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Design and Development of Hydraulic Tensioning Machine

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Abstract

This paper describes Design and Development of a Hydraulic Tensioning Machine is a critical process in industries where precise tension control is required for components such as Saw Blades , Saw Blanks , cables, belts, ropes, or any application demanding accurate tensioning. This machine utilizes hydraulic power to achieve consistent and adjustable tension forces, offering superior control, ease of operation, and increased efficiency compared to mechanical or manual tensioning methods .This paper presents a detailed approach to the design and manufacturing process of a hydraulic tensioning machine addressing the selection of hydraulic components, structural design, and operational mechanisms .The hydraulic system is designed to provide smooth and controlled force application ,consist of pumps ,valves ,actuators ,and pressure gauges to ensure the desired tensioning forces are applied with precision. Key considerations include the selection of appropriate hydraulic fluid, pressure ratings, and system safety features to ensure reliability and safety during operation .The mechanical design of the machine components a robust frame, adjustable spindles, and tensioning rollers that accommodate varying sizes and types of materials. Advanced features such as digital control systems and feedback mechanisms for real-time monitoring are integrated to provide users with accurate, automated control over the tensioning process. Manufacturing techniques, including CNC machining and assembly of hydraulic components, are outlined to ensure quality and accuracy in the production of the machine.

Keywords: Hydraulic Tensioning, Saw Blade, Design and Fabrication, Precision Engineering,

CNC Machining

I.Introduction

Tensioning Saw Blade is crucial step in manufacturing (Tungsten Carbide Tipped) Circular Saw Blade . The process of manufacturing involves hammering the blade on anvil to make it flat and Remove internal stress is called Tensioning. It enhance the blade performance by adjusting tension It also increase the precision of blade during cutting operation . The process of tensioning involves Creating a controlled stress pattern in blade to ensure it remain stable while operation .This process not only improves stability but it additional manual tensioning methods are not only inefficient but also prone to operator error. To address this, an automated or semi-automated tensioning method using hydraulic mechanisms can provide uniform and repeatable force application .This research address on the development of a hydraulic tensioning machine designed to precisely apply pressure across the blade's surface, thereby improving performance and reducing maintenance needs.Industrial saw blades, particularly in the timber, metal, and composite industries, are subject to stress and deformation during cutting operations. Proper tensioning helps to keep the blade flat and precise during rotation. Traditional mechanical tensioning systems are labor-intensive, less accurate, and pose safety risks. Hydraulic tensioning offers greater control and repeatability.

II.LiteratureReview

Studies have been conducted on tensioning systems, including mechanical and pneumatic solutions. However, few focus on hydraulic applications for saw blades. The hydraulic system offers superior force control and uniform distribution of pressure, essential for precision work.The literature on tensioning machines for saw blades reveals several advancements and mechanisms, yet there remains a notable gap in comprehensive studies addressing the

***Blade tensioning device for scroll saw (Verle L. Rice, Richard A. Keener (1991) :** The research paper discusses an auxiliary blade tensioning device specifically designed for a scroll saw. This device allows for quick and selective adjustment of the blade tension. The scroll saw features a pair of arms that support the saw blade and enable its reciprocation through a power assembly. The upper articulated arm is connected to a camming mechanism, facilitating the rapid tensioning of a replacement saw blade, enhancing the efficiency and usability of the scroll saw

***Tensioning effect modeling of circular saw blade after multi spot pressure tensioning process (Zhankuan Zhang ,Bo-Li December (2017) :** This paper describes about the multi spot pressure tensioning it is an method that has been proposed and applied in recent years .However the effects of process parameter of this method on tensioning effect of circular saw blade have not been studied systematically .

***Effects of Tensioning on Buckling and Vibration of Circular Saw Blades (J. F. Carlin; F. C. Appl, H. C. Bridwell; R. P. Du Bois (1971):** The paper describes the effects of concentrated radial in-plane load and initial tensioning stresses on a circular saw blade using energy methods. The buckling and vibrational properties of the blade are analyzed for different levels of initial stress, with non dimensional results provided. An optimal tensioning configuration is suggested to enhance both properties. The analysis is repeated for nine combinations of blade thickness and clamping ratio.

