої експериментальної перевірки в умовах реального виробництва. Верифікація результатів шляхом натурного експерименту дозволить оцінити відповідність розрахункових режимів фактичним показникам обробки, уточнити параметри та врахувати можливі відхилення. Це є актуальним напрямом подальших досліджень у сфері автоматизованого підбору інструменту та оптимізації процесів механічної обробки

Ключові слова: *точіння; обробка; режими різання; продуктивність обробки; автоматизований підбір; ріжучій інструмент; розточування.*

Рис.: 4. Табл. 5. Бібл.: 12.

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