Comparative analysis of the traditional and modern taper tap manufacturing processes

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Abstract:

Introduction/purpose: This paper presents a comparative analysis of traditional and modern manufacturing processes used for producing a taper tap – a fishing tool commonly used during well workover operations. The goal of this research is to examine differences in production time and efficiency between traditional machining (conventional lathe and milling machine) and modern, CNC-based manufacturing, based on the hypothesis that modern techniques offer superior time efficiency.

Methods: The study involved the experimental manufacturing of a taper tap using both the traditional approach (conventional lathe and milling machine) and a CNC machine. Time was measured for all key stages, including production preparation (process sheet creation (traditional method) or 3D modeling and programming (modern method)), machine operating time, and active machining. Fusion 360 software was used for CAD/CAM modeling and CNC programming. Time was recorded using a stopwatch and machine-generated data.

Results: The results show that while the modern process required 37 minutes more for production preparation, it significantly reduced machine operating time by 41.5 minutes and active machining time by 1 hour and 19.3 minutes compared to the traditional method. In total, the CNC-based

approach is faster for the entire manufacturing process of a taper tap in a serial production scenario.

Conclusion: The research confirms that the modern manufacturing process provides clear advantages in terms of time efficiency. Despite the longer preparation time, its overall productivity in repetitive production justifies its implementation. Nevertheless, traditional methods retain relevance in cases requiring manual adjustments or rapid single interventions.

Key words: machining, traditional, modern, CNC, time-efficiency, petroleum industry, machining time.

Introduction

Today's advanced manufacturing conditions impose an accelerated work pace in the industry, making time optimization a crucial factor across all production sectors (Ghafoorpoor Yazdi et al., 2018). In practice, these are very complex requirements, involving the consideration of multiple factors and resulting in multiple local optimal solutions (Zhang, 2025). Integrating modern technologies into both the preparation for production the and manufacturing processes of a component is a key step toward achieving greater time efficiency, which enhances economic efficiency as well (Dunarea de Jos University of Galati, Industrial Engineering Department 800201, Romania et al., 2017; Subramanian et al., 2019; Tönissen et al., 2015). The goal is to maintain, or even improve, the high quality of the final product while optimizing production time through the use of advanced technologies (Puška and Stojanović, 2024; Simić et al., 2023).

This paper presents a detailed analysis of the time required for the complete preparation and manufacturing process of a taper tap (a tool that is commonly used during workover in the petroleum industry) using two approaches: the traditional method (on a conventional lathe and milling machine) and a CNC machine. Additionally, the paper examines the factors that may influence the duration of the production process, such as CNC programming complexity, the interaction between the machine and operators, the expertise and experience of programmers and operators, the need for manual interventions during the manufacturing process, and other related aspects.

This study also aims to provide insights from both technical and technological perspectives into the similarities and differences between traditional and modern manufacturing methods for the same component. Furthermore, it seeks to recommend the most efficient production process in terms of the optimal choice of methods, time, and quality of manufacturing.

Methodology

Research problem

The main problem addressed by this research is the divided opinions among experts regarding the manufacturing of individual components. These opinions are divided regarding the time required for production preparation and the time needed for the actual manufacturing of the component.

Research subject

The subject of this research is the comparison of traditional and modern manufacturing methods for a taper tap from the perspective of time efficiency.

Research objective

The objective of this research is to identify and quantify the differences in the time required to perform the same manufacturing process using traditional and modern methods.

Research task

The research aims to determine which of the two manufacturing processes gives better results in terms of time efficiency. Additionally, the task is to present the advantages and disadvantages of each process relative to the other.

Research hypothesis

Compared to the traditional method, the modern manufacturing process of a taper tap provides an advantage in terms of time efficiency.

Research methods, techniques, and instruments

For the preparation of the manufacturing process and the generation of ISO G-code, a licensed version of Fusion 360 software was used. The manufacturing process was carried out on the Haas ST-40 CNC machine, a PA-30 Potisje Ada conventional lathe, and a GUK-1P Prvomajska milling machine. Additionally, a stopwatch was used to quantify the time spent during the preparation for manufacturing and machining processes.