***Wood saw with adjustable tension (Yan Yixue (2013) : Wood saw with adjustable tension (Yan Yixue (2013)** This design enables the use of saw blades of varying lengths within a specific range and allows for tension adjustments based on different working conditions. Additionally, the saw includes a draught fan to remove sawdust during operation, enhancing the overall efficiency of the wood sawing process .

***Device for holding a saw blade to be clamped at one of its ends (Dipl. Jörg Ing Seyerle (1998) :** The tensioning machine described in the paper utilizes a double-armed lever system to hold a saw blade. The lever features a shorter inner arm and a longer outer arm, which is curved to apply tension to the blade. An eccentric curve at the end of the inner arm biases the tension end of the blade directly. The tension body is cylindrical with a contact bearing face, ensuring effective clamping and tensioning of the saw blade during operation

interplay between tensioning methods and the resulting stability of the sawing process . some research paper published below .

***Blade tension gauge (Jr. Howard L. Snodgrass (2004) :** The blade tension gauge disclosed in the paper is designed for a band saw, measuring the forces that tension the blade. It includes a wheel positioning assembly connected to the moveable wheel and the frame, allowing for relative movement. A load element captures the load between the assembly and the frame, while a sensor measures this load. The tension value is then displayed, providing a constant reading of the blade's tension during operation .

2.1 Problem Statement :

- In manufacturing the process of tensioning is done by manually or by machine that lack the precision needed this result in inconsistent blade performance premature wear , due to material selection .
- Manufacturing products not mating client requirements ,Cracks in blade due to Material so life is less .
- There is a lack of fully automated tensioning Machine that can uniformly apply optimal tension to saw blades varying sizes , material & design this machine must ensure consistent even tension distribution across blade to prevent issue wrapping vibrations Current systems may be either too slow, prone to human error, or unable to accommodate a wide variety of blade types effectively .

2.2 .Research Objectives :

- To Identify reasons for irregular process like vibration , wear , sound etc .
- A well-tensioned blade reduces vibration and flexing during operation .
- It not only improve the sustain of blades but it enhanced the life of blades .
- To identify the key factors that influenced the performance of machines , such as force control , accuracy .

.2.3 .Methodolgy

The physical experiments are crucial for validating the theoretical and simulation models.

- **Tensioning process** : The actual saw blades are tensioned using the roll tensioning machines under the controlled parameters like loading force and rolling width .
- **Stress Measurement** : The residual stress field after tensioning is measured using techniques such as X ray stress test or resistance strain rosettes.

Dynamic characteristics measurement :

i. **Natural frequencies** . The natural frequencies of tensioned saw blade are typically determined using a hammer vibration test method.

ii. **Siffness / Deflection** . The lateral stiffness or transverse displacement (deflection) of the saw blade is measured at a specific point (e.g. on the periphery).A traditional , less precise method for qualitative assessment in industry is the light gap method were the saw blade curvature is measured with a straight edge .

iii. **Critical Rotational speed** : This is a key performance metric and can be assessed experimentally by observing the saw blade behavior at increasing rotational speeds until instability (fluttering or buckling) occurs .

