Design Study of VMC Fixture for Increase Productivity & Reduce Cycle Time

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ABSTRACT

In this project study we are going to focus on improving the manufacturing process of steel casting part by eliminating CNC operation and designing the setup for VMC machining. The objective is to enhance accuracy, minimize cycle time, and improve overall efficiency while maintaining the required tolerances. The methodology involves a thorough analysis of the existing CNC program and machining process, identifying areas for improvement such as operations sequences changes, unnecessary movements, and inefficient fixturing.

We focus on optimizing fixture design for VMCs to enhance machining accuracy and significantly reduce cycle times. By employing a combination of advanced design methodologies, including finite element analysis (FEA) for stress and deformation prediction, robust design techniques for minimizing sensitivity to variations, and innovative clamping mechanisms for improved rigidity and faster setup, this study aims to achieve substantial improvements in manufacturing efficiency and part quality. The findings will contribute to significant cost savings, increased productivity, and enhanced competitiveness in the manufacturing industry.

KEYWORDS: - Optimizing the process, Increased productivity, Cost saving, Minimize cycle time, Fixture designing,

1. INTRODUCTION

In the area of manufacturing, precision and efficiency are paramount. To achieve these goals, manufacturers rely on a variety of tools and techniques, among which jigs and fixtures play a pivotal role. These specialized devices are designed to hold work pieces securely and accurately, guiding cutting tools to ensure consistent and repeatable results. Fixtures are the Backbone of Precision Manufacturing. Jigs and fixtures are essential components in manufacturing processes, offering a many benefits. By precisely locating and holding work pieces, jigs and fixtures minimize human error, leading to consistent part quality. These devices ensure that parts are machined to exact specifications, reducing the need for rework and scrap. Our main focuses on optimizing the manufacturing process of casting by eliminating CNC operation and designing the setup for VMC machining. The objective is to enhance accuracy, minimize cycle time, and improve overall efficiency while maintaining the required tolerances. These all design procedure will be done with process design, Setup design, material selections, Size or dimensional parameters with tolerance accuracy. Our main aim is minimize cycle time and increase productivity with a rigid designed fixture.

2. LITERATURE REVIEW

In Table 1 Shows referred papers and fixture design techniques and data related productivity and, cycle time, and accuracy in which sample papers give various findings, methodology and used techniques

Sr. No	Authors of referred papers	Application	Abstract
1	Aher Atul [2021] et al.	Reduce loading / Cycle time	Design a fixture for a VMC machine as per the requirement of the Industry which will help in reducing the loading time.
2	Utkarsha Dabade[2021] et al.	Productivity Improvement through Cycle Time Reduction	By incorporating spot face cutter and CBN tool, the cycle time reduced by 7 min.
3	N.Gokulakrishnan[2020] et al.	Operational Time and lowering the cycle time in CNC Machine	Cycle time reduction in CNC machines for manufacturing cost reduction.
4	C P Bhagyanath[2021] et al.	Reducing the Cycle Time and Cost of Radial Head Drill Feed Box Housing in VMC	Improving of CNC part program, lowering the cycle time and machining cost is possible with improved programming techniques using Canned cycles.
6	Andrzej Gessner [2022] et al.	Accuracy of the New Method of Alignment of Work piece	Method of positioning the work pieces for machining by means of optical measurements following by the results of verification tests of this method.
7	Rajesh B [2020] et al.	Design of work holding part for wheel hub for drilling of five lug bolts	Said the changing from the traditional job holding methods towards the fixtures that can be controlled by CNC machines or VMC machines itself and gives the needful purpose with low errors as there is not more of interference of human operators.
8	N.N.Mahatme [2020] et al.	Improvement in production and Time of Cycle will Reduction in CNC Operation	Effect of machining parameters including speed of cutting, feed rate and cutting depth on machining rate (MRR) and surface finish (Ra) during turning.
9	Md.Umair [2018] et al.	Design concept of a drilling jig for indexing	This type of jig is used to drill a series of holes in pcd on the face of work piece.
10	Harshwardhan Pandit [2021] et al.	The paper gives us deep information of jigs and fixtures	Identify the multiple advantages that are related with the use of jigs and fixtures in machining industry for: production increase, cost reduction

