Department of Mining Machinery Engineering

Indian Institute of Technology

(Indian School of Mines) Dhanbad

Project Report

On

ENERGY REGENERATIVE EXCAVATOR SWING SYSTEM USING ACCUMULATOR

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Acknowledgement

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Certificate

This is to certify that the project entitled "ENERGY REGENERATIVE EXCAVATOR SWING S**YSTEM USING ACCUMULATOR"** of Prince Kunal (17JE002742) is a bonafide work carried out by them under my supervision and guidance. The results embedded in this work have neither been published before nor submitted to any other institutions for the award of degree or diploma to the best of my knowledge and belief.

Dr Ajit kumar
(Asst Professor)

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ABSTRACT

Excavators are versatile machine used in earthmoving application. In order to increase the efficiency ofHydraulic excavators, we propose a new energy regenerative swing system with hydraulic circuit havingvariable displacement pump, fixed displacement motor, accumulator, direction control valves and flowcontrol valve for high energy efficient construction machine. The proposed hydraulic circuit is design andthe simulation is perform with all actual field data and parameters. Simulation output is concluded and it shows that approximately 15%-20% energy is regenerated by this hydraulic circuit .This store energy(regenerated energy) is used to hydraulic pump in next cycle which decrease the energy consumption of themain pump.

Keywords : Excavators|| Energy regeneration || Accumulator ||

OBJECTIVE

To study the hydraulic circuit of the swing motion of the excavator and design a new hydraulic circuit usingaccumulator that regenerate the energy during swing motion.In order to accomplish the objective of thisproject, the focus is given to following aspects.

1. To study the hydraulic circuit of swing system of excavator.
2. To design the hydraulic circuit using accumulator.
3. To simulate the proposed hydraulic circuit that regenerate the energy during swing motion.

Chapter 1

INTRODUCTION

In order to solve the environmental pollution issue, high efficiency excavators need to develop. Hydraulicexcavators are widely used in many earthmoving application in mining sector. This heavy machinery consumes a lot of energy during operation time. The regenerative hydraulic circuit is efficient way to saveenergy and reduce the energy consumptions.

The regenerative hydraulic circuit consist of variable displacement pump, fixed displacement motor, 2-way directional control valves, hydraulic flow rate sensor, hydraulic pressure sensor. During 90 degree excavationprocess of large scale excavator, 49 % of time consist of swing process. This clearly state thatSwing process is the major process done by excavator to transfer the material from one point to another. Theupper structure of the excavators is driven by the swing hydro motor.

In normal excavator, every time high pressure fluid flow from hydraulic pump to hydro motor. The pressuredifference about the hydro motor is directly proportional to the speed of the hydro motor. This high flow fluidcause the rotation of the upper deck. After accelerating it moved through some angle and need to deaccelerate to stop at desire point, this is done by applying Mechanical brakes during swing mechanism.

In the proposed hydraulic circuit , the return line of the circuit in closed loop is not directly connected to thepump. The return line is connected to the accumulator which store the pressure energy whileapplying the mechanical brake to reduce the speed of the hydro motor. This return line fluid store energy inthe gas charged accumulator which is supplied to the hydraulic pump in next cycle of operation whichdecrease the energy consumption of the main pump.

Chapter 2

ACCUMULATOR

1. Introduction to Accumulators :

A hydraulic accumulator is a device that stores the potential energy of an incompressible fluid held underpressure by an external source against some dynamic force. This dynamic force can come from differentsources. The stored potential energy in the accumulator is a quick secondary source of fluid power capableof doing useful work.

2. Types of Accumulators :

1. Weight-loaded or gravity accumulator:

It is a vertically mounted cylinder with a large weight. When the hydraulic fluid is pumped into it, theweight is raised. The weight applies a force on the piston that generates a pressure on the fluid side ofpiston. The advantage of this type of accumulator over other types is that it applies a constant pressure onthe fluid throughout its range of motion. The main disadvantage is its extremely large size and heavyweight. This makes it unsuitable for mobile application.

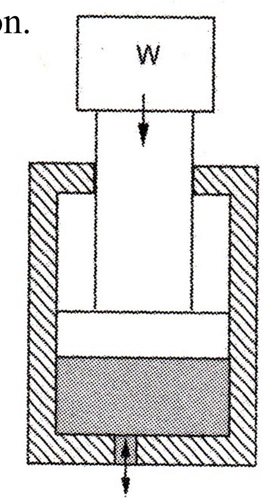


Fig 1. Weight-loaded accumulator:

2. Spring-loaded accumulator:

A spring-loaded accumulator stores energy in the form of a compressed spring. A hydraulic fluid ispumpedinto the accumulator, causing the piston to move up and compress the spring as shown in Fig. .The compressedspring then applies a force on the piston that exerts a pressure on the hydraulic fluid.This type of accumulatordelivers only a small volume of oil at relatively low pressure. Furthermore, the pressure exertedon the oil is not constant as in the dead-weight-type accumulator. As the springs are compressed, theaccumulator pressure reaches its peak, and as the springs approach their free lengths, the accumulator pressuredrops to a minimum.

