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Efficient Operations through Time & Method Study: Reducing Machining Time in Bevel Gear Production

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ABSTRACT

This study delves into the optimization of Bevel Gear machining processes through method study techniques aimed at reducing machining time. By employing method study, various alternatives and improvements are explored to enhance the efficiency of crankshaft manufacturing. The research focuses on analyzing the existing machining procedures, identifying inefficiencies, and implementing strategies to streamline the process while maintaining quality standards. Through a systematic approach, factors contributing to prolonged machining times are identified and addressed, leading to significant time savings. The study evaluates different methods, tools, and technologies to achieve the desired reduction in machining time without compromising product quality or integrity. By implementing the findings of the method study, manufacturers can realize improved productivity, reduced production costs, and enhanced competitiveness in the market.

Key words: Manufacturing Excellence, Motion Study, Work Study, Lean

INTRODUCTION

Work study is the generalized name used to describe a complete set of techniques through which work can be simplified, standardized, and measured. It is mainly related to human work. Work study leads to higher productivity by reducing the wastages and lead time in the present method or process of working. This research is applied in a machining plant where a forged crankshaft is the raw material, and the machining is applied to achieve the desired shape and specifications. A set of processes is applied in the industry to achieve the desired output. The manufacturing industry continually seeks innovative approaches to enhance efficiency and productivity while maintaining product quality. In this context, the machining of crankshafts, vital components in internal combustion engines, stands as a critical process requiring optimization to meet the demands of modern production environments. The machining time of crankshafts plays a pivotal role in determining overall production efficiency and cost-effectiveness. Therefore, reducing machine time while ensuring precision and reliability is paramount for manufacturers to remain competitive in the global marketplace. Traditional approaches to crankshaft machining often involve complex and time-consuming procedures, leading to prolonged production cycles and increased operational costs. As a response, method study techniques have emerged as effective tools for analyzing and improving manufacturing processes. Method study, a systematic approach to analyzing work methods and procedures, offers manufacturers the opportunity to identify inefficiencies, streamline operations, and optimize resource utilization. The optimization of crankshaft machining through method study entails a comprehensive examination of existing processes, from raw material preparation to finished product assembly. By scrutinizing each step of the machining process, including turning, milling, grinding, and finishing operations, manufacturers can pinpoint areas for improvement and implement targeted interventions to reduce machining time. The proposed research aims to explore and implement method study techniques to reduce the machining time of gear. Through a combination of data analysis, process mapping, and performance evaluation, this study seeks to identify bottlenecks and inefficiencies in crankshaft machining processes. By leveraging method study principles, such as data-driven decision-making, project-oriented analysis, and customer-centricity, the research endeavors to develop innovative solutions for optimizing crankshaft manufacturing. The outcomes of this study are expected to contribute to the advancement of crankshaft machining practices, leading to improved productivity, reduced production costs, and enhanced competitiveness for manufacturers. Moreover, the insights gained from this research can inform future method study initiatives in the broader manufacturing domain, driving continuous improvement and innovation in industrial processes. FTS et al. (2005) Examine the TPM program's efficacy and execution for a company that manufactures electronics. The practical features of TPM, both inside and outside fundamental theory, are examined through a case study of its implementation in an electronics manufacturing company. Additionally, challenges in adopting TPM and issues that arose during the implementation are examined and analyzed [1]. Osama considers a Steel Company in Jordan collected data over the course of fifteen working days, and teams were formed over the course of two months to determine the benefits of forming a multidisciplinary team from various departments to remove departmental boundaries and improve the efficiency of the maintenance process. Workers on the production line were also included in the process of adopting autonomous maintenance operations (daily maintenance) [2]. Abdul & Aliza identify issues with the production work process and enhance it in terms of production time, number of processes, and production layout by suggesting an effective work process to SME. Research employed the Time and Motion technique to improve the work process at SME [3]. Nabeel & Rami improve the efficiency of the cutting and printing equipment at a nearby paper manufacturing company, the paper outlines a lean Six Sigma approach. The goal of the study is to identify, evaluate, and reduce all waste kinds in accordance with management and consumer requests. Extensive research identified several factors that significantly lowered overall equipment effectiveness (OEE), increased waste, and decreased output rate [4]. Sunil et. al. (2013) identifies the root causes of the issue through a thorough process analysis and suggests a workable solution. DMAIC is one of the ways used in conjunction with Six Sigma methodologies. This article discusses the effective deployment of FTA with DMAIC. The primary issue in this study was the ongoing rework of up to 16%, which resulted in labor expense and man-hour waste [5]. Efstathiou & Tapoglou (2021) analyzed this gear Because of their great productivity, face milling and face hobbing are two of the most important machining operations for spiral bevel and hypoid gears. Due to the extreme complexity of process kinematics, not many studies have been published in this field of study, even though optimizing these processes is essential for producing high-quality gears and minimizing overall manufacturing costs. Moreover, the two methods' various kinematic variations are used in industry, and the cutting tool geometry has a significant impact on the outcomes. We have built a new simulation model that is integrated into a for-profit CAD platform. The model generates the undeformed solid chip geometry and the 3D kinematic simulation of the face milling and face hobbing processes [21].