Table:-1 Referred Paper

3. RESEARCH AND FINDINGS

3.1- Problem Statement:-

With an understanding of purpose, constraints, and challenges, you can now formulate a clear problem. A well-defined problem statement might look like this:

“The objective is to design a common setup VMC fixture capable of securely holding parts without firing the tolerances or deviation requirements. While accommodating geometric access constraints and ensuring loading accessibility before

clamping. The design must also address potential manufacturing issues by facilitating smooth assembly and minimizing production problems''

- **Who: -** We are facing problem while turning CNC with run out 0.06 mm. After operation it goes out by 0.01 mm, which is not acceptable for production, and setting time is also more.
- **What: -** Tolerance goes out at higher limit and setting time for turning is lengthy, which may lead low productivity with more cycle time.
- **When: -** The problem occurring at the time of finishing the bore at last cut.
- **Why: -** To minimize the rejection and increase accuracy, we need to be address the problem solution.

During trail of development we have taken some readings CNC operations are follows,

Job Sr.No	Run-out (mm)	Operation time Minutes	Setting time Minutes	Total cycle T Minutes
1	0.07	6.0	4.0	10.0
2	0.08	6.0	3.0	9.0
3	0.07	6.0	4.0	10.0
4	0.06	6.0	5.0	11.0
5	0.09	6.0	4.0	10.0

Table: - 2 Check Sheet of CNC

Specifications of CNC turning machine:

- Specifications:
- Tool Station : 8
- Weight Carrying Capacity: 60 kg
- Axis Slides:
- X=500
- Y=650
- Accuracy : ,+,- 0.0015 mm

3.2-Solution:-

Design a new fixture for VMC to significantly reduce cycle times for the specified machining operation. Improve the accuracy and repeatability of the machining process. Minimize setup times and operator intervention. Enhance the safety of the machining operation. So from table-2 observed that we are machining 6 to 7 jobs per hour and we are considering data of two shifts that is day and night with 8hr/shift. So to increase the production rate, we have to improve cycle time and rejection percentage.

Setting Time: - By designing proper locating and holding fixture concept we can minimize setting time like, job truing, clamping and resting adjustment.

Ease of loading and unloading: - The locating and clamping design should be ease of loading and unloading for any operator, which helps to reduce operations time.

Flexible Design: - We will try to design setup which can do milling of more than 2 jobs at one cycle for increasing production per hour rate.During trail of development we have taken some readings VMC operations are follows,

Job Sr.No	Run-out (mm)	Operation time Minutes	Setting time Minutes	Total cycle T Minutes
1	0.055	5.0	2.0	8.0
2	0.045	5.0	2.0	7.0
3	0.05	5.0	2.0	7.0
4	0.06	5.0	2.0	7.0

5	**0.065**	**5.0**	**2.0**	**7.0**

Table: - 3 Check Sheet of VMC

As per table reading shows that the setting time of VMC is very low as compare to CNC, and according the data the production rate is 9 job/hr. From above table it looks we are improving in productions rate by minimizing setting time. So we are machining 9 to 10 jobs per hour and we are considering data of two shifts that is day and night with 8hr/shift, So we machining 145 jobs per day which will get more productivity with accuracy. We are improving by doing study on machining accuracy and cycle time with a flexible and durable fixture design, that will leads enhance the productivity rate and quality operations.

Above table-3 shows the improvement in accuracy in VMC operation.

Specifications of Vertical milling center (VMC):

- Specifications:
- Table size- 1000*500*100
- Tool Changer- ATC -with 20 tools
- Transverse:
- X=560
- Y=410
- Z=450
- Accuracy: +, - 0.005 mm

From above table-3 shows we are reaching toward the accuracy. By proper location and holding technique we can achieve this type of tolerance accuracy. In future by taking more trails for full-finish job operations, we will increase our batch to mass quantity with quality production.

