Strategies to prevent premature failure of chain drive in round balers through lubrication improvement & contaminant control oil filtration

M.Tech. Thesis

By

Sushant G Deshmukh



DEPARTMENT OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY INDORE

MAY 2026

Strategies to prevent premature failure of chain drive in round balers through lubrication improvement & contaminant control oil filtration

A THESIS

Submitted in partial fulfillment of the
requirements for the award of the degree
of
Master of Technology

by

Sushant G Deshmukh



DEPARTMENT OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY INDORE
MAY 2026

INDIAN INSTITUTE OF TECHNOLOGY INDORE

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **Strategies to prevent premature failure of chain drive in round balers through lubrication improvement & contaminant control oil filtration** in the partial fulfillment of the requirements for the award of the degree of **MASTER OF TECHNOLOGY** and submitted in the **DEPARTMENT OF MECHANICAL ENGINEERING Indian Institute of Technology Indore**, is an authentic record of my own work carried out during the time period from July 2025 to May 2026 of M.Tech. Thesis submission under the supervision of Dr. Dan Sathiaraj, Associate Professor, IIT Indore and Mr. Rajasekar Siddheswaran, Deputy General Manager III, John Deere India Pvt Ltd - Pune

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

Signature of the student
(Sushant G Deshmukh)

This is to certify that the above statement made by the candidate is correct to the best of my/our knowledge.

(Dr. DAN SATHIARAJ) **(Mr. RAJASEKAR SIDDHESWARAN)**

Sushant G Deshmukh has successfully given his/her M.Tech. Oral Examination held on **26th May 2026**.

Signatures of Supervisors of M.Tech. thesis
Date: 26th May 2026

Convener, DPGC
Date: 26th May 2026

ACKNOWLEDGEMENTS

I am immensely grateful to my supervisor, Dr. DAN SATHIARAJ, for his exceptional guidance and unwavering support throughout this research project. His insightful feedback and encouragement have been pivotal in shaping this thesis. I also extend my heartfelt gratitude to my industry supervisor,
Mr. RAJASEKAR SIDDHESWARAN, for his invaluable support and for providing critical industrial data that significantly enhanced the relevance and applicability of this research. Their combined mentorship has been instrumental in the successful completion of this work. These contributions have greatly enriched my research experience. I would like to express my heartfelt thanks to OPHELIA FERNANDES, Supervisor at John Deere, for her timely approvals and support. Her assistance has been instrumental in helping me bridge a strong correlation between my work and academic pursuits.

Finally, I extend my gratitude to the valuation board members for their time, expertise, and valuable feedback, which have strengthened this thesis. I am also profoundly thankful to everyone who has supported me throughout my M.Tech journey, including my family, friends, and colleagues. Your encouragement, understanding, and belief in me have been a constant source of inspiration, and this thesis reflects the collective support I have received. I am truly grateful to all who have been part of this rewarding journey.

With Regards

SUSHANT G DESHMUKH

“Dedicated to my family and

friends, who stood by me through

every challenge”

Abstract

A round baler is a widely used agricultural machine designed to collect, compress, and package crop material such as hay, silage, or straw into cylindrical bales. These machines consist of multiple interacting subsystems such as pickup assemblies, rotor feed systems, rollers, belts, and chain-driven mechanisms that synchronize motion across the baler.

Chain drives are particularly critical because they operate continuously in open atmospheric conditions, often exposed to dust, debris, and crop residue. Reliable lubrication is essential to maintain smooth operation, reduce friction, and prevent accelerated wear. However, premature chain drive failures have been repeatedly observed in field applications due to a combination of mechanical, environmental, and maintenance-related factors.

Gaps identified are inadequate modelling of real-world contamination, limited exploration of advanced lubricant formulations and insufficient long-term studies on wear progression. Chain drives fail primarily due to abrasive wear and misalignment. Agricultural environments accelerate corrosion-fatigue. Lubrication film thickness directly influences wear rate. Preventive maintenance increases life by >40%. The proposed oil filter design emphasizes low cost, minimal maintenance, and robust performance under extreme weather.

KEYWORDS: Round baler, Chain drive failure, lubrication, oil filtration, Contamination control Dynamics, Modal Testing, Modal Analysis.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

ACRONYMS

1. Introduction.....11

1.1. Lubrication 12

1.2. Need of Lubrication..... 13

1.3. Components used in lubrication System 15

1.4. Lubrication dynamics.....19

2. Literature Review 23

2.1. Background.....23

2.2. Previous studies 24

3. Methodology 31

3.1. Modal Analysis 31

3.2. Experimental Approach 32

3.3. Analytical Approach 35

4. Results and Discussion.....40

5. Conclusion ..... ……42

6. References.....44

LIST OF FIGURES

Figure 1.2.1 Lubricating Unit.....14

Figure 1.2.2 Controller 14

Figure 1.3.1 Integrated wet sump 15

Figure 1.3.2 External dry sump..... 16

Figure 1.3.3 Gravity feed reservoir 16

Figure 1.3.4 Distribution lines.....17

Figure 1.3.5 Brushes & nozzles 17

Figure 1.3.6 Control unit ……...18

Figure 2.1.1 Opened machine view..... 27

Figure 2.1.2 Clogged chain 27

Figure 2.1.4 Reservoir design.....28

Figure 2.1.5 Experimental test rig (CAD) 28

Figure 3.1.1 &3.1.2 Component location on machine.....30

Figure 3.1.3 Component exploded view..... 31

Figure 3.1.4 Experimental test rig (Actual).....32

Figure 3.3.1 Displacement magnitude distribution 35

Figure 3.3.2 Strain Energy Density distribution..... 36

Figure 3.3.3 Von mises stress distribution 37

Figure 3.3.4 Equivalent strain distribution 37

Figure 3.3.5 Creoflow velocity analysis 38

Figure 4.1.1 Cut section view of reservoir.....41

LIST OF TABLES

Table 1.1 Reservoir Material Properties 29

NOMENCLATURE

τ	Time period
F	frequency
m	Mass in Kg
k	Stiffness of the suspension system in N /m
Fd	Damping force in N
p	Fluid pressure
h	film thickness
u	velocity
Ƞ	viscosity

Reynolds Equation $\frac{d}{dx}\left(\frac{ph^3}{12\eta}\frac{dp}{dx}\right) = \frac{u}{2}\frac{d(\rho h)}{dx}$

Viscosity Calculation $\tau = \eta\frac{du}{dy}$

Film thickness calculation (h(x))

$$h(x) = h_0 + \frac{x^2}{2R} + \delta(x)$$

1 Chapter

Introduction

A round baler is a widely used agricultural machine designed to collect, compress, and package crop material such as hay, silage, or straw into cylindrical bales. These machines consist of multiple interacting subsystems such as pickup assemblies, rotor feed systems, rollers, belts, and chain-driven mechanisms that synchronize motion across the baler.

Chain drives are particularly critical because they operate continuously in open atmospheric conditions, often exposed to dust, debris, and crop residue. Reliable lubrication is essential to maintain smooth operation, reduce friction, and prevent accelerated wear. However, premature chain drive failures have been repeatedly observed in field applications due to a combination of mechanical, environmental, and maintenance-related factors.

Gaps identified are inadequate modelling of real-world contamination, limited exploration of advanced lubricant formulations and insufficient long-term studies on wear progression. Chain drives fail primarily due to abrasive wear and misalignment. Agricultural environments accelerate corrosion-fatigue. Lubrication film thickness directly influences wear rate. Preventive maintenance increases life by >40%. The proposed oil filter design emphasizes low cost, minimal maintenance, and robust performance under extreme weather.

1.1 Lubrication

Lubrication in agricultural machines is the process of applying a lubricant (such as oil, grease, or specialized fluids) between moving surfaces to reduce friction, wear, heat generation, and corrosion. It is one of the most critical maintenance practices for ensuring reliable and efficient operation of farm equipment such as tractors, harvesters, round balers, seed drills, and irrigation pumps.

Inadequate lubrication can cause:

- Increased chain elongation
- Sprocket tooth wear
- Corrosion
- Excessive noise
- Chain breakage

Using a filtered oil bath or automatic lubrication system significantly improves chain life and reliability.

Types of Lubrication Systems

- Manual oiling
- Grease gun lubrication
- Splash lubrication
- Oil bath lubrication
- Automatic centralized lubrication systems

1.2 Need of lubrication in agriculture machines

Reduces Friction

- Forms a thin protective film between moving parts.
- Prevents direct metal-to-metal contact.

Minimizes Wear

- Reduces abrasion and surface fatigue.
- Extends the service life of components such as bearings, gears, and chains.

Dissipates Heat

- Carries heat away from loaded components.
- Helps prevent overheating and seizure.

Protects Against Corrosion

- Shields metal surfaces from moisture, fertilizers, and pesticides.

Removes Contaminants

- Transports dust, metal particles, and debris to filters or settling zones.

Absorbs Shock and Reduces Noise

- Cushions impact loads in gears and chain drives.

Improves Efficiency

- Reduces power losses and fuel consumption.



Fig 1.2.1 lubricating unit of round baler



Fig 1.2.2 Controller of lubrication system

Common Lubricants Used

- **Engine Oil** – For engines and some hydraulic systems.