Downtimes in the petroleum industry

During operations such as drilling and cementation of a well, well completion, workover, or well maintenance, certain delays and interruptions during the ongoing operation may occur (Boldrin et al., 2023; Elgibaly, 2019). A delay represents both a temporal and economic loss for the company performing the work (Aoudia et al., 2008; Maleki et al., 2023). Although modern machine learning and AI tools aim to predict and minimize downtimes (Chuka Anthony Arinze et al., 2024), in practice, most of the oil and gas wells experience a downtime at some point during their construction or completion that requires intervention (Al-Subaiei et al., 2021). To fix the problem, i.e., restoring the well to its previous (operational) state, it is necessary to use special equipment (Lei et al., 2020; Vasić, 2013). Various tools specifically designed for removing stuck equipment from the well can be used during the process (Vasić, 2013), one of which is a taper tap fishing tool.

Downtimes may occur due to various circumstances:

- Pipe breakage,
- Jamming of well equipment components,
- Presence of foreign objects in the well (residual logging equipment, wireline, cables, an object that has fallen into the borehole etc.).

The following section discusses the types of downtimes that can be resolved using a taper tap fishing tool.

Taper tap

If a breakage of drill pipes occurs, which most commonly happens at the pipe joints, the drill pipe line is interrupted, leading to rig downtime (Albdiry and Almensory, 2016). If the other diameter of a drill pipe is slightly smaller than the wellbore diameter, it is impossible to use a fishing tool that engages on the outside surface of a tube or a stuck tool, such as an overshot; so a fishing tool that engages with the internal diameter (such as taper tap) has to be employed to retrieve the broken equipment from the well (Martinović & Moslavac, 2011; Vasić, 2013).

The taper tap (Figure 1) is one of the oldest and simplest tools used for catching equipment stuck in the wellbore. Internal fishing refers to an operation in which the fishing tool is lowered into the well and engages the broken tool or pipe by its inner diameter. The body of the taper tap can vary in diameter, length, thread type, chip groove presence, etc. (Liakh et al., 2021; Martinović and Moslavac, 2011; Vasić, 2013).



Figure 1 - A cross-section of a taper tap (https://runinall.com/fishing-tools/5215-taper-tap.html, n.d.)

Traditional and modern methods - comparison

The traditional method

The three main time parameters relevant to this study are:

- Time for preparing the process sheet,
- Machine operating time and
- Machining time.

To eliminate any potential ambiguities and uncertainties that may occur during the manufacturing process and thereby enhance time efficiency, the development of a high-quality process sheet requires a certain amount of time. In addition to active machining time, the process of manufacturing also requires machine operating time (workpiece centering, tool approach, tool change, workpiece repositioning, transitioning to another machine, etc.).

A stopwatch was used to measure the time required for manufacturing the taper tap. The time required for preparing the process sheet was recorded, along with the active machining time and the machine operating time.

Process sheet creation time

The process sheet was created based on the workshop drawing provided by the client. Before beginning the preparation of the process

sheet, it is necessary to review the drawing. Each process sheet can be created in multiple ways; however, its quality is determined by its precision, clarity, and the minimal number of operations required. Precision and clarity reduce the time needed for interpreting the process sheet, while minimizing the number of operations directly impacts the manufacturing time of the component. The time required for preparing the process sheet largely depends on the expertise of the engineer responsible for its creation. The time spent on creating the process sheet was 2 h 8 min.

Machine operating time

Considering that the time required for machine operating depends on the operator's skill, the most accurate research results will be obtained by taking the average time in minutes for each operation listed in Table 1.

