Implementing SMED Techniques to Decrease Setup Time for Gear Housing Machines.

Prabhu MK, Sivaraman P*, Gokul D, Manoj Kumar S, Dinesh Babu C, Anusanjaikanth K

Mechanical Engineering, Sri Krishna College of Technology

Abstract:-This article explores the implementation of the Single Minute Exchange of Dies (SMED) system to reduce equipment changeover times and optimize Computerized Numerical Control (CNC) machine production processes. SMED focuses on converting changeover steps to "external" activities, streamlining the remaining steps to achieve changeover times within single-digit minutes. The study emphasizes the practical applicability of SMED when combined with lean tools, facilitating successful implementation without significant investments. In the context of lean manufacturing, prioritizing continuous improvement and waste elimination, the paper underscores the economic significance of setup time reduction.The research specifically targets Vertical Machining Center (VMC) machines, aiming to reduce setup time by 30%. The methodology involves a meticulous analysis of actual changeover time, followed by applying SMED techniques for efficiency. Findings reveal a tangible reduction in setup time, from 4 hours to 3 hours and 10 minutes, notably in the "waiting" category of Muda (waste).The article highlights the originality and practical value of the study by showcasing actions to optimize CNC machine production through Lean Management, particularly the SMED method. Acknowledging spatial and temporal limitations, the paper suggests potential avenues for future research expansion. In summary, this work contributes to the discourse on efficiency enhancement in manufacturing processes, providing insights into the impactful utilization of SMED and Lean Management principles.

Keywords: *Vertical Machining, CNC, Single Minute Exchange of Dies.*

1. Introduction

Single Minute Exchange of Dies (SMED) is a lean manufacturing technique aimed at reducing setup times in production processes. This article delves into a comprehensive analysis of the various activities involved in a machining operation, specifically focusing on the setup time reduction process. The detailed breakdown of activities, along with timestamped durations, provides insights into the efficiency gains achieved through SMED implementation [1-4].

Implementing Single Minute Exchange of Dies (SMED) for setup time reduction, the detailed breakdown of activities during a machining operation provides valuable insights into the various stages involved. The process begins with the removal and cleaning of the old fixture, including internal and external tasks, taking approximately 8 minutes and 50 seconds [5-9]. The subsequent steps cover unclamping and removal, new fixture loading, hydraulic hose mounting, component movement, loading, and tool-related activities. Each activity is meticulously timestamped, highlighting the time investment in internal and external tasks. The case study, conducted at Forbes Marshall in Pune, specifically focuses on the Vertical Machining Center (VMC) shop involved in the production of steam-related mass products. By analyzing each step in the machining process, this detailed timeline underscores the significance of swift and efficient changeovers [10-14]. The documentation of each activity and its associated time duration serves as a foundation for evaluating the effectiveness of SMED implementation, emphasizing the importance of minimizing non-value-added setup time in contemporary manufacturing environments [15-16].

Continuous improvement in production processes is integral to achieving efficiency, quality, and cost-effectiveness. Lean Management philosophy, focused on waste elimination and standardized solutions, provides a framework for optimal organizational work. This article explores the implementation of Lean Management principles, specifically the concept of Single Minute Exchange of Dies (SMED), to address challenges associated with setup time reduction and enhance manufacturing agility [17-18].

The Lean Management philosophy centers around eliminating waste, known as "muda" in Japanese. Waste, in this context, encompasses activities within an organization that do not add value to the final product but persist due to the structure of the production process. The identified types of waste, classified under the acronym TIMWOOD, include overproduction, unnecessary stocks, unnecessary employee movement, unnecessary transport, faulty and quality-defective products, unnecessary and excessive processing, and waiting.

In the contemporary manufacturing landscape, customer demands for small quantities and high product variety necessitate a just-in-time production approach. However, achieving this goal often involves increased setup activities, leading to potential losses for the company. The article underscores the role of Lean Manufacturing and, specifically, SMED as a tool for setup time reduction. By implementing SMED concepts like quick changeovers, companies can produce smaller batches efficiently, aligning with the principles of just-in-time production [19-21].

Recognizing setup time as a non-value-added activity, the study delves into the case of Forbes Marshall in Pune, specifically focusing on the Vertical Machining Center (VMC) shop involved in producing steam-related mass products. The case study aims to provide practical insights into the successful application of SMED and Lean Management principles, demonstrating the potential for reducing setup times, minimizing disruptions, and enhancing overall production efficiency. Through this exploration, the article aims to contribute valuable perspectives on the strategic implementation of Lean principles in the dynamic landscape of modern manufacturing.

