ENCODER BASED STEERING SYSTEM

[1]Pranav Bairagi, [2]Soniya Vaidya, [3]Nitish Gurav

Department of Mechanical Engineering,
Pune, India.

***Abstract*: Due to increase in technology humans becomes addicted to it. The technology which is been build earlier has modified and redeveloped to form a new one with less efforts, better results, less weight, high resolution and precise control. In this paper we are developing such system which will eliminate the weight and increase the precise control of the steering system. With the help of quadrature rotary encoder we are going to record the rotation of the steering, this record is then processed and used to control the hydraulic system. The Hydraulic system is connected to the Ackermann steering mechanism where for each degree of rotation of steering wheel there is a result in movement of hydraulic piston. This will create the wheels to rotate back and forth using steering.**

***Index Terms*: Hydraulics system, Quadrature Rotary Encoder, Steering System, Ackermann steering, Electronics**

I. INTRODUCTION

There are many types of steering mechanism, based on the mechanism used they are categories as rack and pinion types of steering mechanism and recirculating ball screw type of steering mechanism. When we considered the position to control wheel there are two types of steering mechanism they are Ackermann types of steering mechanism and Davis steering type of steering mechanism. Due to increase in technology, in order to reduce the efforts required to rotate the steering wheel is also eliminated with the help of hydraulics systems. This type of steering system is called as power steering. This type of the steering system requires the long shaft to reach till the end and connect it with the one of the four bar mechanism. The most widely used type of steering mechanism is Ackermann steering mechanism. In order to eliminate the long shaft and increase the precision to control the steering mechanism, we uses the hydraulics systems along with the quadrature rotary encoder as a key element. The hydraulics system is used as is used as a primary actuator and encoder is used as the primary sensing device. The quadrature rotary encoder is the device which is having structure similar to the motor with the only difference that there is a Hall Effect sensor or an optical sensor is mounted at the end of the shaft. This encoder brought the revolution carried out by the shaft. The more the number of sensor's mounted the precise the value will be as well as we get the greater resolution. This advancement results into high accuracy and less weight.