Table 1 - Number of individual operations and machine operating time per operation

Operation	Number of repetitions of operations	Measured operation time	Average operation time	Total average operation time
Tool preparing	1	11 min 49 s	12 min	12 min
First centering of the workpiece	1	4 min 49 s	5 min	5 min
Setting the operating mode of the machine	11	14 s - 22 s	0,3 min	3.3 min
Tool approach to the workpiece and tool retract stroke	63	8 s - 21 s	0,4 min	25,2 min
Tool change	15	46 s - 1 min 20 s	1 min	15 min
Workpiece rotation and recentering	2	52 s - 1 min 12 s	1 min	2 min
Machine changeover (positioning the workpiece in the milling machine)	1	2 min 49 s	3 min	3 min
Total average duration of all operations				1 h 5.5 min

Considering the total time required for performing individual operations, the total average duration of all operations amounts to 65.5 minutes, i.e., 1 hour and 5.5 minutes.

Active machining time

The active machining time is defined as the period during which material is removed from the workpiece. The time consumption during these operations mainly depends on the machining parameters applied during the process and only to a small extent on the operator's skill.

Table 2 - Number of individual operations and machining time per operation

Operation	Number of repetitions of operation	Measured operation time	Total average operation time
Facing	2	16 s	32 s
Spot drilling	2	14 s	28 s
Drilling a smaller diameter	2	10 min 15 s	20 min 30 s
Drilling a bigger diameter	1	5 min 51 s	5 min 51 s
Chamfering	5	2 s	10 s
Rough turning - external	1	33 min 45 s	33 min 45 s
Finish turning - external	1	7 min 34 s	7 min 34 s
Rough turning - internal	1	9 min 1 s	9 min 1 s
Finish turning - internal	1	4 min 45 s	4 min 45 s
Thread cutting on a cone - external	1	22 min 4 s	22 min 4 s
Thread cutting on a cone - internal	1	11 min 24 s	11 min 24 s
Thread cutting for guider	1	12 min 24 s	12 min 24 s
Chip groove milling	4	1 min 58 s	7 min 52 s
Total duration of all operations			2 h 16.3 min

By summing the machining time per operation, the total duration of all operations amounts to 2 hours, 16 minutes, and 20 seconds.

The total time required to manufacture the taper tap using the traditional method is 5 hours, 29.8 minutes.

The modern method

The three main time parameters relevant to this study are:

- Time needed for 3D modeling in the software Fusion 360,
- Machine operating time, and
- Machining time.

Before starting work in the software, it is essential to review the workshop drawing provided by the client. 3D modeling and CNC machine programming of the Haas ST-40 CNC machine were performed using Fusion 360 software. The duration of work in the software is a relative factor, as it depends on the engineer's expertise and familiarity with the software environment. The efficiency of modeling relies on the user's proficiency with the software interface, whereas the efficiency of programming, in addition to software knowledge, also requires an understanding of tool properties, machining parameters, and machine performance. The total time spent on modeling the taper tap and programming the CNC machine was 2 hours and 43 minutes.

Machine operating time

Unlike the traditional manufacturing method, which requires continuous machine servicing, the modern manufacturing approach significantly reduces the time spent on physical interaction with the machine. The CNC machine used in this study does not require any operator intervention during the material removal process.
Table 3 presents the CNC machine servicing operations along with the measured, average, and total operating times.

It is important to emphasize that CNC machine operating time depends on the operator's expertise and efficiency, as in traditional manufacturing. Therefore, the precisely measured operating time cannot be considered a universal reference; instead, the average servicing time must be determined from the recorded values.

The number of machine servicing operations in modern manufacturing is lower than in traditional machining. This is a direct result of the high level of process automation. In CNC machining, the total average duration of all operations for manufacturing the taper tap was 24 minutes.

To determine the active machining time, using a stopwatch is not necessary. Upon completion of the programming process, the software automatically calculates and sums the time required for each operation during the technological process. The software calculated that the time

required to manufacture the taper tap on the CNC machine is 56 minutes and 54 seconds, approximately 57 minutes (Figure 2).

