College of Electrical and Mechanical Engineering

THESIS REPORT

OPTIMIZATION OF HYDRAULIC SYSTEM OF MOBILE CRANE

Submitted to the Department of Mechatronics Engineering
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ABSTRACT

The purpose of the study was to remove extra tensioning in the rope of tension winch and to maintain constant tension. Tension winch is attached between the crane boom and the trench cutter to create tension in a fixed rope. The problem was identified by the technical operations manager/in charge of construction machinery. A study was carried out to solve this issue. Various research papers, books and technical articles were consulted in order to devise a method by changing the existing hydraulic circuitry to achieve constant tensioning in the rope.

An optimized hydraulic circuitry was made for the purpose which finally resulted in a solution that was more power efficient, economical and less space consuming than the existing circuitry. Another major benefit was the increase in the cutter weight being exerted on ground due to the removal of extra tensioning.

DECLARATION

I hereby declare that no portion of the work referred to in this Thesis report has been submitted in support of an application for another degree or qualification of this of any other university or other institute of learning. If any act of plagiarism found, I am fully responsible for every disciplinary action taken against me depending upon the seriousness of the proven offense, even the cancellation of my degree.

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LIST OF SYMBOLS

Δp	Pressure difference at motor ports…………………….…………………..	bar
V_{st}	Displacement of motor……………………………………..………………	cc/rev
η_{hm}	Mechanical Efficiency of motor i.e. 0.86	

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CHAPTER 1

INTRODUCTION

1. Introduction

The system under consideration in this thesis work comprises of a system including the **Base Machine** which is **Crane** attached with a **Cutting Tool** which is **Trench Cutter**.

1.1 Base Machine (Crane):

Carnes are huge machines taking up tons of material hundreds of meters in height. There are plenty of types and they are in use for centuries. The cranes are formed by one or more machines used to create a mechanical advantage and thus move large loads. It is equipped with a hoist, wire ropes or chains, and sheaves that can be used both to lift and lower materials and to move them horizontally. Cranes are extensively used in construction industry for the movement of materials and in the manufacturing industry for the assembling of heavy equipment. Modern cranes usually use internal combustion engines or electric motors and hydraulic systems to provide a much greater capability to lift weights than in the past.

Fig-1.1 Base Machine LIEBHERR HS885HD

There are several forms and varieties of cranes to the present day, each created for a specific use. Sizes ranging from the smallest jib cranes, used in workshops, to the highest tower crane used in the construction of the tallest buildings and the larger floating cranes, used to build oil platforms and recover the sunken ships.

In our case, the crane being used is **LIEBHERR HS885HD (fig-1.1)**. This crane is fitted with an engine of **670 kW (898hp) power @ 1900rpm**. The hydraulic system of the crane includes the pumps which provide the required flow & pressure to various actuators. Two **main winches** of **300kN** capacity are installed in the crane. The rope of the main winch passes over the main boom of the crane. **Two tension winches** are attached with the main boom.

1.2 Cutting Tool (Trench Cutters):

Trench cutter is a tool used in the construction industry to make deep trenches in the ground. Trench cutter is fitted with cutting wheels, flaps and Mud Pump. The cutting wheels are fitted with cutting teeth (used to cut the ground), the flaps (used to direct the cutter) and the Mud pump (used to remove mud/small stones being crushed while cutting). The trench cutter (Fig-1.2) being used in this thesis work weighs **37.5 tons**. Hydraulic and Mud hoses are connected between the trench cutter and the base machine. These hoses pass over the moveable and fixed sheaves as shown in the figure. The cutter can go deep in the ground to a depth of **100 meters**.

Fig-1.2 Trench Cutter

1.3 Base Machine and Trench Cutter:

When the cutter is attached with the base machine by means of Main hook of the crane, number of hoses is being attached in between. These hoses include the Mud hose and Hydraulic Hoses. These hoses pass over moveable and fixed pulleys as shown in **Fig-1.3 and Fig 1.4**. The rope of tension winches are attached with moveable pulleys. A fixed wire rope passes over two small pulleys of the Main moveable sheave 1a and 1b frame and is connected from one end to the Cutter and from the other end to Base Machine.

When the Trench Cutter moves up/down, the moveable sheaves also move up/down. As the rope of the tension winches is attached with the moveable sheaves, the rope also winds/unwinds. Moveable sheave 1a moves from 0-60meters and moveable sheave 2a moves further from 60-120 meters. The purpose of tension winches is to develop tension in fixed wire ropes so that when the cutter is being moved with the main winch of the crane, the moveables sheaves also move by maintain certain amount of tension. This tension is maintained by means of valves installed in the hydraulic circuitry of the crane.

1.4 Aim/Objectives:

This Thesis work aims to target an area of improvement associated with the operation of Trench Cutter which is attached with a Crane. In a nut shell, following issues are focused in this thesis work:

- Identification of the cause for extra tension being developed in wire rope.
- Literature study for improvement in existing hydraulic circuitry.
- To suggest better hydraulic circuit in order to reduce unwanted/extra tension in rope.
- Simulation of new Hydraulic circuitry on Simulation Software
- Practical verification of simulated circuitry on crane.
- Summary of benefits achieved in terms of Power Saving, Cost Reduction and increased Cutter weight on Ground.

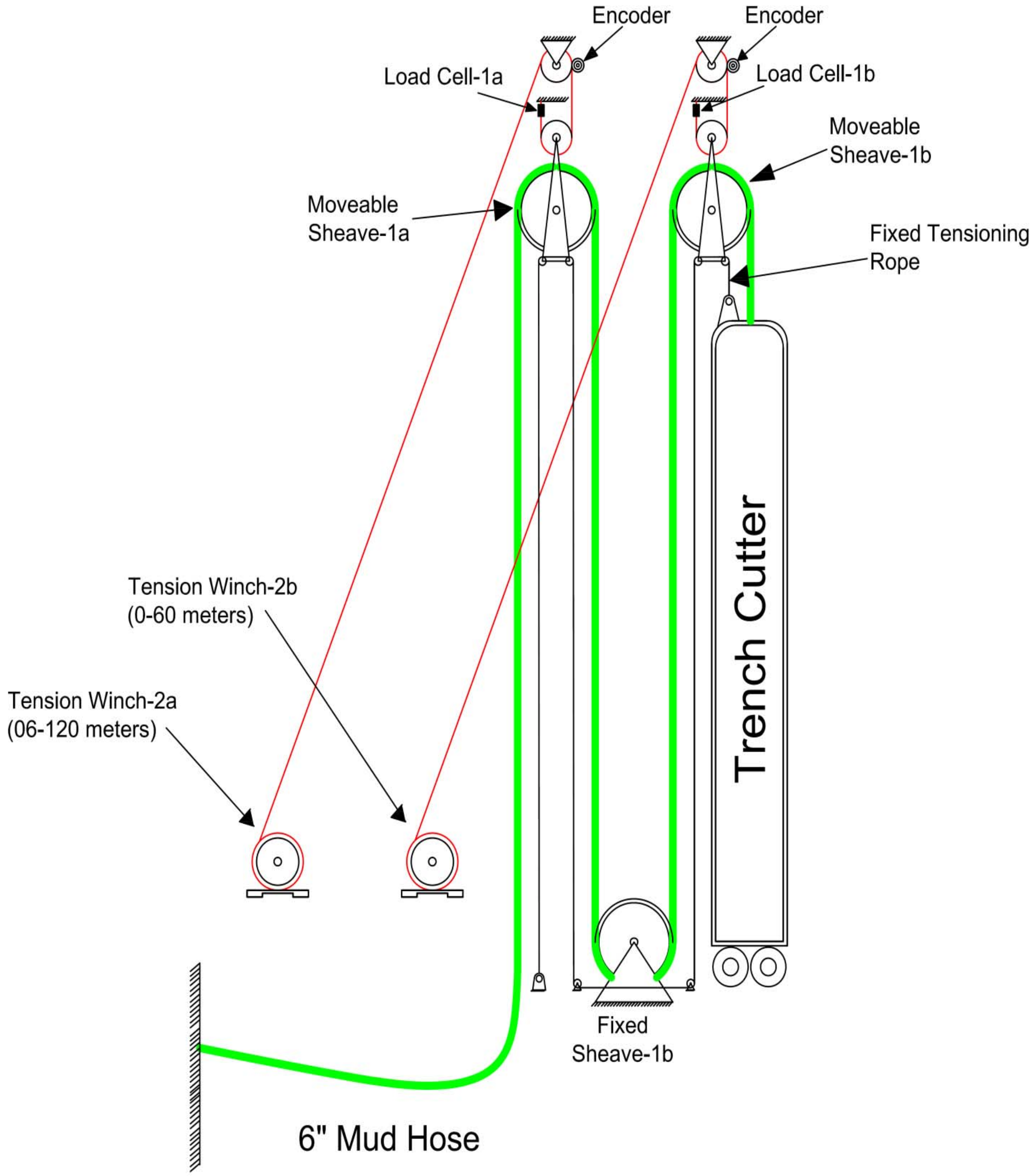


Fig1.3 Schematic showing how Mud hose, Tension winches, Cutter, Sheaves & Wire rope are inter connected

