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INCREASING THE MACHINING PRODUCTIVITY OF THE FIRING PIN BODY PART THROUGH AUTOMATED TOOL SELECTION

О. Євдокимов, В. Колесник, А. Довгополов. В. Басов, А. Лазаренко. **Підвищення продуктивності обробки деталі корпус бойка методом автоматизованого підбору.** В дослідженні розглянуто питання підвищення продуктивності обробки деталі «корпус бойка» димової аерозольної системи АЕК-902 «Хмара». Система Хмара активно застосовується Силами оборони України для створення щільних димових завіс, в тому числі при евакуації особового складу з поля бою. Підтримання працездатності системи «Хмара» є актуальним питанням. Деталь корпус бойка є важливою складовою частиною пуску димових гранат. Запропоновано з використанням метода автоматизованого підбору підвищити продуктивність обробки шляхом підбору ріжучого інструменту та режимів різання. Було виконано порівняння рішень від трьох провідних виробників ріжучого інструменту: Walter, Sandvik Coromant та Iscar. Підбір виконано з використанням програмного забезпечення від виробників Walter “GPS”, Sandvik Coromant “ToolGuide” та Iscar “ToolAdvisor”. Порівняння проводилось за показником продуктивності обробки та часу стійкості ріжучого інструменту. Для обробки деталі запропоновано наступне технічне рішення для операції 010 використовувати – різець прохідний DSSNL2020K12 пластина SNMG120416-PR4335, різець прохідний CP-25BL-2020-12 пластина CP-B1216D-M7 4425, різець прохідний DCLNL 2525M 19 пластина CNMG 190612-PR 4425, Свердло – 462.1-1020-051A1-XM-X2BM, різець розточувальний A08H-SCLCL06 пластина CCMT 060208-UM 1125, приводний інструмент Свердло – 862.1-2500-225A1-GM X2BM, приводний інструмент Мітчик T300-PM100JA-M3 P1PM, відрізний різець QD-NN2F33-25A пластина QD-NF-0250-0003-CH 1225. Для операції 020 – різець прохідний DSSNL 2020K 12 пластина SNMG 120416-PR 4425, різець розточувальний A08H-SCLCL06 пластина CCMT 060208-UM 1125, різець розточний A16PR-SSKCL09 пластина SCMT 09T312-PR 4425, приводний інструмент Свердло 462.1-0650-020A1-XM X2BM. Застосування запропонованого набору ріжучого інструменту дозволяє провести повноцінну і продуктивну обробку деталі корпус бойка.

Ключові слова: автоматизований підбір, ріжучий інструмент, токарна обробка, режими різання, аерозольна система, корпус бойка

O. Yevdokymov, V. Kolesnyk, A. Dovhopolov, V. Basov, A. Lazarenko. **Increasing the machining productivity of the firing pin body part through automated tool selection.** The research addresses the issue of increasing the machining productivity of the “Firing Pin Body” part of the aerosol smoke system AEK-902 “Khmara”. The Ukrainian Armed Forces actively use the “Khmara” system to create dense smoke screens, including during the evacuation of personnel from the battlefield. Ensuring the operational readiness of the “Khmara” system is a relevant issue. The “firing pin body” part is important to the smoke grenade launch system. Automated tool selection is proposed to enhance the machining productivity through optimal tool and cutting parameters. A comparison of solutions from three leading cutting tool manufacturers – Walter, Sandvik Coromant, and Iscar – was conducted. The selection was made using software from the manufacturers: Walter “GPS”, Sandvik Coromant “ToolGuide”, and Iscar “ToolAdvisor”. The comparison was based on machining productivity and tool life. For machining the part, the following technical solutions were proposed: for operation 010, use the following tools: through cutter DSSNL2020K12 with SNMG120416-PR4335 insert, through cutter CP-25BL-2020-12 with CP-B1216D-M7 4425 insert, through cutter DCLNL 2525M 19 with CNMG 190612-PR 4425 insert, drill 462.1-1020-051A1-XM-X2BM, boring tool A08H-SCLCL06 with CCMT 060208-UM 1125 insert, drive tool drill 862.1-2500-225A1-GM X2BM, drive tool tap T300-PM100JA-M3 P1PM, cutoff tool QD-NN2F33-25A with QD-NF-0250-0003-CH 1225 insert. For operation 020, use: through cutter DSSNL 2020K 12 with SNMG 120416-PR 4425 insert, boring tool A08H-SCLCL06 with CCMT 060208-UM 1125 insert, boring tool A16PR-SSKCL09 with SCMT 09T312-PR 4425 insert, and drive tool drill 462.1-0650-020A1-XM-X2BM. The proposed set of cutting tools enables full and efficient machining of the firing pin body part.