Table 3 - Number of individual operations and machine operating time per operation

Operation	Number of repetitions of operations	Measured operation time	Average operation time	Total average operation time
Tool preparation and tool mounting on the turret	1	17 min 2 s	17 min	17 min
Workpiece setup	1	1 min 53 s	2 min	2 min
Workpiece rotation	1	1 min 2 s	1 min	1 min
Steady rest setup	1	1 min 49 s	2 min	2 min
Steady rest removal	1	46 s	1 min	1 min
Tailstock setup	1	49 s	1 min	1 min
Total average duration of all operations				24 min

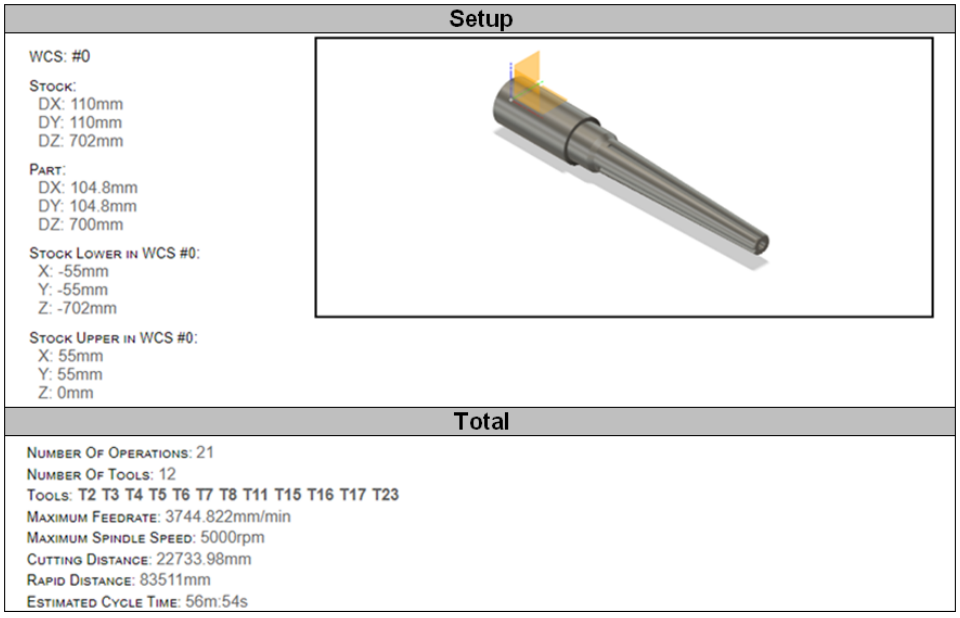


Figure 2 - Basic data on the machining operations on the CNC machine, as well as the duration of all operations calculated by the Fusion 360 software

The total time required to manufacture the taper tap using the modern method is 4 hours and 6 minutes.

Discussion

The two manufacturing methods used the same tools during the manufacturing process, while the primary difference is the order of operations. The order of operations in each method is adapted to the machining conditions in such a way that the manufacturing time of the given part is minimized (the fewer interruptions in the process due to workpiece positioning, the less time is needed for machine operating).

The next aspect to discuss is the time spent on preparation for the machining process: in traditional manufacturing, this involves creating the process sheet, while in modern manufacturing, it involves 3D modeling and CNC machine programming. Research has shown that preparation time for modern manufacturing is 37 minutes longer than the time required to create the process sheet for traditional machining.

Machine operating time for manufacturing the taper tap using the modern method is 41.5 minutes shorter than the machine operating time for the same element using the traditional method, which is a significant difference. This segment highlights the advantage of automated machining, as many operations that need to be performed manually on a conventional lathe or milling machine (such as a cutting tool approach to the workpiece) are performed quickly and more precisely by guiding the cutting tool via computer control.

The last factor considered in this study, which affects the overall duration of the manufacturing process, is the active machining time. Analyzing the results obtained, it is evident that, in terms of time efficiency, modern manufacturing has an advantage over traditional methods by 1 hour and 19.3 minutes (approximately 1 hour and 20 minutes).

