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INCREASING THE MACHINING PRODUCTIVITY OF THE MORTAR BREECH THROUGH AUTOMATED TOOL SELECTION

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ABSTRACT *In the study, an automated selection of cutting tools and cutting parameters was performed for the turning of the breech component of the stationary smoke mortar of the AEK-902 "Khmara" aerosol system. The AEK-902 is actively used by the Armed Forces of Ukraine to create a dense smoke screen in order to conceal military equipment from enemy visual, infrared, and thermal detection systems. The breech is a critical mortar component subjected to significant mechanical and thermal loads during operation, which imposes high demands on the quality of its manufacturing, geometric accuracy, and wear resistance. An automated selection of cutting tools and cutting parameters for each turning operation of the breech was carried out using specialized software from two leading global manufacturers of cutting tools: Walter GPS (Walter company) and Sandvik Coromant ToolGuide (Sandvik Coromant company). The selection was made taking into account the type of machining, the geometry of the workpiece, material characteristics, and the requirements for accuracy and surface quality. As a result, a nomenclature of tooling (toolholder and insert types) recommended for each specific turning operation was obtained, as well as productive cutting parameters. For operation 010, the following set of cutting tools is proposed: DSSNL2020K12 turning tool with SNMG120416-PR4335 insert, 462.1-1850-056A1-XM-X2VM drill, DCLNL2525M19 turning tool with CNMG190608-PR4335 insert, A12M-STFCL11 boring tool with TCMT110208-UM4335 insert, A25T-SSKCL12 turning tool with SCMT120412-PR4425 insert. For operation 020, the following tool set is proposed: DCLNL2525M19 turning tool with CNMG190608-PR4335 insert, A16R-SSKCL09 and A25T-SSKCL12 boring tools with SCMT09T308-PR4425 inserts, C2R-CE25-L-J08GB and C2R-CE25-LH07GB grooving tools with corresponding inserts C2I-J2N-0500-0004-TF1225 and C2I-J2N-0400-0004-TF1225, as well as L166.0KF-16-1220-11B threading tool with L166.0L-11MM01-200 1020 insert and 266LKF-20-16 threading tool with 266LL-16MM01A200M 1125 insert.*
Keywords: *Breech of the mortar; automated selection; turning; machining; cutting parameters; cutting tool; productivity.*

ПІДВИЩЕННЯ ПРОДУКТИВНІСТІ ОБРОБКИ ДЕТАЛІ КАЗЕННИК МОРТИРИ МЕТОДОМ АВТОМАТИЗОВАНОГО ПІДБОРУ ІНСТРУМЕНТУ

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АНОТАЦІЯ *У дослідженні виконано автоматизований підбір ріжучого інструменту та режимів різання для токарної обробки деталі казенника стаціонарної димової мортири аерозольної системи АЕК-902 «Хмара». АЕК-902 активно застосовується у Збройних Силах України для створення щільної димової завіси з метою маскування військової техніки від засобів візуального, інфрачервоного та теплового виявлення противника. Було проведено автоматизований підбір ріжучого інструменту та параметрів режимів різання для кожного переходу токарної обробки казенника з використанням спеціалізованого програмного забезпечення двох провідних світових виробників ріжучого інструменту: Walter GPS (компанія Walter) та Sandvik Coromant ToolGuide (компанія Sandvik Coromant). Підбір здійснювався з урахуванням типу обробки, геометрії заготовки, характеристик матеріалу, вимог до точності та якості поверхні. У результаті було отримано номенклатуру інструментального оснащення (тип державки та пластини), рекомендовану для кожного окремого переходу токарної обробки, а також продуктивні режими різання. Для операції 010 запропоновано використовувати наступний набір ріжучого інструменту: різець прохідний DSSNL2020K12 з пластиною SNMG120416-PR4335, свердло 462.1-1850-056A1-XM-X2BM, різець прохідний DCLNL2525M19 з пластиною CNMG190608-PR4335, різець розточний A12M-STFCL11 з пластиною TCMT110208-UM4335, різець розточний A25T-SSKCL12 з пластиною SCMT120412-PR4425. Для операції 020 запропоновано: різець прохідний DCLNL2525M19 з пластиною CNMG190608-PR4335, розточні різці A16R-SSKCL09 та A25T-SSKCL12 з пластинами SCMT09T308-PR4425, канавочні різці C2R-CE25-L-J08GB і C2R-CE25-LH07GB з відповідними пластинами C2I-J2N-0500-0004-TF1225 та C2I-J2N-0400-0004-TF1225, а також різьбові різці L166.0KF-16-1220-11B з пластиною L166.0L-11MM01-200 1020 і 266LKF-20-16 з пластиною 266LL-16MM01A200M 1125. Для операції 020 запропоновано використовувати наступний інструментальний комплект: різець прохідний DCLNL2525M19 з пластиною CNMG190608-PR4335, розточні різці A16R-SSKCL09 та A25T-SSKCL12 з пластинами SCMT09T308-PR4425, канавочні різці C2R-CE25-L-J08GB і C2R-CE25-LH07GB з відповідними пластинами C2I-J2N-0500-*