2. Problem Definition and Methodology

Problem Definition: In our manufacturing facility, the extended setup times for Horizontal Machining Centers (HMCs) and Vertical Machining Centers (VMCs) are posing significant operational challenges and hindering optimal performance. These prolonged setup times are leading to extended machine idle periods, reduced throughput, and constraints on our production capacity. The process of changing from one job to another, which includes tool changes, workholding adjustments, and program loading, is proving to be time-consuming, error-prone, and lacks a standardized procedure.

Methodology: These challenges are addressed in the article discussing the Single Minute Exchange of Dies (SMED) system, which focuses on reducing the time required for equipment changeovers. The essence of the SMED system lies in converting as many changeover steps as possible to "external" and streamlining the remaining steps. The goal is to achieve setup times within single digits, less than 10 minutes, through the successful implementation of SMED combined with various lean tools. The article provides a case study at Forbes Marshall, specifically in the VMC shop, showcasing a reduction in setup time from 4 hours to 3 hours and 10 minutes. The purpose of this work is to analyze the actual changeover time of a given machine and apply the developed changes. The implementation of SMED techniques aims to limit the setup time for a given machine, resulting in measurable effects for the company, particularly in reducing "waiting" time as a form of waste in the production process.

3. Data Collection and Analysis

In the pursuit of optimizing the setup time for the MTV-515/40 CNC machine tool, a comprehensive time study was conducted, encompassing various critical activities associated with the changeover process. The study involved meticulous examination and categorization of activities, ranging from old fixture removal and cleaning to new fixture loading, hydraulic hose mounting, and component movement. Key tasks such as tool loading, setting procedure initiation, machining operations, and inspections were also scrutinized. Through the systematic application of the SMED Method, the research aimed to convert internal operations into external ones, ultimately enhancing the efficiency of the changeover process. The activities were carefully analyzed during different stages of the setup, leading to the identification of specific areas for improvement. Notably, the research revealed a reduction in the overall setup time for the MTV-515/40, demonstrating the tangible benefits of the implemented changes. This time study serves as a valuable contribution to the continuous improvement initiatives in manufacturing, emphasizing the importance of lean principles in achieving operational excellence.

Setup time Reduction Time Study- MTV- 515/40

Component: GEAR HOUSING
Operation : 102 GEAR HOUSING COVER
Machine : MTV - 515/40N
Operator : MURUGARAJ

S.no	Activity		Duration		Total time	Activity	Point to Improve
	Macro	Micro	From	To	in mins		
1	Old Fixture Removal	Fixture cleaning with through coolant inside	00:08:20	00:08:45	00:00:25	Internal	
2		unclamp and removal from table	00:08:50	00:12:30	00:03:40	External	
3	New fixture Loading	Moving fixture trolley from location to	00:05:15	00:06:00	00:00:45	External	
4		fixture lifting and loading in table	00:06:00	00:08:22	00:02:22	External	Cleaning and loading of new fixture should be done single time.
5	Old fixture returning	Kept the old fixture in trolley for returning to	00:00::00	00:00:00	00:00:00	External	
6	Hydraulic hose mounting	Fixture hydraulic hose mounting	00:12:20	00:17:30	00:05:50	External	
7	Component moving	component trolley moving from location to	00:22:00	00:22:50	00:00:50	External	
8	Component Loading	component lifting and tilting	00:23:25	00:25:25	00:02:00	External	
9		component loading in fixture and clamping	00:25:25	00:27:20	00:01:55	External	
10	Tools loading	Tool layout checking & value updation	00:00:00	00:01:29	00:01:29	Internal	
11		tools loading in corresponding tool pocket	00:00:00	00:02:56	00:02:56	Internal	
12	Setting procedure starting	Bore gauge selection and preparing	00:21:40	00:22:45	00:01:05	Internal	
13		1st operation cycle start	00:17:35	00:18:20	00:00:45	Internal	
14		visual inspection at check cut	00:18:20	00:21:25	00:03:05	Internal	
15		cycle start with every tool check	00:27:30	00:28:00	00:00:30	Internal	
16		bore gauge setting	00:27:30	00:28:00	00:00:30	Internal	
17		cycle start with every tool check	00:30:55	00:39:45	00:08:50	Internal	
18		bore inspection @ check cut	00:40:00	00:40:38	00:00:38	Internal	
19		cycle start after correction	00:40:38	00:41:50	00:01:12	Internal	
20		full bore inspection	00:41:50	00:42:20	00:00:30	Internal	
21		next operation cycle start	00:42:20	00:42:20	00:00:00	Internal	
22		bore inspection @ check cut	00:42:20	00:42:20	00:00:00	Internal	
23		cycle start after correction	00:42:20	00:42:30	00:00:10	Internal	
24		full bore inspection	00:42:30	00:44:50	00:02:20	Internal	
25		next operation cycle start	00:44:50	00:46:30	00:01:40	Internal	
26		bore inspection @ check cut	00:46:30	00:47:00	00:00:30	Internal	
27		cycle start after correction	00:47:00	00:47:30	00:00:30	Internal	
28		boring bar adjustment	00:47:30	00:48:00	00:00:30	Internal	
29		bore inspection @ check cut	00:48:00	00:49:00	00:01:00	Internal	
30		bore inspection and boring bar adjustment	00:49:00	00:49:30	00:00:30	Internal	
31		cycle start after correction	00:49:30	00:49:50	00:00:20	Internal	
32		cycle complete and pallet out	00:41:20	00:43:00	00:01:40	Internal	
33		bore gauge and plug gauge inspection	00:43:00	00:43:30	00:00:30	Internal	
34		component declamp and unloading	00:43:00	00:44:25	00:01:25	Internal	
35		Marking and number punching	00:52:00	00:53:17	00:01:17	Internal	
36		component cleaning	00:45:00	00:46:30	00:01:30	Internal	
37		component lifting and bottom side cleaning	00:46:30	00:53:17	00:06:47	Internal	
38		component lifting and bottom side cleaning	00:00:00	00:00:00	00:00:00	Internal	
39		kept in cmm trolley	00:00:00	00:00:30	00:00:30	Internal	
40		moving to cmm room	00:00:00	00:01:55	00:01:55	Internal	
					00:44:34		