- **Grease** – For bearings, joints, and universal couplings.
- **Gear Oil** – For gearboxes, differentials, and chain cases.
- **Hydraulic Oil** – For hydraulic circuits.
- **Chain Lubricants** – For exposed chains in balers and conveyors.

Importance in Agricultural Conditions

Agricultural machines operate in harsh environments with:

- Dust and soil
- Crop residue
- Moisture and mud
- Wide temperature variations

These contaminants can degrade lubricants and accelerate wear. Proper lubrication and filtration are therefore essential to prevent premature failure.

1.3 Components used in lubrication system.

- **Lubricant reservoir**
- **Pump or gravity feeding system**
- **Distribution lines**
- **Nozzles or brushes**
- **Control unit**

1. Lubricant Reservoir

- The lubricant reservoir is the storage tank that holds the lubricating oil or grease before it is delivered to machine components. It is designed to provide a continuous supply of clean lubricant and often includes a filler cap, level indicator, breather, and drain plug. In agricultural machines, the reservoir capacity is selected based on operating duration and the number of lubrication points. Some reservoirs also incorporate filters and magnetic plugs to remove contaminants and extend lubricant life.

- **Integrated wet sump**

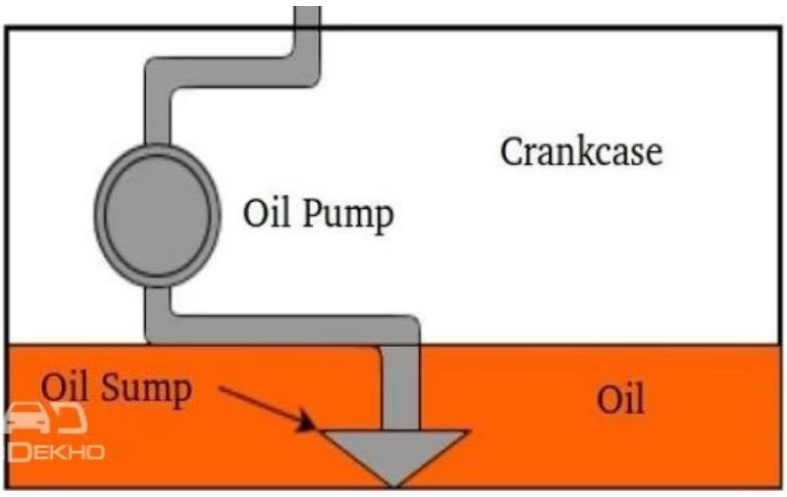


Fig 1.3.1 Integrated wet sump

- **External dry sump reservoir**



Fig 1.3.2 External dry sump

- **Gravity feed reservoir**

This component is responsible for moving the lubricant from the reservoir to the lubrication points. In automatic systems, an electric, hydraulic, or mechanically driven pump supplies lubricant at a controlled pressure and flow rate. In simpler systems, gravity feeding uses the natural force of gravity to allow lubricant to drip slowly through valves and tubes. The pumping or feed mechanism ensures that each component receives lubricant in the correct quantity and at regular intervals.



Fig 1.3.3 Gravity feed reservoir

2. Distribution lines-

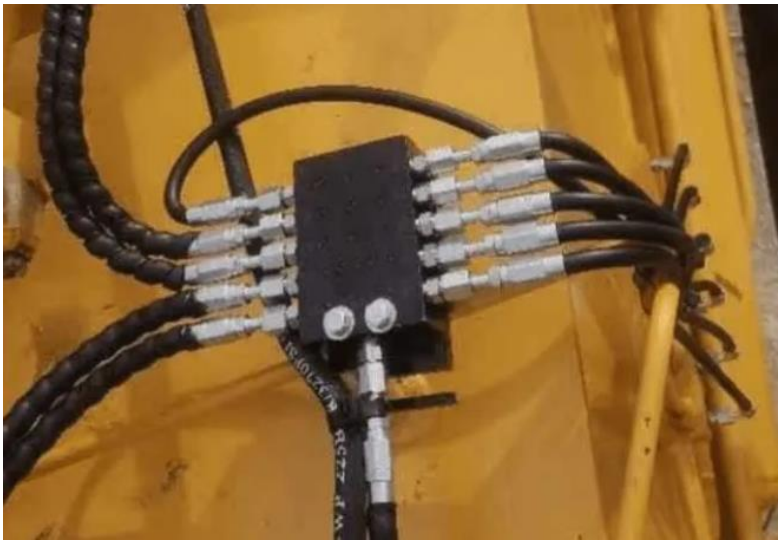


Fig 1.3.4 Distribution lines

Distribution lines are pipes, hoses, or flexible tubes that transport lubricant from the reservoir or pump to various machine components. They are designed to withstand pressure, vibration, and harsh environmental conditions such as dust, moisture, and temperature changes. Proper routing and sizing of these lines are essential to maintain uniform flow and prevent leakage or blockage.

---

3. Nozzles or brushes

Nozzles and brushes are the final delivery devices that apply lubricant directly to the contact surfaces. Nozzles spray or drip oil onto specific areas such as chains and gears, while brushes spread the lubricant evenly across the moving surfaces. These devices ensure accurate placement of the lubricant and help minimize wastage while improving penetration into critical wear zones.



Fig 1.3.5 brushes & nozzles

4. **Control Unit**

The control unit regulates the timing, duration, and quantity of lubricant delivered to the machine. It may include timers, sensors, solenoid valves, and programmable controllers. Advanced systems monitor operating conditions such as machine speed, temperature, or load and adjust lubrication automatically. The control unit improves lubrication efficiency, reduces maintenance requirements, and helps prevent both under-lubrication and over-lubrication.



Fig 1.3.6 Control Unit

1.4 Lubrication dynamics.

Lubrication dynamics is the study of how a lubricant behaves and interacts with moving surfaces under varying operating conditions such as speed, load, temperature, viscosity, and contamination. It explains how the lubricant flows, forms a protective film, generates pressure, and separates contacting surfaces to reduce friction and wear. In machine elements such as bearings, gears, and chains, lubricant dynamics governs film thickness, shear stress, heat generation, and the removal of contaminants from the contact zone. The behavior is typically described using the principles of fluid mechanics and tribology. Lubricant film thickness h increases with lubricant viscosity η and relative speed U, and decreases as load or contact pressure P increases. Lubrication dynamics also considers transitions between boundary, mixed, and hydrodynamic lubrication regimes, which determine whether surfaces are fully separated or partially in contact. In agricultural machinery such as round balers, understanding lubrication dynamics is essential for designing oil delivery systems that ensure adequate lubricant reaches chains, sprockets, and bearings despite dust, vibration, and changing operating conditions.

Formulas used in lubrication dynamics

1. Reynolds Equation (Fundamental Lubrication Equation)

The pressure distribution in a thin lubricant film is described by:

$$\frac{\partial}{\partial x}\left(\frac{h^3}{12\mu}\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{h^3}{12\mu}\frac{\partial p}{\partial y}\right)=\frac{U}{2}\frac{\partial h}{\partial x}+\frac{\partial h}{\partial t}$$

Nomenclature

- p = Hydrodynamic pressure in lubricant film (Pa)
- h = Lubricant film thickness (m)
- μ = Dynamic viscosity (Pa·s)
- U = Relative sliding speed between surfaces (m/s)
- x,y = Spatial coordinates along and across the contact (m)
- t = Time (s)

Significance

This equation predicts the pressure generated by the moving lubricant film and forms the basis for bearing and gear lubrication analysis.

2. Shear Stress in the Lubricant Film

$$\tau = \mu \frac{U}{h}$$

Nomenclature

- τ = Shear stress (Pa)
- μ = Dynamic viscosity (Pa·s)
- U = Relative speed (m/s)
- h = Film thickness (m)

Significance

Represents the viscous resistance developed within the lubricant layer.

---

3. Friction Force

$$F_f = \tau A$$

Nomenclature

- F_f = Friction force (N)
- τ= Shear stress (Pa)
- A = Contact area (m^2)

Significance

Calculates total friction force due to lubricant shear.

---

4. Coefficient of Friction

$$\mu_f = \frac{F_f}{W}$$

Nomenclature

- μ_f = Coefficient of friction (dimensionless)
- F_f = Friction force (N)
- W = Normal load (N)

Significance

Measures the ratio of friction force to applied load.

---

5. Power Loss Due to Friction

$$P_f = F_f U$$

Nomenclature

- P_f = Frictional power loss (W)
- F_f = Friction force (N)
- U = Sliding speed (m/s)

Significance

Determines energy lost as heat in the lubricated contact.

---

6. Heat Generation Rate

$$Q=\mu_f WU$$

Nomenclature

- Q = Heat generated (W)
- μ_f = Coefficient of friction
- W = Normal load (N)
- U = Sliding speed (m/s)

Significance

Used for estimating temperature rise in the lubricant.