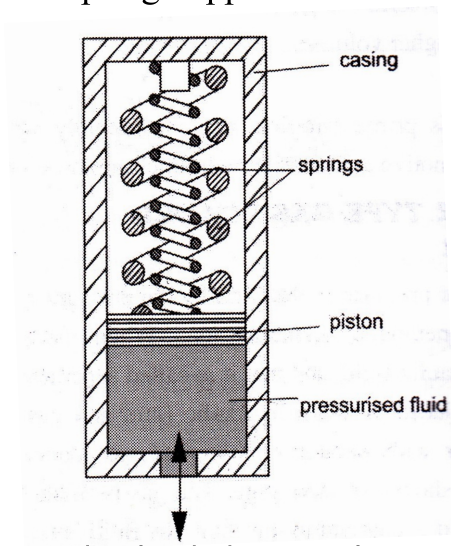


Fig 2. Spring-loaded accumulator

3. Gas-Loaded accumulator:

A gas-loaded accumulator is popularly used in industries. Here the force is applied to the oilusing compressedair. Schematic diagram of a gas loaded accumulator is shown inFig. A gas accumulator can bevery large and is often used with water or highwater-based fluids using air as a gas charge. Typicalapplication is on water turbines toabsorb pressure surges owing to valve closure and on ram pumps to smoothout the deliveryflow.

There are two types of gas-loaded accumulators:

1. Non-separator-type accumulator: Here the oil and gas are not separated. Hence, they are always placedvertically.

2. Separator-type accumulator: Here the oil and gas are separated by an element.

(a) Piston-type accumulator:

Schematic diagram of a piston type accumulator is shown in Fig..It consists of a cylinder with a freelyfloating piston with proper seals. Its operation begins by charging the gas chamber with a gas (nitrogen)under a pre-determined pressure. This causes the free sliding piston to move down. Once the accumulator ispre-charged, a hydraulic fluid can be pumped into the hydraulic fluid port. As the fluid enters theaccumulator, it causes the piston to slide up, thereby compressing the gas that increases its pressure and this pressure is then applied to the hydraulic fluid through the piston. Because the piston is free sliding, thepressure on the gas and that on the hydraulic fluid are always equal.

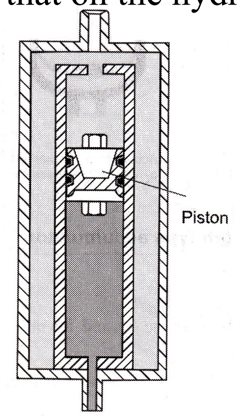


Fig 3 : Piston-type accumulator

(b) Diaphragm accumulator:

In this type, the hydraulic fluid and nitrogen gas are separated by a synthetic rubber diaphragm. Schematicdiagram of diaphragm accumulator is shown in Fig. The advantage of a diaphragm accumulator over a pistonaccumulator is that it has no sliding surface that requires lubrication and can therefore be used with fluidshaving poor lubricating qualities. It is less sensitive to contamination due to lack of any close-fittingcomponents

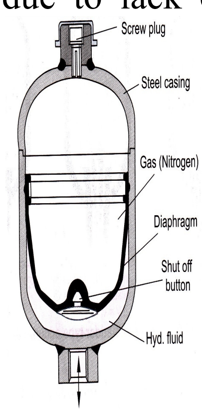


Fig 4: Diaphragm accumulator

(c) Bladder accumulator:

It functions in the same way as the other two accumulators. Schematic diagram of bladder accumulator isshown in Fig. Here the gas and the hydraulic fluid are separated by a synthetic rubber bladder. The bladderis filled with nitrogen until the designed pre-charge pressure is achieved. The hydraulic fluid is then pumpedinto the accumulator, thereby compressing the gas and increasing the pressure in the accumulator. The portcover is a small piece of metal that protects the bladder from damage as it expands and contacts the fluidport.

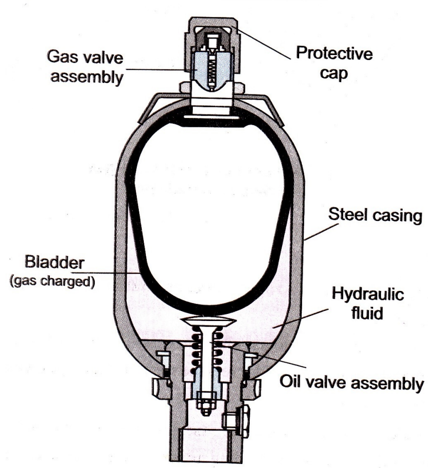


Fig 5 : Bladder accumulator

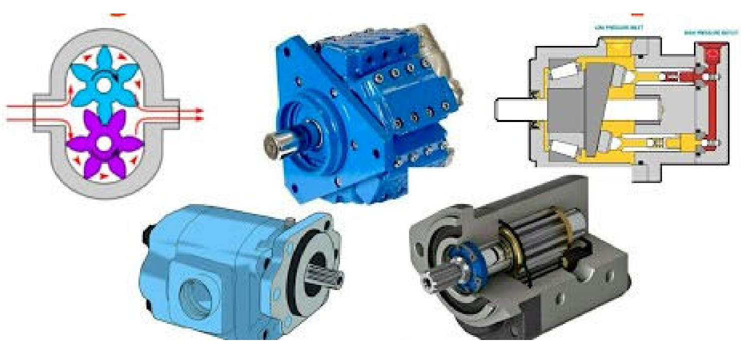
Chapter 3

COMPONENTS USED IN THE CIRCUIT

Hydraulic components and devices used in the hydraulic circuit of the swing motion of excavator.

1) HYDRAULIC PUMP :

A Hydraulic Pump is a tool that is used in hydraulic drive systems which are either hydrodynamic or hydrostatic. This is the source of power that is used to convert themechanical power to hydraulic energy. The pump generates a flow with enough power thatovercomes the pressure produced by the load at the outlet of the pump. A vacuum is createdat the outlet of the pump when the pump is operated. The vacuum forces the liquid into the inlet of the pump and delivers it to the pump outlet with mechanical actions andfinally forces the liquid into the hydraulic system.