II. CIRCUIT DIAGRAM:

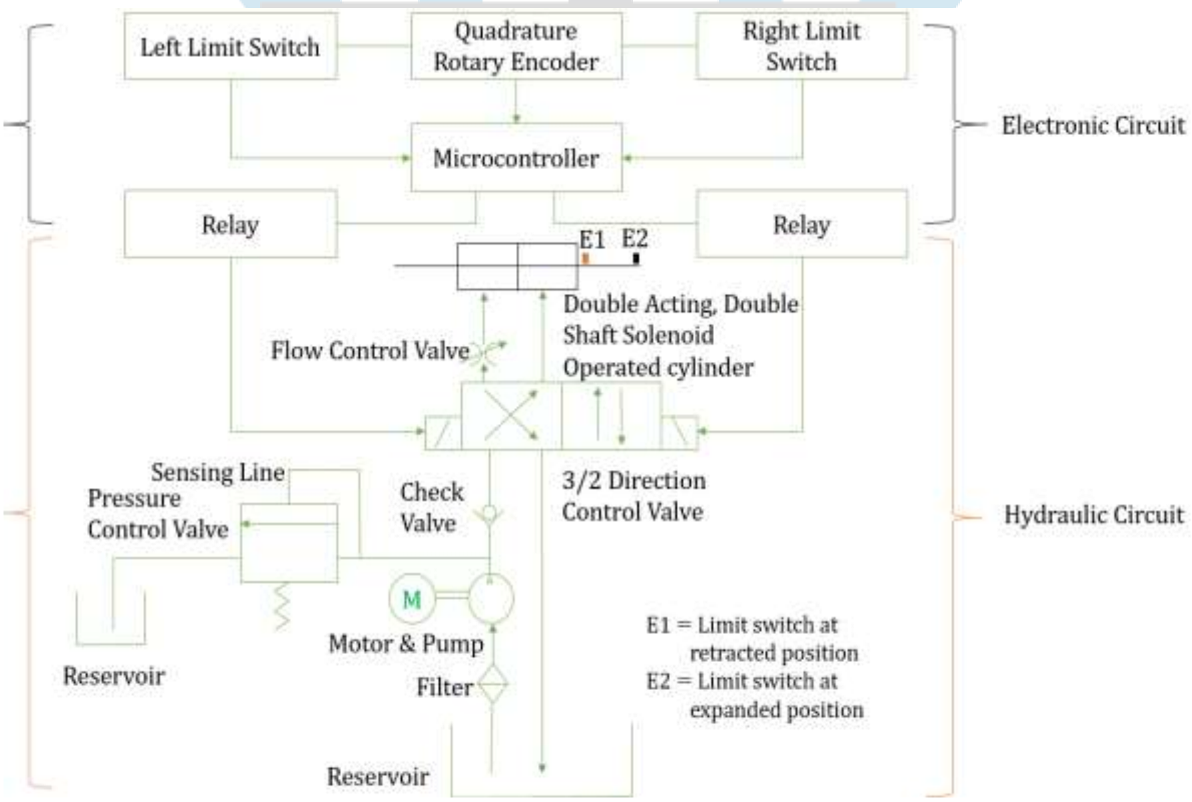

FIGURE 1: CIRCUIT DIAGRAM

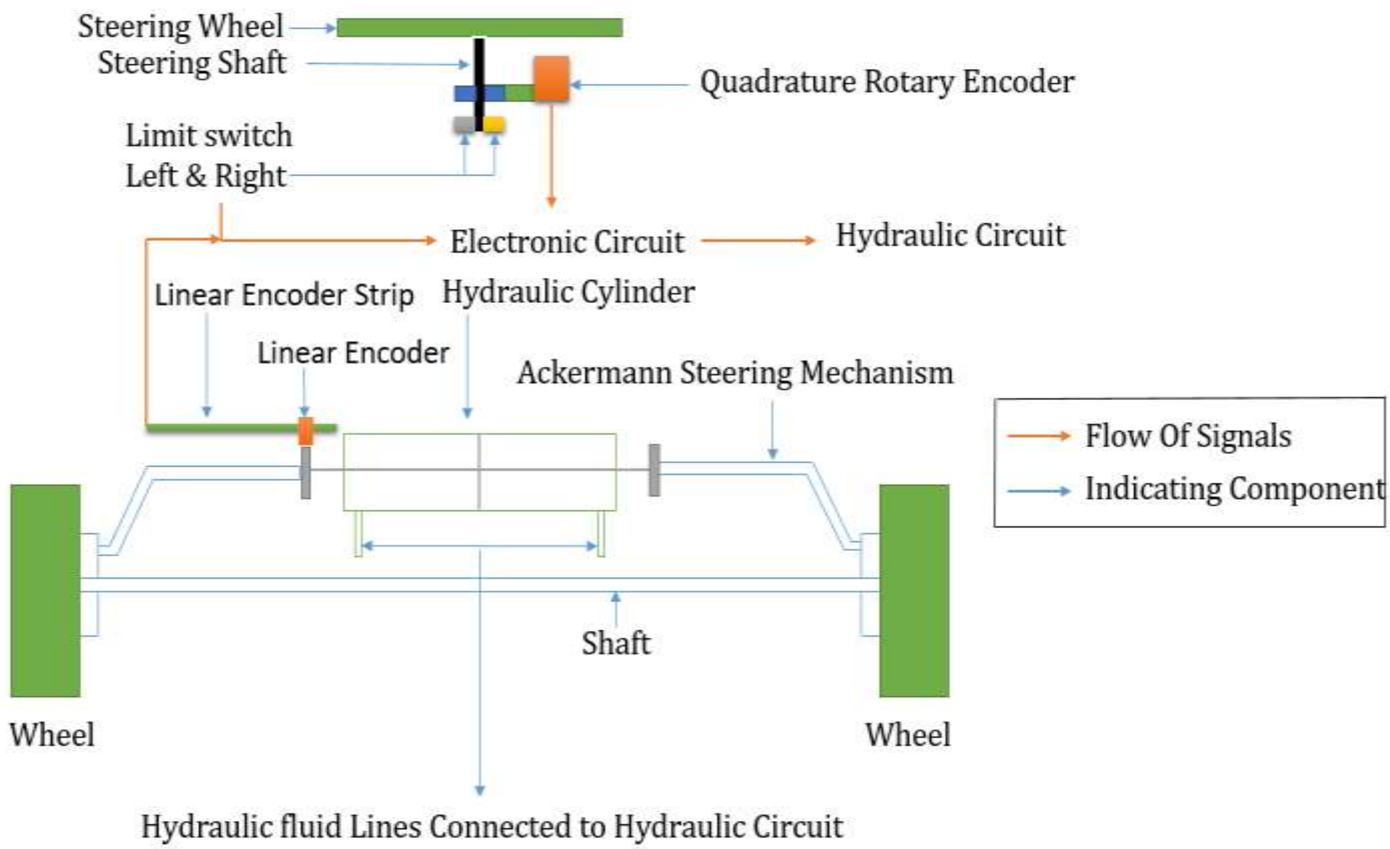

FIGURE 2: ACTUAL COMPONENT POSITIONAL SYSTEM

III. MODEL:

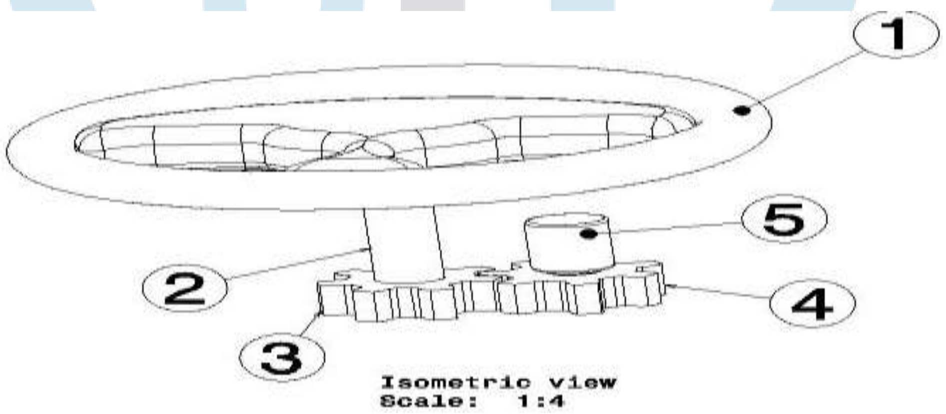

FIGURE 3: STEERING SYSTEM ASSEMBLY WITH ENCODER

IV. PARTS DESCRIPTION:

Part 1: Steering Wheel:
Steering wheel connected to the steering shaft (part 2) coupled rigidly. Steering wheel transmits the power from itself to steering shaft. It is having only one degree of freedom.

Part 2: Steering Shaft:
Steering shaft connected in between steering wheel part 1 and steering gear part 3. Steering shaft coupled rigidly with the steering wheel part 1 and steering gear part 3. Steering shaft transmits the power from itself to steering gear. It is having only one degree of freedom. This type of gear is helical gear.

Part 3: Steering Gear:
Steering gear connected with the encoder gear part 4. Steering gear transmits the power from itself to encoder gear. It is having only one degree of freedom. This type of gear is helical gear.

Part 4: Encoder Gear:
Encoder gear connected with the encoder part 5. Encoder gear transmits the power from itself to encoder. It is having only one degree of freedom. This type of gear is helical gear.

Part 5: Encoder:
Encoder is electronic device also known as quadrature rotary encoder. Records the rotational value transmitted from the encoder gear. It is connected to electronic circuit which is then performs the rest of the operation.

V. WORKING:

The working is as follows:
Whenever the user rotates the steering wheel part 1, it transfers the rotation motion to the steering shaft part 2. This shaft which is connected to the steering gear part 3 transfers the positive motion to the encoder gear part 4. At last the rotational motion is reached towards the quadrature rotary encoder part 5. This rotary encoder rotates and senses the revolution. Each degree of revolution is converted into