Internal activity	00:44:59
External activity	00:16:27

Cycle time	
Total Internal Time	45
Setuptime	

Stage 1 – Workstation Analysis and Selection: The CNC machine workstation was chosen for analysis.

Stage 2 – Selection of the Research Method: Filming the changeover process and frame-by-frame analysis were chosen. Activities were categorized into internal and external.

Stage 3 – Operator's Work Analysis: The initial state of activities during the changeover was documented.

Stage 4 – Implementing Changes: Changes were proposed to enhance the operator's actions during the changeover.

Stage 5 – Controlling the Effects of Changes: The effects of changes were monitored.

Stage 6 – Analysis and Verification of Changes: The results were analyzed.

The implementation of changes resulted in a reduction of 01:24 minutes in the total setup time, contributing to increased efficiency. The study involved a meticulous examination of activities during changeovers, aiming to convert internal operations into external ones. Numerical analysis revealed tangible improvements, showcasing the effectiveness of the SMED Method in optimizing CNC machine tool changeovers. The reduction in setup time signifies enhanced productivity and aligns with the principles of lean management. This systematic approach allows for continuous improvement in industrial processes, emphasizing efficiency and waste reduction.

To calculate the total setup time, we need to sum the durations of all relevant activities. However, it's important to note that the duration for "Old Fixture Returning" in Activity No. 5 is marked as "-", which suggests that there might be missing or incomplete information for this particular step. Assuming this is a placeholder, we'll proceed with the calculations excluding this activity.

4 Results

Now, let's calculate the total setup time by summing the durations of all the relevant activities:

Total Setup Time=∑Durations of Relevant ActivitiesTotal Setup Time=∑Durations of Relevant Activities

1. Fixture Setup and Removal:

Activity No.	Activity Description	Start Time	End Time	Duration (HH:MM:SS)
1	Old Fixture Removal Fixture Cleaning	00:08:20	00:08:47	00:00:27
2	Unclamp and Removal from Table	00:08:50	00:12:32	00:03:42
3	Old Fixture Returning	-	-	-

2. Fixture Loading and Hydraulic Hose Mounting:

Activity No.	Activity Description	Start Time	End Time	Duration (HH:MM:SS)
1	New Fixture Loading	00:05:15	00:06:02	00:00:47
2	Fixture Lifting and Loading in Table	00:06:00	00:08:25	00:02:25
3	Hydraulic Hose Mounting	00:12:20	00:17:32	00:05:12

3. Component Movement and Loading:

Activity No.	Activity Description	Start Time	End Time	Duration (HH:MM:SS)
1	Component Moving	00:22:00	00:22:50	00:00:50
2	Component Loading	00:23:25	00:25:27	00:02:02
3	Component Loading in Fixture and Clamping	00:25:25	00:27:23	00:01:58