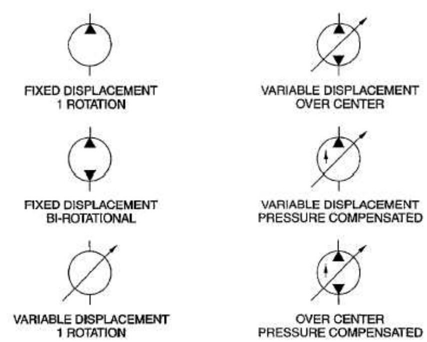


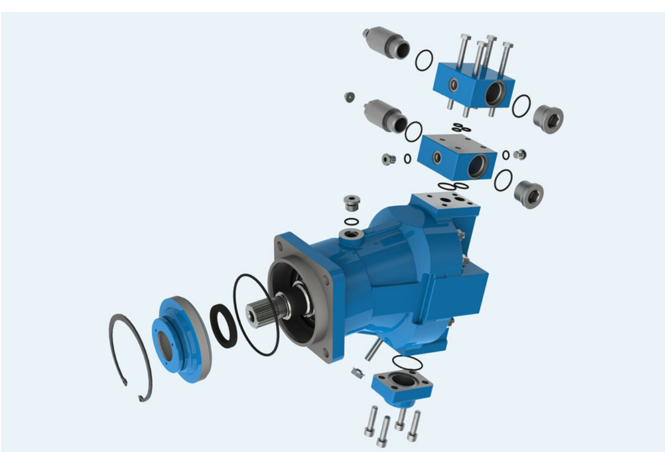
Fig 6: Hydraulic pump

Fig 7: Hydraulic pump symbol

2) Hydraulic Motor

A hydraulic motor converts hydraulic energy, in the form of pressure and flow, into rotational mechanicalenergy. The hydraulic energy is transmitted into the system via the pump, where it itself had used mechanicalforce as its source of input energy. The pump pushed on the hydraulic fluid, which in turnpushes on the gears, vanes or pistons of the hydraulic motor. It is really that simple; the pump pushes thefluid and the fluid pushes the motor.

Two qualities of a hydraulic motor are its torque and speed capability. Hydraulic motor torque is a functionof its displacement and the pressure drop across the motor, both of which deserve explanation. Displacementis defined as the theoretical volume of fluid the motor will require to turn one revolution, and this is a product of the size of the gear/vane/piston and how far the gear/vane/piston is away from its center ofrotation (i.e., the radius). A 100 cc motor will theoretically spin one revolution if you stuff 100 cc (100 ml)of fluid into it.



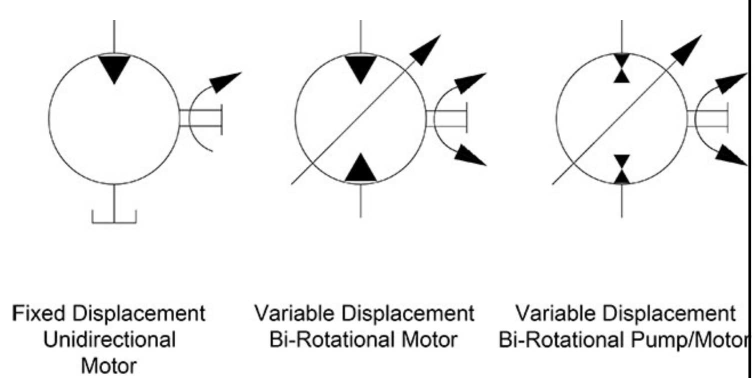


Fig 8: Hydraulic Motor

Fig 9: Hydraulic Motor symbol

4. DIRECTION CONTROL VALVE

Directional control valves (DCVs) are one of the most fundamental parts of hydraulic and pneumaticsystems. DCVs allow fluid flow (hydraulic oil, water or air) into different paths from one or more sources.DCVs will usually consist of a spool inside a cylinder which is mechanically or electrically actuated.Thesimplest DCV (Direction Control Valve) is a check valve. A check valve allows flow in one direction, butblocks the flow in the opposite direction. It is a two-way valve because it contains two ports. Figure showsthe graphical symbol of a check valve along with its no-flow and free-flow directions.