---

7. Film Thickness Relationship

$$h \propto \frac{\eta U}{P}$$

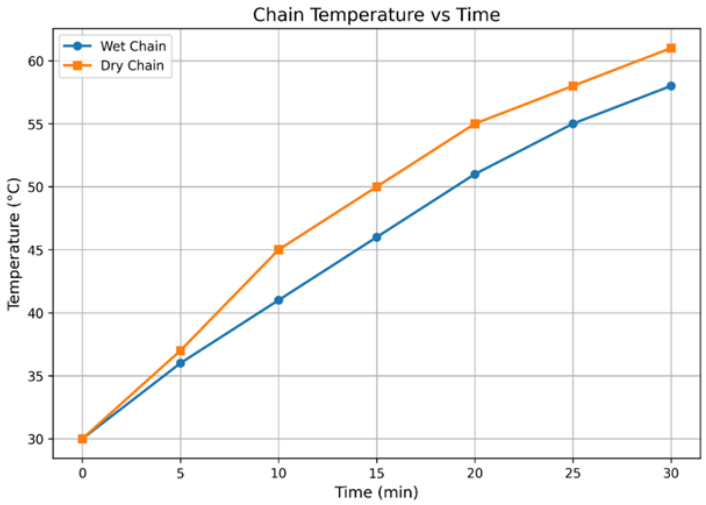
Nomenclature

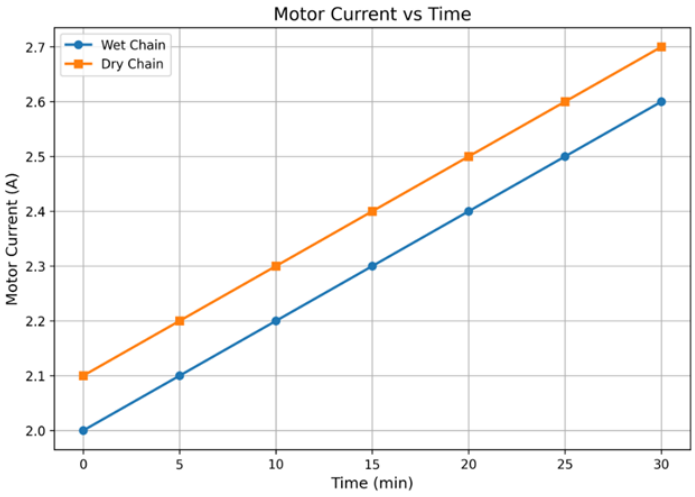
- h = Lubricant film thickness (m)
- η = Dynamic viscosity (Pa·s)
- U = Surface speed (m/s)
- P = Contact pressure (Pa)

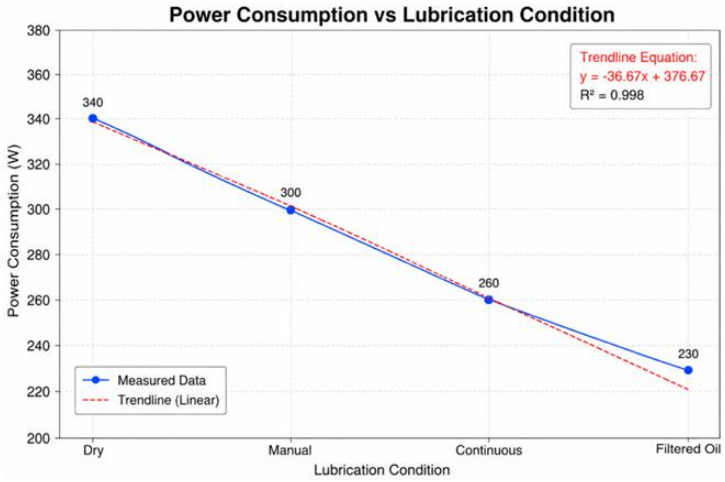
Significance

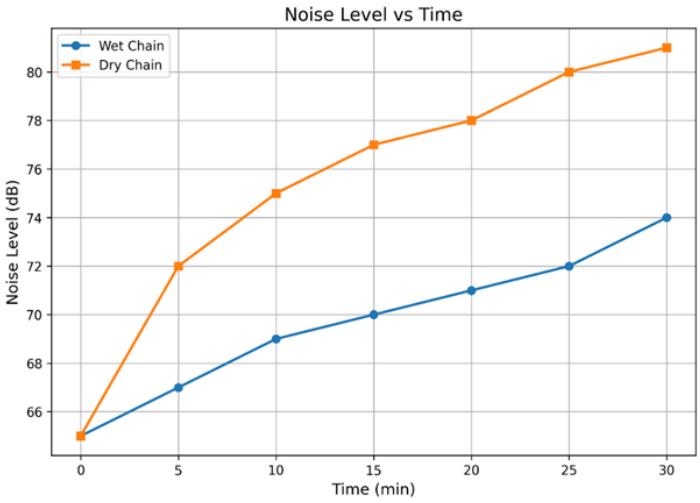
Shows how film thickness increases with viscosity and speed and decreases with pressure.

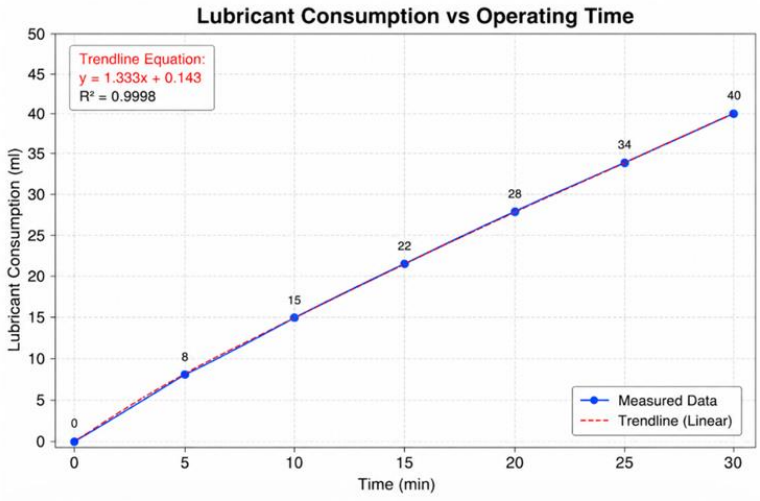
Time (min)	Chain Temp (°C)	Noise (dB)	Current (A)	Lubricant consumption (ml)
Stopwatch	Digital Thermometer	Sound level meter	Clamp meter	Level indicator
0	30	65	2.0	9
5	36	67	2.1	16
10	41	69	2.2	19
15	46	70	2.3	25
20	51	71	2.4	31
25	55	72	2.5	37
30	58	74	2.6	46
Trend	Uptrend	Uptrend	Uptrend	Uptrend
Delta	28	9	0.6	40











2 Chapter

Literature Review

2.1 Background

Lubrication plays a vital role in the reliable operation and long service life of round baler agricultural machines, where numerous moving components such as chains and sprockets, roller bearings, gearboxes, PTO shafts, and hydraulic systems are subjected to heavy loads and continuous operation in dusty, humid, and highly contaminated field conditions. A proper lubricant forms a protective film between contacting surfaces, reducing friction, wear, and heat generation while preventing corrosion caused by moisture and crop residues. In round balers, chain drives are especially critical because they transmit power to the bale-forming rollers and are prone to elongation and premature failure if lubrication is inadequate. Effective lubrication ensures smooth power transmission, minimizes maintenance requirements, lowers energy consumption, and significantly reduces downtime during harvesting. Consequently, a well-designed lubrication and filtration system is essential for improving the durability, efficiency, and overall productivity of round balers such as the John Deere Compact Round Baler.

Extensive research has been conducted on the lubrication of agricultural machinery operating in harsh outdoor environments where components are continuously exposed to dust, soil particles, crop residue, moisture, and temperature fluctuations. These contaminants readily enter open chain drives, bearings, and gear housings, causing abrasive wear, lubricant degradation, and corrosion. Studies in tribology have shown that solid particles such as silica and dirt significantly increase friction and accelerate wear when they contaminate oils and greases, highlighting the importance of contamination control and filtration. Research on open chain drives has reported that abrasive contamination can increase chain wear by 17–20 times even with periodic lubrication, and by as much as 300 times when lubrication is absent, demonstrating the critical role of proper lubricant selection and delivery. Recent studies on agricultural tractors have also used wear-debris and oil analysis to correlate lubricant cleanliness with machine age and operating hours, confirming that cleaner lubricants improve component life and reliability. Overall, published research consistently concludes that effective lubrication systems combined with contaminant-control measures—such as seals, filters, and automatic lubricators—are essential to prevent premature failure of chains, bearings, and hydraulic components in agricultural machines, including round balers and other field equipment exposed to severe environmental conditions.

2.2 Previous Studies

1 Oil injection lubrication analysis of a silent chain drive system

[1] Jinxing Yang, Zengming Feng, Xiaoguang Wang. July 2022
https://doi.org/10.1016/j.advengsoft.2022.103210

The study systematically varies sprocket speed, oil quantity, viscosity, and injection angle to map flow field distribution and lubrication effectiveness. It highlights the trade-off between improved lubrication and increased churning losses, giving design guidance for optimized oil supply in chain drives.

2 Experimental Evaluation of Chain Transmissions Lubricants Quality Using a New Method Based on Additional Inertia Moment Use

[2] K.E. Kozlova, A.V. Egorovb, V.N. Beloguseva. - December 2017

The approach allows measurement of mechanical losses across wide ranges of speed, load and transient regimes without strain sensors. Experimental results show the method can sensitively detect the impact of inappropriate lubricants on energy efficiency, offering a practical tool for in-service lubricant assessment.