0004-TF1225 та C2I-J2N-0400-0004-TF1225, а також різьбові різці L166.0KF-16-1220-11B з пластиною L166.0L-11MM01-200 1020 і 266LKF-20-16 з пластиною 266LL-16MM01A200M 1125.
Ключові слова: *Казенник мортири; автоматизований підбір; точіння; механічна обробка; режими різання; ріжучий інструмент; продуктивність.*

Introduction

Using aerosol smoke screens is an effective and reliable way to protect personnel and military equipment from enemy fire [1]. In modern warfare, the issue of preserving the lives of service members and increasing the level of protection of equipment becomes particularly relevant. Smoke masking, particularly aerosol screens, creates a temporary obstacle to visual, infrared, and radar object detection, significantly complicating the enemy's ability to conduct accurate fire [2,3]. This is especially important during active combat phases, wounded evacuation, and rapid equipment or personnel relocation under heightened threat conditions [4]. Among the technical means that enable the formation of such screens, stationary smoke mortars play a key role and are widely used in the Armed Forces of Ukraine. Their primary purpose is to create dense aerosol screens that mask troops and equipment and disorient the enemy, reducing the effectiveness of reconnaissance and fire adjustment. Thanks to the versatility of their design, mortars can be used in offensive or defensive operations, performing combat support tasks in a wide range of tactical situations.

One of the most widespread and effective smoke screening systems actively used by the Ukrainian Defense Forces is the AEK-902 “Khmara” aerosol system. Its primary function is to generate a dense smoke screen to conceal military equipment from enemy visual and thermal detection systems [5]. The system consists of several launchers and smoothbore mortars with a caliber of 81 mm. Each mortar has a barrel length of 270 mm and weighs approximately 1.35 kg. They are mounted directly on the hull or turret of the combat vehicle, and the smoke grenades are launched remotely via an electric mechanism — from the crew cabin or combat compartment, which enhances safety and operational efficiency. The ammunition load of the “Khmara” system includes smoke grenades of 3D6, 3D6M, or 3D17, which create a dense smoke screen up to 300 meters from the launch point. The smoke screen forms within 10–20 seconds and remains in the atmosphere for approximately 2.5 minutes [6,7]. This duration ensures adequate equipment concealment from targeting systems, thermal imagers, laser rangefinders, and enemy electro-optical devices.

The “Khmara” masking system is installed on Soviet-made equipment (T-62, T-64, T-72, T-80 tanks, BMP-1P, and BMP-2 infantry fighting vehicles) and modern Ukrainian combat platforms. These include the main battle tank T-84 "Oplot" and next-generation armored personnel carriers — BTR-3 and BTR-4 "Bucephalus." Additionally, the system is integrated into modernized variants of Soviet armored personnel carriers, such as the BTR-80UP, and improved infantry fighting vehicles like the BMP-1U.