Keywords: Automated selection, cutting tool, turning machining, cutting parameters, aerosol system, firing pin body

Introduction

Aerosol smoke screens are one of the most effective and reliable ways to protect personnel and military equipment from enemy fire [1]. In modern combat operations, the issue of preserving the lives of service members and increasing the level of equipment protection is of particular importance. Aerosol camouflage creates a temporary obstacle to visual observation and infrared and radar detection of objects, which significantly complicates the enemy’s ability to conduct aimed fire [2, 3]. This is particularly important during active combat phases, wounded evacuation, and equipment or personnel operational movement under increased threat conditions [4].

Among the technical means of creating smoke screens, a significant place is occupied by stationary smoke mortars, which are actively used in the Armed Forces of Ukraine. Their main purpose is to

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create dense aerosol screens that mask troops and equipment, complicate enemy reconnaissance, and reduce the effectiveness of adjusting its fire. Due to their constructive versatility, mortars can be used in both offensive and defensive operations, providing combat support in various tactical situations.

The body of the mortar's firing pin is an important component of the smoke grenade launch mechanism. It directs and holds the firing pin, ensuring the accuracy and reliability of the impact on the grenade detonator capsule. Structurally, the body has a cylindrical shape with an internal channel for the movement of the firing pin, and it also provides a place for installing a mainspring or electric trigger elements. When an electrical signal is triggered, the firing pin quickly moves inside the body and hits the capsule, leading to the initiation of a grenade shot. The firing pin housing is installed in the breech of the mortar. It provides the axial direction of the firing pin movement, which is critically important for the system's stability. Thanks to precise machining and selection of materials, the housing offers a long service life even under intensive operating conditions.

Analysis of research publications

The firing pin body is made of Steel 20. Steel 20 is a carbon structural steel widely used in mechanical engineering and metalworking due to its good mechanical properties, processing technology, and affordable cost. The choice of steel 20 for manufacturing the striker body of a mortar launcher is advisable due to its advantages: good machinability, excellent weldability, sufficient plasticity and strength, and resistance to thermal loads. In addition, this steel is cost-effective and widely available on the market. Among the most common foreign analogs of steel 20, AISI 1020 or SAE 1020 in the USA, S20C in Japan, and C22 (1.0402) in Germany can be distinguished. These steel grades have similar chemical composition and mechanical characteristics, which allows them to be used without significant changes in processing technology. They are characterized by good machinability on metalworking machines, high plasticity, good welding properties, and possible heat treatment to strengthen surface layers [5, 6].