2.4 Design Specifications

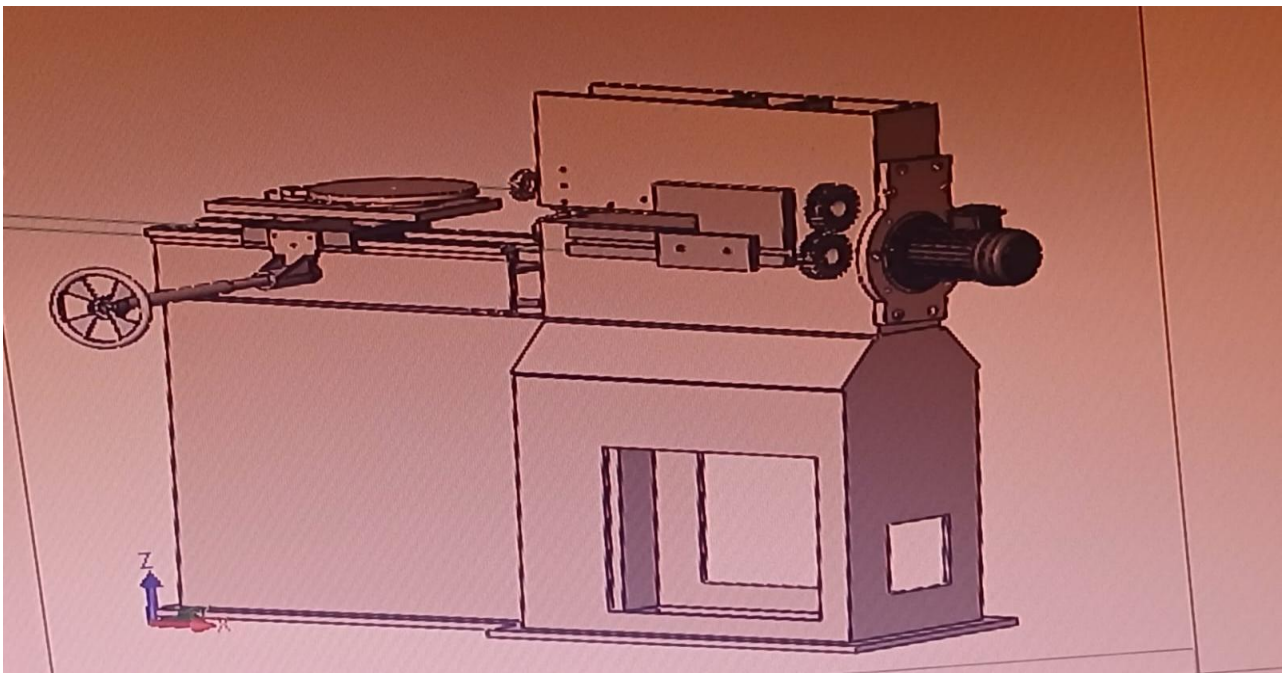
- Blade diameter range: 300–800 mm
- Max tensioning force: 60 KN
- Pressure regulation: up to 250 bar
- Material: Mild steel frame, Aluminium alloy clamping units

2.5 Components Used

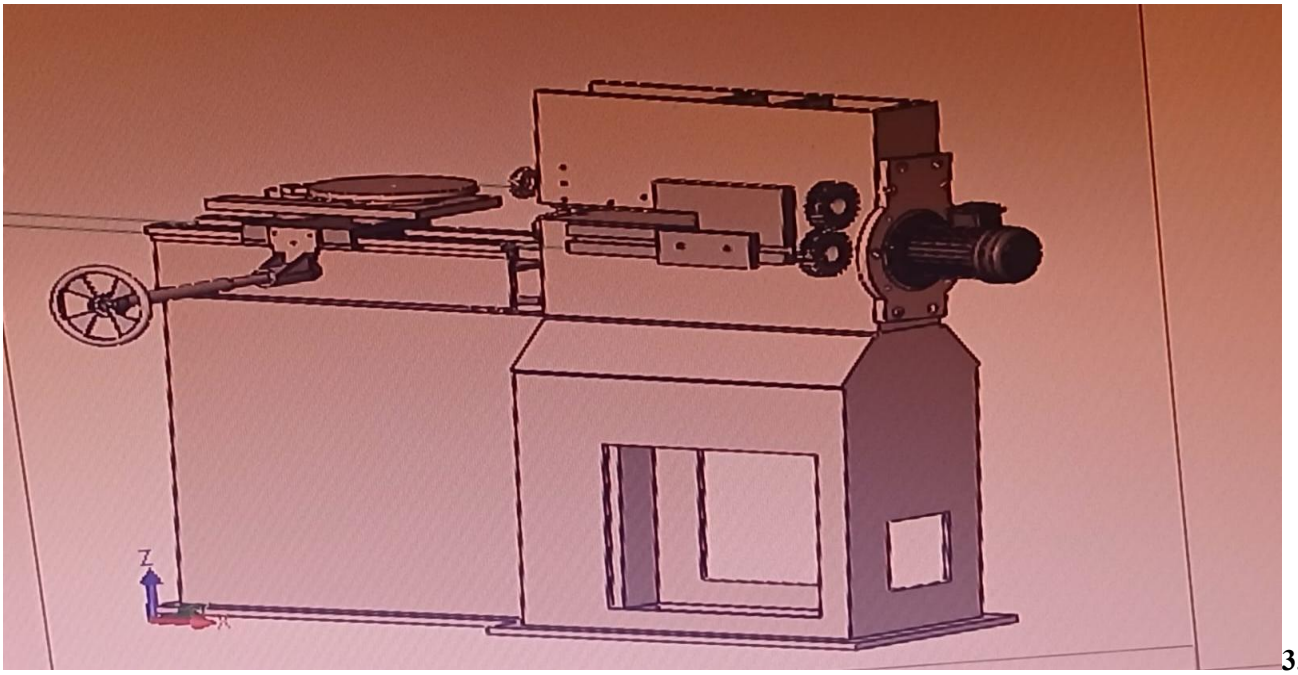
- Hydraulic cylinder (double-acting, 50 mm bore, 100 mm stroke)
- Manual or electro-hydraulic pump
- Pressure gauge (0–250 bar)
- Digital displacement sensor (LVDT)