A key advantage of the 902 system is its ability to effectively counter a wide range of detection systems. The smoke screen it creates artificially reduces the transparency of the atmosphere in the coverage zone, blocks thermal and visible radiation from objects, and partially disperses electromagnetic radiation in the radar range. Compex of these measures ensures a high level of concealment even in complex tactical conditions, including when the enemy uses advanced reconnaissance systems, such as uncrewed aerial vehicles, thermal imaging complexes, and other high-precision means [7,8].

Given the active use of the “Khmara” system in the Armed Forces of Ukraine, maintaining its operability and timely modernization are critically important. The uninterrupted operation of this system directly affects the survival of combat vehicle crews and the success of combat missions [9]. The operation's reliability depends on the quality of service and the technical condition of its main components, including mortars, electric triggers, and smoke grenades.

One of the key elements of a mortar is the breech, which performs the functions of fixing, feeding, and holding a smoke grenade until it is launched. The breech is subjected to significant mechanical and thermal loads, so its design must be highly reliable. The functioning of the entire system directly depends on its accuracy and durability. In the event of a breech malfunction, there is a risk of the mortar failing at a critical moment, which can have serious consequences on the battlefield.

Therefore, manufacturing the breechblock requires high standards: compliance with geometric parameters, high surface finish quality, sufficient material strength, and wear resistance. Several factors affect manufacturing quality — from construction material selection to machining parameters. Hence, optimizing the turning process, one of the main stages in producing this part is a relevant task.

Modern enterprises producing such units must increase the efficiency of turning operations, which is a key stage in shaping the breechblock's critical surfaces. The implementation of automated tool selection systems is becoming particularly relevant. The improvement of production processes, the implementation of innovative machining technologies, and automated quality control all contribute to enhancing the reliability of the breechblock as a critical element of a stationary smoke mortar, which, in turn, affects the effectiveness of masking systems and the overall combat capability of the units.

One of the key areas for increasing the machining efficiency of breech of a mortar with a smoke aerosol system production, is the introduction of automated cutting tool selection systems [10]. Using such systems

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ensures high accuracy in the selection of tooling by considering a set of technological parameters: physical and mechanical properties of the workpiece material, machining type, fastening conditions, surface geometry, and requirements for accuracy and roughness. This ensures that the tool meets specific machining conditions, which is especially important for military parts requiring increased mechanical strength, tightness, and reliability in operation. Automated tool selection is usually accompanied by selecting productive cutting parameters, which helps increase tool stability, reduce wear, and improve machining conditions. In turn, this reduces the duration of preparatory and finishing operations and the likelihood of errors when selecting tooling, and it allows you to move more quickly to serial or small-scale production. This is especially relevant when machining complex body parts with internal thread elements, chambers, and cylindrical or conical fits.

An advantage of automated systems is ensuring the stability of the cutting process. The correct tool selection prevents the occurrence of such negative phenomena as vibrations, local overheating, overload, and shape deviations, which directly affect the quality of the machined surface and the part's service life. In addition, automated systems allow you to quickly adapt to changes in production conditions, particularly when switching to new steel grades or changing the product's design, automatically updating recommendations without needing in-depth intervention by a process engineer.

Automated selection of cutting tools not only contributes to increasing the technical and economic indicators of the machining but also ensures high-quality and reliable manufacturing of high-precision elements of smoke aerosol systems for defense purposes.

The aim of the article

The aim of the article is to increase the productivity of machining the breech part of the mortar of the AEK-902 “Khmara” aerosol system using the method of automated selection of the cutting tool and cutting parameters.

Materials and methods

The breech of the mortar is made of steel grade 20. Steel 20 is a carbon structural steel widely used in mechanical engineering and metalworking due to its good mechanical properties, machinability, and availability. It is well-suited for manufacturing the mortar body component, as it offers several advantages, including good machinability, excellent weldability, sufficient ductility and strength, resistance to thermal loads, and cost-effectiveness and accessibility.