Machining of 20 steel is generally considered easy due to its low carbon content and good ductility. However, specific problems may arise during machining that affect the quality of the machined surfaces and tool wear. Due to the relative softness of 20 steel, there is a tendency for build-up on the cutting tool, especially when using inappropriate cutting modes or poor-quality coolant, which can lead to a deterioration in the quality of the machined surface and a decrease in accuracy [7]. When machining parts with small wall thicknesses, vibrations may occur, which makes it challenging to achieve the required accuracy and surface quality, especially at high cutting speeds or insufficiently rigid clamping systems [8]. Incorrectly selected cutting modes, in particular feed rate and depth of cut, can lead to increased surface roughness and decreased machining accuracy [9]. Optimizing these parameters, including using TiN or TiAlN-coated tools, can reduce tool wear and improve machining quality [10]. It is also essential to consider the geometry of the tool and its material. Although 20 steel has limited hardenability, it can be normalized or case-hardened, which improves mechanical properties, but at the same time requires adjustment of machining conditions [11]. Thus, although 20 steel is a well-machined material, it is necessary to consider the above factors and adjust the process accordingly to achieve high machining quality.

Automated selection of cutting tools and cutting parameters has several significant advantages that allow engineers to solve most of the problems associated with steel processing. First of all, the use of specialized software, such as Sandvik Coromant "ToolGuide", Walter "GPS", or Iscar "ToolAdvisor", allows you to take into account a large number of parameters — from the type of material being processed to the characteristics of the machine tool — which minimizes the likelihood of human error when choosing a tool. The programs analyze the workpiece material, system rigidity, type of processing, desired roughness, and other parameters and then offer the most optimal tools, considering the geometry, coating, type of fastening, and cutting modes. This, in turn, significantly reduces the risks of vibrations, the formation of growth on the tool, overheating of the workpiece, or spindle overload, which ultimately increases the accuracy of processing and surface quality. Automated tool selection helps increase tool wear resistance through a rational combination of feed, speed, and cut depth, directly affecting the machining cost. Thus, automated tool selection is an effective tool for both improving part quality and rationalizing production costs.

The purpose and objectives of the research

The research aims to increase the productivity of machining the "firing pin body" part by automatically selecting cutting tools and cutting parameters. The criterion of productivity was defined as the material removal rate (MRR). Increasing the machining productivity of the firing pin body by defining a rational combination of material removal rate and tool life, which should contribute to increasing the overall efficiency of repair and production of military equipment. The use of automated cutting tool selection allows for reducing the time for choosing the proper combination of cutting tools or technological equipment and cutting parameters. Currently, several leading tool manufacturer, namely Sandvik Coromant, Walter, and Iscar, have proposed their digital services for choosing cutting tools, so the purpose of the present paper is to evaluate the better choice of cutting tools for turning operations and the technological process of firing pin body.

Materials and methods

To perform automated selection, we will use software solutions from leading manufacturers of cutting tools – Sandvik Coromant, Walter, and Iscar. This will allow us to obtain the most rational version of the cutting tool for each specific operation and transition and optimal cutting modes following the processing conditions, workpiece material, and surface quality requirements.

The Sandvik Coromant "ToolGuide", Walter "GPS" and Iscar "ToolAdvisor" programs are developed taking into account the vast practical experience and knowledge bases of manufacturers and also contain up-to-date data on the latest tools, coatings, insert, and holder geometries. They allow us to consider a wide range of parameters: type of equipment, type of operation (turning, milling, drilling), workpiece dimensions, accuracy requirements, productivity level, and economic criteria.

The selection methodology in these programs is shown in Figure 1.

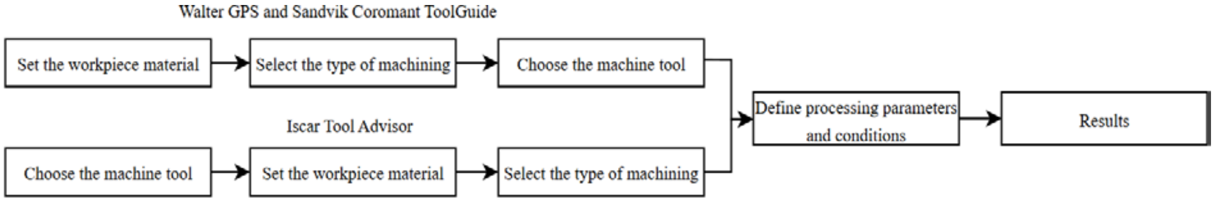

Fig. 1. Algorithm for automated selection in the software from Sandvik, Walter, and Iscar