3 Lubricant Performance in Bicycle Roller Chains

[3] Teal Dowd, Patrick Cavanaugh1 & Jan-Anders Mansson.
Research Gate, Sept 2024.

The work finds high-quality wax lubes provide durable, repeatable low losses over >60 hours, while most dry lubes degrade more rapidly, though one dry product excels at higher speeds. The study fills a gap in long-term, peer-reviewed data on cycling lubricants and links lubricant type and contamination resistance to drivetrain efficiency and wear.

4 A comprehensive review and trends in lubrication modelling.

[4] Suhaib Ardah, Francisco J. Profito , Daniele Dini. Elsevier, March 2025.
https://doi.org/10.1016/j.cis.2025.103492

This research emphasise the multiscale, multiphysics nature of tribological interfaces and discuss coupling strategies for multiscale frameworks. The pa

per also highlights emerging integration of machine learning to accelerate simulations and improve constitutive descriptions, outlining key challenges and future directions for predictive tribology models.

5 Design and Fabrication of Autonomous Lubrication of Chain.

[5] Rakesh.C. ,Vikas kumar , Utkarsh Singh, Pappu Saha, Saroj Kumar.
IJLERA, May 2016.

Design an automated chain lubrication system for motorcycle/industrial chains that meters lubricant based on operating conditions, replacing inconsistent manual greasing. The system uses a microcontroller-based timing and actuation setup to deliver small, precise quantities to critical link–stud interfaces. Results and discussion indicate potential for significantly reduced wear, noise and downtime, with improved environmental and cost performance due to controlled oil usage.

6 Concept of Automatic Lubrication System and Comparison with Conventional Lubrication System.

[6] Agam Kumar Malik1, Ankit Singh2, Mohit Hooda.
IJERT, April 2017.

This paper present the concept and design considerations of centralized automatic lubrication systems (ALS) and compare them with traditional manual lubrication. They argue ALS can deliver metered lubricant to multiple points during operation, improving safety, reducing shutdowns and avoiding over- or under-greasing. The paper outlines key components (controller, pump, reservoir, metering valves) and highlights how continuous small-dose lubrication enhances component life and reduces maintenance labour.

7 Automatic chain cleaning and lubrication system.

[7] Kemparaju C R, Manish.S.Neelgar, Nithin.R, Preetham.G, Sendeep.P.
IJTIMES, June 2018.

Study propose an integrated system for motorcycles that both cleans and lubricates the drive chain using separate reservoirs for cleaning fluid and lubricant plus an injection mechanism. The motivation is to combat wear, frictional heating and power loss caused by dirt-laden oil films and poor manual maintenance. Their concept targets smoother rides, longer chain/sprocket life and reduced need to dismantle chains for cleaning, aligning with broader trends toward automated chain care.

8 How lubricant formulations and properties influence the performance of rotorcraft transmissions under loss of lubrication conditions.

[8] Azhaarudeen Anifa Mohamed Faruck, Chia-Jui Hsu, Nicole Doerr b, Michael Weigand, Carsten Gachot.

Elsevier, May 2020. https://doi.org/10.1016/j.triboint.2020.106390

This investigate synthetic and mineral aviation oils in boundary-lubrication, loss-of-lubrication scenarios using an FZG test rig and lab-scale tribometers. By relating scuffing resistance and load-carrying capacity to base oil type and additive chemistry (e.g. ZDDP, TCP), they rank oils for extended survivability under oil-starved conditions. The study shows that robust boundary films and thermally stable additives are critical to delay catastrophic gear failure during loss-of-lubrication events in rotorcraft transmissions.

9 Failure analysis of a pair of failed chain links.

[9] Luigi Solazzi , Nicola Danzi, Marcello Gelfi, Lucio Enrico Zavanella.
Elsevier, July 2023. https://doi.org/10.1016/j.engfailanal.2023.107481

Study of failed towing chains operating in an aggressive environment using visual inspection, SEM, hardness and tensile tests. They find severe section loss at inter-link contact zones and heavy corrosion products, concluding that corrosive wear removed the case-hardened layer and reduced load-carrying area until overload failure occurred. An analytical evaluation is proposed to estimate strength reduction, and the authors stress the need for better inspection regimes and more corrosion-resistant materials.

10 Failures of chain systems.

[10] ALAN JAMES.
FAILURES OF CHAIN SYSTEMS. Elsevier, August 1997.

Three case studies of chain failures in very different applications: a furnace conveyor, a rock drilling rig, and a dragline crane. Through metallurgical examination and fracture analysis, the paper shows how operating beyond design parameters, material defects, and inadequate maintenance lead to brittle fracture, wear, and other failure modes. The work underlines that matching material and design to service environment and respecting operating limits are essential for chain system reliability.



Fig 2.1.1. Opened machine view



Fig 2.1.2 Clogged chain.

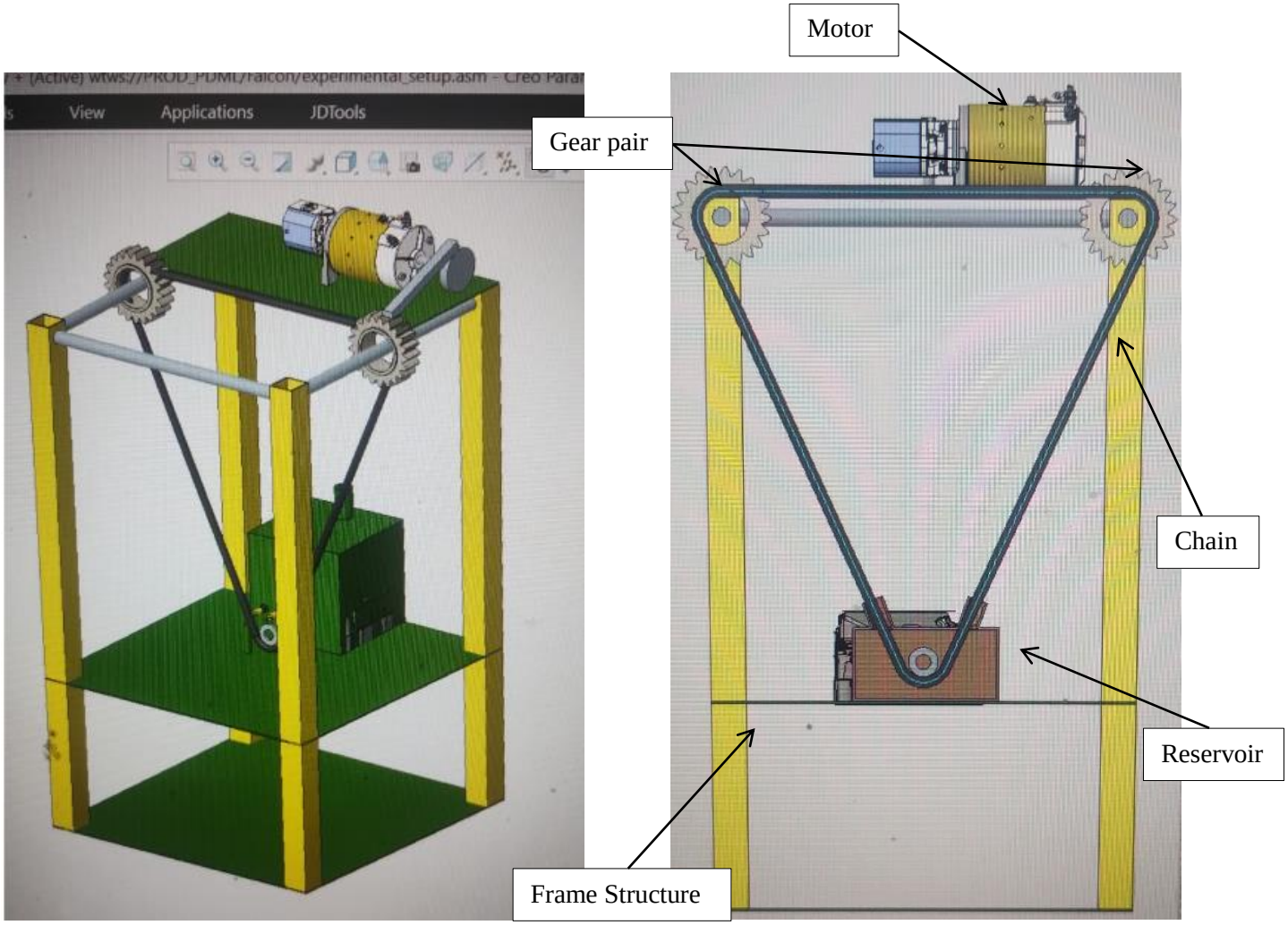


Fig 2.1.3 Experimental test rig (CAD model)

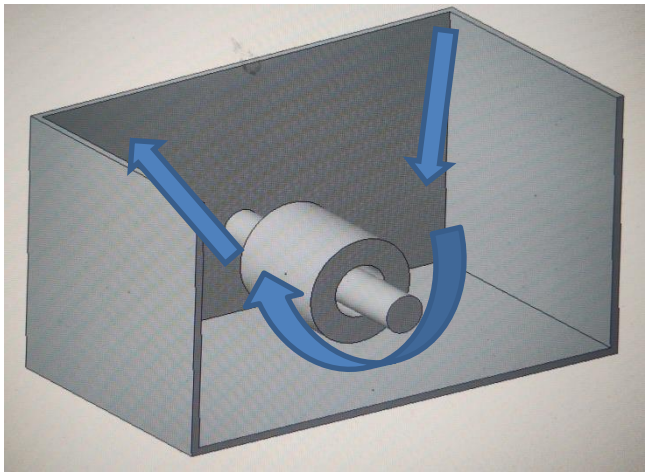


Fig 2.1.4 Reservoir design

3 Chapter

Methodology

3.1 Modal Analysis

Modal parameters like frequency, mode shapes etc are properties of the system, and are dependent on the mass, stiffness, damping and boundary conditions of the structure. These properties can be computed analytically using Modal Analysis. Equation 1 is the governing equation of motion.

$$M\ddot{x}(t) + C\dot{x}(t) + Kx(t) = f(t) \qquad (1)$$

where M, C and K are mass, damping and stiffness matrices respectively.

