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Study and Manufacturing of Fixture for Yoke Spline on Patson Milling Machine

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Abstract: *Fixtures play a crucial role in manufacturing processes by facilitating efficient and accurate operations such as drilling, milling, and tapping on workpieces. This paper presents the design and manufacturing of a specialized fixture for performing side milling operations on Yoke Splines. Without an appropriate fixture, this process becomes complicated, time-consuming, and prone to inaccuracies, leading to increased product rejection rates, higher machining costs, and time wastage for reworking. The developed fixture enables the secure positioning of Yoke Splines on a Horizontal Patson Milling Machine for precise side milling operations. Experimental results demonstrate that the fixture significantly improves machining accuracy, surface finish quality, and processing time compared to conventional methods. The fixture design incorporates hydraulic clamping mechanisms and precisely engineered supporting components to ensure optimal workpiece stability during high-speed machining operations.*

Keywords: Fixture Design, Yoke Spline, Side Milling, Manufacturing Efficiency, Hydraulic Clamping, Machining Accuracy

I. INTRODUCTION

In today's competitive manufacturing environment, product quality must be exceptionally high while maintaining optimal production rates [1]. A critical balance between quality and productivity must be achieved to ensure manufacturing success. Fixtures represent essential work-holding devices that support, locate, and secure workpieces during specific manufacturing operations but do not guide the cutting tool [2]. They differ from jigs, which guide the tool to its correct position in addition to workpiece positioning functions [3].

The primary purpose of fixtures is to precisely locate and, in certain applications, hold workpieces during machining or other industrial processes. Fixtures represent an economical approach to processing components in mass production environments. The quality of a manufacturing process is significantly influenced by the quality of fixtures used for this purpose [4]. Typically, fixtures are designed for specific operations to process particular workpieces and are individually manufactured to meet unique requirements.

Fixture designs vary considerably, ranging from relatively simple tools to expensive, complicated devices. Fixtures used in machine shops are strong, rigid mechanical devices that enable easy, quick, and consistently accurate locating, supporting, and clamping of blanks against cutting tools. This results in faster machining with consistent quality, functional reliability, and interchangeability of manufactured parts [5].

In recent years, fixtures have received significant attention in research and development. However, fixture layout design optimization remains an area requiring further investigation [6]. This project focuses on the manufacturing of a specialized fixture in the tool room of Kinetic Engineering Ltd., designed specifically for Yoke Spline processing on a Horizontal Patson Milling Machine.

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A. Objectives

The fixture for Yoke Spline was developed with the following objectives:

- To locate the workpiece quickly and accurately, support it properly, and hold it securely during machining operations.
- To design and manufacture a fixture that ensures operations performed on the workpiece maintain accurate dimensions.
- To minimize the loading and unloading time of workpieces while ensuring proper workholding throughout the machining process.
- To create a fixture that is easily installable on the target machine.
- To effectively hold the workpiece in position against all cutting forces, vibrations, and abrasions.
- To facilitate side milling operations on Yoke Splines with simple workpiece loading and unloading procedures.
- To achieve accurate dimensional results in reduced operation time under efficient working conditions.

B. Need for the Specialized Fixture

The development of this specialized fixture addresses several critical manufacturing needs:

- To perform side milling operations on Yoke Splines with precision and consistency.
- To provide a fixture design that facilitates easy loading and unloading of workpieces.
- To ensure the fixture can withstand all cutting forces, vibrations, and abrasions during machining.
- To achieve accurate dimensions in reduced operation time under efficient working conditions.
- To provide a new fixture construction design that accommodates specified input parameters for Yoke Spline machining.

II. LITERATURE REVIEW

Modular fixture design and optimization have been extensively studied by researchers to improve manufacturing efficiency. Pelinescu and Mihăilă [7] proposed, planned, and assembled modular fixture setups relative to cutting forces. Their research discussed positioning strategies and offered optimal solutions, emphasizing that tool movement influences the final quality of workpieces and that fixtures significantly impact tool movement. Their work demonstrated that modular elements make fixture components interchangeable and reusable, transforming fixture design into a task of selecting and assembling appropriate elements. They identified that the primary criterion for grouping manufacturing features into setups is typically the tool approach direction, accommodating considerations for loading/unloading and pin placements.