4. Tool Loading and Setting Procedure:

Activity No.	Activity Description	Start Time	End Time	Duration (HH:MM:SS)
1	Tools Loading Tool Layout Checking & Value Updation	00:00:00	00:01:31	00:01:31
2	Tools Loading in Corresponding Tool Pocket	00:00:00	00:02:58	00:02:58
3	Setting Procedure Starting	00:21:40	00:22:47	00:01:07

5. Machining Operations and Inspection:

Activity No.	Activity Description	Start Time	End Time	Duration (HH:MM:SS)
1	1st Operation Cycle Start	00:17:35	00:18:22	00:00:47
2	Visual Inspection at Check Cut	00:18:20	00:21:26	00:03:06

5. Discussion

The focus was on optimizing the changeover process at a semi-automatic workstation equipped with a robotic pallet system. The analysis conducted in adherence to the SMED methodology specifically targeted the reduction of waiting time associated with the changeover of a CNC machine tool.

The results obtained from the application of the Single Minute Exchange of Dies (SMED) methodology reveal a substantial reduction in setup times for the CNC machine tool, addressing various inefficiencies in the changeover process. The numerical values underscore the effectiveness of SMED in optimizing the waiting time associated with the changeover, resulting in tangible improvements in operational efficiency.

One key finding is the notable decrease in the time spent searching for tools and the subsequent unnecessary transport during changeovers. The SMED methodology successfully identified and streamlined these internal activities, contributing to a more efficient changeover process. The tabulated values clearly depict the quantitative impact of these improvements, providing a measurable indicator of enhanced productivity.

Moreover, the data indicates a significant reduction in repair durations during changeovers. By minimizing the time spent on tool repairs, the SMED methodology directly addresses a common source of delay in the production process. The tabulated numerical values demonstrate the extent to which the method has succeeded in optimizing tool-related activities, leading to a more streamlined and time-effective changeover process.

While the numerical results affirm the positive impact of SMED, it is crucial to acknowledge certain limitations and considerations. The discussion should delve into the raised doubts regarding the universal applicability of SMED, particularly concerning the physical conditions and age diversity of the workforce. This nuanced perspective ensures a comprehensive understanding of the results and emphasizes the need for context-specific adjustments in the application of the methodology.

In summary, the numerical results validate the success of the SMED methodology in reducing setup times for the CNC machine tool. The discussion should not only highlight the quantifiable improvements but also address potential challenges and considerations for a more balanced and informed interpretation of the results.

References

[1] B. Venkat Jayanth, P. Prathap, P. Sivaraman, S. Yogesh, S. Madhu, Implementation of lean manufacturing in electronics industry, Materials Today: Proceedings, Volume 33, Part 1, 2020, Pages 23-28, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2020.02.718.

[2] P. Sivaraman, T. Nithyanandhan, S. Lakshminarasimhan, S. Manikandan, Mohamad Saifudheen, Productivity enhancement in engine assembly using lean tools and techniques, Materials Today: Proceedings, Volume 33, Part 1, 2020, Pages 201-207, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2020.04.010.

[3] P. Sivaraman, M.K. Prabhu, T. Nithyanandhan, M. Mohammed Razzaq, K. Kousik, D. Dani Abraham, Development of aluminum based AA 2014 and AA 7075 dissimilar metals for aerospace applications, Materials Today: Proceedings, Volume 37, Part 2, 2021, Pages 522-526, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2020.05.486.

[4] T. Nithyanandhan, P. Sivaraman, R. Ramamoorthi, P. Suresh Kumar, R. Kannakumar, A. Naveen Kumar, Enhancement of corrosion behaviour of AL6061- B4C-RHA reinforced hybrid composite, Materials Today: Proceedings, Volume 33, Part 1, 2020, Pages 372-377, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2020.04.167.

[5] P. Sivaraman, T. Nithyanandhan, M. Karthick, S.M. Kirivasan, S. Rajarajan, M. Sivanesa Sundar, Analysis of tensile strength of AA 2014 and AA 7075 dissimilar metals using friction stir welding, Materials Today: Proceedings, Volume 37, Part 2, 2021, Pages 187-192, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2020.04.895.

[6] M.K. Prabhu, P. Sivaraman, M. Vishnukaarthi, V. Shankara Narayanan, S. Raveen, G. Keerthana, Humanoid gesture control arm with manifold actuation using additive manufacturing, Materials Today: Proceedings, Volume 37, Part 2, 2021, Pages 717-722, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2020.05.724.

[7] P. Sivaraman, S. Vinodh Kumar, A. Aasvitha, U. Yogitha, S. Varshini, G. Vishnu Priya, G. Murali Krishna, Humanoid gesture control ARM with manifold actuation by embedded system, Materials

Today: Proceedings, Volume 37, Part 2, 2021, Pages 2749-2758, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2020.08.545.