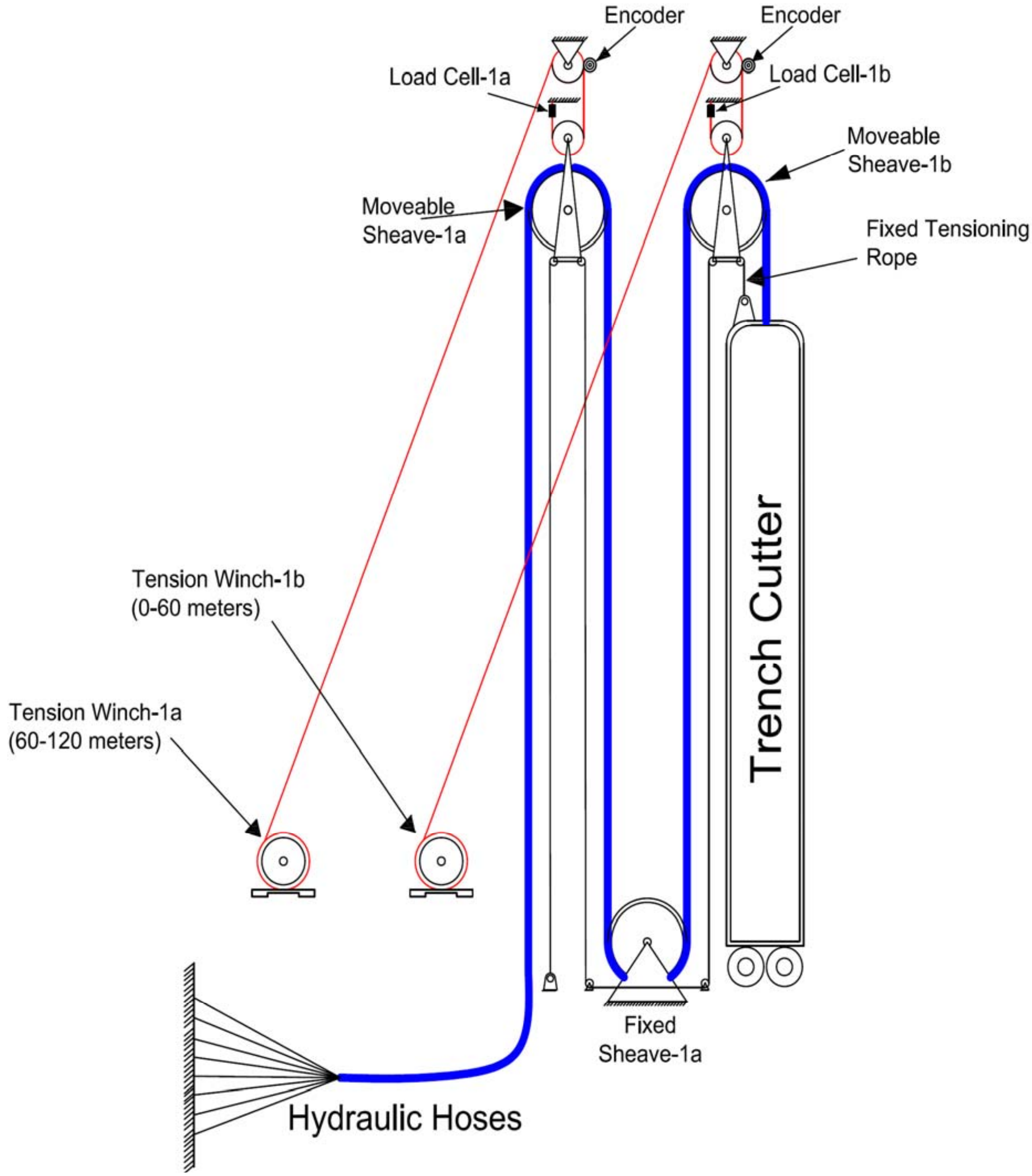


Fig1.4 Schematic showing how Hydraulic hoses, Tension winches, Cutter, Sheaves & Wire rope are inter connected

CHAPTER 2

LITERATURE REVIEW

2. Literature Review:

In order to address the issue of maintaining a constant tension in the rope, number of relevant books, technical articles and papers were studied. The objective was to handle this problem by doing appropriate changes in the hydraulic circuitry of the existing crane hydraulic circuit to understand the functionality of valves and its usage in cranes. Various books related to the field of hydraulics were consulted to implement new and modern techniques being used in today's time.

Most of the systems involved in the crane operation are accomplished by the use of Hydraulic power. In hydraulic systems, the pump generating flow of oil is being fed to the actuator through number of control blocks called **Valves**. Various types of valves are used in hydraulic systems to control or regulate the flow medium including **Direction Control Valve, Pressure Control Valves and Flow Control Valves**.

2.1 Direction Control valve:

Direction control valves are employed in hydraulic systems to determine the direction of the fluid in the hydraulic circuit. In direction control valve, the flow path may connect a supply port to an outlet (P to A or B) or may allow a pressurized port to unload to tank (A or B to T). Direction control valves are used sometimes as selector switch.

Two types of construction are generally used:

- Seat valve or Poppet valve
- Spool valve or Sliding valve

The operation of the direction valve could be manual, mechanical or hydraulic. Mostly, electrical signals are used for valve actuation. These valves use a solenoid to operate the valve spool. Solenoid can either be AC or DC. The armature plunger of the electromagnet presses on the spool when the electromagnet is excited. Electromagnets are basically of two types.

- Dry type
- Wet type

The switching time of the DC solenoid fitted valve is 40 to 50 milliseconds.

2.1.1 'Ways' of Valve:

The term 'way' is used to mean flow path in through the valve, including reverse flow. One-way, two way, three way and four way valves are common. One way valve will allow flow in one direction where as two way valves consist of two ports or opening P and A which are connected or disconnected by the moving spool. In one extreme position, no flow is allowed from P to A and the flow is stopped.

2.1.2 Positions of Valve:

Position of the valve determines the internal moveable parts of the valves and the resultant flow conditions determined by that position. Normally, direction control valves have 2 or 3 positions. They are:

- 0 Neutral position
- 1 Operating position
- 2 Operation position

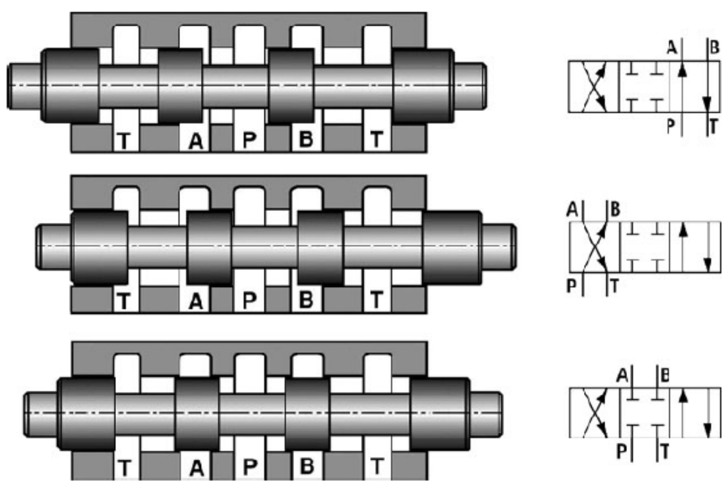


Fig 2.1: 4/3 Direction Control Valve all ports closed in center position

It is necessary to differentiate between the neutral and operating positions. Neutral position is defined as the position where the spool returns after the actuating force has been removed. A spring is used to bring the spool to its mean position once the actuating signal is being removed. Operating position is determined as the position where the spool is held once a DC volt signal is provided.

Our circuit is equipped with a 4/2 way directional control valve which is 24 volts DC operated and is spring return as shown in the figure below.

2.2 Direct Operated Pressure Relief Valve:

Pressure relief valve is a normally closed valve connected between the pressure line and the oil reservoir. Its main purpose is to limit the pressure in a system to a prescribed maximum level by diverting some or all the pump output to the tank, when the designated set pressure is reached. A simple relief valve consists of a poppet /ball held seated in the valve body by the compressive force of the heavy spring.

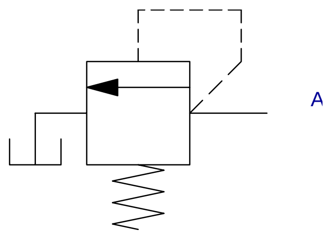


Fig 2.2: Direct Operated Relief Valve- symbol

When the pressure in the inlet is insufficient to overcome the force of the spring, the valve remains closed and hence it is very often referred as a normally closed valve. When the preset pressure is reached, the ball unseats and allows the flow through the outlet to tank. Thus the valve could be set to any pressure within the specified range.

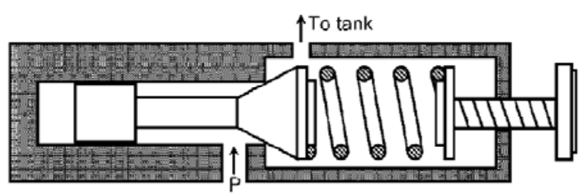


Fig 2.3: Direct operated relief valve

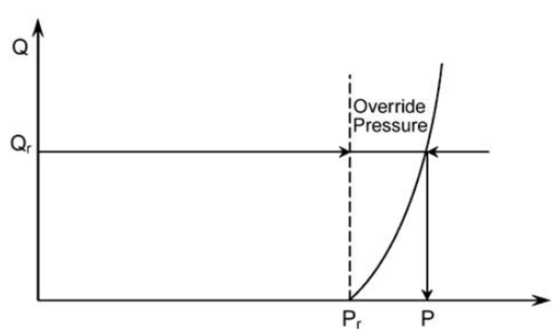
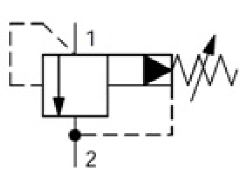


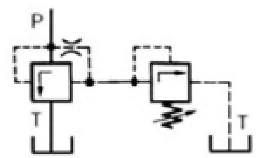
Figure 2.4: Static Characteristics of Relief Valve

2.3 Pilot Operated Pressure Relief Valve:

Direct operated pressure relief valves are used where the flow rate and the system pressure are reasonably smaller or there is not much variation in system pressure or flow rate. When a valve has to maintain the poppet or spool seated in its place to sustain a large pressure, there is a need to provide a bigger spring to maintain the high system pressure. But the bigger spring has a higher spring rate with its attendant problems and its cross section will also be larger requiring more space and sometimes being not feasible at all in a compact hydraulic system as are being used nowadays.



Simplified Symbol



Detailed Symbol

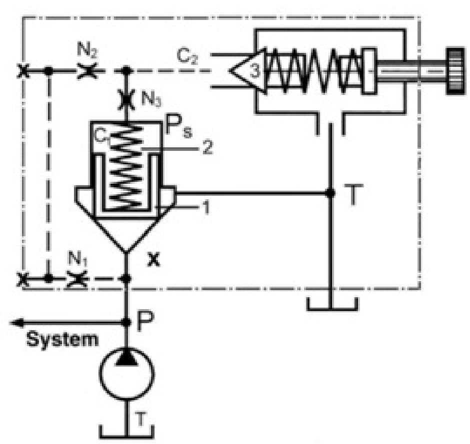


Fig 2.5: Functional Scheme and symbol of Relief Valve, pilot operated

Hence a direct pressure relief valve is used where the hydraulic system does not need excellent P-Q characteristics. But for a large flow rate and hydraulic pressure, the use of an indirectly operated valve, i.e. pilot operated valve is most common. This valve is also called compound relief valve.