PROBLEM STATEMENT

The manufacturing industry is continually challenged to enhance operational efficiency and productivity while maintaining product quality and competitiveness. In the realm of bevel gear production, machining time stands as a critical factor influencing overall process efficiency and cost-effectiveness. However, existing machining processes often suffer from inefficiencies and suboptimal practices that result in prolonged machining times, leading to increased production costs and reduced competitiveness. Referring to this challenge requires a comprehensive understanding of the underlying factors contributing to excessive machining times and the implementation of targeted strategies to streamline operations. Furthermore, the integration of time and method study methodologies presents a promising approach to identify and eliminate bottlenecks, optimize process workflows, and enhance overall operational efficiency in bevel gear production. However, despite the potential benefits of time and method study, research in this area remains limited, with few studies specifically focusing on reducing machining time in bevel gear production. Therefore, there exists a critical need for research that investigates the application of time and method study techniques to analyze and improve machining processes in bevel gear production. This research aims to address this gap by examining the current state of machining operations, identifying areas for improvement, and implementing targeted interventions to reduce machining time while maintaining or improving product quality. By leveraging time and method study methodologies, this research seeks to develop practical solutions that enable manufacturers to achieve significant reductions in machining time, enhance productivity, and gain a competitive edge in the market.

METHODOLOGY

During the machine unit's process, a work measurement (time study) is carried out, indicating that some operations run smoothly, while others act as bottlenecks impeding overall productivity in the industry. Work is predominantly classified into rough machining and finished machining. Rough machining entails removing excess material from the forged crankshaft through turning at various workstations. Conversely, finished machines concentrate on surface finishing, primarily accomplished through grinding, albeit at a slower material removal rate. Mustofa and Biswas et al. describe production and supply chain related data in three different papers from which we have taken the decision for material and production scheduling update work in gear manufacturing production [9-13]. Shaikh & Jain (2015) interprets the effects of electrolyte composition and finishing time on straight bevel gears' geometric precision and surface quality using the electrochemical honing (ECH) process to extend their lifespan and enhance their operational efficiency. Using the novel idea of twin complimentary cathode gears, ECH created an experimental arrangement for the precise finishing of straight bevel gears [20].

