Mechanism and Machine Theory

Design of a Hydraulic Circuit for a Four-Sided Shaper Machine

--Manuscript Draft--

Manuscript Number:	MECHMT-D-24-02422
Article Type:	Research Paper
Keywords:	Hydraulic circuit, Four-sided shaper machine, Automatic reciprocation, Synchronized operation
Corresponding Author:	KUMARAN THANIKASALAM, BE Anna University Chennai, Tamil Nadu INDIA
First Author:	KUMARAN THANIKASALAM, BE
Order of Authors:	KUMARAN THANIKASALAM, BE
Abstract:	This paper introduces a hydraulic circuit designed specifically for a four-sided shaper machine, featuring two double-acting cylinders in synchronized operation. Powered by a dual-pump system, the circuit includes an automatic mechanism to achieve continuous reciprocation, enabling precise and coordinated movement of the cylinders. This setup enhances shaping accuracy and significantly reduces operation time. The design emphasizes efficient fluid control and a compact structure, optimizing workflows for increased productivity in shaping applications. Tailored for shaping tasks in various manufacturing contexts, this circuit offers a practical and versatile solution for industrial operations. The study details the circuit's schematic layout, functionality, and operational benefits, providing a foundation for practical application and potential advancements in hydraulic-driven shaping systems.
Opposed Reviewers:	

Cover Letter

Kumaran T
Final Year Student
Department of Mechanical Engineering
College of Engineering Guindy, Anna University
Chennai, Tamil Nadu, 600025, India
kumaranias09@gmail.com
Contact: +91-7305310328
November 6, 2024

Editor-in-Chief
Mechanism and Machine Theory

Dear Editor,

I am submitting my manuscript titled **"Design of a Hydraulic Circuit for a Four-Sided Shaper Machine"** for possible publication in your esteemed journal. This work presents an innovative approach to enhancing productivity and accuracy in machining operations through a hydraulic circuit specifically designed for four-sided shaper machines. The proposed circuit features two double-acting cylinders, synchronized for continuous reciprocation, powered by a dual-pump system to enable high-speed and precise shaping.

This design allows for automated, coordinated movement across multiple sides, optimizing shaping accuracy and reducing cycle times. By automating the reciprocation process and improving fluid control, this setup addresses key challenges associated with traditional shaper machines, including the need for manual intervention and inefficient workflow. We believe this research offers valuable insights for the field of hydraulic circuit design and its applications in industrial automation, making it suitable for high-demand manufacturing contexts.

Thank you for considering this manuscript for publication. I look forward to your feedback.

Sincerely,
Kumaran T
Final Year Student
College of Engineering Guindy, Anna University

Design of a Hydraulic Circuit for a Four-Sided Shaper Machine

Highlights

- Hydraulic circuit developed for a **four-sided shaper machine** enhances automation and precision.
- **Dual double-acting cylinders** provide synchronized, continuous reciprocation.
- The **dual-pump configuration** enables both high-speed and controlled strokes, reducing cycle times.
- Optimized **flow and pressure control** ensures accuracy and consistent performance in shaping tasks.
- Offers a **robust solution** for industrial applications, improving productivity in metalworking and fabrication sectors.

Design of a Hydraulic Circuit for a Four-Sided Shaper Machine

Kumaran T[a,1,*]

[a]*Department Of Mechanical Engineering, College Of Engineering Guindy, Anna University, Sardar Patel Road, Chennai, 600025, Tamil Nadu, India.*

Abstract

This paper introduces a hydraulic circuit designed specifically for a four-sided shaper machine, featuring two double-acting cylinders in synchronized operation. Powered by a dual-pump system, the circuit includes an automatic mechanism to achieve continuous reciprocation, enabling precise and coordinated movement of the cylinders. This setup enhances shaping accuracy and significantly reduces operation time. The design emphasizes efficient fluid control and a compact structure, optimizing workflows for increased productivity in shaping applications. Tailored for shaping tasks in various manufacturing contexts, this circuit offers a practical and versatile solution for industrial operations. The study details the circuit's schematic layout, functionality, and operational benefits, providing a foundation for practical application and potential advancements in hydraulic-driven shaping systems.

Keywords: Hydraulic circuit, Four-sided shaper machine, Automatic reciprocation, Synchronized operation

JEL: O33

1. Introduction

The need for precise and efficient shaping methods in industrial settings has driven the development of specialized hydraulic circuits for machining operations. Shaper machines are essential for producing accurate linear cuts and are widely used across manufacturing. However, traditional shaper machines, often limited to single-direction shaping, can be time-consuming when multiple sides of a workpiece require shaping. To improve efficiency, this paper presents a four-sided shaper machine driven by a hydraulic circuit designed to reduce processing time.

The focus of this study is a hydraulic circuit for a four-sided shaper machine, utilizing two double-acting cylinders and a dual-pump system. The circuit incorporates an automatic mechanism for reciprocation, allowing synchronized movement of the cylinders for precise shaping. This automatic circuit enables continuous reciprocation without manual control, simplifying the process and reducing time for multi-directional shaping tasks.