The generalized method of cutting tool selection includes five main stages. For Walter and Sandvik, the workpiece material is selected at the first stage, and the hardness and the ISO material group are selected. In the second stage, the type of machine tool and its characteristics are selected, affecting the processing type. In the third stage, the type of processing is selected, after which, at the next stage, we set the processing parameters and conditions, and at the fifth stage, we obtain the selection result in the form of the recommended cutting tool and cutting modes for this transition. The selection methodology for Iscar differs in the sequence of stages but has the same result.

The tools will be compared based on machining productivity (MRR – material removal rate, cm³) and tool life (t_{life}, min), the values obtained during the selection process using the specified software programs.

According to the specified algorithm (Fig. 1), it is necessary to define the machine parameters and the material characteristics of the part to ensure uniform selection conditions. As the machine tool, we select the one available across all programs, with the following factors: maximum spindle speed $n = 5000$ rpm, power 15 kW. These parameters are entirely sufficient for the productive machining of the part. Since not all programs include Steel 20, we will use the AISI 1020 steel equivalent for the calculations. Hardness – 142 HB, ISO group P1. Machining conditions – with the use of 10% emulsion. A sketch of the part is shown in Fig. 2.

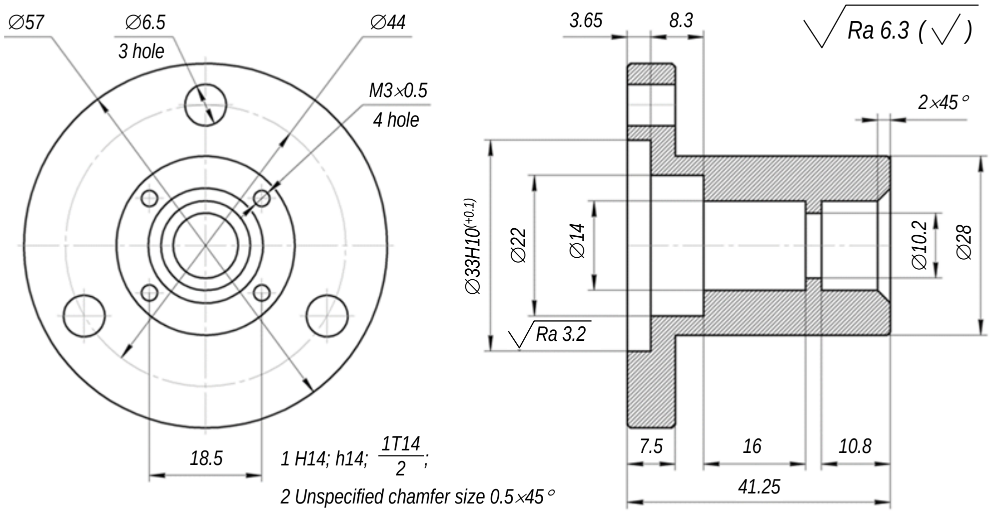

Fig. 2. Sketch of the firing pin body part

Step 1. Choose the machine tool

Step 2. Set the workpiece material

Step 3. Select the type of machining

Step 4. Define processing parameters and condition

Step 5. Results

Fig. 3. Automated selection process in the Iscar "ToolAdvisor" software

As the workpiece, considering the type of production (single or small-batch), we will use standardized rolled stock with a diameter of ∅58 mm. This is the most rational solution since developing and producing a specialized blank for such conditions is not economically feasible: it would require additional costs for design, manufacturing, transportation, and inspection, significantly increasing the product's price at low production volumes.