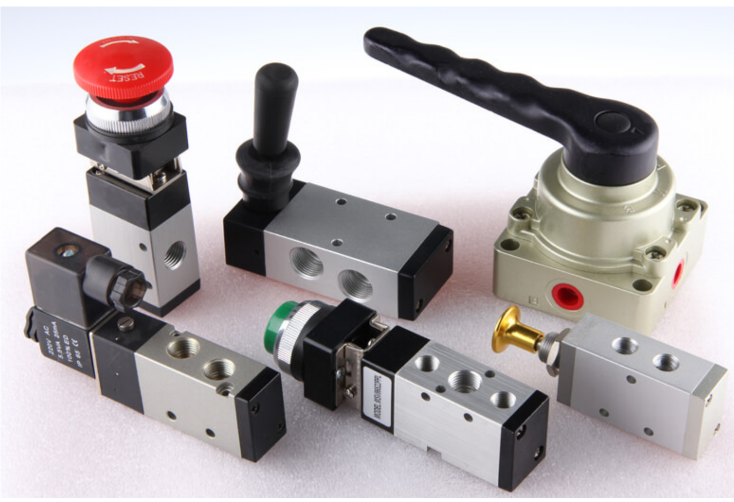


Fig 10: Direction control valve

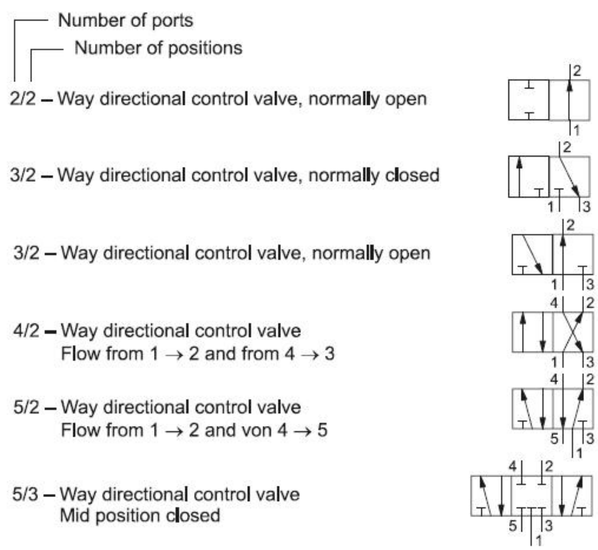


Fig 11 : DCV Symbol

5. PRESSURE RELIEF VALVE

Relief valve or pressure relief valve (PRV) is a type of safety valve used to control or limit the pressurein asystem; pressure might otherwise build up and create a process upset, instrument or equipmentfailure, orfire.The pressure is relieved by allowing the pressurized fluid to flow from an auxiliarypassage out of thesystem. The relief valve is designed or set to open at a predetermined set pressure toprotect pressure vessels and other equipment from being subjected to pressures that exceed their designlimits.When the set pressure isexceeded, the relief valve becomes the “path of least resistance” as thevalve is forced open and a portion of the fluid is diverted through the auxiliary route.

The diverted fluid (liquid, gas or liquid–gas mixture) is usually routed through a piping system known as aflare header or relief header to a central, elevated gas flare where it is usually burned and the resultingcombustion gases are released to the atmosphere.
As the fluid is diverted, the pressure inside the vessel will stop rising. Once it reaches the valve’sre-seating pressure, the valve will close. The blow down is usually stated as a percentage of set pressure andrefers to how executes opposite functions that ADC performs. This evice is generally employed tosupervise analog

Fig 12. PRV

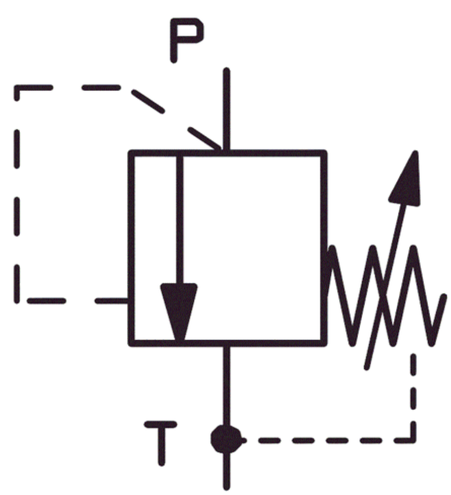


Fig 13. PRV Symbol

Chapter 4

DESIGN LAYOUT

The energy regeerative circuit of swing motion designed in this project consists of hydraulic components.The design layout shown here show the movement of fluid in different component during the completemotion.

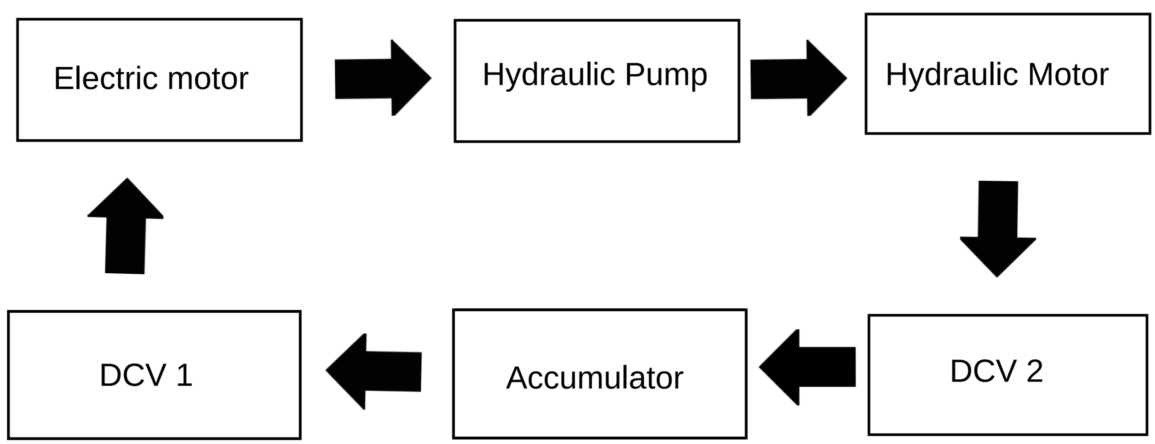


Fig 14 - Block Diagram of Model

Specification of different components used in circuit

Specification	Hydraulic Pump	Auxiliary Pump	Hydraulic Motor
Max Displacement (cm^3/rev)	400	64	240
Normal shaft angular speed (rad/sec)	188	188	188
Volumetric efficiency at normal condition	0.92	0.92	0.92

Specification	PRV	Check Valve	DCV
Max passage area(m^2)	1e^-4	1e^-4	0.5e^-4
Flow discharge coeff.	0.7	0.7	0.7
Valve Max Opening(m^2)	-	-	0.005
Cracking pressure(pa)	-	0.3e^5	-
Max Opening pressure(pa)	-	1.2e^5	-
Valve pressure Setting(bar)	250	-	-
Valve regulation range(pa)	5e5	-	-

Specification	Accumulator
Total accumulated volume(L)	20
Min gas volume(mm^3)	4
Gauge Pressure(bar)	150

Gear Box reduction ratio	200

CHAPTER 5
HYDRAULIC MODEL

The actual hydraulic circuit is shown in the fig shown below. The circuit consists of hydraulic pump,hydraulicmotor, Direction control valve ,Pressure relief valve,check valve,accumulator,hydraulic pressure sensor andhydraulic flow rate sensor.