The great advantage of such a valve is that here the pilot valve can be kept spatially separated from the main valve such as on a control panel and one can introduce suitable valves in between to set different pressures by pilot valves.

2.4 Proportional control Valves:

A proportional solenoid allows movement of the spool in proportion to the input current fed to it. In this device, armature position within the solenoid can be controlled by the input signal to the solenoid. The armature interacts with the hydraulic valve spool which can be shifted by the armature in a counterbalance manner allowing for the accurate proportional control of the spool position providing precise control of fluid flow and appropriate load movement.

Proportional valves are usually used in open loop control systems. They are controlled electronically to produce an output pressure or flow rate proportional to the input signal. They offer advantages such as control reversal, step-less variation of the controlled parameters, and reduction of the number of hydraulic devices required for particular control jobs.

Proportional valves use one or two proportional solenoids to move the spool by driving it against a set of balanced springs. The resultant spool displacement is proportional to the current driving the solenoids. The springs also center the main stage spool. Repeatability of the main-stage spool position is a function of the springs' symmetry and ability of the design to minimize nonlinear effects of spring hysteresis, friction, and machining tolerance variations.

2.4.1 Proportional Pressure Relief Valves:

Proportional pressure relief valves, are “control valves for oil hydraulic systems, where the inlet pressure is controlled by opening the outlet port to the tank against a counter force (solenoid spring system) “as specified by DIN-ISO 1219. The pressure is controlled electrically, the signal being supplied by appropriate control electronics which operate the solenoid.

2.4.2 Pilot Operated Proportional Pressure Relief Valve:

The Proportional pressure relief valve, Pilot operated is a spool-type pilot-operated proportional pressure relief valve. When the pressure across port 1 rises and exceeds the value defined by the electrical signal, the pilot-stage opens and oil flows from behind the main spool to the tank port 2. The resulting pressure differential causes the main spool to move against the reset-spring and allows oil to flow from port 1 to port 2. The pressure to be set at port 1 is infinitely adjustable in proportion to the electrical signal.

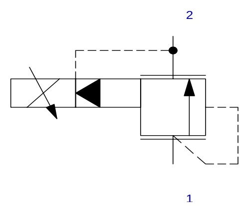


Fig-2.6: Symbol for Proportional pressure relief valve, Pilot operated.

CHAPTER 3
MATHEMATICAL MODEL
& CALCULATIONS

3. Mathematical Model & Calculations

3.1 Wire Rope Tension Calculation:

The existing hydraulic system for tensioning was installed with 02 x Manually Adjusted Fixed Pressure Sequence valves and 01 x Directional Control Valve. One was set at 160bar for Auto Mode Operation and the other at 220bar for Manual Mode Operation. The cutter operates in Manual mode only when commissioning or pre-tensioning stages. Otherwise, the cutter operates in Auto Mode whether it is moving up or down.

As the cutter goes down deep in the ground, the rope of the tension winch is also released. As the rope is released, the layer on the winch decreases which decreases the winding radius of rope on the winch drum. With the decrease in the winding radius of rope, the **Tension 'F'** in the rope increases according to the following relationship:

$$\boldsymbol{T = r \times F}$$

This increase in the tension is not required. It is occurring due to the relationship between torque, force and radius. This phenomenon can be better understood from Fig-3.1

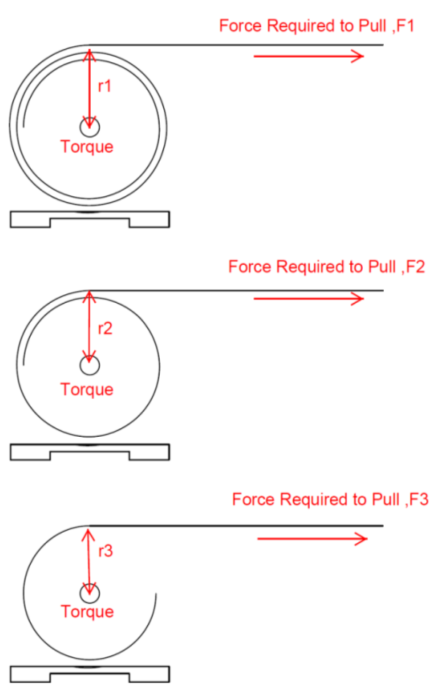


Fig 3.1: Force, torque and radius relationship

According to Fig 4.1, F3 > F2 > F1 due to constant torque. If we change torque, we could achieve F1=F2=F3. Changing torque means to change Pressure setting of Pressure Relief/ Sequence valve as the layer changes.

First discuss our existing circuit (shown in Fig-3.2).

Number of Pressure Sequence Valves (encircled RED) installed = 02

Number of Direction Control valve installed = 01

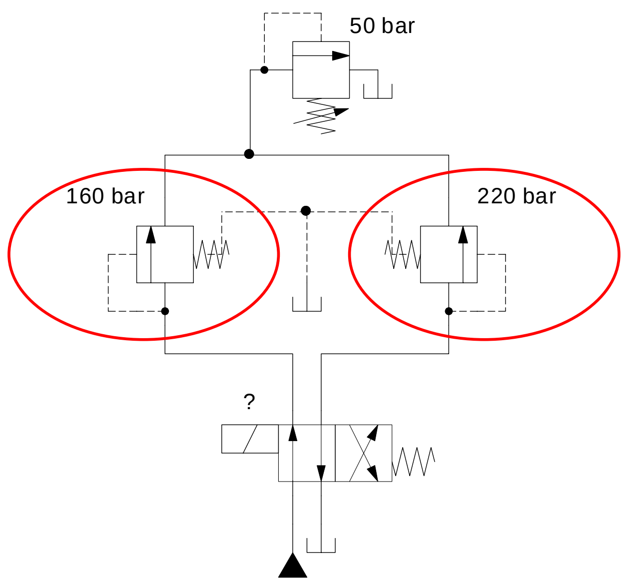


Fig-3.2: Existing hydraulic circuit for Wire Rope Tensioning

Where the pressure sequence valves are set as follows:

01 x set at 220bar for Manual Mode of Cutter

01 x set at 160bar for Auto Mode of Cutter

As most of the operation is being done in Auto Mode, so Torque developed by Hydraulic Motor @ 160bar,

$$\boldsymbol{T_{motor}} = \frac{\boldsymbol{\Delta p \, V_{st} \eta_{hm}}}{\boldsymbol{20\,\pi}}$$

Where

$\Delta p = 160$ bar in Auto Mode

$$V_{st} = 28cc/rev$$

$$\eta_{hm} = 0.86$$

Now substituting values in Eq-01:

$$T_{motor} = \frac{160 * 28 * 0.86}{20 * 3.14}$$

$$T_{motor} = 61.35\ N.m$$

There is a gear box between the Hydraulic Motor and the Winch Drum.

Winch Gear box gear ratio, $\boldsymbol{i} = \mathbf{83.57}$

$$\boldsymbol{T_{motor}} = \boldsymbol{i} \times \boldsymbol{T_{motor}}$$

$$T_{motor} = 83.57 * 61.35\ N.m$$

$$\boldsymbol{T_{motor}} = \mathbf{5127}\ \boldsymbol{N.m}$$

The radius of layers is:

$$r_1 = 2135.5$$

$$r_2 = 235.5$$

$$r_3 = 257.5$$

3.1.1 Rope Tension in 1st Layer:

$$F_1 = \frac{T_{motor}}{r_1}$$

$$F_1 = \frac{5127}{213.5} * 1000$$

$$\boldsymbol{F_1} = \mathbf{24,014}\ \boldsymbol{N}$$

3.1.2 Rope Tension in 2nd Layer:

$$F_2 = \frac{T_{motor}}{r_2}$$

$$F_2 = \frac{5127}{235.5} * 1000$$

$$\boldsymbol{F_2 = 21,770.7\ N}$$

3.1.3 Rope Tension in 3rd Layer:

$$F_3 = \frac{T_{motor}}{r_3}$$

$$F_3 = \frac{5127}{257.5} * 1000$$

$$\boldsymbol{F_3 = 19,910.6\ N}$$

It is clear from the above calculation that the tension in the rope changes from **24,014N to 19,910.6 N** as the layer changes from **1st to 3rd** layer.

3.2 Pressure Required At each Layer:

In order to keep the tension in the wire rope constant, we need to change the pressure setting of the valve. Thus, we have to first calculate how much pressure we need in each layer in order to keep the tension in the layers constant. As was shown in the earlier calculation, the force developed in 1st and 2nd layer was more than the force developed in 3rd layer, so we need to maintain the force developed in 3rd layer in all the layers.

3.2.1 Pressure Setting at 1st Layer:

$$T_1 = r_1 \times F$$

$$T_1 = 213.5 \times 19{,}910.6$$

$$T_1 = 4{,}250{,}913\ Nmm$$

$$T_1 = 4{,}250.9\ Nm$$

Torque on motor:

$$T_1 = \frac{T_1}{i}$$

$$T_1 = \frac{4250.9}{83.57}$$

$$T_1 = 50.86 \ \ Nm$$

Pressure Required:

$$T_{motor} = \frac{\Delta p \ V_{st} \eta_{hm}}{20 \ \pi}$$

$$\Delta p_1 = \frac{T_{motor} \ 20 \ \pi}{V_{st} \eta_{hm}}$$

$$\Delta p_1 = \frac{50.86 \ \times 20 \ \pi}{28 \ \times 0.86}$$

$$\boldsymbol{\Delta p_1 = 132.64 \ bar}$$

3.2.2 Pressure Required in 2nd Layer:

$$T_2 = r_2 \ \times F$$

$$T_2 = 235.5 \ \times 19{,}910.6$$

$$T_2 = 4{,}688.9 \ Nm$$

Torque on motor:

$$T_2 = \frac{T_2}{i}$$

$$T_2 = \frac{4688.9}{83.57}$$

$$T_2 = 56.10 \ Nm$$

Pressure Required:

$$T_{motor} = \frac{\Delta p \ V_{st} \eta_{hm}}{20 \ \pi}$$

$$\Delta p_2 = \frac{T_{motor} \ 20 \ \pi}{V_{st} \eta_{hm}}$$

$$\Delta p_2 = \frac{56.10 \times 20 \ \pi}{28 \ \times 0.86}$$

$$\boldsymbol{\Delta p_2 = 146.40 \ bar}$$

3.2.3 Pressure Required in 3rd Layer:

$$T_3 = r_3 \times F$$

$$T_3 = 257.5 \times 19{,}910.6$$

$$T_3 = 5{,}126.9\ Nm$$

Torque at motor:

$$T_3 = \frac{T_3}{i}$$

$$T_3 = \frac{5126.9}{83.57}$$

$$T_3 = 61.34\ Nm$$

Pressure Required:

$$T_{motor} = \frac{\Delta p\ V_{st}\eta_{hm}}{20\ \pi}$$

$$\Delta p_3 = \frac{T_{motor}\ 20\ \pi}{V_{st}\eta_{hm}}$$

$$\Delta p_3 = \frac{61.34 \times 20\ \pi}{28 \times 0.86}$$

$$\boldsymbol{\Delta p_3 = 160.0\ bar}$$

Next is to devise a method to set the above mentioned pressure values in each layer.