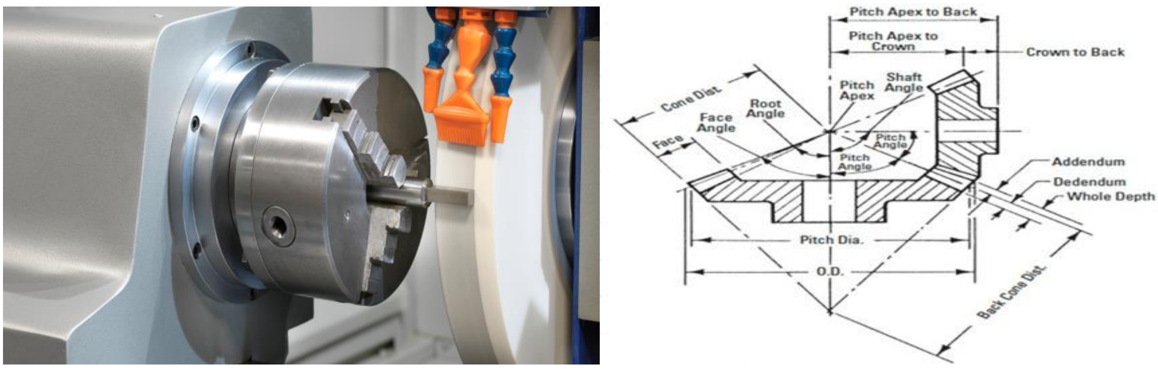

Figure 1: Gear Pin Grinding and turning processes and the gear tooth terminology

Time study before altercation:

The observations by time study are analyzed to reduce the time of operation required where the wastage of time takes place. The two combinations of processes where turning is followed by grinding are selected to implement the improvement to reduce the machining time. The maximum amount of material is suggested to be removed in the turning operation in which the MRR is comparatively higher than grinding. Molla et al. (2023&2024) undertake a comprehensive investigation to determine the optimal scenario for production for operational improvement in the industry using TPM technology and SMED set up functions [16-19].

Table 1: The duration monitored during a machining operation prior to any alterations

S.No.	Manufacturing process	Climbing Period	Machining Time	Un installing Time
1.	Stick pin Turning	00:50.01	01:08.0	00:20.0
2.	Pinion Grinding	00:10.32	04:40.0	00:10.0
3.	Turning groover	00:17.76	03:22.0	00:07.0
4.	Taper dia turning	00:09.21	05:43.0	00:09.0

Before alterations, the total machining duration. = 14:53 minutes

The provided table presents key details regarding various manufacturing processes, including climbing period, machining time, and uninstalling time for each process. The climbing period refers to the time taken for the machine to reach its optimal operational state before the actual machining begins. Machining time signifies the duration required to perform the machining operation itself, while uninstalling time indicates the time needed to remove the workpiece from the machine after machining is completed. In the context of stick pin turning, the climbing period is relatively short at 00:50.01, followed by a machining time of 01:08.0 and an uninstalling time of 00:20.0. This process involves turning stick pins to achieve desired dimensions and surface finishes. Pinion grinding, on the other hand, requires a longer climbing period of 00:10.32, followed by a significantly extended machining time of 04:40.0, indicating the intricacy and precision involved in this grinding operation. The uninstalling time for pinion grinding is relatively short at 00:10.0. Turning groover operations entail a climbing period of 00:17.76, followed by a machining time of 03:22.0 and an uninstalling time of 00:07.0. This process involves the turning of grooves in workpieces, requiring precision and accuracy. Lastly, taper Dia turning involves a climbing period of 00:09.21, followed by a notably long machining time of 07:43.0, indicating the complexity of taper turning operations. The uninstalling time for this process is 00:09.0. Overall, these descriptions provide insights into the time requirements and complexities associated with different manufacturing processes. Understanding these time metrics is crucial for optimizing production schedules, resource allocation, and overall operational efficiency in manufacturing environments.