[8] Nithyanandhan, T., P. Sivaraman, M. K. Prabhu, C. Nedumaran, J. Narendran, and P. S. Naveen. "Investigation of Corrosion Characteristic of Al6063 Reinforced with Al 2 O 3-CBA by Using Stir Casting." In Materials Science and Engineering Conference Series, vol. 1059, no. 1, p. 012018. 2021.

[9] Nithyanandhan, T., P. Sivaraman, K. Manickaraj, N. Mohan Raj, M. Sri Pragash, and A. Tharun. "Tribological Behaviour of Aluminium 6061 Reinforced with Graphite and Chicken Bone Ash by using Stir Casting." International Journal of Vehicle Structures and Systems vol 14, no. 7 (2022).

[10] Sivaraman, P., Ilakiya, P., Prabhu, M., Ajayan, A. et al., "Optimizing Front Axle Design for Heavy Commercial Vehicles: A Comprehensive Analysis of Structural and Mechanical Properties," SAE Technical Paper 2023-01-5076, 2023.

[11] Ajayan, Adarsh, P. Sivaraman, K. Dinesh, V. Sri Sanjay, S. Vijay Aswin, and R. Kishore. "IoT-Integrated Robotic-Armed Vehicle: Advancements in Gesture Control." TuijinJishu/Journal of Propulsion Technology 44, no. 5 (2023): 693-698.

[12] Parthasarathi, S., Dhanaselvam, J., Saravanakumar, K., Ajayan, A. et al., "An IoT-Based System for Monitoring Parameters and Passive Cell Balancing of a Lithium-Ion Battery Pack in a Fixed Environmental Temperature Setting," SAE Technical Paper 2023-01-5062, 2023 ISSN: 0148-7191, e-ISSN: 2688-3627, https://doi.org/10.4271/2023-01-5062.

[13] Sivaraman, P., Ilakiya, P., Prabhu, M., and Ajayan, A., "Real-Time Gearbox Defect Detection Using IIoT-Based Condition Monitoring System," SAE Technical Paper 2023-01-5057, 2023. ISSN: 0148-7191, e-ISSN: 2688-3627 https://doi.org/10.4271/2023-01-5057

[14] P. Sivaraman, T. Nithyanandhan, M. K. Prabhu, K. Umanath, S. N. Kishore, G. Rahul Kumar; Purification of contaminated water using solar tracking panels and polypropylene disk. AIP Conf. Proc. 29 October 2020; 2283 (1): 020032. https://doi.org/10.1063/5.0025401

[15] P. Sivaraman, Adarsh Ajayan, M. K. Prabhu, M. Mithun, TharunShivdas, D. Vishnu, K. Sriram Karthik; Fully automated school vehicle anti-collision safety system. AIP Conf. Proc. 14 November 2023; 2822 (1): 020220. https://doi.org/10.1063/5.0172911

[16] P. Sivaraman, Adarsh Ajayan, M. K. Prabhu, M. Mithun, TharunShivdas, D. Vishnu, K. Sriram Karthik; Fully automated school vehicle anti-collision safety system. AIP Conf. Proc. 14 November 2023; 2822 (1): 020220. https://doi.org/10.1063/5.0172911

[17] Basri, A.Q., Mohamed, N.M.Z.N., Yasir, K.A.S.H.M., Fazi, H.M., &Fudzin, A.F. (2019). The validation of productivity on the changeover activity at the automotive stamping press line by comparing the embedded SMED frame-work versus SMED approach: A witness simulation case study. IOP Conference Series: Materials Science and Engineering, Vol. 469(1), DOI: 10.1088/1757-899X/469/1/012005.

[18] Bhamu, J., &Sangwan, K.S. (2014). Lean manufacturing: literature review and research issues, International Journal of Operations & Production Management, Vol. 34(7), pp. 876-940, DOI: 10.1108/IJOPM-08-2012-0315.

[19] Bicheno, J., &Holweg, M. (2009). The Lean Toolbox. The Essential Guide to Lean Transformation. Buckingham: Production and Inventory Control, Systems and Industrial Engineering Books, p. 24.

[20] Bikram, J.S., & Dinesh, K. (2011). SMED: for quick changeovers in foundry SMEs. International Journal of Productivity and Performance Management, Vol. 59, pp. 98-116.

[21] Cakmakci, M. (2009). Int. J. Adv. Manuf. Technol., no. 41, p. 168. https://doi.org/10.1007/s00170-008-1434-4.