3.3 Proposed Hydraulic Circuits:

Following two hydraulic circuits were developed as a result of the literature studied in order to maintain a constant tension in the rope by changing the pressure setting values as the layer changes:

Option#1: By means of Fixed Pressure Relief Valves and Direction Control valves.

Option#2: By means of Proportional Pressure Relief Valve.

3.3.1 Option#1: By means of Fixed Pressure Relief Valves and Direction Control Valves:

In this method, we require 04 x fixed pressure relief/sequence valves and 04 x 2/2 way direction control valve. 03 out of 04 Pressure Sequence valves were chosen for the 03 x wire rope layers being developed on tension winch while cutter moves up to a depth of 120 meters. Remaining 01 x pressure relief/sequence valve was dedicated for the Manual Mode operation. Similarly, 03 x Directional control valves were meant to direct the flow of hydraulic oil to the 03 x specific pressure sequence valves depending upon the winch rope is in which layer. Remaining 01 x direction control valve was to direct the flow of oil to the pressure sequence valve for Manual mode operation.

The circuit formed with these valves is shown in fig 3.3

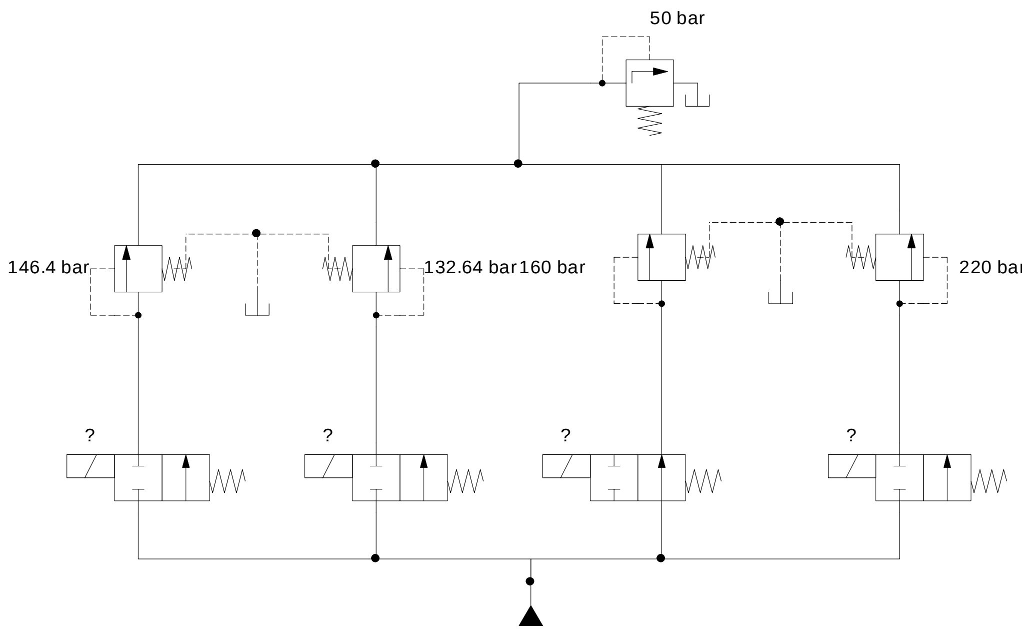


Fig 3.3: Hydraulic Circuit of Option # 1 with 04x Fixed Pressure Relief/Sequencing valve & 04xDirectional Control valves

3.3.2 Option#2: By means of Proportional Pressure Relief Valve:

This hydraulic circuit consists of 01 x Proportional Pressure Sequence valve which is being used in place of 02 x fixed pressure sequence valves and 01 x directional control valve originally fitted in the crane hydraulic circuit. Proportional Electrical signal is being used to change the Pressure setting of the proportional valve. This changes the torque being developed by the motor which in turns provides the required tensioning in the rope. The circuit being made with the proportional valve is shown in fig-3.4.

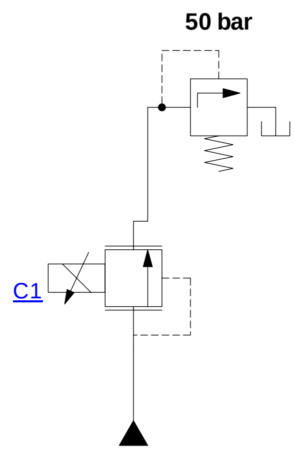


Fig 3.4: Hydraulic Circuit of Option # 2 including Proportional pressure sequence valve.

3.3.3 Comparison between Option#1 & option#2:

A comparative study was carried out between the two proposed hydraulic circuits. Option#2 was found better than Option#1 due to following reasons:

1. The price for the valves and manifold used in Option# 2 was less than in Option#1 i.e. it is more Economical
2. Option#2 requires Smaller Manifold for valve mounting which means less space will be consumed.
3. Proportional Pressure Sequence valve can be set at various pressure settings than Fixed Sequence valves so giving steeples controllable pressure setting.
4. Option# 2 has less number of valves to malfunction.
5. Lesser inventories to maintain in option#2.
6. In Option#2, there is only one valve to troubleshoot.
7. Proportional Valve in option#2 can be reconfigured from the Operator's cabin with ease for fine tuning.

3.4 Valve Selection:

Now it is decided that we will be using a proportionally operated pressure sequence valve, we need to find the appropriate valve for our application. In a Proportionally controlled Sequence Valve, the Pressure setting is changed proportionally with the change in the current. In the existing system, the Pressure is set according to the tension being produced in the 3rd layer of the winch because the 3rd layer has largest radius.

Table-3.1 and 3.2 shows a comparison between the servo valve and proportional solenoid valve.

Servo Valve	Proportional Solenoid Valve
Used for Closed loop systems	Used for Open Loop system
Expensive	Comparatively Cheaper
Low Coil Current	High coil current
Less Response Time	More Response time
High frequency response	Low frequency response
Shorter Dead Band	Greater Dead Band
Less Tolerant to contamination	More tolerant to contamination

Table 3.1

Properties [21]	Proportional valve	Servo valve
Response (frequency at 29.3% flow reduction)	2 to 10 Hz	10 to 300 Hz
Spool Center Condition (dead band)	10 to 30%	Nil
Hysteresis/repeatability/threshold	Up to 10 %	Less than 3%
Filtration Requirement	10 micron	3 micron

Table 3.2

Although the servo valve characteristics is better that the proportional valve characteristics in terms of Response time, Dead band, Coil current, Repeatability and Hysteresis but opted for Proportional valve due to following reasons:

a. The crane's hydraulic circuit is already installed with proportional valves and the filtration of the existing system is being done accordingly i.e. up to 10μ (micron), so it was not practical to add a servo valve and to bring the filtration of the complete hydraulic system of crane to 3µ.

Once it is decided that proportional valve would be used, there are two basic types of pressure relief valves.

b. Direct Pressure Relief valve
c. Pilot operated pressure Relief Valve

Table 3.3 shows the difference between the two types of valve.

Direct Pressure Relief Valve	**Pilot Operated Pressure Relief Valve**
Used for less flow rates	Used for large flow rates
Big pressure difference to unseat the spool	Small pressure difference to unseat the spool
Bigger spring required to unseat the spool	Small spring for pressure setting
Large space due to bigger spring	Less space required
No good PQ characteristics is achieved	Good PQ characteristics

Table 3.3

It was beneficial to Pilot operated pressure relief valve because it has small pressure difference to unseat the spool than the Direction pressure relief valve wherein a big pressure difference is required to unseat the spool. Moreover less space is required to install a pilot operated pressure relief valve. The P and Q characteristics of the pilot operated Relief valve are better than Direct Operated pressure relief valves. The direct relief valve are fitted with bigger springs that the pilot operated relief valve.

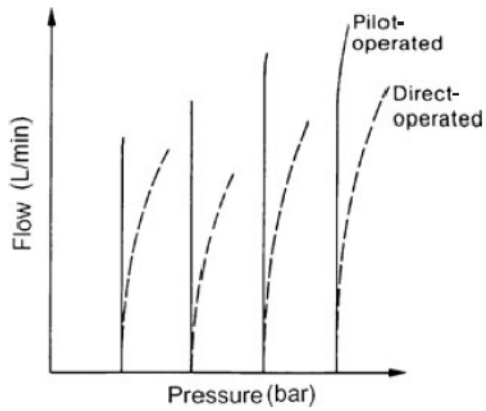


Fig 3.5: Static Flow-pressure characteristics of direct & pilot-operated relief values

Once it's decided that pilot operated pressure relief valve will be used, we need to select either to use the pilot operated with Drain Line or to used Pilot operated without drain line.

Table-3.4 shows the difference between the pilot operated relief valve with drain and pilot operated without drain line.

Pilot operated With Drain	**Pilot operated without drain**
Insensitive to the back pressure being developed at outlet port.	Sensitive to back pressure developed at outlet port.
Pressure at port 4 is directly additive to the valve setting at a 1:1	Back pressure on the tank port (port 2) is directly additive to the valve setting at a 1:1 ratio

Table-3.4

Relief valves with drain line have benefits over valve without drain line i.e. they are insensitive to back pressure which is developed at outlet port. Also the Pressure at port 4 is directly additive to the valve setting at a 1:1 where as in valve without drain line have back pressure on the tank port (port 2) is directly additive to the valve setting at a 1:1 ratio.

So, it was finalized to use ***Proportional Pilot operated pressure relief valve*** with Drain port.