The most common international equivalents of Steel 20 include AISI 1020 or SAE 1020 (USA), S20C (Japan), and C22 (1.0402) (Germany). These steels have similar chemical compositions and mechanical properties, allowing them to be used in comparable applications without requiring significant adjustments in machining technology. They perform well on metal-cutting machines, have sufficient ductility and good weldability, and allow heat treatment to strengthen surface layers [11,12].

Given the conditions of single or small-batch production, it is reasonable to use a standard-sized steel bar stock closest in dimensions [13]. The optimal choice in this case is a diameter of Ø135 mm. The machining allowance for the end faces is 2.5 mm on each side.

The characteristics of the selected lathes in the tool selection software will be used for calculation purposes. For both manufacturers will choose a lathe with a power output of 24 kW and a spindle speed of 5000 rpm. Machining conditions involve the use of cutting fluids (coolants/lubricants). Cutting fluids is essential for productive machining [14,15]. The material will be set as the steel equivalent AISI 1020 for specifying machining parameters in automated selection programs. The hardness of AISI 1020 steel is 142 HB. A sketch of the component is shown in Fig. 1.

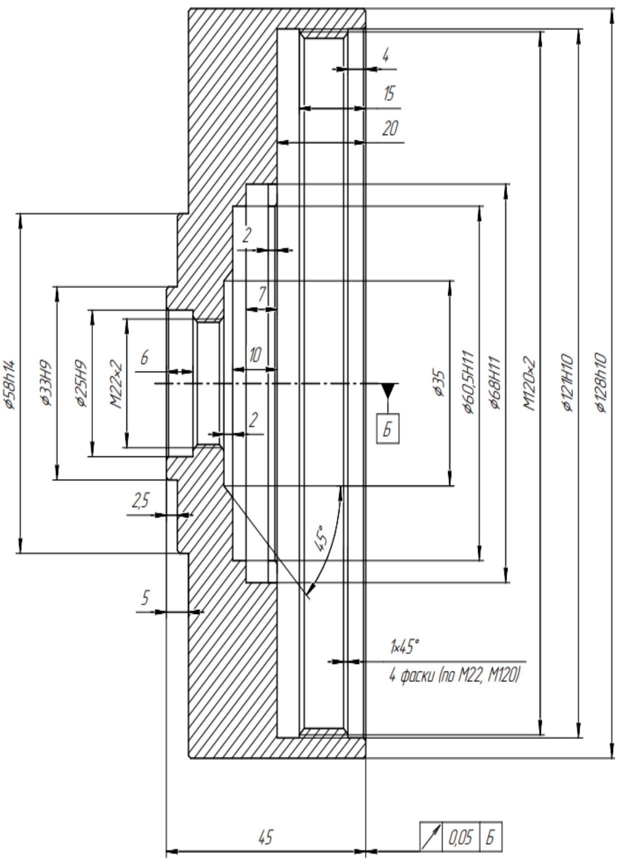

Fig. 1 – Sketch of the Mortar Breech

Automated selection of tools and cutting parameters will be carried out using software products from cutting tool manufacturers Sandvik Coromant (ToolGuide) and Walter (GPS) for turning operations. The general methodology for selecting cutting tools consists of five main steps [16,17]. The decision-making algorithms for Sandvik Coromant Tool Guide, Walter GPS, and Iscar Tool Advisor are the same. Sandvik Coromant Tool Guide proposes a more detailed classification of machined material and the possibility of choosing vibration-resilient cutting tools to avoid chatter on the machined surface. The first step is selecting the workpiece material, which is determined according to the ISO classification. This classification influences the choice of tool material and cutting parameters. The second step involves selecting the type of surface to be machined, which determines the lead angle, type of tool holder, insert shape, and insert clamping method. Next, the software prompts the user to choose the type of equipment to refine the selection of cutting tools, considering the lathe's maximum spindle torque and spindle speed. In the subsequent dialog menu, machining parameters must be entered. These include the initial diameter of the surface, the final diameter after machining, surface roughness, or other parameters depending on the type of operation. Finally, the software offers suitable cutting tools, ranked according to material removal efficiency and the cost-to-tool life ratio (Fig. 2).