Different color line shown are:

1. Brown line - Hydraulic line
2. green line - Mechanical line
3. black line - electrical line

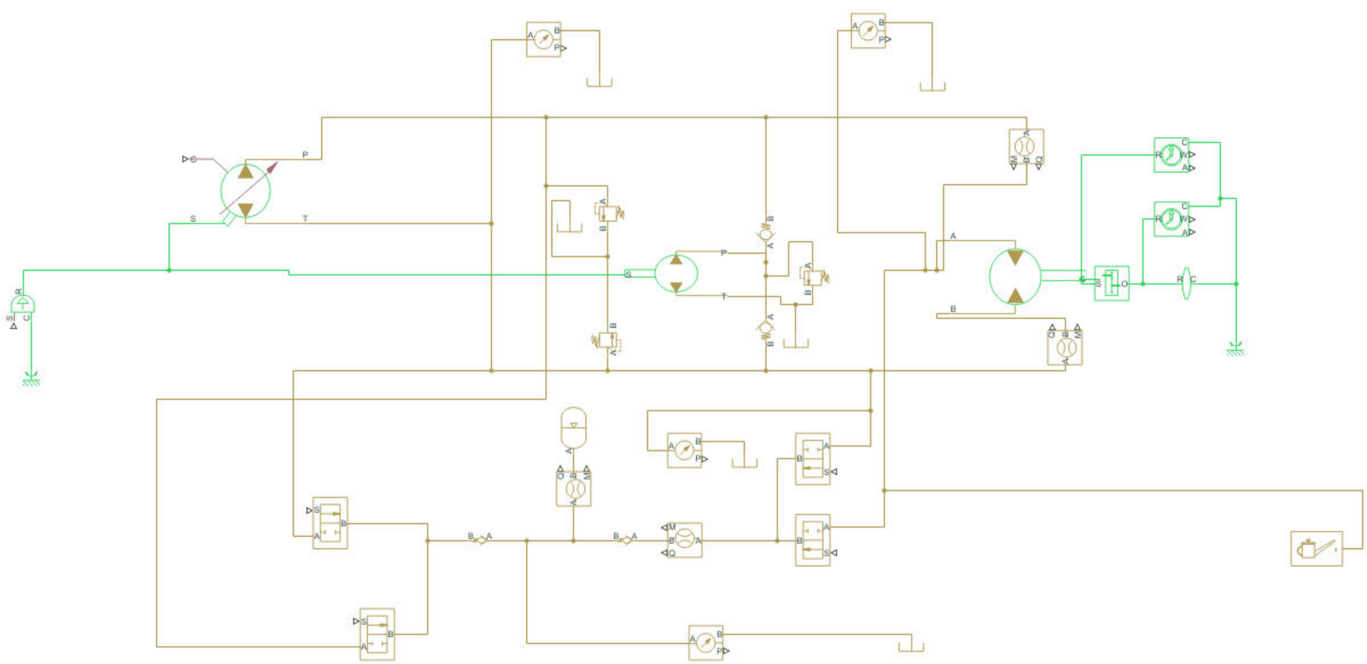


Fig 15 :Proposed Hydraulic circuit

CHAPTER 6
WORKING PRINCIPLE

In excavator, every time high pressure fluid flow from hydraulic pump to hydro motor. The pressuredifference about the hydro motor is directly proportional to the speed of the hydro motor. This highflow fluid cause the rotation of the upper deck. After accelerating it moved through some angle andneed to deaccelerate to stop at desire point, this is done by applying Mechanical brakes during swingmechanism.

In the proposed hydraulic circuit (Fig 16), the return line of the circuit in closed loop is not directlyconnected to the pump. The return line is connected to the accumulator which store the pressureenergy while applying the mechanical brake to reduce the speed of the hydro motor. This return linefluid store energy in the gas charged accumulator which is supplied to the hydraulic pump in next cycle of operation which decrease the energy consumption of the main pump.

The cycle time of one complete rotation is taken in Matlab simulation is 50 sec and the degree of rotationis 180 degree from hauling to dumping point.In complete rotation it move 360 degree.The cycle time consist of bucket loading time of loads like soil,rocks or coal,swing motion with load fordumping, dumping time for load and swing time to reach point of hauling.During this time thepump,DCV1 and DCV2 are Open/Close according to the requirements.