Boyle et al. [8] presented the development of an expert system for machining fixture design based on adequate production guidelines. Their paper outlined the applied methodology's basic structure, reviewed specific system segments, and provided examples of system implementation in industrial production environments. They concluded with an analysis of the developed system's advantages and disadvantages, along with directions for future research.

Workpiece deformation during machining can cause significant dimensional problems. Kulankara et al. [9] studied how supports and locators can be used to reduce errors caused by elastic deformation of workpieces. Their research identified that optimizing support, locator, and clamp positions represents a critical problem in minimizing geometrical errors in workpiece machining. They presented the application of genetic algorithms to fixture layout optimization, developing an approach that integrated finite element analysis running in batch mode to compute objective function values for each generation. Their optimized designs demonstrated similar performance despite lacking apparent similarities in configuration.

Additional research by Wang [10] explored computer-aided fixture design systems that incorporate knowledge-based approaches and finite element analysis to predict workpiece deformation under clamping and cutting forces. Nee et al. [11] conducted comprehensive reviews of fixture design principles and approaches, highlighting the evolution from manual design methods to computer-aided and automated fixture design systems.

III. CONSTRUCTION AND WORKING

The fixture for Yoke Spline consists of several key components designed to work together to provide optimal support, location, and clamping during machining operations. Each component serves a specific purpose within the overall fixture system.

A. Supporting Plates

The fixture includes five types of supporting plates, each with distinct functions:

Base Plate: The foundation of the milling fixture consists of a base plate with a flat, accurate undersurface that forms the main body on which various components are mounted. This surface aligns with the mill table surface and establishes the reference plane relative to the mill feed movement. The base plate may be constructed from steel plate or cast iron, depending on the size and complexity of the component. Slots are provided in the base for clamping the fixture to the mill table. The base plate also features keyways along its length to accommodate two keys that align the fixture on the milling machine table. These keys are pressed into the keyway at both ends of the fixture and secured by socket head cap screws, as shown in Fig. 1.

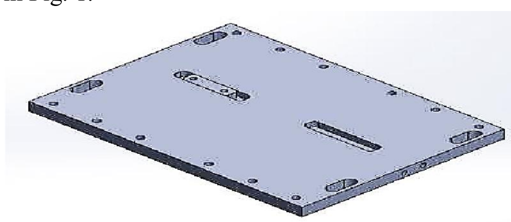

Fig.1 SW Base Plate.

L.H. & R.H. Bracket Assembly: The Left Hand (L.H.) and Right Hand (R.H.) bottom plates are mounted on the base plate. These plates feature slots on their bottom side to facilitate movement according to operational requirements. The L.H.-R.H. bottom plates are assembled with ribs that maintain the appropriate height from the base plate to the milling cutter. These components are illustrated in Fig. 2 and Fig. 3.

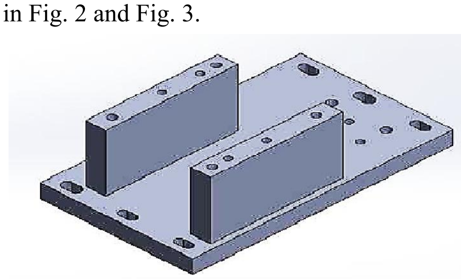

Fig. 2 SW Design of R.H. & L.H. Bracket Assembly(Top).

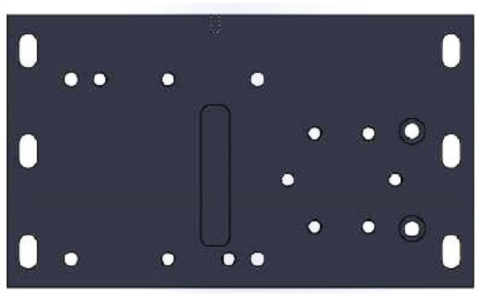

Fig.3 SW Design of R.H. & L.H. Bracket Assembly (Bottom).

L.H. & R.H. Top Plate: These two plates are mounted on the L.H. & R.H. bottom plates, respectively, at a specific height relative to the milling cutter height from the machine table, using supporting ribs (2 per plate). A supporting block is assembled on each plate to provide resting and supporting functions for the workpiece, as shown in Fig. 4.