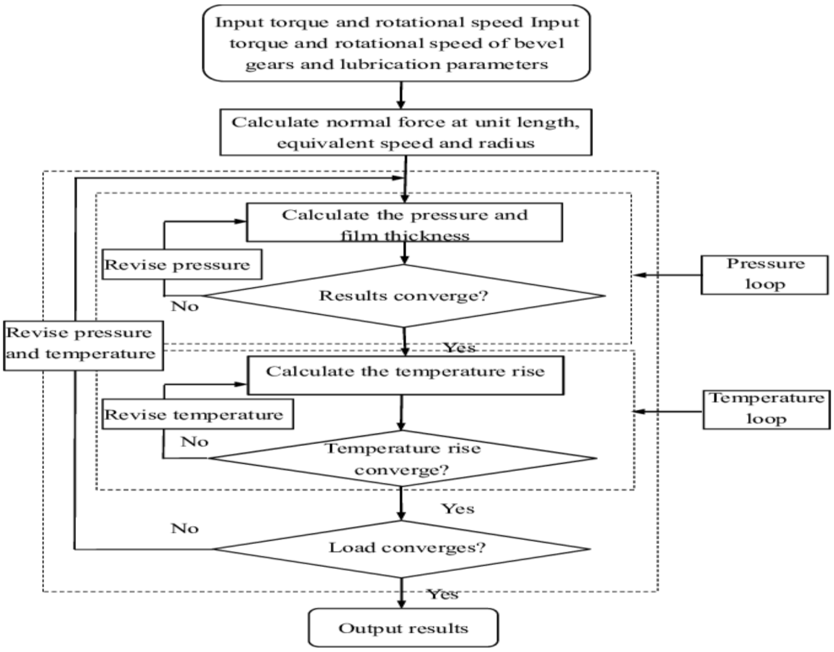

Figure 2: Flowchart for the gear manufacturing production

The machine's erratic behavior stemmed from various factors, notably dimensional variations predominantly observed on the left bank of the block, despite identical machining conditions on both sides. Furthermore, the finished bores exhibited inconsistent patterns of dimensional variation, with some blocks displaying oversized bores, others undersized, and occasional occurrences where all bore categories were affected. This lack of consistency posed significant challenges in predicting and addressing dimensional inaccuracies. To confront these issues head-on, a set of objectives was established. First and foremost was the aim to drastically reduce the rework of bores from 16% per month to nearly zero, without compromising on cycle time. This goal not only sought to minimize waste but also aimed to enhance operational efficiency and resource utilization. Additionally, there was a strong emphasis on improving the overall quality of the process to ensure consistent and reliable output. Moreover, reducing energy consumption associated with rework emerged as a crucial objective, aligning with sustainability and cost-saving initiatives. Lastly, efforts were directed towards mitigating the financial impact of rework by lowering associated costs while maintaining or even enhancing product quality standards. By addressing these objectives, the organization aimed to establish a more reliable and efficient machining process, ultimately bolstering competitiveness and customer satisfaction.

Table 2: Time Observed in Machining Operation before Modifications

S.No.	Process/ operation	Mounting Time	Machining Time	Un mounting Time
1.	Pin Turning	00:44.62	**02:06.86**	00:19.18
2.	Pin Grinding	00:09.24	**03:29.78**	00:08.38
3.	Turning Taper side	00:16.71	**02:33.16**	00:06.20
4.	Taper dia Grinding	00:08.43	**05:43.51**	00:07.44

Total Time of Machining before modifications = 14:52.31 minutes (selected Operations only)
The observations by time study are analyzed to reduce the time of operation required where the wastage of time takes place. The two combinations of processes where turning is followed by grinding are selected to implement the improvement to reduce the machining time. The maximum amount of material is suggested to be removed in the turning operation in which the MRR is comparatively higher than grinding.

Implementation of Modifications:

Increasing the depth of cut during turning operations can lead to a reduction in the amount of material needing to be removed during subsequent grinding processes. This is advantageous as grinding primarily focuses on achieving surface finishing and roundness. Therefore, increasing the depth of cut by 0.25 mm during the pin turning operation results in an additional pass, leading to an increase in machining time but a decrease in grinding time. Consequently, there is a net reduction in the overall time required for the complete process of rough and finished machinery. It is noteworthy that the mounting and unmounting times remain unchanged in both scenarios, hence only the machining time is considered when evaluating the results. By optimizing the machining parameters, such as the depth of cut, manufacturers can achieve efficiencies in the overall production process, enhancing productivity and reducing costs while maintaining product quality and integrity. This approach underscores the importance of strategic decision-making and process optimization in modern manufacturing environments, where minimizing time and maximizing efficiency are paramount for staying competitive in the market.