The input signal for Pump,DCV1and DCV2 are shown below:

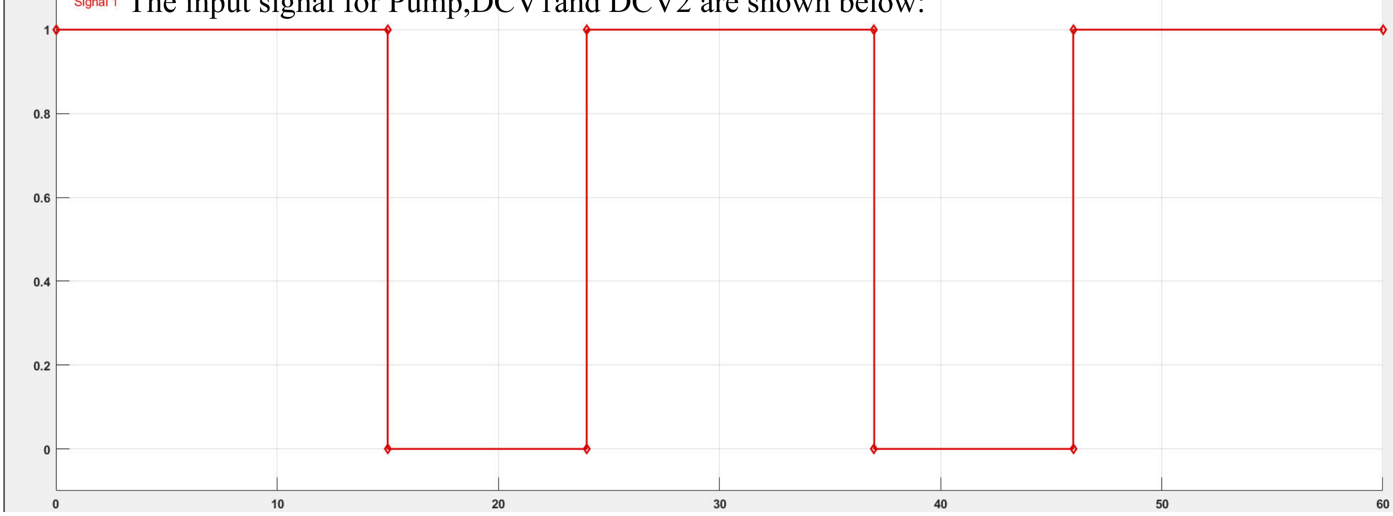


Fig 16 (a) Pump Signal

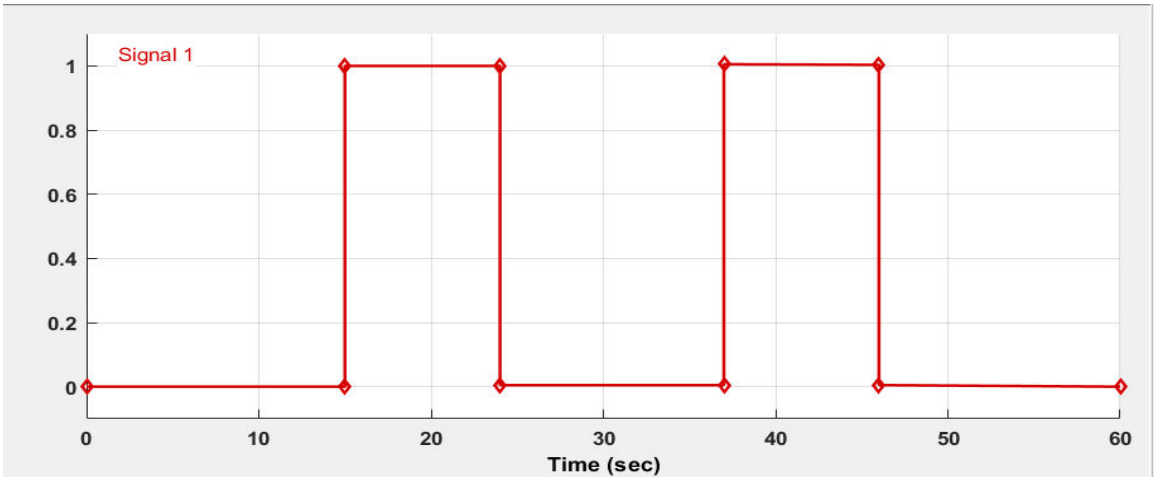


Fig 16 (b) DCV Signal [Between Motor To Accumulator]

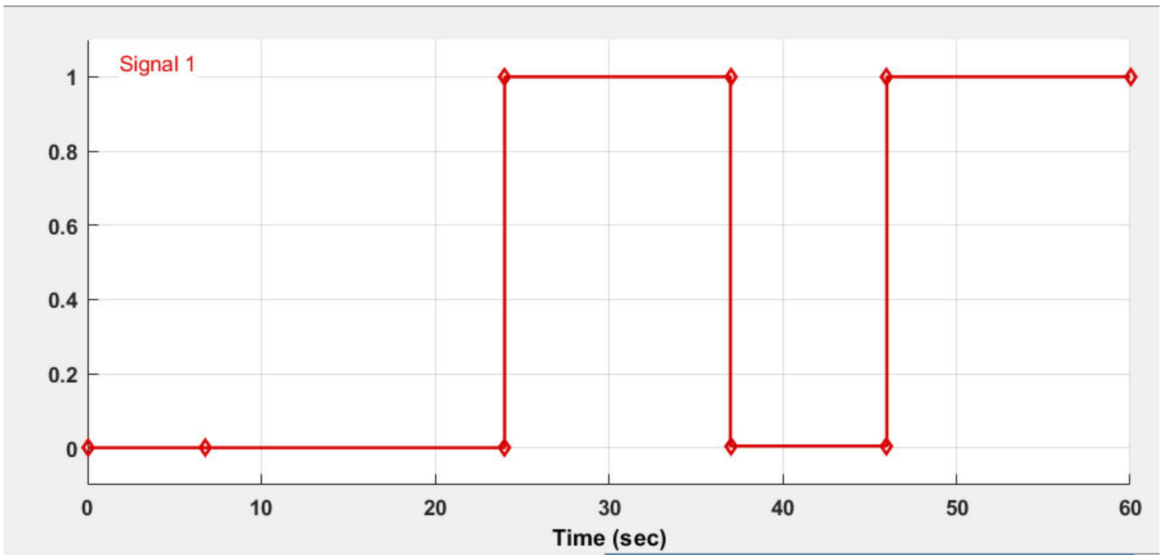


Fig 16 (c) DCV Signal [Between Accumulator To Pump]