3.4.1 Proportional Pressure Sequence Valve:

We have used ***Proportional Sequence Valve EPDZA valve*** in our circuit in order to maintain a constant Pressure in the circuit. The EPDZA consists of a mechanical pressure relief valve, which is pilot-controlled by a proportional pressure relief valve. The spring chamber of the mechanical valve is separately relieved over channel T. If the pressure fluctuations are negligible in the T-channel, the pilot flow can be led also after T (plug 1, see symbol). Otherwise it must flow off after channel B (plug 2). The valve has a mechanical maximum pressure setting. Below this setting the valve works proportionally.

Fig- 3.6: Proportional Pressure Relief Valve image with Symbol

The proportional sequence valve EPDZA lets the oil of P flow after A, starting from a proportionally adjustable opening pressure. If the pressure drops again, the valve closes with small hysteresis. Contrary to standard pressure relief valves the actual opening pressure remains constantly, independent of pressure fluctuations in channel A.

Make *FLUIDTEAM AUTOMATIONSTECHNIK's*

Type Proportional Pressure Sequence valve

Series EPDZA

Model EPDZA 06-350-0-2-24V-FNH

The Current vs. Pressure graph of the valve is shown in fig 1.5:

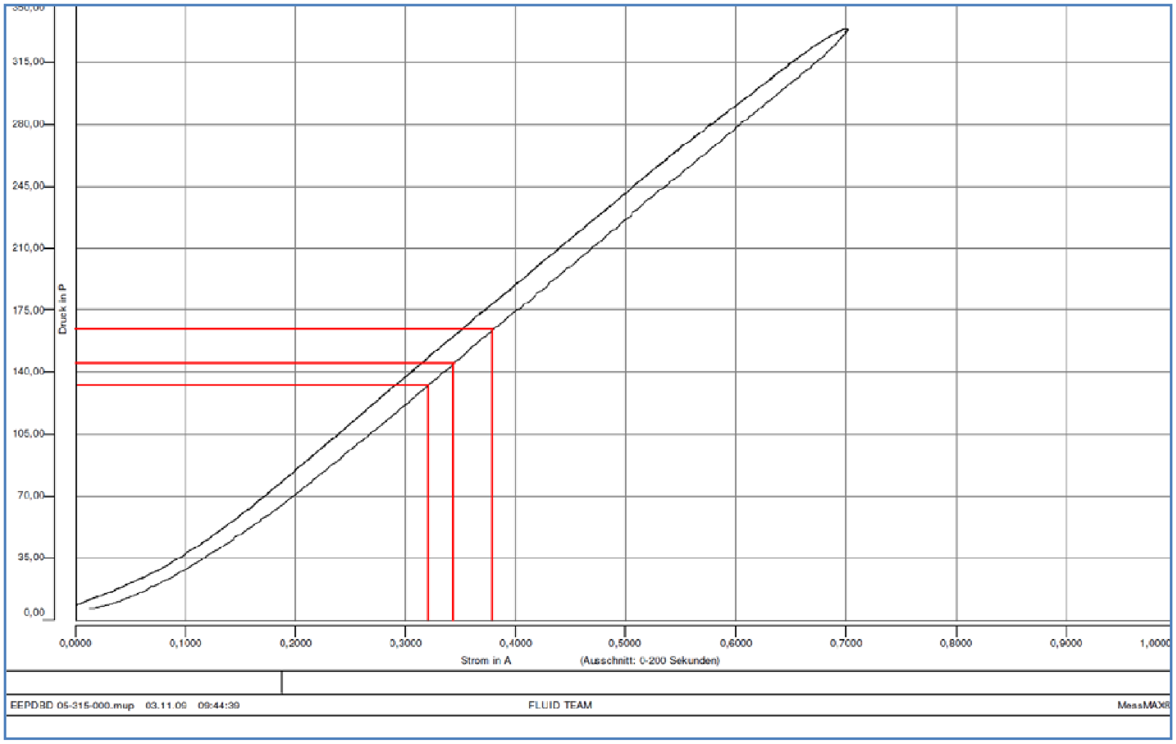


Fig 3.7 Pressure Vs Current graph of Relief Valve

3.4.2 Valve Properties:-

Max rated Pressure :	350 bar
Maximum Rated Flow:	40 lpm
Filtration:	class 18/16/13, filter ß 6...10 ≥ 75
Nominal Voltage:	24 V DC; 12 V DC
Rated Current:	700 mA (24 V); 1700 mA (12 V)
Nominal Resistance (R20):	25 Ω (24 V); 4 Ω (12 V)
Wattage:	Max. 20 W
Control Command:	PWM (Pulse-Width-Modulated DC)
Dither Frequency:	preferably 140 Hz
Design	piston-sleeve style pilot operated
Ambient Temperature	-20 °C – +50 °C
Fluid Temperature:	-20 °C – +80 °C
Environmental Protection	IP 65

This valve consists of further two valves in a single body.

a. Pilot Operated Relief Valve of Sun hydraulics.

b. Proportional Pressure Relief Valve of FLUIDTEAM AUTOMATIONSTECHNIK.

3.4.3 Pilot Operated Relief Valve- Sun-Hydraulics:

Ventable, pilot-operated, balanced piston relief cartridges with external drain are normally closed pressure regulating valves. When the pressure at the inlet (port 1) reaches the valve setting, the valve starts to open to tank (port 2), throttling flow to regulate the pressure. They provide a vent port (port 3) that connects between the main piston and pilot stage to provide for remote control by other pilot or 2-way valves and a drain (port 4) that makes them insensitive to back pressure. These valves are accurate, have low pressure rise vs. flow, they are smooth and quiet, and are moderately fast.

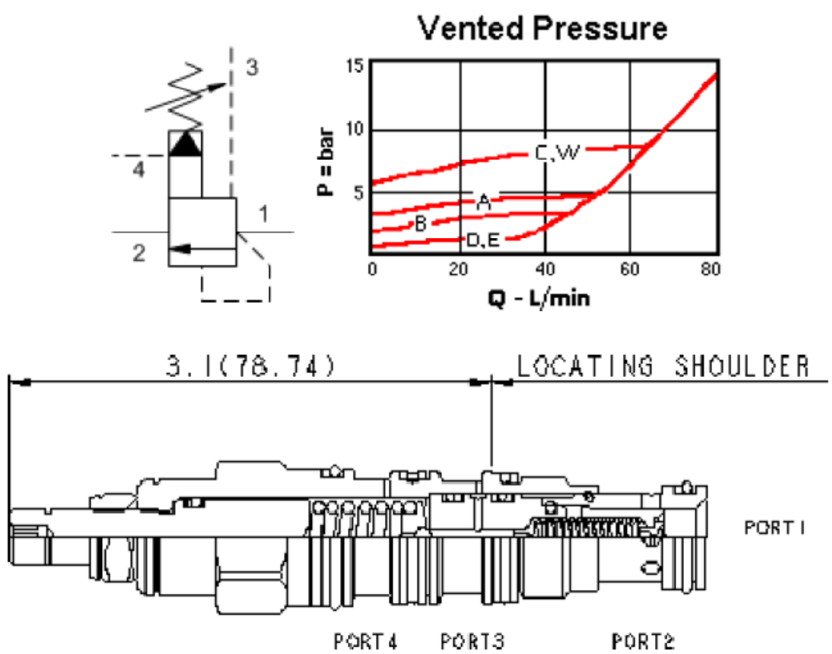


Fig 3.8: Proportional Remote pressure relief valve

3.4.3.1 Technical Features:

- A remote pilot relief on port 3 (vent) will control the valve below its own setting.
- Will accept maximum pressure at port 2; suitable for use in cross port relief circuits. If used in cross port relief circuits, consider spool leakage.
- Main stage orifice is protected by a 150 micron stainless steel screen.
- Not suitable for use in load holding applications due to spool leakage.

- Pressure at port 4 is directly additive to the valve setting at a 1:1 ratio and should not exceed 5000 psi (350 bar).
- Incorporates the Sun floating style construction to minimize the possibility of internal parts binding due to excessive installation torque and/or cavity/cartridge machining variations.

3.4.3.2 Specifications:

Cavity	T-21A	
Capacity	15 gpm	60 L/min.
Control Pilot Flow	7 - 10 in8/min.	0,11 - 0,16 L/min.
Factory Pressure Settings Established at	4 gpm	15 L/min.
Maximum Operating Pressure	5000 psi	350 bar
Maximum Valve Leakage at 110 SUS (24 cSt)	2 in8/min.@1000 psi	30 cc/min.@70 bar
Response Time - Typical	10 ms	
Adjustment - Number of Clockwise Turns to Increase Setting	5	
Valve Hex Size	7/8 in.	22,2 mm
Valve Installation Torque	30 - 35 lbf	ft 40 - 50 Nm
Adjustment Screw Internal Hex Size	5/32 in.	4 mm
Adjustment Locknut/Cap Hex Size	9/16 in.	15 mm
Adjustment Nut Torque	80 - 90 lbf in.	9 - 10 Nm

3.4.4 Proportional Pressure Relief Valve - FLUIDTEAM AUTOMATIONSTECHNIK**:**

The proportional pressure relief valve of the size 05 is a direct operated valve. With this valve pressures can be set proportionally to the solenoid current. If the pressure at the port P is rising over the momentary setting (solenoid current), the valve opens and lets the medium flow after port T. If the pressure drops again, the valve closes with small hysteresis. The ports P and T are loadable up to 350 bar. In order to achieve an optimal dissolution, many pressure ranges are available. The valve has a fast, precise and good-natured responding mode. It is relatively insensitive in relation to oil pollutions. All important parts are hardened and grinded.

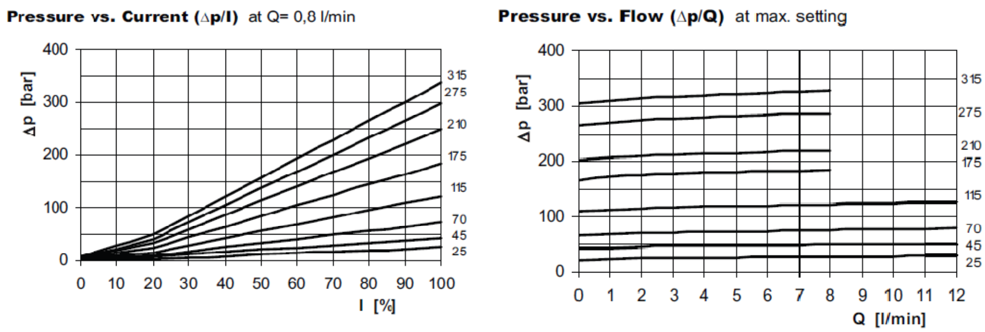


Fig 3.9: Graph showing Δp vs I current relationship of valve

3.5 Current Setting at Different Layers:

Now we need to set the Current of the valve to a specific value as required by our system in order to reduce the extra tension in the rope.

