International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Develop a Fixture for VMC Machining Using Error Proofing Technique (Poka-Yoke)

SHUBHAM DATTU DESHMANE[1], NISHANT JAGDISH BAGUL[2], JAGDISH KHANDU SONAWANE[3], SURAJ MOHAN UMAPE[4] ,GUIDE BY :- PROF. C. K. BAKSHI[5]

SANDIP FOUNDATION'S SANDIP POLYTECHNIC

ABSTRACT

The precision and repeatability of part positioning are critical in modern manufacturing, especially in CNC operations such as Vertical Machining Centers (VMCs). A poorly designed fixture can result in misaligned components, increased cycle times, and higher rejection rates. This research paper presents a practical study on designing a foolproof fixture for machining a steering knuckle using VMCs, applying the Japanese *Poka-Yoke* technique to prevent operator errors. Conducted in collaboration with **Super Auto Forge Pvt. Ltd.,** the study involved conceptualizing, designing, fabricating, and testing a customized fixture that ensures only one correct orientation for loading the component. The implementation demonstrated a significant reduction in setup errors, improved machining quality, and enhanced overall productivity.

1. Introduction

In the manufacturing industry, components like the **steering knuckle** require extremely tight tolerances and precise geometries to ensure safety and performance. Manual loading of parts onto machining fixtures can lead to errors in orientation or placement, especially in high-throughput environments. These errors often result in misalignment during machining, leading to defective products and production downtime.

Poka-Yoke, a Japanese term meaning "mistake-proofing," involves designing tools and processes in such a way that mistakes are either impossible to make or immediately visible. In the context of VMC machining, this means designing fixtures that only accept components in the correct orientation and position, making incorrect loading physically impossible.

This project focuses on developing a **Poka-Yoke-enabled fixture** for VMC machining that ensures reliable and error-free clamping of steering knuckle components.

2. Literature Review

Several researchers and industry professionals have addressed the issue of operator error in fixture design:

- **Shigeo Shingo** introduced the concept of Poka-Yoke in Toyota's lean manufacturing system to eliminate defects at the source.
- A study by **Gupta and Patel (2019)** on VMC fixtures demonstrated that integrating visual and physical foolproofing reduced rejection rates by 65%.
- **Vijaykumar et al. (2021)** proposed using dowel pins and asymmetric location slots in jigs for reducing errors in multi-stage machining processes.

This project builds on such research, applying proven concepts in a real-world industrial environment with modifications tailored for the steering knuckle geometry.

3. Objectives

The main objectives of the project are:

- To design a fixture that ensures correct positioning and orientation of the steering knuckle.
- To implement foolproof mechanisms to eliminate operator error during part loading.
- To validate the fixture's performance through shop-floor testing and analysis.
- To improve machining accuracy, reduce cycle time, and increase throughput.

4. Component and Process Analysis

4.1 Steering Knuckle

The steering knuckle is a complex component made of forged steel. It connects the suspension and steering systems in a vehicle and typically features multiple holes, flat surfaces, and mounting points. Due to its asymmetrical design, improper loading can lead to machining in the wrong orientation.

4.2 Existing Problems

The earlier setup allowed operators to place the component in two or more orientations. Mistakes were only detected after the machining process, leading to material waste and downtime.

4.3 VMC Process Overview

VMC (Vertical Machining Center) operations for the knuckle include:

- Facing and drilling
- Slotting
- Chamfering
- Thread tapping

These require precise orientation and holding to ensure all features are machined within tolerances.

5. Design and Development of Poka-Yoke Fixture

5.1 Design Considerations

- **Material**: Mild steel (MS) for the fixture body with hardened contact surfaces.
- **Clamping**: Manual toggle clamps for simplicity and reliability.
- **Location System**: Dowel pins and V-blocks to define exact position.
- **Foolproofing**: One asymmetric locator pin and a stopper block to block incorrect loading.

5.2 CAD Modeling

The fixture was modeled using **SolidWorks**. The component was simulated in all possible orientations, and only one fit was allowed by design. The CAD model included:

- Baseplate with standard VMC mounting slots.
- Rear locating pin and asymmetric slot for foolproofing.
- Clamps positioned to avoid interference with the toolpath.

Figure 1: Fixture Assembly CAD Model
(Placeholder for image)

6. Fabrication and Implementation

6.1 Fabrication Process

- Baseplate was machined and ground flat.
- Pins and locators were hardened to HRC 60.
- All dimensions were verified using coordinate measuring machine (CMM).

6.2 Shop-Floor Setup

- The fixture was mounted on the VMC table using T-bolts.
- The component was loaded, clamped, and machined in a trial run.
- Operator training was conducted to introduce the new loading procedure.

7. Results and Discussion

Parameter	Before Fixture	After Poka-Yoke Fixture
Setup Time (avg)	10 min	4 min

Parameter	Before Fixture	After Poka-Yoke Fixture
Orientation Errors/Day	4–5 parts	0
Operator Training Time	2 hours	30 min
Part Rejections/Month	40+	<5
Machining Accuracy Deviation	±0.15 mm	±0.05 mm

7.1 Observations

- **Error Elimination**: The Poka-Yoke design completely prevented reverse or incorrect loading.
- **Improved Productivity**: Reduced operator fatigue and mental load contributed to faster setup and consistent quality.
- **Enhanced Quality**: Rework and rejections were minimized, and tool life improved due to consistent engagement.

8. Cost-Benefit Analysis

Factor	Estimated Cost
Fixture Fabrication	₹ 18,000
Lost Production (per rejection)	₹ 2,500
Monthly Savings (approx.)	₹ 1,00,000+
Payback Period	<1 month

The investment in the fixture was quickly recovered through reduced rework, improved productivity, and lower rejection rates.

9. Limitations

- The fixture was designed specifically for one component model.
- It is manually clamped—future versions may benefit from hydraulic clamping.
- The initial design was not compatible with other steering knuckle variants.

10. Future Scope

- Integration of sensors to detect correct placement before machining starts.
- Modular fixture design for different component families.
- Use of hydraulic or pneumatic clamping for automation.

11. Conclusion

This study demonstrates the successful application of **Poka-Yoke principles in fixture design** for VMC machining. The developed fixture for the steering knuckle component ensured zero orientation errors, reduced setup time, and improved overall machining performance. Its adoption in production lines can significantly enhance process reliability and operational efficiency, especially in high-volume manufacturing environments.

12. REFERENCES

1. Shingo, S. (1986). *Zero Quality Control: Source Inspection and the Poka-Yoke System*. Productivity Press.
2. Gupta, A., & Patel, M. (2019). "Design of Foolproof Fixtures for CNC Applications", *International Journal of Engineering Research*, 8(3), 41-46.
3. Vijaykumar, R., et al. (2021). "Error-Proof Fixtures in Precision Manufacturing", *Journal of Modern Manufacturing*, 9(2), 89-97.
4. Super Auto Forge Pvt. Ltd. – Internal documentation and observations.
5. Boothroyd, G., & Knight, W. (2005). *Fundamentals of Machining and Machine Tools*. CRC Press.