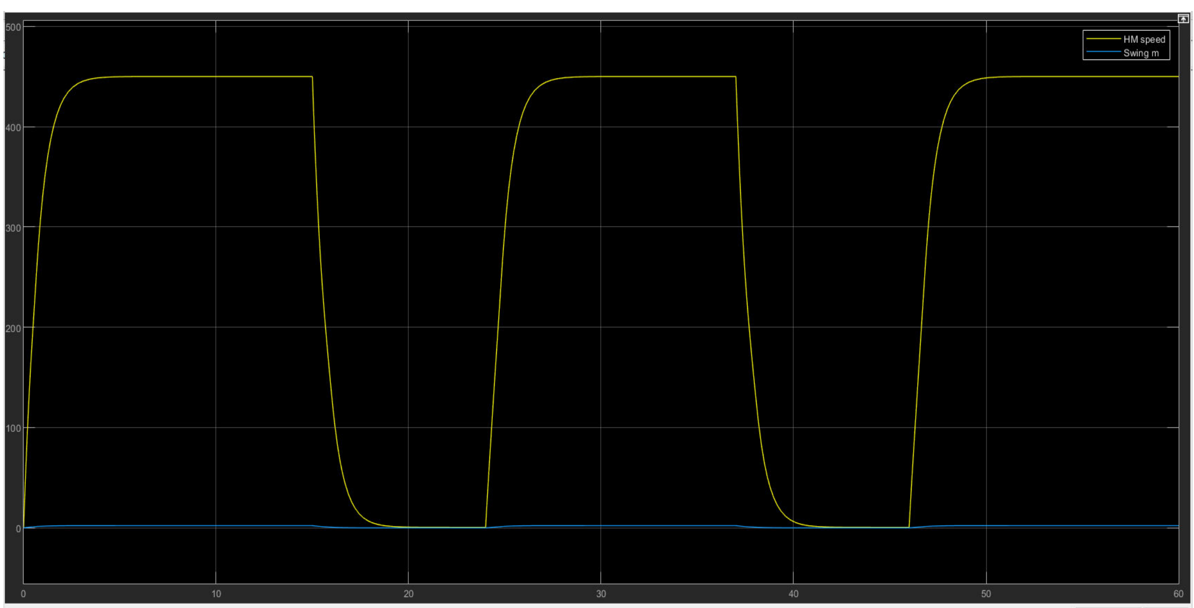
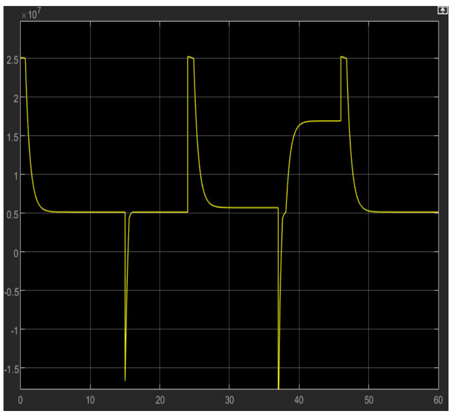


Fig 17 Hydro Motor speed and Swing speed

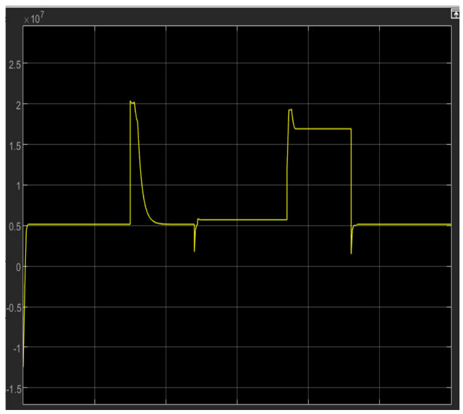
The graph shown below represent the power Vs time graph of the pump.The area under thegraph give the work done by the pump.In the first part of the graph the complete work isdone by the pump only.but in later part the stored energy in the accumulator is also send withthe pump energy which reduce the work load of the pump.

The difference in the area of the upper part will equal to the energy supplied by theaccumulator
during the swing process.In this way accumulator store energy and supplied itto next cycle
to reduce the workload of pump.

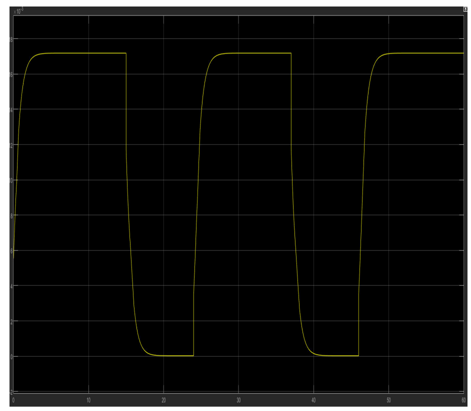
Power consumed by Pump = Pressure difference across pump * flow rate.