pulses and this pulses is depends upon the resolution of the encoder. The more the resolution the more the precise control of the steering. In the structure we uses the 2500 PPR (pulse per revolution) this pulses are recorded inside a microcontroller in this case we are using the arduino. With the help of interrupt pins and the pull up resistors the fluctuation and wrong value is eliminated from that pin. The pulses is then converted into the number of counts in this case each revolution is converted into the 10000 CPR (counts per revolution). There are two linear encoder connected to the arduino, this linear encoder is then connected to the top of piston shaft. The linear encoder allows the directional controlled valve with solenoid operated to start and stop at the specified position. The flow of the signal is as follows the linear encoder sends the positional signal (position of the piston shaft top) to the microcontroller, then the microcontroller decodes the value and transfers the motion from microcontroller towards the directional control valve. The count value from the quadrature rotary encoder recorded is then mapped to a lower i.e. inside the visible band range and then given to the directional control valve which allows the piston to move forward. When the steering wheel rotates in the clockwise direction then the encoder encodes the positive valve and when the steering wheel rotates in the anticlockwise direction then the encoder records the negative value. This difference creates the motion which rotates the wheel as follows:

When the steering rotates in clockwise direction the left side relay is activated and right side relay is at the off condition which also allows the flow from left side valve of the direction control valve towards the piston cylinder at the same time the right side valve is connected to the reservoir. This moves the piston to right side which results into the steering the wheel towards right direction.