III. Clamping jaw with polyurethane pads .

IV.. Design Layout of Tensioning Machine .



3.1 Working Mechanism .



3.2 Tensioning Methods for Saw Blades.

- **Hammer Tensioning** .Hammer Tensioning is a manual tensioning which is less consistent .Also accuracy of tensioning is less accurate. Also marking of Hammering on Blade which impacts the quality and finishing of Saw Blade .

- **Hydraulic Press Tensioning** is a method used for large industrial saws manufactured also the accuracy of tensioning is more .The process of tensioning is faster also it is easy to use .

V.Design Considerations .

- Load Capacity : The tensioning machine must be designed to handle maximum load it dependupon the material ,application for which cutting the Blade used .

- Pressure Rating : The hydraulic system pressure rating must be sufficient to generate the desired force while ensuring safety and reliability of the system .

- Hydraulic pressure control : The hydraulic pressure control is done with help of pressure valve which is easy to operate .Also it adjust force as necessary .This reduces human error and improves consistency.

- Safety Features : Applying the high forces involved safety mechanism like pressure relief valve ,emergency shutdown system and overload center are incorporated into design .

VI.Validation & Testing of Saw Blade .

For flatness and tension testing dial gauge is used to check the blade before and after applying tension of saw blade .For checking of tension with help of compressed air it is checked also it can be done manually .

Pressure Chart for Tension .

Blade Size	Thickness	Target Tension	Required Pressure
800 mm	3.2 mm	50 MPa	500 bar
1000 mm	3.5 mm	55 MPa	550 bar
1200 mm	4.0 mm	60 MPa	600 bar

Finding Hydraulic force while tensioning as per formula .

$$F=T\cdot\pi\cdot D\cdot t$$

Symbol	**Description**	**Unit**
FFF	Hydraulic force required	Newtons (N)
TTT	Desired tension stress	Pa (N/m² or MPa)
DDD	Blade diameter	meters (m)
Ttt	Blade thickness	meters (m)

Example

- Blade diameter D = 800 mm = 0.8 m
- Blade thickness t = 3.2 mm = 0.0032 m
- Desired tension T = 50 MPa = 50×106 Pa

Applying the formula

$F = 50 \times 106 \cdot\pi\cdot 0.8 \cdot 0.0032 = 50 \times {}^{106\cdot}0.008042 = 4021$ N

We get **402.1 kn** (kilonewtons) of hydraulic force to achieve 50 MPa tension on an 800 mm, 3.2 mm thick blade.