These results directly indicate that, if serial production were to be implemented, manufacturing using the modern method would save 2 hours and 0.8 minutes (approximately 2 hours) for each subsequent element compared to traditional manufacturing. The research conducted in this paper confirms the initial hypothesis that the modern process of manufacturing the taper tap offers a time efficiency advantage over traditional methods.

Conclusion

The analysis of the conducted research clearly shows that the modern manufacturing method has numerous advantages over the traditional method. Although the modern manufacturing method requires more time for preparation, it should be considered that the preparation needs to be done only once for each manufacturing method. This directly indicates that

in the long run, when multiple identical parts need to be produced, the modern manufacturing method is more time-efficient.

Even though machining time is shorter on CNC machines compared to conventional lathes and milling machines, the traditional manufacturing method still plays a very important role in modern production, especially when quick manual adjustments are required on a workpiece, for which 3D modeling and CNC programming would take a lot of time. This directly indicates that the traditional manufacturing method still plays a key role in the manufacturing industry, despite the advantages provided by modern technologies.

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Uporedna analiza tradicionalnog i savremenog tehnološkog postupka izrade instrumentacionog trna

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Sažetak:

Uvod/cilj: Ovaj rad predstavlja komparativnu analizu tradicionalnog i modernog načina izrade instrumentacionog trna - alata koji se koristi u procesu instrumentacije u naftnim bušotinama tokom remontnih radova. Cilj ovog istraživanja je da ispita razlike u pogledu vremenske efikasnosti između tradicionalnog načina obrade (univerzalni strug i glodalica) i

modernog (obrada na CNC mašini), polazeći od hipoteze da savremene tehnike izrade pružaju veću vremensku efikasnost.

Metode: Ovo istraživanje bazirano je na eksperimentalnoj praktičnoj izradi instrumentacionog trna na dva načina: tradicionalni i moderni. Izmereno je potrebno vreme za izvršenje svake ključne operacije koja je sprovedena prilikom izrade instrumentacionog trna, uključujući pripremu izrade (kreiranje tehnološke liste (kod tradicionalnog načina izrade) ili 3D modelovanje i programiranje u softveru (kod morednog načina izrade)), vremena opsluživanja mašine, kao i vremena aktivne obrade (skidanja strugotine). Za potrebe 3D modelovanja i programiranja CNC mašine, korišćen je softver Fjužn 360. Vreme je mereno štopericom, te evidentirano, dok je jedan deo vremenskog parametra pridobijen iz samog softvera (pocenjeno vreme izrade na moderan način koje pruža softver).

Rezultati: Rezultati pokazuju da iako je moderan način izrade zahtevao 37 minuta više za radove koji obuhvataju pripremu proizvodnje, on ipak ima prednost u odnosu na tradicionalan metod u drugim segmentima. Vreme opsluživanja mašine je kod modernog metoda skraćeno za 41,5 minuta, dok je vreme skidanja strugotine kraće za 1 sat i 19,3 minuta u poređenju sa tradicionalnim metodom. Generalno gledano, moderan način izrade pruža znatno veću vremensku efikasnost prilikom proizvodnje instrumentacionog trna u slučaju masovne proizvodnje.

Zaključak: Istraživanje je potvrdilo polaznu hipotezu da moderan način izrade pruža veću vremensku efikasnost u poređenju sa tradicionalnim načinom izrade. Uprkos dužem procesu pripreme izrade, prilikom masovne proizvodnje moderan način je daleko efikasniji od tradicionalnog u domenu vremenske efikasnosti. Ipak, tradicionalna metoda i dalje može imati ključnu ulogu u proizvodnji pojedinačnih elemenata ili brzih manuelnih prepravki.

Ključne reči: mašinska obrada, tradicionalno, moderno, CNC, vremenska efikasnost, naftna industrija, vreme izrade.

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