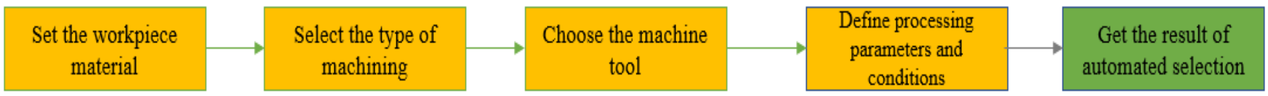

Fig. 2 – Automated Tool Selection Algorithm in Sandvik ToolGuide and Walter GPS Systems

After entering the specified data, the result is provided in the form of a recommended cutting tool and productive cutting parameters from the manufacturer. The selection sequence (implementation of the flowchart shown in Fig. 2) using the Sandvik Coromant ToolGuide software is illustrated in Fig. 3. The comparison was proposed based on the following parameters: cutting speed, feed rate, depth of cut, tool life, and material removal rate (MRR). All of these parameters are calculated automatically within the software.

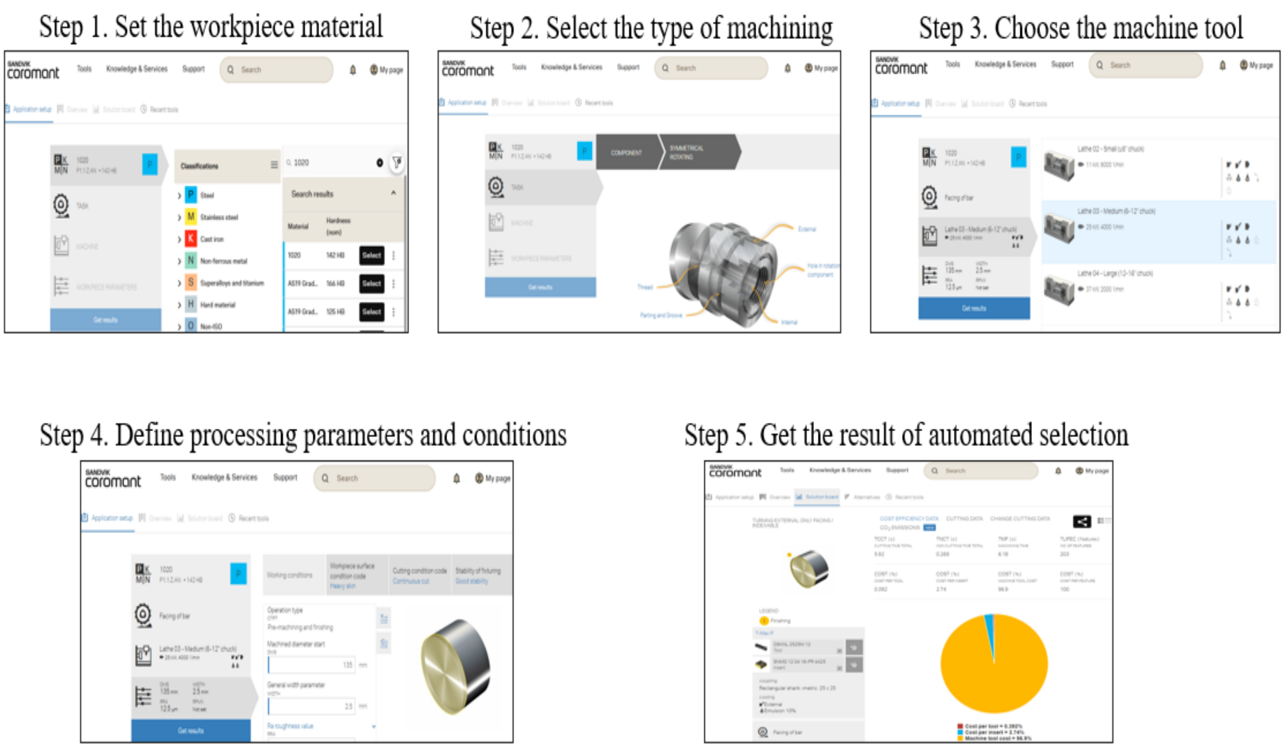

Fig. 3 – The Process of Automated Tool and Cutting Parameter Selection Using Sandvik Coromant ToolGuide