This paper provides an overview of the circuit's design, main components, and operation, highlighting its practical use in shaping applications. Additionally, the study discusses the advantages of this design in various manufacturing scenarios, presenting a practical solution for enhancing conventional shaping systems.

*Corresponding author

Email addresses: kumaranias09@gmail.com (KUMARAN T)

2. Design and Components of the Hydraulic Circuit

This section outlines the key components of the hydraulic circuit designed for a four-sided shaper machine, detailing the function of each component and its role in enabling efficient, automatic reciprocation for synchronized shaping tasks.

Overview of the Hydraulic Circuit Design

The hydraulic circuit is designed to enable the continuous, automated reciprocating motion necessary for a four-sided shaper machine. Utilizing a dual-pump system alongside two double-acting cylinders, the circuit provides efficient control over both forward and return strokes of the shaping process. This configuration supports high-speed operation with minimal manual control, meeting industrial automation standards to improve productivity.

Key Components and Their Functions

1. **Double-Acting Cylinder**

   The double-acting cylinders serve as the primary actuators within the hydraulic circuit, delivering the essential reciprocating motion for the shaping process. Each cylinder enables bidirectional movement, with hydraulic fluid alternately driving the piston for both forward and return strokes. This feature is crucial for the four-sided shaping operation, ensuring consistent and smooth motion throughout each cycle.

2. **Dual Pump Mechanism[1]**

   The circuit incorporates a dual-pump system, managing distinct flow rates during the shaping cycle. One pump provides the high flow rate required for the return stroke, accelerating this phase and reducing overall cycle time, while the second pump supplies a controlled flow for the forward stroke, allowing for precise shaping. This dual-pump arrangement optimizes efficiency by enhancing speed for non-cutting motions while ensuring control during the shaping phase.

3. **Automatic Reciprocating Circuit[1]**

   The automatic reciprocating circuit enables continuous operation without manual intervention, maintaining a steady sequence of forward and return strokes to improve workflow efficiency. This automatic functionality is especially valuable in industrial settings requiring constant operation, minimizing downtime and labor requirements.

4. **Synchronous Circuit[1]**

   The synchronous circuit is integral to the design, ensuring coordinated operation of the two double-acting cylinders. By synchronizing the movements, this circuit maintains consistent alignment between the cylinders, which is essential for precise and uniform shaping across all sides. This synchronization is vital for achieving the accuracy and efficiency required in complex, multi-sided shaping tasks.

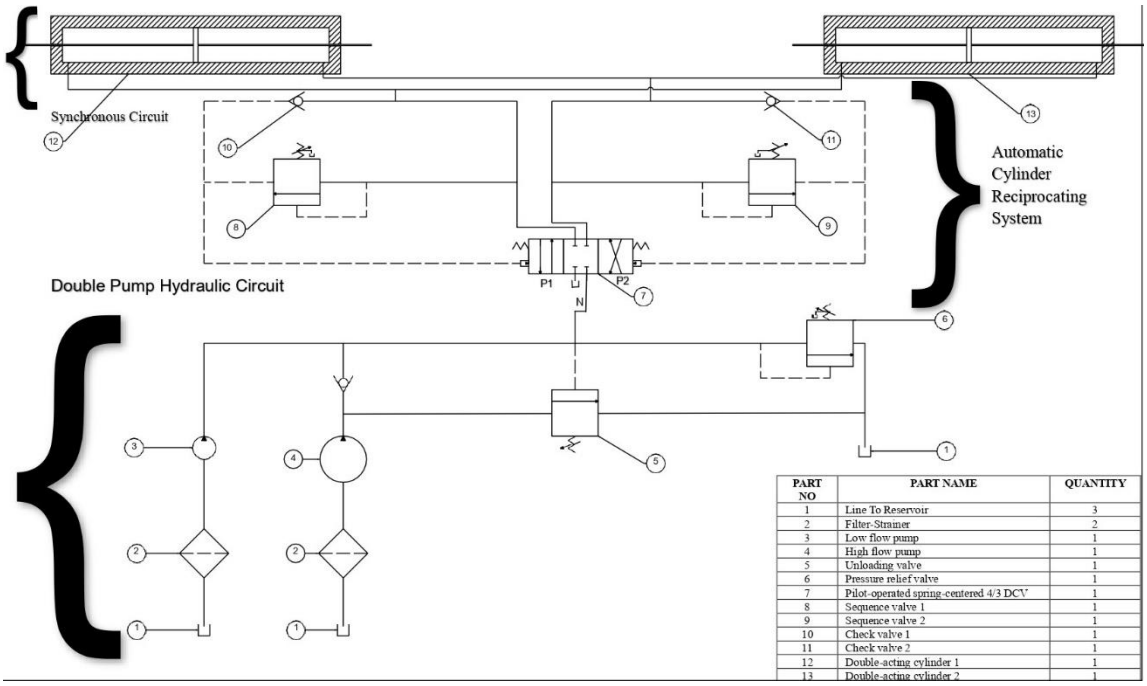
5. Control Valves

Control valves manage the direction and pressure of hydraulic fluid within the circuit. They play a crucial role in directing flow to either side of the double-acting cylinders, enabling alternating forward and return strokes. Pressure-relief valves may also be included to prevent over-pressurization, ensuring safe and stable operation.