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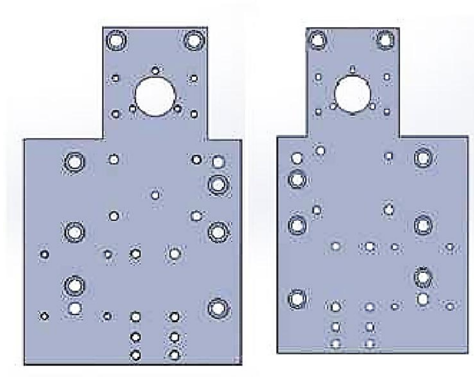

Fig.4 SW Design of R.H. & L.H. Top Plate.

B. Supporting Blocks

Several specialized blocks provide support and location for the Yoke Spline:

V-Block: This component features a V-shaped profile and supports the end side of the workpiece while holding it securely. The V-Block is mounted on each Top Plate using fasteners and is case hardened to 50-55 HRC for durability, as shown in Fig. 5.

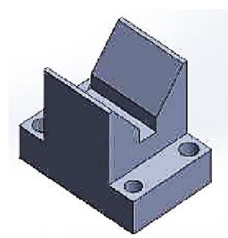

Fig.5 SW Design of V-Block.

U-Block: This component holds and supports the Yoke Spline at its maximum diameter. The U-Block is assembled with the HcHcr Pad on its inner side to provide better gripping, as illustrated in Fig. 6.

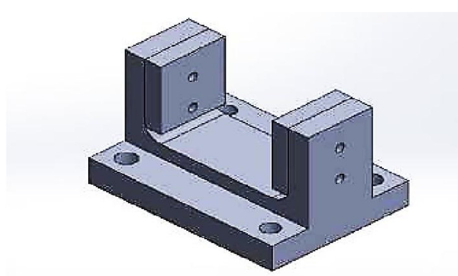

Fig.6 SW Design of U-Block.

Block: This component features a slight slope on which the front portion of the Yoke rests, as shown in Fig. 7.

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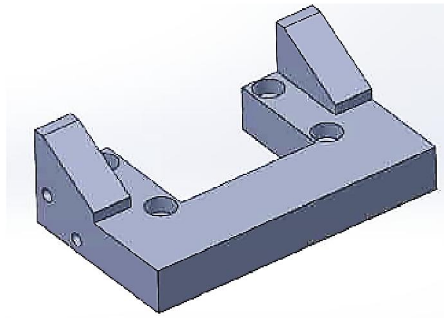

Fig.7 SW Design of Block.

L-Plate: This component supports the backward portion of the Yoke and is mounted with a stopper button that grips and restricts the linear motion of the workpiece during cutting operations, as depicted in Fig. 8.

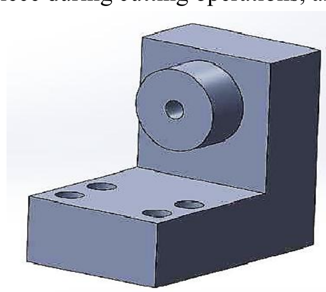

Fig.8 SW Design of L-Plate.

C. Clamping Mechanism

The fixture incorporates a sophisticated clamping system to secure the workpiece:

Tie Rod-Clamp-Hydraulic Cylinder Assembly: This assembly clamps the head of the Yoke. It consists of a clamp, tie rod, and hydraulic cylinder, as shown in Fig. 9.

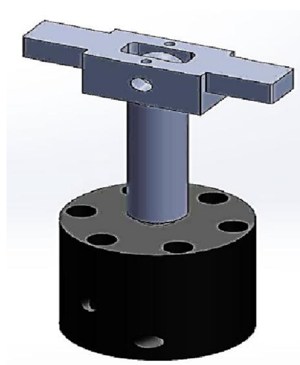

Fig.9 SW Design of Tie Rod-Clamp- Hydraulic Cylinder Assembly.

Hydraulic Cylinder: This component operates using pressurized oil through inlet and outlet ports. The pressurized oil exerts force on the tie rod, moving it in upward and downward directions. This movement controls the clamping and release of the workpiece. Upward movement releases the workpiece, while downward movement secures it, as illustrated in Fig. 10.

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Fig.10 SW Design of Hydraulic Cylinder.

Hydraulic Swing Cylinder: This component also secures the Yoke using pressurized oil through inlet and outlet ports. When oil enters the inlet port, the internal piston rod moves downward to hold the workpiece; when oil exits through the outlet port, the piston arm moves upward to release the workpiece, as shown in Fig. 11.