3.5.1 1st Layer Current Requirement:

According to the Graph-01

Pressure Required in 1st Layer = 132.64

Current Required, $\mathbf{I_1 = 325\ mA\ @\ 132.64\ bar}$

3.5.2 2nd Layer Current Requirement:

According to the Pressure Vs Current Graph-01

Pressure Required in 1st Layer = 146.40

Current Required, $\mathbf{I_2 = 345\ mA\ @\ 146.40\ bar}$

3.5.3 3rd Layer Current Requirement:

According to the Pressure Vs Current Graph-01

Pressure Required in 1st Layer = 160.0

Current Required, $\mathbf{I_3 = 375\ mA\ @\ 160.0\ bar}$

The current calculated above given to the valve will set the valve at the required pressure which in turn will produce the desired tensioning in the rope.

CHAPTER 4

RESULTS

4. Results:

By introducing new hydraulic circuit, following results & benefits were achieved:

1. Increased Cutter Weight on Ground
2. Less Power Consumption
3. Cost Effective

4.1 Increased Cutter Weight On Ground:

One of the most important factors during trench cutting operation is the effective weight acted upon on ground by the trench cutter. Its importance increases especially when the Strata is Hard. With the change in existing hydraulic circuit in order to maintain the tension in the wire rope constant, the weight of cutter increased on ground because the extra pull experienced by the cutter due to change layer of tension winch is removed.

Pull on the Cutter due to Tension Winch wire rope in 1st Layer:

$$\boldsymbol{F_1 = 24{,}014\ N}$$

Pull on the Cutter due to Tension Winch wire rope in 2nd Layer:

$$\boldsymbol{F_2 = 21{,}770.7\ N}$$

Total weight of Cutter	= 37,500 Kg = 37.5 ton
Displaced volume of the Cutter	= 4.08 cubic meter
Density of Bentonite	= 1,100 kg/m^3
Weight of Displaced Bentonite	= 1,100 x 4.08
	= 4,488 kg
Weight of Cutter in Bentonite	= 37,500-4,488
	= 33,012 Kg
Number of wire tensioning ropes attached with cutter	= 02

4.1.1 Weight increased in 1st Layer

Pull on the cutter due to wire tensioning ropes in 1st Layer before modification	= 02 x 24,014 N 48,028 N
	= 4,900.8 Kg

Net Weight of Cutter on Ground Before Circuit Amendment in 1st Layer: = 33,012-4,900.8

= 28,111.2 Kg

Pull on the cutter due to wire tensioning ropes 1st Layer after modification = 02 x 19,910.6 N

39,821.2 N

= 4063.3 Kg

Net Weight of Cutter on Ground After Circuit Amendment in 1st Layer: = 33,012-4,063.3

= 28,948.7 Kg

4.1.1.1 Net increase in Weight on Ground = 28,948.7 – 28,111.2

= **837.5kg**

4.1.1.2 % increase of Load on ground in 1st Layer

$$= \frac{Wt_{before} - Wt_{after}}{Wt_{after}} \times 100$$

$$= \frac{28{,}948.7 - 28{,}111.2}{28{,}111.2} \times 100$$

= **2.97 %**

4.1.2 Weight increased in 2nd Layer

Pull on the cutter due to wire tensioning ropes 2nd Layer before modification = 02 x 21,770.7 N

43,541.4 N

= 4,443 Kg

Net Weight of Cutter on Ground Before Circuit Amendment in 1st Layer: = 33,012-4,443

= 28,569 Kg

Pull on the cutter due to wire tensioning ropes 2nd Layer after modification = 02 x 19,910.6 N

39,821.2 N

= 4,063.3 Kg

Net Weight of Cutter on Ground After Circuit Amendment in 2nd Layer: = 33,012-4,063.3

= 28,948.7 Kg

4.1.2.1 Net increase in Weight on Ground = 28,948.7 – 28,569

= **379.7 kg**

4.1.2.2 % increase of Load on ground in 1st Layer

$$= \frac{Wt_{before} - Wt_{after}}{Wt_{after}} \times 100$$

$$= \frac{28{,}948.7 - 28{,}569}{28{,}569} \times 100$$

= **1.32 %**

As a result of the circuit amendment, the weight of cutter was increased on ground

- Cutter Weight increased by **837.5 Kg in 1st layer i.e. a % increase of 2.97 weight**
- Cutter Weight increased by **379.7 Kg in 2nd layer i.e. a % increase of 1.32 weight**

4.2 Less Power Consumption:

The hydraulic power consumed is calculated in two modes.

Cutting Mode

Normal up/down mode

In Cutting Mode the cutter is moves very slowly in to the ground while cutting the rock/ground. In Normal up/down mode, the cutter moves fast i.e. the winch of the cutter moves up to its maximum speed.

4.2.1 Cutting Mode:

The cutting speed of the cutter depends on the Ground strata. If the earth strength is less than 10 MPa, the trench cutting speed of cutter is usually 10-12 m/hour.

$$Maximum\ speed\ of\ cutter\ up\ \&\ down\ movement = 12\ m/hr$$

$$Maximum\ speed\ of\ cutter\ up\ \&\ down\ movement = 200\ mm/min$$

4.2.1.1 Before Modification:

4.2.1.1.1 1st Layer:

$$Circumference\ of\ tension\ winch\ drum\ 1st\ Layer$$
$$= 2 \times 3.14 \times 213.5mm$$

$$Circumference\ of\ tension\ winch\ drum\ 1st\ Layer = 1{,}340.78\ mm$$

$$Speed\ of\ Drum\ = 200/\ 1{,}340\ =\ 0.149\ revolution\ per\ min$$

$$Gear\ Ratio\ =\ 83.57$$

$$Speed\ of\ Motor\ = 0.149 * \ 83.57$$

$$Speed\ of\ Motor\ = 12.45\ rpm$$

$$Volumetric\ Efficiency\ of\ Piston\ motor\ =\ 0.86$$

$$Hydraulic\ Oil\ Flow\ rate\ = \frac{V_g\ \times n}{1000\ \times\ \eta_v}$$

$$Hydraulic\ Oil\ Flow\ rate\ = \frac{28\ \times 12.45}{1000\ \times\ 0.86}$$

$$Hydraulic\ Oil\ Flow\ rate\ in\ 01\ motor = 0.405\ lpm$$

$$Hydraulic\ Oil\ Flow\ rate\ in\ 02\ motors = 0.810\ lpm$$

$$Power\ consumption\ in\ 1st\ layer\ =\ \frac{pQ}{600}$$

$$Power\ consumption\ in\ 1st\ layer\ =\ \frac{160.0 \times\ 0.810}{600}$$

$$\boldsymbol{Power\ consumption\ in\ 1st\ layer\ =\ 216watt}$$

4.2.1.1.2 2nd Layer:

$$Circumference\ of\ tension\ winch\ drum\ 2nd\ Layer\ =\ 2\ *\ 3.14\ *\ 235.5mm$$

$$Circumference\ of\ tension\ winch\ drum\ 2nd\ Layer =\ 1{,}478.94\ mm$$

$$Speed\ of\ Drum\ =\ \frac{200}{1{,}478.94}\ =\ 0.135\ revolution\ per\ min$$

$$Gear\ Ratio\ =\ 83.57$$

$$Speed\ of\ Motor\ = 0.135\ *\ 83.57$$

$$Speed\ of\ Motor\ = 11.2\ rpm$$

$$Volumetric\ Efficiency\ of\ Piston\ motor\ =\ 0.86$$

$$Hydraulic\ Oil\ Flow\ rate\ = \frac{V_g\ \times n}{1000\ \times\ \eta_v}$$

$$Hydraulic\ Oil\ Flow\ rate\ = \frac{28\ \times 11.2}{1000\ \times\ 0.86}$$

$$Hydraulic\ Oil\ Flow\ rate\ in\ 1st\ \ motor\ = 0.367\ lpm$$

$$Hydraulic\ Oil\ Flow\ rate\ in\ 2nd\ motor\ = 0.735 lpm$$

$$Power\ consumption\ in\ 2nd\ \ layer\ = \frac{pQ}{600}$$

$$Power\ consumption\ in\ 1st\ layer\ = \frac{160.0\ \times 0.735}{600}$$

$$\boldsymbol{Power\ consumption\ in\ 2nd\ layer\ = 196\ watt}$$

4.2.1.1.3 3rd Layer:

$$Circumference\ of\ tension\ winch\ drum\ 2nd\ Layer\ =\ 2\ *\ 3.14\ *\ 235.5mm$$

$$Circumference\ of\ tension\ winch\ drum\ 2nd\ Layer =\ 1{,}617.1mm$$

$$Speed\ of\ Drum\ =\ \frac{200}{1{,}617.1}\ =\ 0.123 revolution\ per\ min$$

$$Gear\ Ratio\ =\ 83.57$$

$$Speed\ of\ Motor\ = 0.123\ *\ 83.57$$

$$Speed\ of\ Motor\ = 10.27\ rpm$$

$$Volumetric\ Efficiency\ of\ Piston\ motor\ =\ 0.86$$

$$Hydraulic\ Oil\ Flow\ rate\ = \frac{V_g\ \times n}{1000\ \times\ \eta_v}$$

$$Hydraulic\ Oil\ Flow\ rate\ = \frac{28\ \times 10.27}{1000\ \times\ 0.86}$$

$$Hydraulic\ Oil\ Flow\ rate\ in\ 1st\ motor\ = 0.334\ lpm$$

$$Hydraulic\ Oil\ Flow\ rate\ in\ 2nd\ motor = 0.669\ lpm$$

$$Power\ consumption\ in\ 3rd\ \ layer\ =\ \frac{pQ}{600}$$

$$Power\ consumption\ in\ 1st\ layer\ =\ \frac{160\ \times\ 0.669}{600}$$

$$\boldsymbol{Power\ consumption\ in\ 3rd\ \ layer\ =\ 178.8\ watt}$$

4.2.1.2 After Modification:

4.2.1.2.1 1st Layer:

$$Power\ consumption\ in\ 1st\ layer\ =\ \frac{132.64\ \times\ 1.352}{600}$$

$$\boldsymbol{Power\ consumption\ in\ 1st\ layer\ =\ 179\ watt}$$

4.2.1.2.2 2nd Layer:

$$Power\ consumption\ in\ 1st\ layer\ =\ \frac{146.40\ \times\ 1.22}{600}$$

$$\boldsymbol{Power\ consumption\ in\ 2nd\ layer\ =179\ watt}$$

4.2.1.2.3 3rd Layer:

$$Power\ consumption\ in\ 1st\ layer\ =\ \frac{160\ \times\ 1.120}{600}$$

$$\boldsymbol{Power\ consumption\ in\ 3rd\ \ layer\ =\ 179\ watt}$$

4.2.1.3 Power Saved – 1st Layer:

$$P_{saved} = P_{before} - P_{after}$$

$$P_{saved} = 216 - 179$$

$$\boldsymbol{P_{saved} = 37\ Watt}$$

% Increase in Efficiency of Winch Hydraulic System:

$$Efficiency = \frac{P_{before} - P_{after}}{P_{before}} \times 100$$

$$Efficiency = \frac{216 - 179}{216} \times 100$$

$$\boldsymbol{Efficiency = 17.12}\ \%$$

4.2.1.4 Power Saved – 2nd Layer:

$$P_{saved} = P_{before} - P_{after}$$

$$P_{saved} = 196 - 179$$

$$\boldsymbol{P_{saved} = 17\ Watt}$$

$$\boldsymbol{P_{saved} = 17\ Watt}$$

% Increase In Efficiency Of Winch Hydraulic System:

$$Efficiency = \frac{P_{before} - P_{after}}{P_{before}} \times 100$$

$$Efficiency = \frac{196 - 179}{196} \times 100$$

$$\boldsymbol{Efficiency = 8.67}\ \%$$

4.2.2 Normal Up/DN Mode:

In Normal up/Down mode, the cutter is being moved with a speed range of 0- 25 m/min. the tension winch rope also moves with this speed. When the cutter moves down, maximum oil flow is passed through the pressure sequence /relief valve

$$Maximum\ speed\ of\ cutter\ up\ \&\ down\ movement = 25\ m/min$$

$$Maximum\ speed\ of\ cutter\ up\ \&\ down\ movement = 25000\ mm/min$$

4.2.2.1 Before Modification:

4.2.2.1.1 1st Layer:

$$Circumference\ of\ tension\ winch\ drum\ 1st\ Layer$$
$$= 2 \times 3.14 \times 213.5mm$$

$$Circumference\ of\ tension\ winch\ drum\ 1st\ Layer = 1{,}340.78\ mm$$

$$Speed\ of\ Drum = 25000/\ 1{,}340 = 18.65\ revolution\ per\ min$$

$$Gear\ Ratio\ =\ 83.57$$

$$Speed\ of\ Motor\ = 18.65 * \ 83.57$$

$$Speed\ of\ Motor\ = 1559.14\ rpm$$

$$Volumetric\ Efficiency\ of\ Piston\ motor\ =\ 0.86$$

$$Hydraulic\ Oil\ Flow\ rate\ = \frac{V_g\ \times n}{1000\ \times\ \eta_v}$$

$$Hydraulic\ Oil\ Flow\ rate\ = \frac{28\ \times 1559.14}{1000\ \times\ 0.86}$$

$$Hydraulic\ Oil\ Flow\ rate\ in\ 01\ motor = 50.76\ lpm$$

$$Hydraulic\ Oil\ Flow\ rate\ in\ 02\ motors = 101.52\ lpm$$

$$Power\ consumption\ in\ 1st\ layer\ =\ \frac{pQ}{600}$$

$$Power\ consumption\ in\ 1st\ layer\ =\ \frac{160.0 \times\ 101.52}{600}$$

$$\boldsymbol{Power\ consumption\ in\ 1st\ layer\ =\ 27,073\ watt}$$

4.2.2.1.2 2nd Layer:

$$Circumference\ of\ tension\ winch\ drum\ 2nd\ Layer\ =\ 2\ *\ 3.14\ *\ 235.5mm$$

$$Circumference\ of\ tension\ winch\ drum\ 2nd\ Layer =\ 1{,}478.94\ mm$$

$$Speed\ of\ Drum\ =\ \frac{25{,}000}{1{,}478.94}\ =\ 16.90\ revolution\ per\ min$$

$$Gear\ Ratio\ =\ 83.57$$

$$Speed\ of\ Motor\ = 16.90\ *\ 83.57$$

$$Speed\ of\ Motor\ = 1412.3\ rpm$$

$$Volumetric\ Efficiency\ of\ Piston\ motor\ =\ 0.86$$

$$Hydraulic\ Oil\ Flow\ rate\ = \frac{V_g\ \times n}{1000\ \times\ \eta_v}$$

$$Hydraulic\ Oil\ Flow\ rate\ = \frac{28\ \times 1412.6}{1000\ \times\ 0.86}$$

$$Hydraulic\ Oil\ Flow\ rate\ in\ 1st\ \ motor\ = 45.9\ lpm$$

$$Hydraulic\ Oil\ Flow\ rate\ in\ 2nd\ motor\ = 91.96\ lpm$$

$$Power\ consumption\ in\ 2nd\ \ layer\ = \frac{pQ}{600}$$

$$Power\ consumption\ in\ 1st\ layer\ = \frac{160.0\ \times 91.96}{600}$$

$$\boldsymbol{Power\ consumption\ in\ 2nd\ layer\ = 24,524\ watt}$$

4.2.2.1.3 3rd Layer:

$$Circumference\ of\ tension\ winch\ drum\ 2nd\ Layer\ =\ 2\ *\ 3.14\ *\ 235.5mm$$

$$Circumference\ of\ tension\ winch\ drum\ 2nd\ Layer =\ 1{,}617.1mm$$

$$Speed\ of\ Drum\ = \frac{25{,}000}{1{,}617.1}\ =\ 15.45 revolution\ per\ min$$

$$Gear\ Ratio\ =\ 83.57$$

$$Speed\ of\ Motor\ = 15.45\ *\ 83.57$$

$$Speed\ of\ Motor\ = 1291.9\ rpm$$

$$Volumetric\ Efficiency\ of\ Piston\ motor\ =\ 0.86$$

$$Hydraulic\ Oil\ Flow\ rate\ = \frac{V_g\ \times n}{1000\ \times\ \eta_v}$$

$$Hydraulic\ Oil\ Flow\ rate\ = \frac{28\ \times 1291.9}{1000\ \times\ 0.86}$$

$$Hydraulic\ Oil\ Flow\ rate\ in\ 1st\ motor\ = 42.06\ lpm$$

$$Hydraulic\ Oil\ Flow\ rate\ in\ 2nd\ motor = 84.12\ lpm$$

$$Power\ consumption\ in\ 3rd\ \ layer\ =\ \frac{pQ}{600}$$

$$Power\ consumption\ in\ 1st\ layer\ =\ \frac{160\ \times\ 84.12}{600}$$

$$\boldsymbol{Power\ consumption\ in\ 3rd\ \ layer\ =\ 22,434\ watt}$$

4.2.2.2 After Modification:

4.2.2.2.1 1st Layer:

$$Power\ consumption\ in\ 1st\ layer\ =\ \frac{132.64\ \times 101.52}{600}$$

$$\boldsymbol{Power\ consumption\ in\ 1st\ layer\ =\ 22,442\ watt}$$

4.2.2.2.2 2nd Layer:

$$Power\ consumption\ in\ 1st\ layer\ =\ \frac{146.40\ \times 91.96}{600}$$

$$\boldsymbol{Power\ consumption\ in\ 2nd\ layer\ = 21,518\ watt}$$

4.2.2.2.3 3rd Layer:

$$Power\ consumption\ in\ 1st\ layer\ =\ \frac{160\ \times 84.12}{600}$$

$$\boldsymbol{Power\ consumption\ in\ 3rd\ \ layer\ =\ 22,432\ watt}$$

4.2.2.3 Power Saved – 1st Layer:

$$P_{saved} =\ P_{before} -\ P_{after}$$

$$P_{saved} = 27{,}073 - 22{,}442$$

$$\boldsymbol{P_{saved} = 4,631\ Watt}$$

% Increase in Efficiency of Winch Hydraulic System:

$$Efficiency = \frac{P_{before} -\ P_{after}}{P_{before}} \times 100$$

$$Efficiency = \frac{27{,}073 - 22{,}442}{27{,}073} \times 100$$

$$\boldsymbol{Efficiency = 17.1}\ \%$$

4.2.2.4 Power Saved – 2nd Layer:

$$P_{saved} = P_{before} - P_{after}$$

$$P_{saved} = 24{,}524 - 21{,}518$$

$$\boldsymbol{P_{saved} = 3{,}006\ Watt}$$

% Increase In Efficiency Of Winch Hydraulic System:

$$Efficiency = \frac{P_{before} - P_{after}}{P_{before}} \times 100$$

$$Efficiency = \frac{24{,}524 - 21{,}518}{24{,}524} \times 100$$

$$\boldsymbol{Efficiency = 12.25}\ \%$$

4.3 Cost Effective:

The project is done for a contracting company. One of the major requirements of such companies is to complete the job/task in an economical way. The cost incurred on this new amendment was much less than the old valve setup.

4.3.1 Cost of Valves with Existing Circuit:

Sequence Valve:	890.00 x 2 = USD 1,780.00
Directional Valve:	USD 200.00
Hydraulic Manifolds:	USD 300.00
Total:	**USD 2,280.00 Approx.**

4.3.2 Cost of Valves with Amended Circuit:

Prop. Pressure Sequence valve:	USD 790.00
Hydraulic Manifold:	USD 80.00

Hydraulic Filter	USD 100.00
Total:	**USD 1,000.00 Approx.**

The amount saved by using new proposed circuit was

USD (2,280 – 1000) = USD 1,280/-

4.4 Summary of Benefits Achieved:

Optimization was done using Proportional pressure sequence Valve and following results and benefits were achieved in return:

a. The weight of cutter was increased on Ground up to **837.5 Kg** which is **2.97% in 1st Layer** and **379.71Kg** which is **1.32%** in **2nd layer**
b. The power consumed was reduced to **37watt** which is **17.12%** in **1st layer** and **17watt** which is **8.67%** in **2nd layer**
c. The cost of the valves was reduced from **USD 2,280.00** to **USD 1,000.00**
d. It became easy for the operator to set the pressure setting from the operator's cabin rather than going back to the valve to set it manually in case if the pressure is disturbed or changed.
e. Now there are fewer components to trouble shoot than with the previous hydraulic circuit.
f. Fewer inventories are needed to maintain so less capital is involved.
g. Due to the removal of extra line pull in rope, the service life of the rope will increase.