A machining allowance of 1.5 mm on each side is provided – this ensures a sufficient margin to achieve the design dimensions and surface finish, considering possible workpiece deviations and dimensional fluctuations during rough machining. A detailed selection of the cutting tool and machining parameters will be carried out using the example of the Iscar "ToolAdvisor" software (Fig. 3).

This system allows users to set task parameters interactively: workpiece material, type of operation (turning, milling, drilling), part dimensions, desired productivity indicators, and available equipment. Based on the entered data, "ToolAdvisor" selects the optimal tool type, inserts geometry, and recommends cutting parameters (speed, feed, depth of cut).

Research results

During the study, the automated selection method selected a cutting tool for each turning operation. The selection results are presented in Tables 1, 2, and 3. Here, № – operation number (010 CNC turning, 020 CNC turning); Machining Step Description – the dimensions being machined at the specified transition; i – number of passes; a_p – depth of cut per pass; f – feed in mm/rev; v – cutting speed in m/min; t_{life} – tool lifetime for the given transition in minutes; MRR – material removal rate in cm³. Table 1 summarizes the results of the automated tool selection using Walter tools in the Walter "GPS" program. Table 2 summarizes the data obtained through automated selection in the Sandvik Coromant "Tool Guide" program, and Table 3 presents the data obtained using the Iscar "Tool Advisor" program.

The solution provided by Walter offers a balanced approach between productivity and tool life. This approach is particularly relevant for production environments where it is necessary to find a compromise between maximum tool durability, stable and controlled machining, and a sufficiently high level of productivity.

Table 1

Cutting parameters obtained through the automated selection process in the Walter “GPS” software

№	Machining Step Description	i	a_p	f	v	t_{life}	MRR
010	Face the end ∅58 mm, $L = 1.5$ mm	1	1.5	1.16	203	23	353.22
	Turn ∅57 mm and length $L = 43$ mm	1	0.5	0.444	340	23	75.48
	Turn ∅28 mm to a length of $L = 33.75$ mm	5	2.19…4.1	0.423	304	29	527.2
	Drill ∅10.2 mm to a depth of $L = 45$ mm	1	45	0.319	184	74	–
	Bore ∅14 to a length of $L = 100.8$ mm and apply a 2×45° chamfer	3	0.59…0.717	0.152	132	89	14.38
	Drill 4 blind holes ∅2.5 mm to a depth of $L = 10$ mm;	4	10	0.097	105	46	–
	Cut M3 threads in 4 holes	–	–	0.5	28.3	–	–
	Cut to a length of $L = 41.25$ mm	1	5	0.072	149	23	53.64
020	Face the end ∅57 mm and apply a 0.5×45° chamfer	1	1.5	1.16	203	23	353.22
	Bore ∅14 mm to a length of $L = 27.95$ mm	3	0.59…0.717	0.152	132	89	14.38
	Bore ∅22 mm to a length of $L = 11.95$ mm	5	0.8	0.139	188	26	20.90
	Bore ∅33 mm to a length of $L = 3.65$ mm	5	0.99…1.13	0.149	250	20	42.09
	Drill 3 through holes ∅6.5 mm	3	7.5	0.271	197	50	–

Table 2

Cutting parameters obtained through the automated selection process in the Sandvik Coromant “ToolGuide” software