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VII.Design of Tensioning Machine Experimentally Setup :

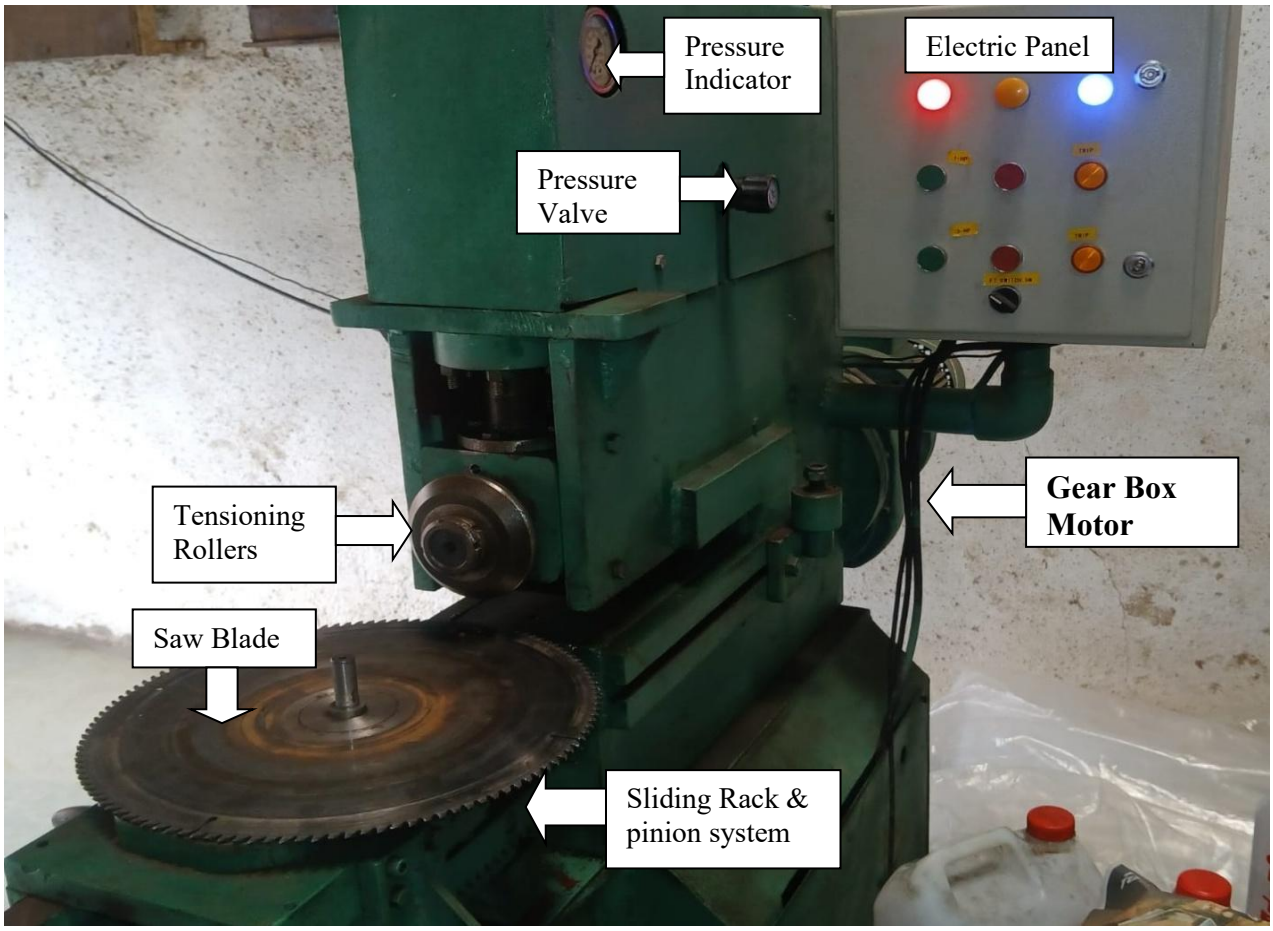

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Fig .2 . Saw Blade

VIII.Observations :

When tensioning a saw blade a skilled operator primarily observes the blade deflection .The primary observations are .