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Results

Manufacturing the mortar breech is a complex and responsible process that requires high precision, stable cutting parameters, and effective wear management of the cutting tool. The breech is a key component of the mortar's design, which directly interacts with the ammunition, and therefore, it must meet strict geometric and strength requirements. Any deviations in shape, surface roughness, or hardness can lead to malfunctioning the entire system or even result in an emergency during combat use. That is why machining accuracy, the selection of optimal cutting parameters, and reliable tooling are critically important factors in producing this component. The economic aspect must also be considered — efficient tool usage helps reduce production costs, increase quality consistency, and ensure high repeatability in mass production. In modern manufacturing, especially in the defense industry, implementing automated tool selection systems and optimizing machining processes have become an integral part of technical upgrades and production line improvements. Two leading manufacturers - Sandvik and Walter - were analyzed to evaluate the effectiveness of different cutting tools during turning operations.

During the study, cutting tools for each turning operation were selected using automated selection methods. The results are presented in Tables 1 and 2. In these tables, “No.” indicates the operation number (010 — rough turning, 020 — finish turning); operation types include roughing, semi-finishing, or finishing; “Operation content” describes the dimensions processed during a specific step*;* i — the number of passes; a_p — depth of cut for the given pass; f — feed rate in mm/rev; v — cutting speed in m/min; and t_{life} — tool life for the specified operation in minutes. Table 1 summarizes the results of the automated tool selection using the Sandvik Coromant “Tool Guide” software. Table 2 presents the data obtained using the Walter GPS software:

Table 1 – Table of Parameters for Automated Tool Selection – Sandvik

№	Type of Op.	Machining Step Description	i	a_p	f	v	t_{life}
010	rough	Face turning Ø135 mm	1	2,5	0,707	229	20
	rough	Machine to Ø130 mm L = 20 mm;	1	2,5	0,707	229	20
	-	Drill the hole Ø18,5 mm.	1	-	-	-	-
	semi-fin	Turn Ø60 mm to L = 5 mm with facing the 130/Ø60 mm	7	2,8-5,83	0,4	319	20
	semi-fin	Turn Ø35 mm to L = 2.5 mm with facing the 60/Ø35 mm	1	2,5	0,4	319	20
	semi-fin	Ream Ø23 to a depth of 6 mm	2	1,12	0,25	261	28
	rough	Face the Ø135 mm	1	2,5	0,707	229	20
	rough	Turn to Ø130 mm L = 20 mm;	1	2,5	0,707	229	20
	semi-fin	Ream the hole from Ø18.5 to Ø60, L = 30 mm.	13	1,6	0,23	273	20
	semi-fin	Ream the hole from Ø60 to Ø115, L = 20 mm	10	2,75	0,373	333	20
020	finish	Turn to Ø128h10 mm	1	1	0,579	384	20
	finish	Turn to Ø58 L = 5 mm	1	1	0,592	381	20
	finish	Turn to Ø33h9 L = 2.5 mm with facing Ø58/Ø33 mm	1	2,5	0,288	363	20
	finish	Ream to Ø25 H9 L6 mm	1	1	0,259	314	40
	finish	Ream the chamfer 2x45°	1	1	0,259	314	40
	finish	Ream Ø60.5H11 mm L = 10 mm	1	0,25	0,326	408	20
	finish	Ream hole Ø68H11 mm L = 7 mm	2	1,96-2,04	0,373	333	20
	finish	Ream hole Ø118 mm for M120x2 L = 20 mm	1	1,5	0,373	333	20
	finish	Ream groove Ø121H10 L5 mm	1	5	0,15	198	20
	finish	Ream groove Ø121 H10 L4 mm	1	4	0,12	212	20
	finish	Cut thread M22x1	6	-	2	171	15
	finish	Cut thread M120x2	7	-	2	213	15