The calculations presented encapsulate a comprehensive assessment of the time-saving benefits achieved through modifications in the machining process. Initially, the total time of machine before modifications is determined to be 14 hours, 46 minutes, and 35 seconds for selected operations. Upon implementing modifications, a notable reduction in machining time is observed, resulting in a difference of 7 hours, 5 minutes, and 96 seconds. This significant timesaving highlights the efficacy of the modifications in streamlining operations and enhancing efficiency. Bagzir & Rahman (2024) finds the machine learning algorithm in their paper from which we can predict our machine accuracy for our turning process as well [6,7,8,22]. Noman et al. (2020) & (2024) undertake a noteworthy project on data retrieval approaches, with coding technology playing a pivotal role in our research, specifically when adjusting different parameters in production environments for the production [14,15].

Table 3: Time Observed in Machining Operation after Modifications

S.No.	Process/ operation	Mounting Time	Machining Time	Un mounting Time
1.	Pin Turning	00:44.62	**02:20.0**	00:19.18
2.	Pin Grinding	00:09.24	**01:20.0**	00:08.38
3.	Turning Taper side	00:16.71	**00:57.0**	00:06.20
4.	Taper dia Grinding	00:08.43	**02:58.0**	00:07.44

Further analysis delves into the cycle time, with the present cycle time established at 85.66 minutes. Following modifications, the cycle time is reduced to 78.64 minutes, showcasing a reduction of 7.3 minutes. This reduction translates to a 6.87% decrease in cycle time, signifying substantial improvements in process efficiency and productivity. By optimizing cycle times, manufacturers can achieve faster production rates and enhanced throughput, ultimately leading to cost savings and increased competitiveness in the market. These calculations underscore the importance of continuously evaluating and refining manufacturing processes to achieve optimal performance. The significant reduction in machine time and cycle time demonstrates the tangible benefits of implementing modifications aimed at enhancing operational efficiency. Moreover, the precise quantification of time savings provides valuable insights into the impact of these modifications on overall production metrics.

CONCLUSION

In conclusion, the application of time and method study techniques in bevel gear production has demonstrated significant potential for reducing machining time and improving overall efficiency. By meticulously analyzing and optimizing the manufacturing process, manufacturers can identify inefficiencies, streamline operations, and enhance productivity. Through the implementation of strategic modifications, such as adjusting machining parameters and refining work methods, substantial reductions in machining time can be achieved, leading to increased throughput and cost savings. Moreover, the systematic approach of time and method study ensures that improvements are data-driven, systematic, and sustainable, fostering a culture of continuous improvement within the organization. Ultimately, the successful implementation of time and method study in bevel gear production not only enhances operational efficiency but also strengthens competitiveness in the market by delivering high-quality products in a timely and cost-effective manner which is 6.87 Percent decrease in the cycle time.

FUTURE WORK

Future research could focus on leveraging advanced data analytics and machine learning algorithms to analyze vast amounts of production data and identify patterns and trends that may lead to further optimization opportunities. Additionally, conducting in-depth case studies and benchmarking exercises across a range of manufacturing facilities could provide valuable insights into best practices and innovative strategies for reducing machining time in bevel gear production. Furthermore, there is potential for exploring the integration of emerging technologies such as additive manufacturing and digital twinning to enhance the efficiency and accuracy of machining processes. Moreover, investigating the impact of workforce training and skill development programs on enhancing method study implementation and fostering a culture of continuous improvement could yield valuable insights into human factors influencing operational efficiency. Collaborative research initiatives with industry partners and academic institutions could facilitate knowledge sharing and foster innovation in the field, while also providing opportunities for real-world validation and implementation of novel methodologies and techniques. Ultimately, future work in this area should strive to develop holistic and integrated approaches that consider both technological advancements and human factors to achieve sustainable improvements in efficiency and productivity in bevel gear production and beyond.

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