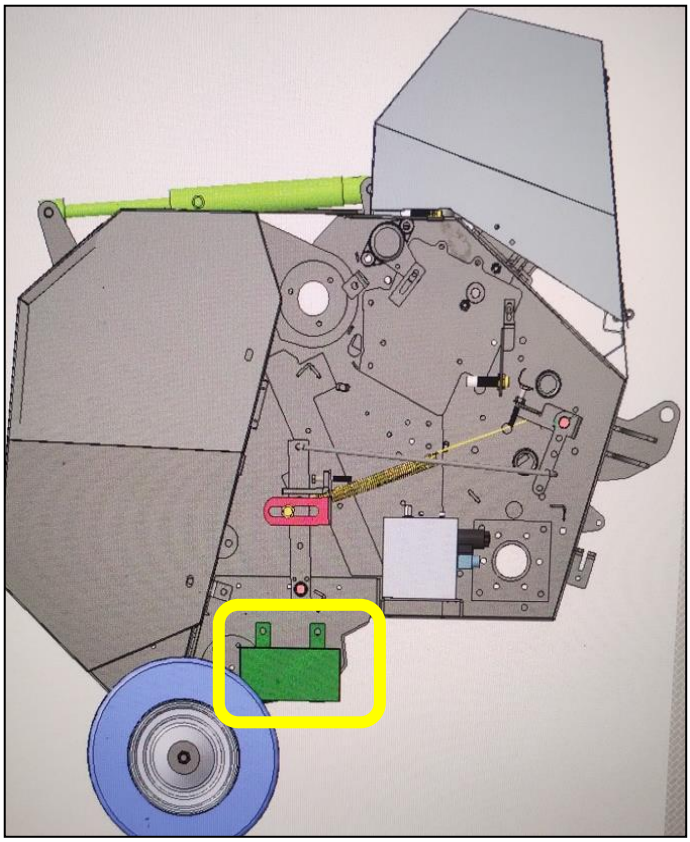
Material Properties of reservoir

Properties	Value	Unit
Material used	HSLA (ISO 4950-2)	
Young's Modulus	360	MPa
Poisson ratio	0.3	
Density	7850	Kg/m^3
Mass	2.13	Kg
Oil Density	850	Kg/m^3

Material HSLA provides good weight to strength ratio, weld ability, corrosion resistant, cost effective.

Tools used-

1. CAD Software- CREO
2. FEM Software- SimSolid
3. Modal analysis for natural frequency & mode shape-SimSolid
4. Flow Analysis- CreoFlow



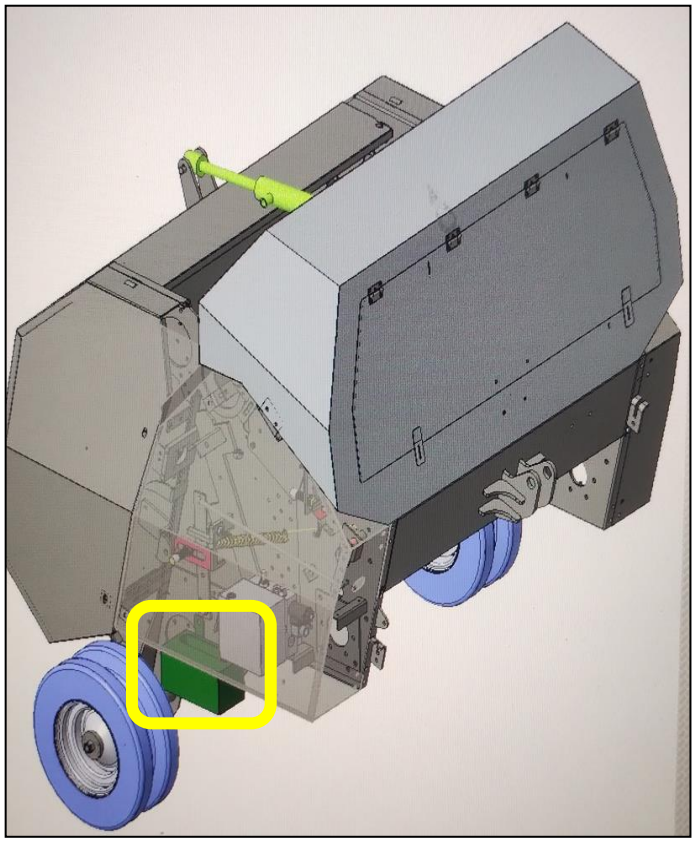


Fig 3.1.1 & 3.1.2 Component location on machine

1. Fixed Support

The left vertical plate of the bracket is assigned a fixed support.

A fixed support constrains all six degrees of freedom

2. Hinged Support

Two circular holes at the top and side are assigned hinged supports.

A hinged (or pin) support restricts translation while allowing rotation.

- Translational displacement is prevented
- Rotational motion is free

3. Applied Load: 20 N Downward Force

A 20 N downward force is applied at the mounting location shown in yellow.

This force represents the combined weight of:

- Lubricant reservoir
- Oil pump
- Filter assembly
- Mounting accessories

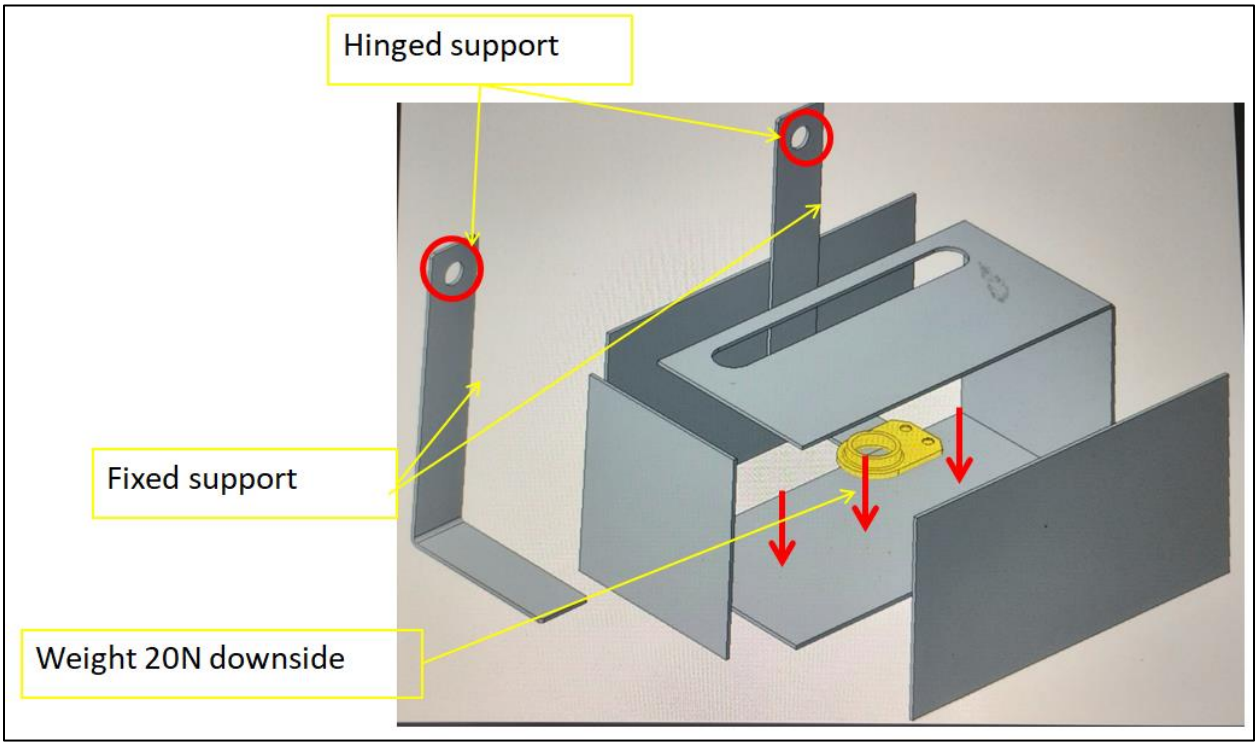


Fig 3.1.3 Component Exploded view

Experimental Procedure

Before starting the experiment, proper alignment of the sprockets and chain is checked to ensure smooth power transmission and to avoid uneven wear. The chain tension is adjusted within acceptable limits, and the lubricant level inside the reservoir is verified. The chain is then inspected carefully for any pre-existing damage, wear, or defects. Prior to measurement, the chain surface is cleaned to remove dirt and excess lubricant. A fixed number of 20 chain pitches is selected for measurement, and the initial chain length is measured using a digital vernier caliper or chain wear gauge. The measured value is recorded as the initial chain length. After completing the preliminary inspection and measurements, the electric motor is switched ON and the setup is operated at a constant speed throughout the experiment. The chain drive system is allowed to run continuously for 30 minutes while ensuring proper circulation of lubricant through the chain system. During operation, readings of chain temperature, motor current, noise level, and ambient temperature are recorded at regular intervals of 5 minutes. Simultaneously, observations are made regarding lubricant flow condition, chain vibration, and any abnormal sound or excessive heating. After completion of the 30-minute test, the motor is switched OFF and the chain is allowed to cool for a few minutes. Excess oil is cleaned from the chain surface, and the same number of chain pitches used during the initial measurement is measured again to determine the final chain length. The final measured value is then recorded for calculation of chain elongation and wear analysis.