- **Deflection Test** : When the saw powered off apply moderate sideways pressure on the blade, halfway between the guides . A properly tensioned blade should deflect only slightly, typically around 1/4 inch to 3/8 inch for most band saw .The blade should feel rigid at the tooth edge when correctly tensioned .
- **Visual Inspection** : While the machine is running without a load , observe the blade. Adjust the tension until the blade stops fluttering (oscillating back and forth) , then increase it slightly (for e.g quarter turn of knob) from that point .
- **Cutting Performance** : The ultimate sign of correct tension is a good quality cut .
- **Blade Performance** : Proper tensioning gives smooth and accurate cutting and finishing under tensioned blade (loose) Blade wanders or drifts off the cuts inconsistent cuts. Over tensioned blade (too tight) Blade may struggle to cut into material, forcing the machine to exert greater thrust.
- **Physical appearance** : The proper tensioning of blade runs smoothly on the wheels slightly appropriate by side to side deflection .Under tensioned blade may slip or even derail during operation . Over tensioned (Too tight) blade has excessive stress , stretching or distortion.

➢ **Sound / Vibration** : Proper Tensioning has minimal vibration normal sound . Under tensioned (Too loose) blade has too much vibration causes more noise . Over tensioned (too tight) Can cause abnormal vibration and excessive noise due to the high strain on machine components.

7.1Methods of Observation

- **Tension Meter/Gauge:** This is the most accurate method. A tension gauge measures the actual stretch (in PSI or equivalent units) on the blade's back edge, often showing a green "correct" zone on the dial.

- **Visual Deflection Test:** With the machine off, press lightly on the side of the blade. A properly tensioned blade should only deflect slightly (around 1/4 to 1/2 inch per foot of blade length, depending on the blade specifications).

- **"Flutter" Method:** Some experienced operators adjust the tension while the machine is running (without load) until the blade flutters slightly, then increase the tension just enough for the fluttering to stop. This method requires skill and caution

IX.Analysis of Tensioning Saw Blade.

The Tensioning machine which we had developed plays a major role in manufacturing saw blade industry. Because 70 % Blade rejections due to improper tension . We had checked Diamond saw Blade which used for Granite Cutting . 1000 mm diameter of blade which earlier has rejected from plant .For Brazing segment Brass rod has used which melts at 900^ C .Due to overheating it tension goes to high positive side which cause more wobbling in Blade .we checked it was 2 millimetre which was unsafe after applying tensioning it shows 0.006 to 0.008 microns which is safe also not only it reduce tension but outness also reduces .

X..Results :

Tensioning of Saw Blade depend upon blade material , strength , material hardness various grade of carbon steel material such as 62Cr1 , C80 , 75Cr1 , 80Cr1 . Tensioning Saw blade consist of two side positive side which indicates (+) . were as negative side indicates (-) . Saw Blade has tension problems such as some blades in positive side very much it should be reduce if it not reduced it causes improper cutting & vibrations . were as negative tension of blade has problem in some applications such as laminate sheets cutting , pvc cutting , Recycled sheets cutting more sound will come also it will take a load while cutting it will damage teeth. As Expermientally Analysis done the New saw blade Diameter 350 mm thickness of Blade 2.5 mm and number of teeth 54 T . Which hardness is 44- 46 HRC . But the Runout of Blade is 3mm also tension plus 2 mm which is too large which vibrates blade also improper cutting After applying tensioning pressure it shows plus 0.004 in micron which is suitable it prevents from wrapping also cutting sound of Saw Blade reduced.Runout of Blade is also reduced . Negative Tension shows the less life of Blade also it would wound while running .Tensioning of Blade process it depend upon the material also standard materials are 75CR1 , 80CR1 . The some material are which tension gets less but the outness of Blade does not . Also it depend upon the Hardness of Blade , & Tempering Process**.**

XI.Conclusion

The development of roller based tensioning machine for circular saw blades offers significant improvements in manufacturing precision , process repeatability, and operation safety .It stands as a robust , scalable solution for modern blade production lines , enabling manufacturers to meet tight tolerances requirements and maintain high quality standards.multi spot Tensioning process has an obvious effect and is advantages for dynamic characteristics improvement of circular saw blade . Loading force and spot distribution have effects on tensioning stress field with different extent .The dynamic characteristic of saw blade is improved with loading force .

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