Compared to the one from Walter (Table 2), the tool from Sandvik demonstrated higher machining performance in most cases due to higher cutting speed and feed rate values. Compared to its counterparts, the Sandvik tool, especially from Walter, demonstrates higher productivity due to greater cutting speed and feed rates. Cutting parameters significantly reduces the turning machining time for the mortar breech, which is especially important in serial or mass production. The increased cutting speed results in higher thermal loads on the tool's cutting edge and the workpiece itself. This may lead to accelerated wear of the cutting edge, reduced tool life, and an increase in the frequency of tool replacement [18]. In addition, another disadvantage of high cutting parameters is the possibility of a decrease in dimensional accuracy and surface quality due to vibrations and instability of the machining process under excessive loads.

Table 2 – Table of Parameters for Automated Tool Selection – Walter

№	Type of Op.	Machining Step Description	i	a_p	f	v	t_{life}
010	rough	Face turning Ø135 mm	1	2,5	0,775	215	23
	rough	Machine to Ø130 mm L = 20 mm;	1	2,5	0,498	227	23
	-	Drill the hole Ø18,5 mm.	-	-	-	-	-
	semi-fin	Turn Ø60 mm to L = 5 mm with facing the 130/Ø60 mm	7	2,39-5,42	0,374	320	23
	semi-fin	Turn Ø35 mm to L = 2.5 mm with facing the 60/Ø35 mm	1	2,5	0,598	254	23
	semi-fin	Ream Ø23 to a depth of 6 mm	5	0,45	0,105	183	19
	rough	Face the Ø135 mm	1	2,5	0,775	215	23
	rough	Turn to Ø130 mm L = 20 mm;	1	2,5	0,498	227	23
	semi-fin	Ream the hole from Ø18.5 to Ø60, L = 30 mm.	16	1,3	0,18	331	23
	semi-fin	Ream the hole from Ø60 to Ø115, L = 20 mm	9	3,06	0,393	313	23
020	finish	Turn to Ø128h10 mm	1	1	0,409	349	23
	finish	Turn to Ø58 L = 5 mm	1	1	0,564	388	23
	finish	Turn to Ø33h9 L = 2.5 mm with facing Ø58/Ø33 mm	4	2,19-3,44	0,423	326	23
	finish	Ream to Ø25 H9 L6 mm	2	0,5	0,14	189	19
	finish	Ream the chamfer 2x45°	2	0,5	0,14	189	19
	finish	Ream Ø60.5H11 mm L = 10 mm	1	0,25	0,145	421	23
	finish	Ream hole Ø68H11 mm L = 7 mm	2	2	0,329	335	23
	finish	Ream hole Ø118 mm for M120x2 L = 20 mm	1	1,5	0,329	335	23
	finish	Ream groove Ø121H10 L5 mm	1	5	0,235	161	19
	finish	Ream groove Ø121 H10 L4 mm	1	4	0,24	136	23
	finish	Cut thread M22x1	5	-	1	195	19
	finish	Cut thread M120x2	8	-	2	210	19

The comparative graphs of machining productivity and tool life for the specified manufacturers are shown in Fig. 4 and 5. The graphs show that the tool from Walter had slightly lower cutting parameters, but at the same time, in most cases, it had a longer tool life. This could be an advantage depending on the type of production and its needs, where productivity is less critical than the tool life.

Since the goal of the study is to select the most productive tool and cutting conditions, we choose the tool from Sandvik. The nomenclature of the proposed cutting tools, selected using automated selection, is summarized in Table 3.