№	Machining Step Description	i	a_p	f	v	t_{life}	MRR
010	Face the end ∅58 mm, $L = 1.5$ mm	1	1.5	0.707	288	20	305.42
	Turn ∅57 mm and length $L = 43$ mm	1	0.5	0.592	381	20	112.77
	Turn ∅28 mm to a length of $L = 33.75$ mm	4	2.8…5.85	0.4	319	20	746.46
	Drill ∅10.2 mm to a depth of $L = 45$ mm	1	45	0.252	128	72	–
	Bore ∅14 to a length of $L = 100.8$ mm and apply a 2×45° chamfer	2	0.9…1	0.25	132	15	33
	Drill 4 blind holes ∅2.5 mm to a depth of $L = 10$ mm	4	10	0.07	87.3	33	–
	Cut M3 threads in 4 holes	–	–	0.5	31.6	–	–
	Cut to a length of $L = 41.25$ mm	1	2.5	0.06	172	20	25.8
020	Face the end ∅57 mm and apply a 0.5×45° chamfer	1	1.5	0.707	288	20	305.42
	Bore ∅14 mm to a length of $L = 27.95$ mm	2	0.9…1	0.25	132	15	33
	Bore ∅22 mm to a length of $L = 11.95$ mm	5	0.775…0.9	0.25	132	15	29.7
	Bore ∅33 mm to a length of $L = 3.65$ mm	3	1.76…1.87	0.311	358	24	208.20
	Drill 3 through holes ∅6.5 mm	3	7.5	0.184	190	44	–

Table 3

Cutting parameters obtained through the automated selection process in the Iscar “Tool Advisor” software

№	Machining Step Description	i	a_p	f	v	t_{life}	MRR
010	Face the end ∅58 mm, $L = 1.5$ mm	1	1.5	0.39	292	34	170.82
	Turn ∅57 mm and length $L = 43$ mm	1	0.5	0.46	325	34	74.75
	Turn ∅28 mm to a length of $L = 33.75$ mm	5	2.9	0.36	284	39	296.49
	Drill ∅10.2 mm to a depth of $L = 45$ mm	1	45	0.54	92.4	37	–
	Bore ∅14 to a length of $L = 100.8$ mm and apply a 2×45° chamfer	4	0.5	0.06	65	34	1.95
	Drill 4 blind holes ∅2.5 mm to a depth of $L = 10$ mm	4	10	0.168	47.5	125	–
	Cut M3 threads in 4 holes	–	–	–	45	–	–
	Cut to a length of $L = 41.25$ mm	1	4	0.2	129	24	103.2
020	Face the end ∅57 mm and apply a 0.5×45° chamfer	1	1.5	0.39	292	34	170.82
	Bore ∅14 mm to a length of $L = 27.95$ mm	4	0.5	0.06	65	34	1.95
	Bore ∅22 mm to a length of $L = 11.95$ mm	6	0.7	0.06	87	34	3.65
	Bore ∅33 mm to a length of $L = 3.65$ mm	8	0.7	0.06	87	34	3.65
	Drill 3 through holes ∅6.5 mm	3	7.5	0.36	92.4	29	–

The solution offered by Sandvik provides the highest productivity among the compared manufacturers. This high productivity can be particularly relevant when machining large batches of parts or in production settings where machining time is critical. However, since the increased productivity is achieved through higher cutting parameters, the Sandvik solution results in the shortest tool life.

The Iscar solution offers a tool with a significant (but generally lower than the Walter solution) tool life but significantly lower productivity than Sandvik and Walter.

Comparative graphs of productivity and tool life for all manufacturers are shown in Figures 4 and 5.