Fig 3.1.4 Experimental test rig (actual)

The purpose of this experimental setup is to evaluate the effect of lubrication conditions on the performance and wear behavior of roller chain drives. The rig is designed to simulate operating conditions similar to those encountered in agricultural machinery such as round balers. The experiment compares dry running, manual lubrication, and automatic lubrication to determine their influence on chain wear, friction, temperature rise, and power consumption.

The test rig consists of the following major components:

1. Electric Motor – Provides rotational motion to the drive shaft.
2. Gear Pair – Transmits power and reduces/increases speed as required.
3. Roller Chain Drive – Main test component under investigation.
4. Driven Sprocket and Reservoir Load – Applies a constant tensile load to the chain through a hanging reservoir.
5. Lubrication Reservoir – Supplies lubricant to the chain in automatic lubrication mode.
6. Supporting Frame Structure – Mild steel frame to hold all components rigidly.
7. Measurement Instruments – Tachometer, thermocouples, sound meter, power analyzer, and vernier caliper.

The electric motor drives the top shaft through a coupling. A gear pair mounted on the upper shaft rotates the two sprockets connected by the roller chain. The chain passes over the lower sprocket attached to a weighted reservoir that provides a constant tension. During operation chain is continuously passed by dipping in oil filled reservoir. The response of the chain is monitored over time to assess lubrication effectiveness.

Mount the chain on the drive and driven sprockets and adjust tension according to the specified load.

Record:

- Initial chain length
- Ambient temperature
- Motor current
- Noise level

Automatic lubrication (continuous oil dipped)

Adjust:

- Motor speed
- Chain tension
- Lubricant flow rate

At 30-minute intervals, record:

- Chain temperature
- Motor power consumption
- Noise level
- Lubricant consumption

After completion:

- Stop the rig
- Clean the chain
- Measure chain elongation
- Weigh wear debris
- Inspect rollers and pins

To perform an operational deflection shape analysis, three steps are required:

- Geometry: Create a geometry of the test object
- Measurement: Acquire data with consistent phasing at different points
- Analysis: Create animation utilizing the geometry and measurement data

Any type of measurement (order, frequency, time) can be animated. The key is that the phase relationship between all the different channels (corresponding to various points and directions) is preserved during the measurement.

3.3 Analytical Approach

1. Displacement Magnitude

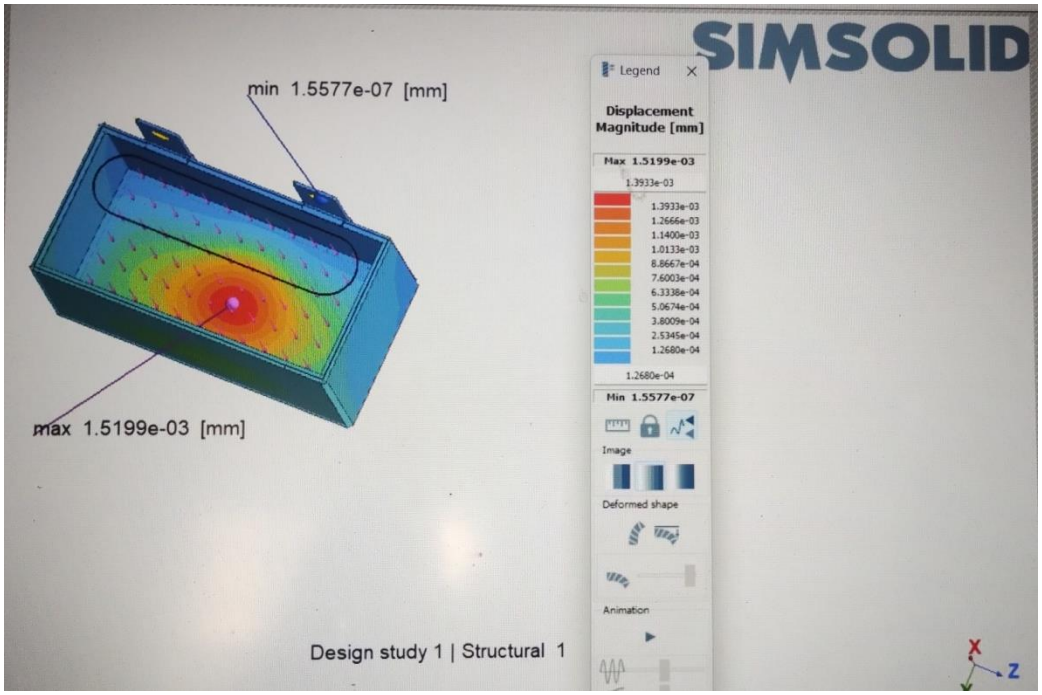


Fig.3.3 1. Displacement Magnitude distribution

Max displacement- 1.5199 X 10^{-3}mm

Min displacement- 1.5577 X 10^{-7}mm

- The base region is fixed & fully constrained.
- The red zone shows the max displacement.
- Arrow indicate applied loading.

- Structure is very stiff
- Load level is relatively small
- Material likely high stiffness (steel).

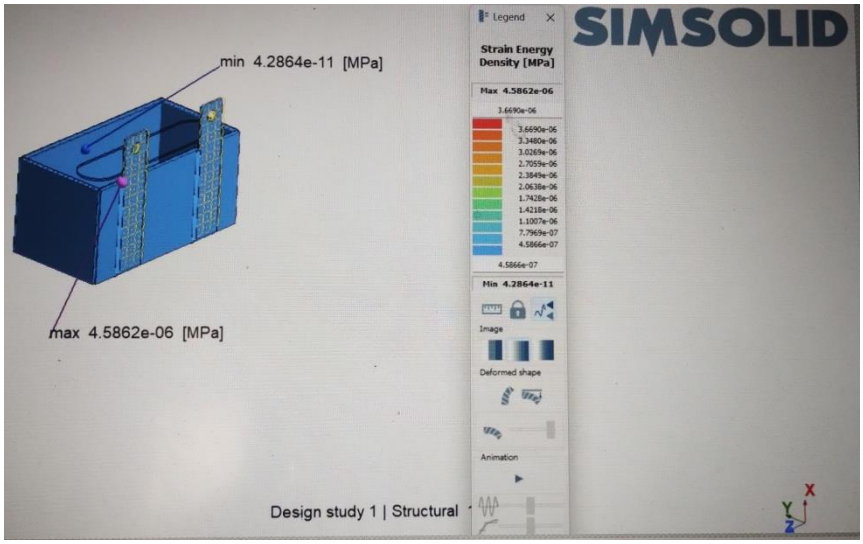


Fig.3.3.2 Strain Energy Density distribution

Max SED- 4.5862 X 10^{-6}MPa
Min SED- 4.2864 X 10^{-11}MPa

- Very low stored elastic energy
- Highly stiff structure under given loading.
- Overall smooth SED gradient
- No sharp spikes observed