CHAPTER 5

CONCLUSIONS

5. Conclusions:

The circuit was drawn in Automation Studio software. Automation Studio™ is an innovative system design, simulation and project documentation software solution for the design and support of automation and fluid power systems.

P-type controller was used in order to change the current setting of the valve from one layer to other layer. An already installed encoder for some other purpose in the crane boom was used to detect that the rope is in which layer but the simulation didn't include the encoder feedback and is given the signal in order to send information to the controller that the layer has changed.

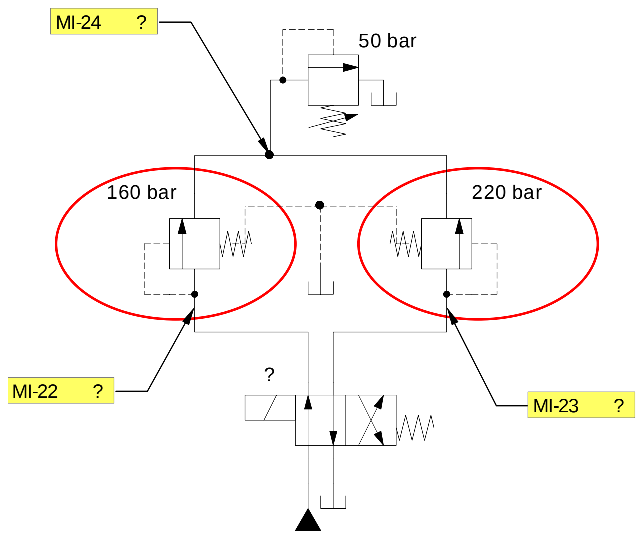


Figure 5.1: Existing Hydraulic circuit

The signal is given by means of a set point generator. This set point generator gives signal to the Controller which further set the current value of the proportional valve. A graph is being among the Set Point Generator value, the controller output and the pressure setting of the valve. Below are given the graphs showing simulation results of pressure relief /sequence valve at various current setting.

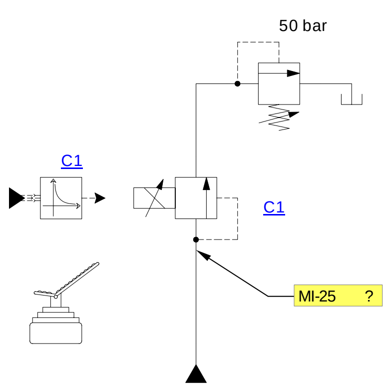


Figure 5.2: New Proposed Hydraulic circuit

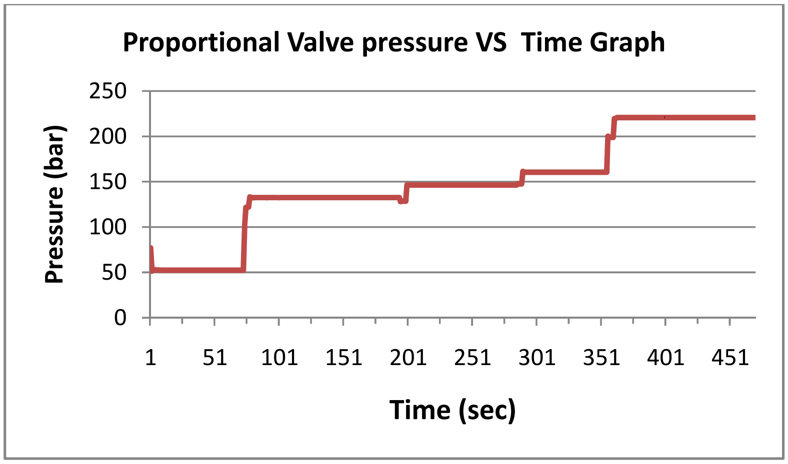


Fig 5.3 Proportional Valve pressure VS Time Graph

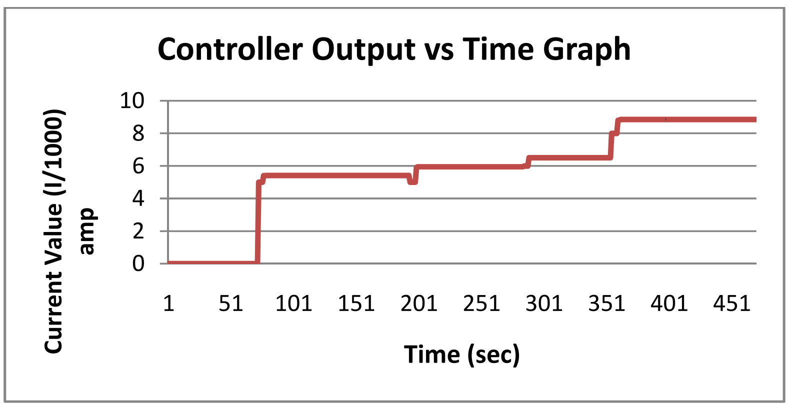


Fig 5.4 Controller Output vs Time Graph

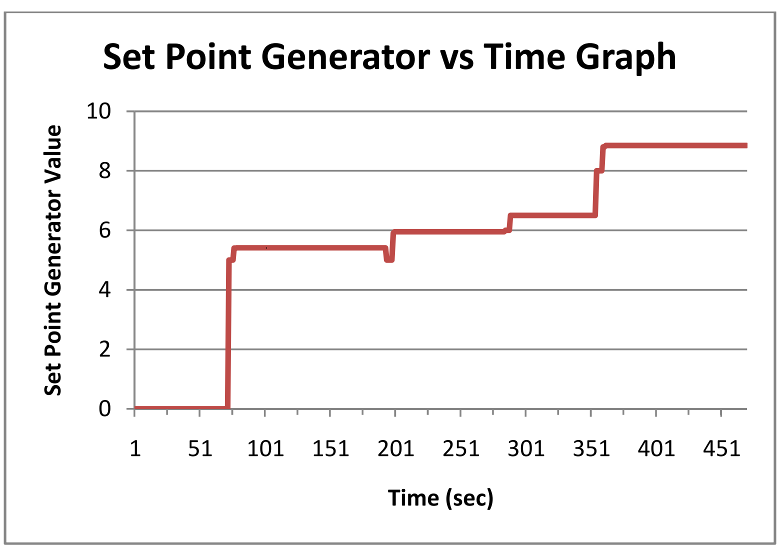


Fig 5.5 Set Point Generator vs Time Graph

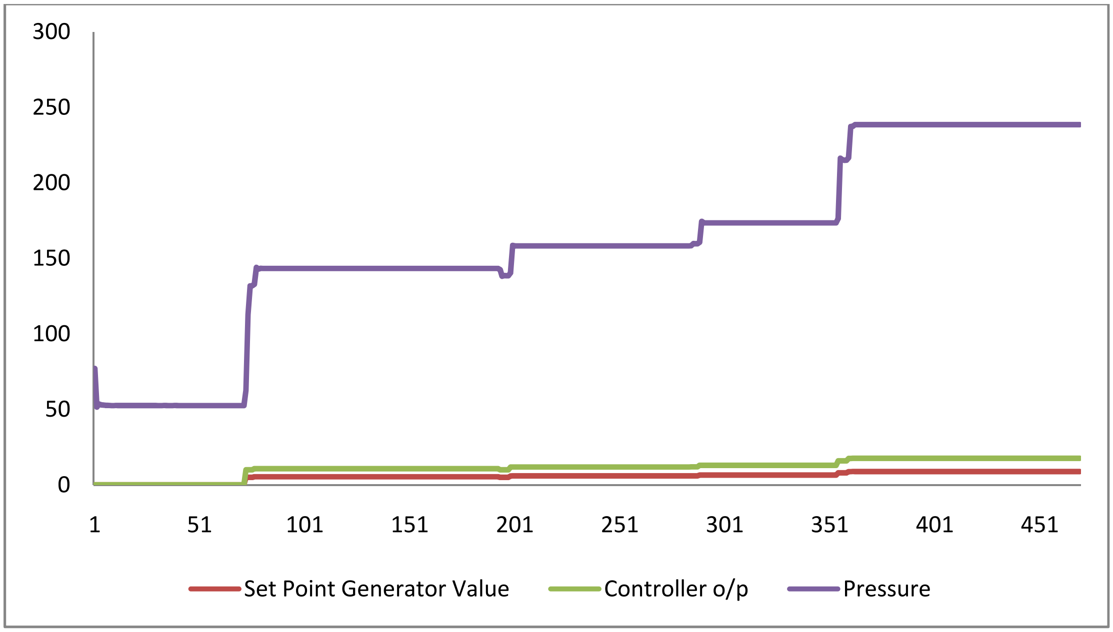


Figure 5.6: Graph showing Set point generator value, controller o/p and pressure of valve w.r.t. to time.

CHAPTER 6

SNAPSHOTS OF EMPERIMENT

6. Snapshots of Experiment

Below are shown the snapshots of the valves which were being mounted on the crane.

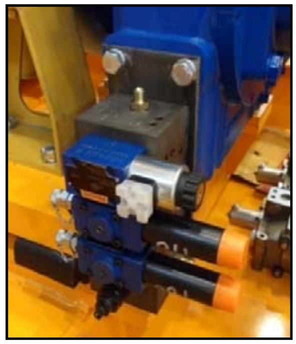


Fig 6.1: Old/Existing hydraulic Circuit Valves and Manifold

Fig 6.2: New/Amended hydraulic Circuit Valves and Manifold

Fig 6.3: Valves installed in the crane LIEBHERR HS885HD with the pump.

Fig 6.4: Old and New Hydraulic Circuit Valves installed in the crane LIEBHERR HS885HD with the pump for Testing Purpose.

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