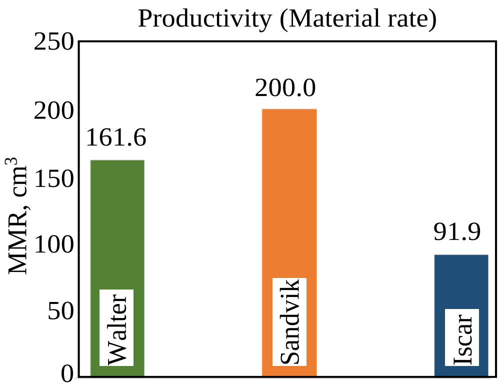

Fig. 4. Comparison chart of machining productivity

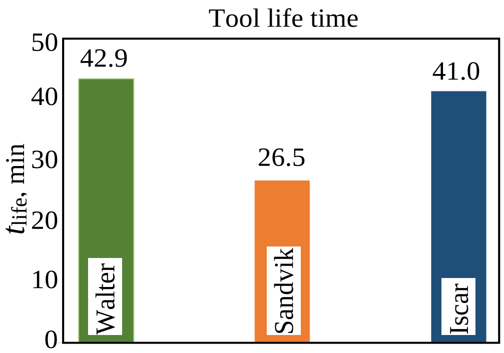

Fig. 5. Comparison chart of tool life

In summary, the most productive solution offered by Sandvik Coromant is one that provides the highest material removal rates and the shortest machining cycle time. In second place in terms of productivity is the solution from Walter, while Iscar ranks third. At the same time, when analyzing tool life (the tool's working resource before wear), Walter demonstrates the best results, with Iscar in second place and Sandvik having a somewhat lower tool life. This compromises maximum productivity and tool durability: high productivity is often accompanied by more intensive wear of the cutting elements [12]. Since the primary goal of this study is to increase machining productivity, we deliberately chose the solution from Sandvik Coromant. This will reduce the overall production time of the part and increase output using the available production resources, even if it entails somewhat higher tool replacement costs.

The set of recommended tools for the productive machining of the "firing pin body" is presented in Table 4.

Table 4

Technical solution for efficient machining of the "Firing Pin Body" part

Op №	Adapter	Tool (insert)	Toolholder
010	–	SNMG 120416-PR 4425	DSSNL 2020K 12
	–	CP-B1216D-M7 4425	CP-25BL-2020-12
	–	CNMG 190612-PR 4425	DCLNL 2525M 19
	–	Drill 462.1-1020-051A1-XM-X2BM	
	–	CCMT 060208-UM 1125	A08H-SCLCL06
	Driven tool	Drill 862.1-2500-225A1-GM X2BM	
	Driven tool	Tap T300-PM100JA-M3 P1PM	
	–	QD-NF-0250-0003-CH 1225	QD-NN2F33-25A
020	–	SNMG 120416-PR 4425	DSSNL 2020K 12
	–	CCMT 060208-UM 1125	A08H-SCLCL06
	–	SCMT 09T312-PR 4425	A16PR-SSKCL09
	Driven tool	Drill 462.1-0650-020A1-XM X2BM	

Conclusions

In this study, an automated selection of cutting tools and cutting parameters was carried out for the productive machining of the “firing pin body” of the AEK-902 “Khmara” smoke mortar. A comparison was made between the technical machining solutions from three leading cutting tool manufacturers: Walter, Sandvik Coromant, and Iscar. The selection process was performed using the manufacturers’ proprietary software: Walter “GPS”, Sandvik Coromant “ToolGuide”, and Iscar “ToolAdvisor”. The comparison focused on machining productivity and tool life. The following was proposed:

1. For operation 010, use the following set of cutting tools – turning tool DSSNL2020K12 with insert SNMG120416-PR4335, turning tool CP-25BL-2020-12 with insert CP-B1216D-M7 4425, turning tool DCLNL 2525M 19 with insert CNMG 190612-PR 4425, drill 462.1-1020-051A1-XM-X2VM, boring bar A08H-SCLCL06 with insert CCMT 060208-UM 1125, driven tool drill 862.1-2500-225A1-GM X2BM, driven tool tap T300-PM100JA-M3 P1PM, parting-off tool QD-NN2F33-25A with insert QD-NF-0250-0003-CH 1225.
2. For operation 020 – turning tool DSSNL 2020K12 with insert SNMG 120416-PR 4425, boring bar A08H-SCLCL06 with insert CCMT 060208-UM 1125, boring bar A16PR-SSKCL09 with insert SCMT 09T312-PR 4425, driven tool drill 462.1-0650-020A1-XM X2VM.

Applying the proposed cutting tools enables complete and productive machining of the firing pin body part. The automated selection method raises the relevant issue of physical verification of the obtained data through laboratory experiments, an important topic for future research.

Acknowledgments

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