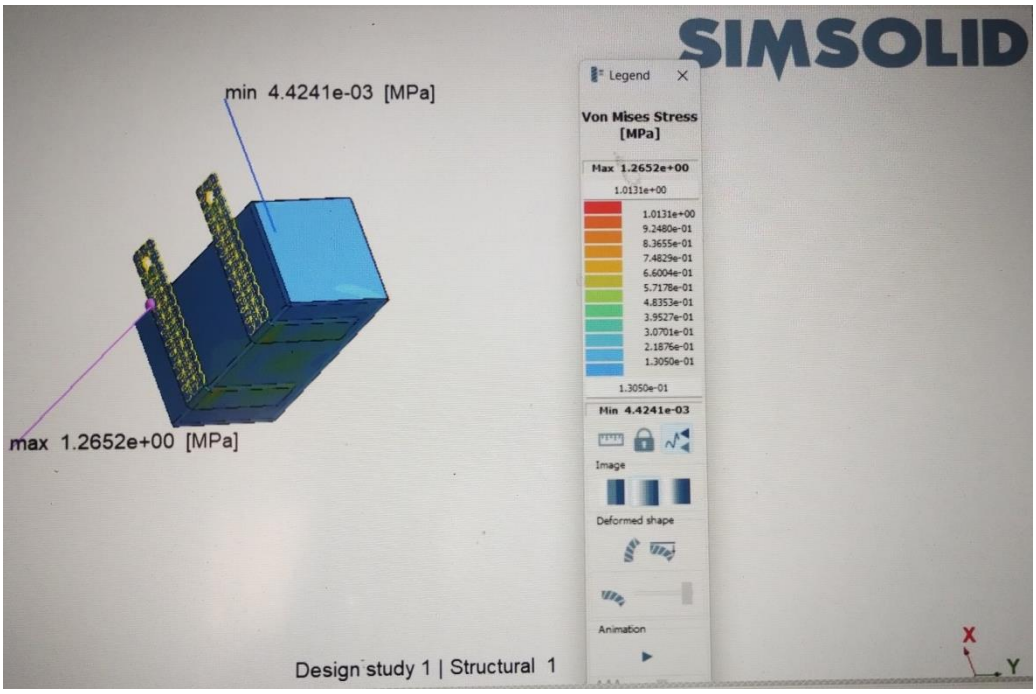


Fig. 3.3.3 Von Mises stress distribution

Max Stress- 1.2652 MPa

Min Stress- 4.4241 X 10^{-3}MPa

- Two vertical members subjected to high stress zone.
- Top region shown mostly low stresses.
- Scope for material grade reduction due to high FOS.
- Weight optimization.

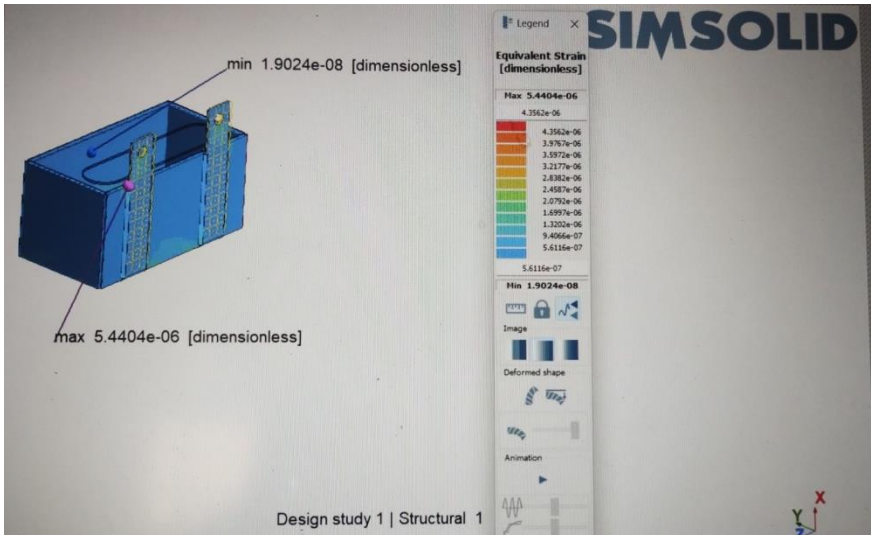


Fig.3.3.4 Equivalent strain distribution

Max Strain- 5.4404 X 10^{-6}
Min Strain- 1.9024 X 10^{-8}

- The max strain appears between vertical members & base.
- Structure is very stiff relative to applied load.

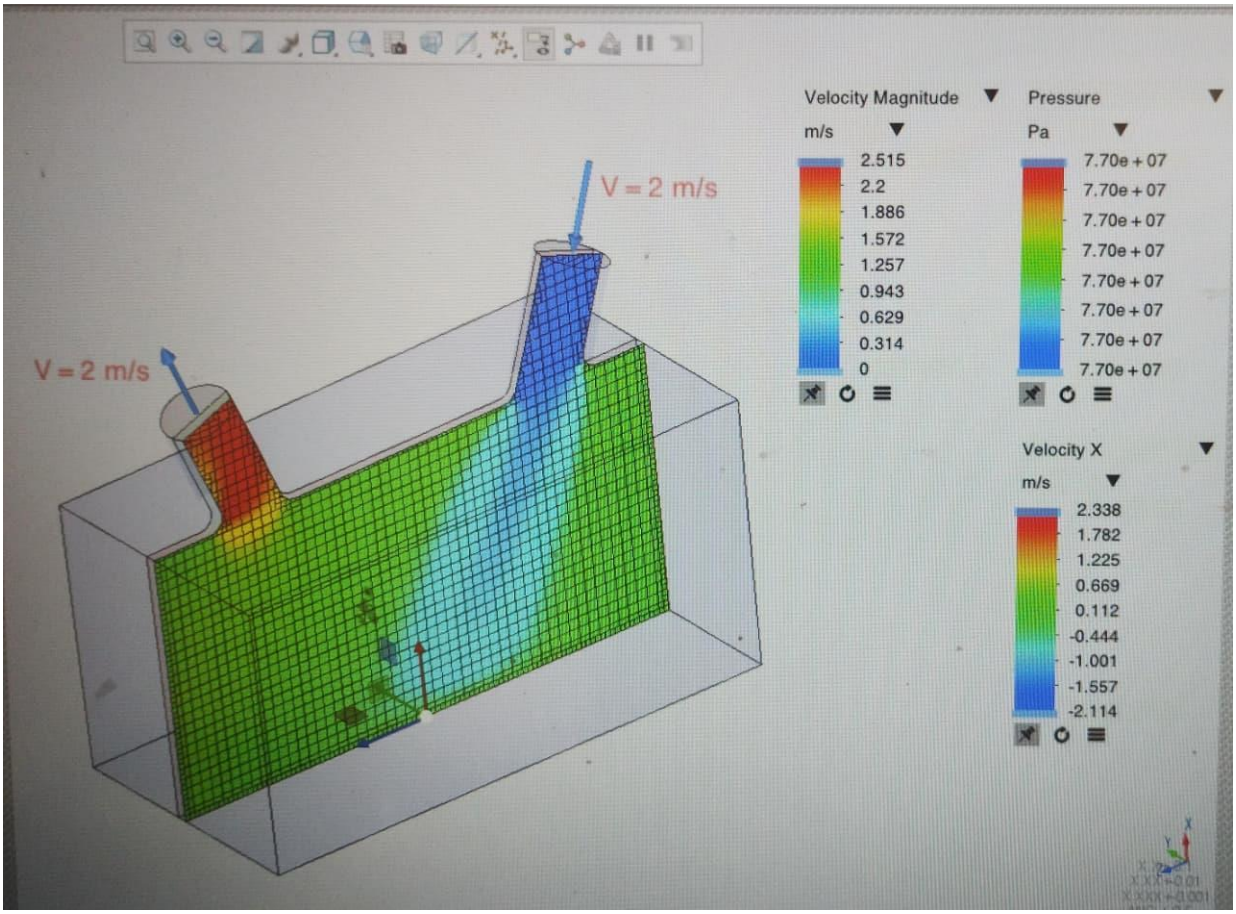


Fig 3.3.5 Creoflow velocity magnitude analysis

The colored contour represents the **velocity magnitude distribution** of oil within the reservoir. Red and orange colors near the inlet indicate the highest fluid velocity, while green and blue regions represent lower velocities as the oil spreads through the chamber. The flow decelerates significantly in the larger reservoir section due to the sudden expansion, which allows the oil to settle and distribute uniformly before reaching the outlet.

A low-velocity zone (light blue) is visible in the center of the reservoir, showing a recirculation or stagnation region. Such regions are beneficial because they allow suspended contaminants and wear particles to settle at the bottom of the reservoir, improving oil cleanliness before recirculation.

The pressure contour indicates an almost uniform pressure distribution throughout the reservoir, suggesting minimal pressure drop and efficient flow through the system. The Velocity X plot shows positive and negative velocity components, confirming internal circulation patterns and directional changes in the flow.

Conclusion

This CFD analysis demonstrates that the reservoir design provides smooth oil circulation with reduced velocity in the central chamber, promoting contaminant settling and ensuring clean lubricant delivery to the chain lubrication system. The results validate that the oil reservoir geometry is suitable for filtration and effective lubricant management in agricultural machinery.

4. Chapter

Result And Discussion

The proposed baffled oil reservoir design is a highly effective and practical improvement for the lubrication system used in agricultural, primarily focused on preventing premature chain drive failure through improved lubrication and contaminant-control filtration. The reservoir incorporates several advanced features such as internal baffle plates, separate inlet and outlet zones, a sloped bottom with a bottom drain port, an oil level gauge, a breather cap with filter, and rounded internal corners for smooth oil flow. The inclusion of internal baffles helps in controlling turbulent oil recirculation and minimizes air entrainment within the lubricant, thereby improving lubrication stability and ensuring a consistent oil supply to the chain mechanism. The separate inlet and outlet zones increase oil residence time, allowing contaminants and wear particles to settle effectively before the oil is recirculated.