Pressure variation of pump in supply line



Pressure variation of pump in return line



Flow rate of pump

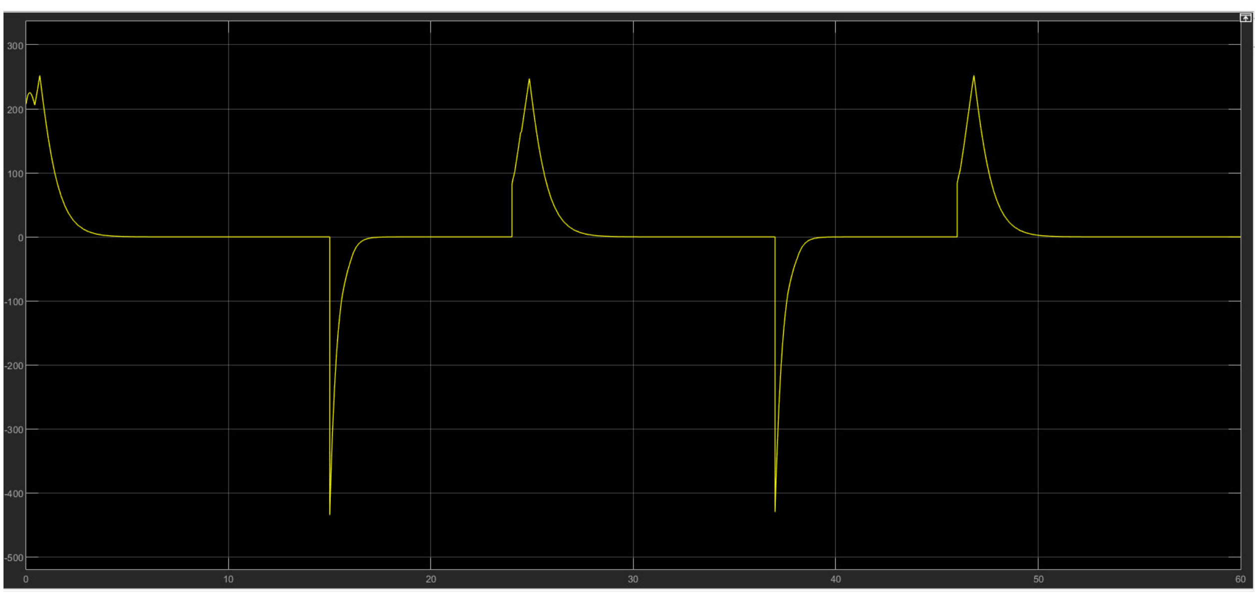


Fig 18 . Pressure Vs Time graph of the Pump

Chapter 7

Calculations

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** Power required by pump to supply fluid to motor initially = 342.51409 KW

** Energy stored in accumulator = 170.0344 - 192.29621 KW

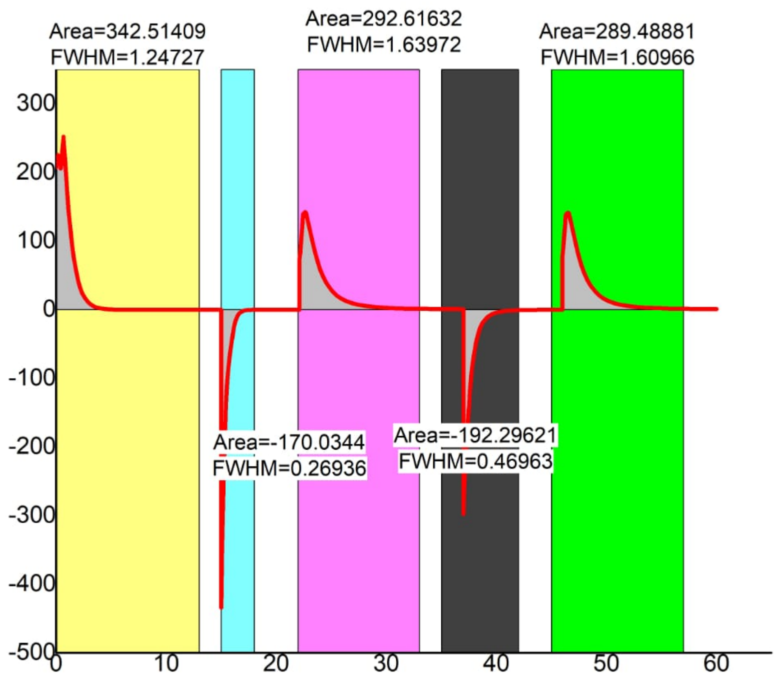
** Power required by pump to supply fluid to motor (after energy stored in accumulator) = 289.48881 KW

** Power supplied by accumulator = (342.51409 - 289.48881)

= 53.02528 KW

** **Energy regenerative percentage = (53.02528/342.51409)*100**

= 15.49 %



Chapter 8

Conclusion

A method to regenerate energy using accumulator is described for the excavator.The hydrauliccircuit was designed with real data of different parameters. The given hydraulic design aim toreduce the work load by regenerating energy which ultimately reduce the fuel consumption.oncomparing energy use, we successfully simulate the circuit and find that around (15-16)% energyis regenerated.

FUTURE SCOPE

The current hydraulic circuit is capable of regenerating(15-18)% of the energy from the swing motion.The future aim of the project is to increase the regeneration percentage up to(30-35)% . The new method and technique will be developed to get the higher regenerationpercentage. I will also studying about the feasibility of application to implement this in real life to regenerate the energy.

REFERENCES

1.https://learnmech.com/what-is-hydraulic-accumulator-types-of-hydraulic-accumulator/

2. https://www.mobilehydraulictips.com/hydraulic-motor/

3. https://www.definitions.net/definition/hydraulic+pump

4. https://www.bing.com/images/searchq=directional+control+valve+definition&form=HDRSC2&first=1&scenario=ImageBasicHover

5. https://instrumentationtools.com/pressure-relief-valve-principle/

6. https://www.researchgate.net/publication/264858388_ANALYSIS_OF_HYDRAULIC_EXCAVATOR_WORKING_CYCLE