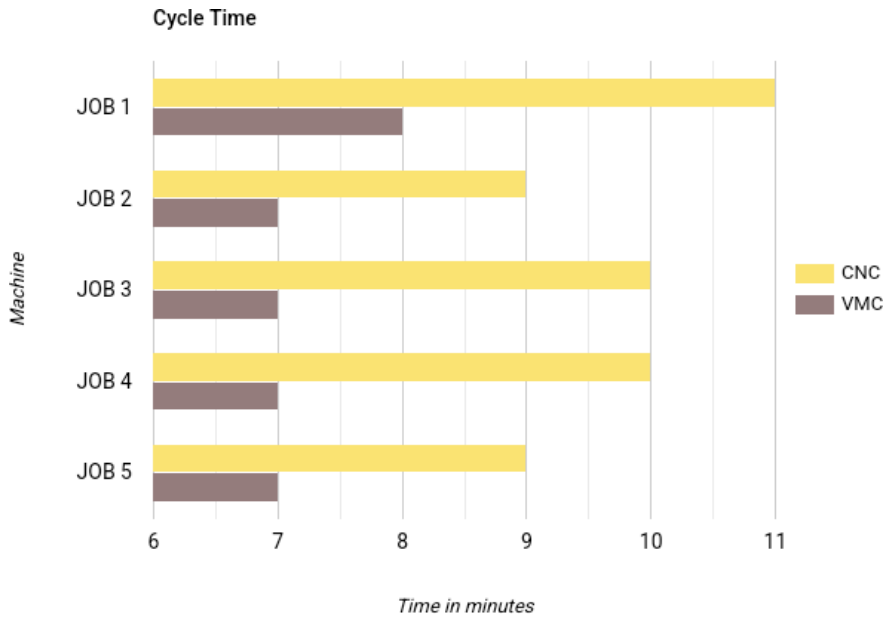


Fig:-1 Cycle of CNC vs. VMC

As per graph we minimize the cycle time of VMC setup and increase the production. So by trail we get good result for improvement in cycle time as compare to CNC machine. So our main aim is to manufacturing at least 200 jobs per day

with less rejections and deviation, also with quality production. To overcome all limitations, innovative fixture designs are necessary to streamline the machining process and maximize the potential of VMCs.

3.3-Project Planning & Scoping

i) Define Objectives:

Clearly state the goals of the fixture design to reduce cycle time, improve part accuracy, minimize operator effort, and enhance safety. Specify the target production volume and rate.

ii) Part Analysis:

Thoroughly analyze the work piece geometry, dimensions, tolerances, and material properties. Identify critical features and areas requiring precise positioning and clamping. Determine the part's weight, center of gravity, and potential for distortion during machining.

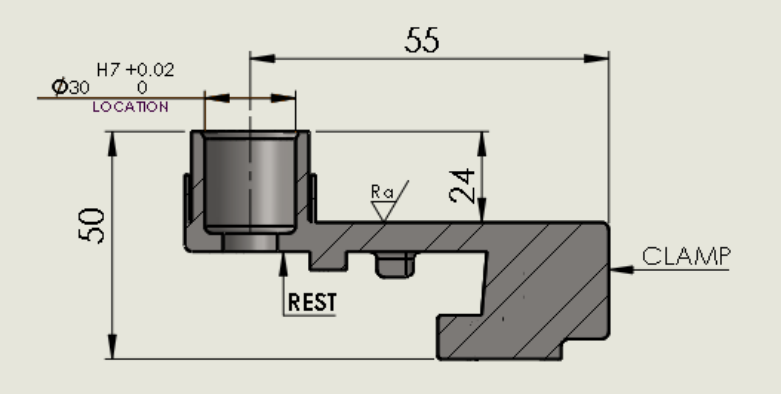


Fig:-4 Part Dimensional Analysis

iii) Conceptual Design:

Explored different clamping methods (e.g., pneumatic, hydraulic, mechanical) and considering their advantages and disadvantages. Evaluated different locating methods (e.g., pins, dowels, V-blocks) for accuracy and repeatability.

iv) Feasibility Analysis:

Studied the feasibility of each concept based on factors like cost, manufacturability, maintainability, and ease of use. Selecting the most flexible concept for further development.

v) Prototyping & Testing:

Fabricate a prototype of the fixture using appropriate materials (e.g., steel, aluminum).Ensure accurate machining and assembly of the prototype. Perform rigorous testing of the prototype on the actual VMC with Test part loading and unloading procedures for speed and ease of use. Verify part accuracy and repeatability using appropriate measuring instruments. Evaluate fixture rigidity and stability during machining. Assess the effectiveness of clamping and locating mechanisms.

vi) The Future Scope:

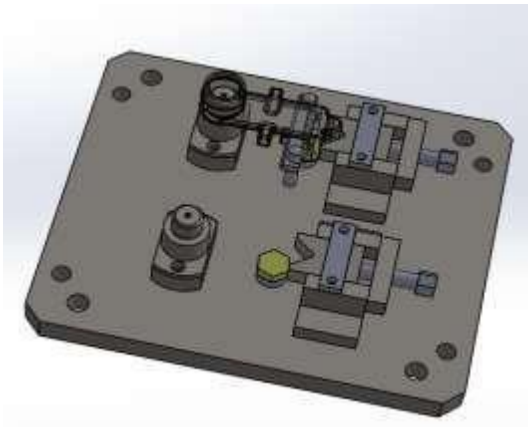
- Scope of fixture design for VMC operation is a dynamic and exciting field, driven by the increasing demand for efficiency, accuracy, and flexibility in manufacturing processes. Adaptability: Fixtures that can be easily reconfigured to accommodate a variety of work pieces will be highly sought after.

- This reduces setup times and costs, especially in high-mix, low-volume production environments.
- Quick Changeover Systems: Modular components and standardized interfaces will enable rapid changes to fixture configurations, minimizing downtime and maximizing machine utilization

4. DETAILED DEIGN

3D Modeling: Created detailed 3D models of the selected fixture design using CAD software e.g., Solid Works. Incorporate all necessary components like.., base plate, clamping elements, locating devices, tooling into the model.

Conduct virtual assembly and interference checks to ensure proper fit and function.



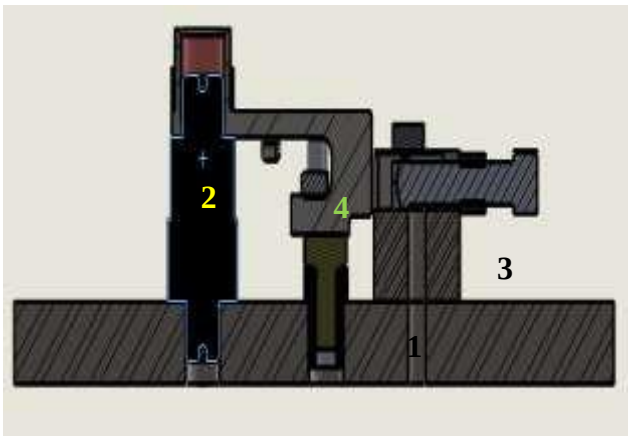


Fig:-4 Fixture for VMC

Fig:-5 Section of fixture

Above fig shows the detailed design of VMC setup fixture for performing milling operation. We have designed the proper constrained fixture that ensures the 3-2-1 principle parameters that is L-Location, H-Hold & third one is S-Support. So from fig-5 L-Locator-2, H-Movable V-block-3 and S-support or resting-4 we used self aligned pad with adjustable height.

Tolerance Stack-up Analysis: Analyze the effect of component tolerances on the overall accuracy of the fixture part. Minimize the impact of tolerances through careful design and selection of components.

FEA Analysis: Perform Finite Element Analysis (FEA) to simulate the fixture's behavior under machining loads. Identify potential stress concentrations and areas of weakness. Optimize the fixture design to improve rigidity and minimize deformation.

Ergonomics: Design the fixture with the operator in mind. Minimize operator reach and lifting requirements. Consider using ergonomic hand movement for clamp and tight the bolt by spanner. Considerations for easing loading & unloading.

Operator Feedback:-Obtain feedback from machine operators on the usability and ergonomics of the fixture. Incorporate operator suggestions into the final design. Like quick-change mechanisms for clamping elements and locating devices to reduce setup times with considerations for easing handling.

5. CONCLUSION

This project successfully designed and developed a new fixture for the VMC machine, specifically aimed at **design of vmc fixture for increase productivity & reduces cycle time.** The primary objectives of minimizing cycle time and increasing production were achieved through the following key features: - A quick-change clamping system enabled

rapid work piece loading and unloading, reducing idle time. Precise locating pins and robust clamping mechanisms ensured accurate and repeatable positioning, minimizing setup time and improving dimensional consistency. The fixture design incorporated features to allow for simultaneous machining of multiple faces, significantly reducing the number of setups and overall machining time. Overall, the new fixture will proven be to a valuable asset in improving the performance and productivity of the VMC machine, demonstrating the significant impact of effective fixture design on manufacturing processes.

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