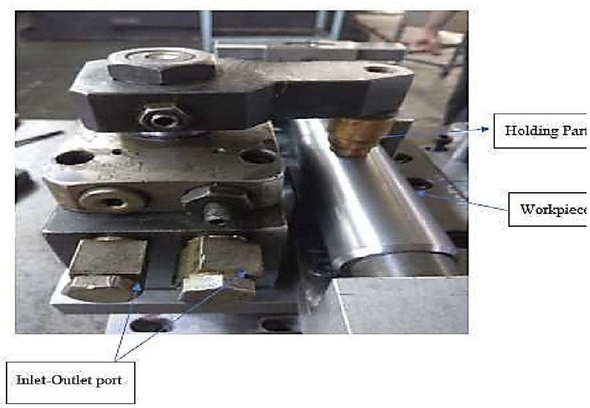

Fig.11 Hydraulic Swing Cylinder.

D. Supporting Components

Additional components enhance the functionality of the fixture:

Bush: This component guides the Tie Rod and Clamp assembly. It features a small hole on one side where a grub screw restricts the angular movement of the Tie Rod, ensuring only linear movement is possible, as shown in Fig. 12.

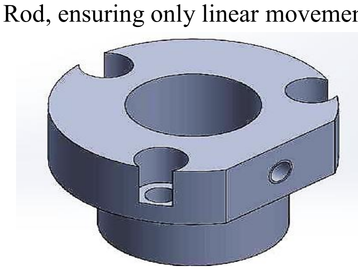

Fig.12 SW Design of Bush.

Pillar: These components support the Top Plates and maintain them at the predetermined height during machining operations, as illustrated in Fig. 13.

Fig.13 SW Design of Piller.

Plate-Cap Assembly: This assembly prevents horizontal motion of the L.H.-R.H. bottom plates and is used to set the distance of the bottom plate according to the cutter position while holding it securely. It attaches to the side of the base plate, as shown in Fig. 14.

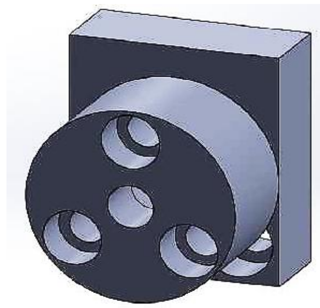

Fig.14 Design of Plate-Cap Assembly.

The complete assembly of the milling fixture for Yoke Spline is illustrated in Fig. 15.

IV. ADVANTAGES

The developed fixture for Yoke Spline machining offers numerous advantages over conventional setups:

- Significant increase in production rates through optimized workholding and reduced setup times.
- Substantial decrease in non-productive time through simplified workpiece loading and unloading.
- Suitability for high-volume mass production environments requiring consistent quality.
- Assured high accuracy of machined components through precise locating and robust clamping.
- Consistent quality maintenance and maximized efficiency throughout production runs.
- Achievement of part interchangeability through dimensional consistency.
- Enhanced operator safety through secure workholding during high-speed machining operations.
- Increased overall productivity through reduced cycle times and setup requirements.
- Reduced operator fatigue due to minimized and simplified handling operations.
- Ability for semi-skilled operators to perform complex machining tasks, resulting in reduced labour costs.

These advantages collectively contribute to the economic viability and technical effectiveness of the fixture in industrial applications.

V. CONCLUSION

This research presents the successful design and manufacturing of a specialized fixture for performing side milling operations on Yoke Splines using a Horizontal Patson Milling Machine. The key conclusions from this work include:

The developed fixture enables multiple machining operations with significant benefits, including reduced work-in-progress material handling time, decreased workpiece setup time, and minimized non-productive time.

The fixture effectively eliminates misalignment issues during Yoke mounting, substantially increasing the accuracy and quality of machining operations.

The innovative design represents not only an academic exercise but a practical industrial solution that enhances production rates and company profitability.

The hydraulic clamping mechanisms provide consistent clamping force, ensuring workpiece stability throughout machining operations.

The modular design approach allows for potential adaptations to accommodate similar workpieces with minimal modifications.

Future work could focus on further optimization of the fixture design using finite element analysis to predict workpiece deformation under cutting forces, as well as exploring the potential for automated fixture adjustment systems to accommodate varying workpiece geometries within the same product family.

VI. ACKNOWLEDGMENT

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