Flow and Pressure Regulation

The hydraulic circuit is designed with optimized flow and pressure regulation to ensure consistent and reliable performance. Flow control valves manage the speed of each stroke according to specific operational needs, while pressure regulation devices prevent fluctuations that might affect shaping accuracy or cause mechanical wear. This regulation enhances productivity and extends the machine's lifespan by minimizing stress on components during intensive shaping cycles.

3. Circuit Diagram



PART NO	PART NAME	QUANTITY
1	Line To Reservoir	3
2	Filter-Strainer	2
3	Low flow pump	1
4	High flow pump	1
5	Unloading valve	1
6	Pressure relief valve	1
7	Pilot-operated spring-centered 4/3 DCV	1
8	Sequence valve 1	1
9	Sequence valve 2	1
10	Check valve 1	1
11	Check valve 2	1
12	Double-acting cylinder 1	1
13	Double-acting cylinder 2	1

Figure 1: Circuit Diagram

4. Working

(i) At position 'N' of DCV

In this spring-centered, neutral position of the 4/3 DCV, both pumps are set to unload, allowing their entire flow to return directly to the tank.

(ii) At position 'P1' of DCV

In this position, fluid from the high-flow, low-pressure pump flows to the right side of both the double-acting cylinder, causing the cylinder to extend leftward at an accelerated rate. As the shaping tools at both ends of the cylinder rods make contact with the material, pressure builds up, triggering the unloading valve, which unloads the low-pressure pump. This allows only the high-pressure, low-flow pump to engage, facilitating the shaping operation. Once the cylinder reaches full extension, pressure builds in sequence valve 2, causing it to open and generate a pilot

signal (pressure). The check valve prevents the DCV from shifting to position P2 until the extension stroke is fully complete, at which point the pilot signal enables the DCV to shift to position P2.

(iii) At position 'P2' of DCV

In this position, fluid from the high-flow, low-pressure pump flows to the left side of both the double-acting cylinder, causing it to retract rightward at an increased speed. Since the shaping tools at both ends of the cylinder rods are not in contact with the material, pressure does not build up, leaving the unloading valve closed. As a result, only the high-flow, low-pressure pump supplies flow. Once the cylinder reaches full retraction, pressure builds in sequence valve 1, causing it to open and generate a pilot signal (pressure). The check valve prevents the DCV from shifting back to position P1 until the retraction stroke is fully complete, at which point the pilot signal enables the DCV to shift to position P1 and the sequence continues.

5. Application

Automated Shaping and Machining

This hydraulic circuit is specifically designed for shaping tasks that demand continuous, precise cutting. The automatic reciprocation function enables smooth and uninterrupted operation, greatly minimizing downtime and reducing the need for manual involvement.

Metalworking and Fabrication

Industries involved in metal fabrication, including automotive, aerospace, and heavy machinery manufacturing, can gain productivity advantages from this circuit. Its efficient design boosts the speed and consistency of shaping processes, making it well-suited for fabricating metal components with improved accuracy.

6. Conclusion

The hydraulic circuit designed for a four-sided shaper machine showcases considerable potential to improve efficiency, precision, and automation in industrial shaping applications. With its dual-pump system and automatic reciprocating circuit, this design enables continuous, high-precision shaping, reducing downtime and minimizing manual intervention. Additionally, the circuit's ability to handle high-volume production lines with quick cycle times and consistent quality makes it well-suited for large-scale manufacturing needs. Overall, this hydraulic circuit provides a versatile, reliable, and efficient solution tailored to meet the demands of modern industrial shaping processes.

7. References

[1] V. Jayakumar, *Hydraulics and Pneumatics*, 3rd revised ed. Chennai, India: Lakshmi Publications, 2023

[2] L. Wang, W. J. Book, and J. D. Huggins, "A hydraulic circuit for single rod cylinders," *Journal of Dynamic Systems, Measurement, and Control*, vol. 134, no. 1, pp. 011019, Jan. 2012

[3] S. Konami and T. Nishiumi, *Hydraulic Control Systems: Theory and Practice.* Singapore: World Scientific Publishing Co. Pte. Ltd., 2017.

Competing Interest Statement

The author declares that there are no competing interests related to this research. The author has no financial, personal, or professional affiliations that could be perceived to influence the work presented in this manuscript.

Declaration of interests

☐The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

KUMARAN T reports administrative support was provided by Anna University. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.