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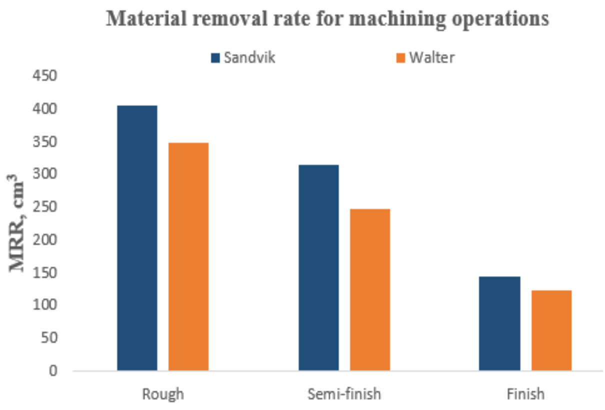

Fig. 4 – Graph of Material removal rate

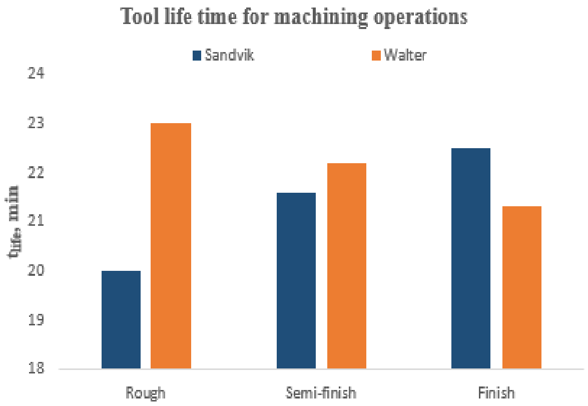

Fig. 5 – Graph of tool life time

Table 3 – List of Recommended Tools for Turning the Breech Component of the Mortar

№	Type of Operation	Toolholder	Insert
010	Turning	DSSNL2020K12	SNMG120416-PR4335
	Drilling	**Drill** 462.1-1850-056A1-XM-X2BM	
	Turning	DCLNL2525M19	CNMG190608-PR4335
	Boring	A12M-STFCL11	TCMT110208-UM4335
	Boring	A25T-SSKCL12	SCMT120412-PR4425
020	Turning	DCLNL2525M19	CNMG190608-PR4335
	Boring	A16R-SSKCL09	SCMT09T308-PR4425
	Boring	C4-TR-V13UBL-27050C1	TR-VB1312-F-4425
	Boring	A25T-SSKCL12	SCMT120412-PR4425
	Grooving 5 mm	C2R-CE25-L-J08GB	C2I-J2N-0500-0004-TF1225
	Grooving 4 mm	C2R-CE25-LH07GB	C2I-J2N-0400-0004-TF1225
	Threading	L166.0KF-16-1220-11B	L166.0L-11MM01-200 1020
	Threading	266LKF-20-16	266LL-16MM01A200M 1125

Conclusions

During the research, automated tool selection and cutting conditions were performed for turning operations. Two leading cutting tool manufacturers, Sandvik Coromant and Walter, were compared by material removal rate and tool life criteria. The Sandvik Coromant ToolGuide and Walter GPS programs were used for automated tool selection. The following results were obtained:

For turning operation 010, the recommended cutting tool set includes turning tool DSSNL2020K12 with SNMG120416-PR4335 insert, Drill 462.1-1850-056A1-XM-X2BM, turning tool DCLNL2525M19 with CNMG190608-PR4335 insert, Boring tool A12M-STFCL11 with TCMT110208-UM4335 insert, Boring tool A25T-SSKCL12 with SCMT120412-PR4425 insert.

For turning operation 020, the recommended tools include turning tool DCLNL2525M19 with CNMG190608-PR4335 insert, Boring tool A16R-SSKCL09 with SCMT09T308-PR4425 insert, Boring tool A25T-SSKCL12 with SCMT09T308-PR4425 insert, Boring tool A25T-SSKCL12 with SCMT09T308-PR4425 insert, Grooving tool C2R-CE25-L-J08GB with C2I-J2N-0500-0004-TF1225 insert, Grooving tool C2R-CE25-LH07GB with C2I-J2N-0400-0004-TF1225 insert, Threading tool L166.0KF-16-1220-11B with L166.0L-11MM01-200 1020 insert, Threading tool 266LKF-20-16 with 266LL-16MM01A200M 1125 insert.

Automated tool selection raises the need for real-world verification of the obtained data through laboratory studies, a relevant issue for future research.

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