To further improve maintenance and oil cleanliness, the conventional flat-bottom reservoir is replaced with a sloped or conical bottom design. This geometry enables easy sludge removal, complete oil drainage, and prevents contaminant accumulation inside the tank. Such a design is highly beneficial for agricultural machines operating in dusty and harsh environmental conditions, where contamination of lubricating oil is a major concern. The reservoir also includes a cartridge filter inside the tank, a replaceable mesh screen, a magnetic drain plug, and a transparent oil level window. These features provide continuous oil purification by trapping dust particles, metal debris, and sludge, thereby reducing chain wear and significantly extending lubricant life.

In addition to the mechanical improvements, the reservoir is designed with advanced CFD-oriented features such as curved internal flow channels, rounded corners, a directed outlet passage, an anti-vortex plate, and an optimized inlet angle. These modifications help in achieving smoother oil circulation and reducing stagnant flow regions within the tank. Computational Fluid Dynamics (CFD) analysis can be used to validate important flow characteristics including velocity distribution, pressure drop, turbulence reduction, and identification of dead oil zones. The optimized flow behavior enhances lubricant delivery efficiency and overall system reliability. Therefore, the proposed reservoir design not only improves lubrication performance and contaminant control but also provides strong research and analytical content for the thesis work.

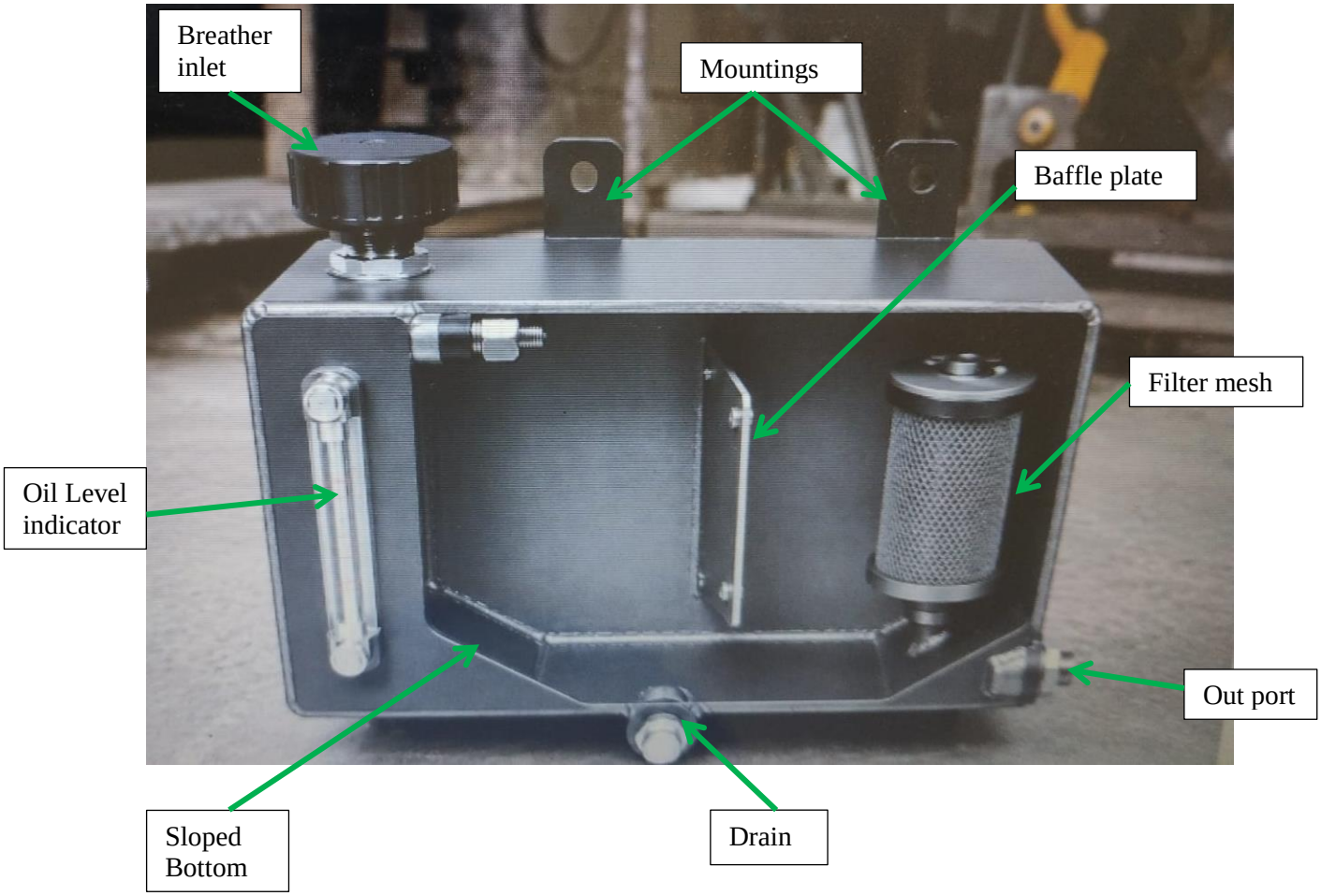


Fig 4.1.1 Cut section view of reservoir

5. Chapter

Conclusion

The comparison between finalized design of reservoir clearly indicates that design is a more advanced, efficient, and reliable lubrication oil storage system suitable for modern agricultural machinery applications. Earlier design of reservoir represents a conventional oil tank design with a simple rectangular geometry and basic oil storage capability, whereas modified geometry incorporates several enhanced engineering features that improve lubrication performance, oil cleanliness, maintenance efficiency, and overall system reliability.

It contains internal baffle plates that reduce turbulent oil recirculation and prevent air entrainment, resulting in lubricant flow to the chain drive system. The presence of separate inlet and outlet zones improves oil circulation and allows contaminants to settle effectively before the oil is reused. In contrast, the initial reservoir design lacks any internal flow-control mechanism, increasing the possibility of turbulent flow and contaminant recirculation.

The sloped bottom design and bottom drain plug provided in reservoir enable complete oil drainage and easy sludge removal during maintenance operations. This significantly reduces contaminant accumulation inside the tank, which is a major issue in agricultural machines operating under dusty environmental conditions. Reservoir having a flat-bottom structure, may retain sludge and debris inside the reservoir, leading to reduced oil quality and increased component wear.

Reservoir 1 also integrates a cartridge filter, replaceable mesh screen, magnetic drain plug, breather filter, and oil level indicator, all of which contribute to continuous oil purification and effective monitoring of lubricant condition. These features improve oil cleanliness, reduce chain wear, and extend lubricant service life. On the other hand, Reservoir 2 does not provide any filtration or monitoring arrangement, making it less effective in contaminant-control applications.

Additionally, Reservoir 1 is designed with CFD-oriented features such as rounded internal corners, optimized outlet flow passages, and smooth internal geometry, which help minimize dead oil zones and pressure losses while improving overall flow distribution. These improvements can be validated through CFD analysis by studying parameters such as velocity distribution, turbulence intensity, and pressure drop. Reservoir 2 lacks such optimized flow characteristics and therefore offers comparatively lower lubrication efficiency.

Overall, Reservoir 1 provides superior lubrication stability, enhanced contaminant control, easier maintenance, better oil circulation, and improved operational reliability compared to Reservoir 2. Therefore, Reservoir 1 is a

more suitable and technically advanced reservoir design for use in chain lubrication systems aimed at preventing premature chain failure in agricultural machinery.

6. REFERENCES

[1] Jinxing Yang, Zengming Feng, Xiaoguang Wang.

Oil injection lubrication analysis of a silent chain drive system – July 2022

[2] K.E. Kozlova, A.V. Egorovb, V.N. Beloguseva.

Experimental Evaluation of Chain Transmissions Lubricants Quality Using a New Method Based on Additional Inertia Moment Use - December 2017

[3] Teal Dowd, Patrick Cavanaugh1 & Jan-Anders Mansson.

Lubricant Performance in Bicycle Roller Chains. Research Gate, Sept 2024.

[4] Suhaib Ardah, Francisco J. Profito , Daniele Dini.

A comprehensive review and trends in lubrication modelling. Elsevier, March 2025.

[5] Rakesh.C. ,Vikas kumar , Utkarsh Singh, Pappu Saha, Saroj Kumar.

Design and fabrication of autonomous lubrication of chain. IJLERA, May 2016.

[6] Agam Kumar Malik1, Ankit Singh2, Mohit Hooda.

Concept of Automatic Lubrication System and Comparison with Conventional Lubrication

System. IJERT, April 2017.

[7] Kemparaju C R, Manish.S.Neelgar, Nithin.R, Preetham.G, Sendeep.P.

Automatic chain cleaning and lubrication system. IJTIMES, June 2018.

[8] Azhaarudeen Anifa Mohamed Faruck, Chia-Jui Hsu, Nicole Doerr b, Michael Weigand, Carsten Gachot.

How lubricant formulations and properties influence the performance of rotorcraft transmissions under loss of lubrication conditions. Elsevier, May 2020.

[9] Luigi Solazzi , Nicola Danzi, Marcello Gelfi, Lucio Enrico Zavanella.

Failure analysis of a pair of failed chain links. Elsevier, July 2023.

[10] ALAN JAMES.

FAILURES OF CHAIN SYSTEMS. Elsevier, August 1997.