When the steering rotates in anticlockwise direction the right side relay is activated and left side relay is at the off condition which also allows the flow from right side valve of the direction control valve towards the piston cylinder at the same time the left side valve is connected to the reservoir. This moves the piston to left side which results into the steering the wheel towards left direction.

At each end of the rotation of steering wheel there is a limit switch attached, so when the limit of the clockwise direction is reached then the limit switch is pressed and microcontroller knows that the right side limit is reached and when the steering wheel reaches the anticlockwise direction then the second limit switch is pressed and then microcontroller knows there is an end of the anticlockwise direction. The same kind of limit switch is attached to the hydraulic piston at retracted and expanded position, in order to know the limits of the piston cylinder and to cut off the fluid line to avoid the bursting of the fluid lines. This also stops the motor of the fluid pump to avoid excess use of the power. On the second note there is a pressure control valve placed in between the pump and the check valve to avoid bursting of the fluid lines.

VI. CALCULATION:

Z1 = Number of teeth on steering gear = 66 teeth's
D1 = Diameter of steering gear = 90 mm
Z2 = Number of teeth on encoder gear
D2 = Diameter of encoder gear
G = Gear Ratio = 1:3
N1 = Speed of Steering Gear
N2 = Speed of Encoder Gear

$$G = \frac{N1}{N2} = \frac{D2}{D1} = \frac{Z2}{Z1} \qquad (1)$$

$$Assuming\ The\ Gear\ Ratio\ As = 1:3$$

$$G = \frac{1}{3} = \frac{D2}{D1} = \frac{D2}{90}$$

$$D2 = \frac{90}{3} = 30\ mm \qquad (2)$$

$$G = \frac{1}{3} = \frac{Z2}{Z1} = \frac{Z2}{66}$$

$$Z2 = \frac{66}{3} = 22\ Teeth's \qquad (3)$$

When The Steering Gear rotates 3600 then According to the gear ratio encoder gear will rotates:

3 X 360 = 10800
The steering wheel has a limit of 7200 in clockwise direction and steering wheel has limit of -7200 in anticlockwise direction. Therefore, the encoder will rotate to 3 X 2 X 360 = 21600. i.e. 21600 in clockwise and -21600 in anticlockwise direction.

```
---------------------------------------------------Encoder Coding-----------------------------------------------------------
int encoderPin1 = 2;        // Connect the encoder pin 1 to Arduino pin 2
int encoderPin2 = 3;        //Connect the encoder pin 2 to Arduino pin 3
int encoderPin3 = 18;       // Connect the encoder pin 3 to Arduino pin 18
int encoderPin4 = 19;       //Connect the encoder pin 4 to Arduino pin 19

volatile int lastEncoded1 = 0;
volatile long RotaryEncoderValue = 0;

volatile int lastEncoded2 = 0;
volatile long LinearEncoderValue = 0;

long lastencoderValue1 = 0;
long lastencoderValue2 = 0;

int lastMSB1 = 0;
int lastLSB1 = 0;

int lastMSB2 = 0;
int lastLSB2 = 0;

int LeftRelay = 5;
int RightRelay = 6;

Void setup ()
 {
        Serial.begin (9600);
        pinMode (encoderPin1, INPUT);
        pinMode (encoderPin2, INPUT);
        digitalWrite (encoderPin1, HIGH);          //turn pullup resistor on
        digitalWrite (encoderPin2, HIGH);          //turn pullup resistor on

        pinMode (encoderPin3, INPUT);
        pinMode (encoderPin4, INPUT);
        digitalWrite (encoderPin3, HIGH);          //turn pullup resistor on
        digitalWrite (encoderPin4, HIGH);          //turn pullup resistor on

        pinMode (LeftRelay, OUTPUT);
        pinMode (RightRelay, OUTPUT);
        digitalWrite (LeftRelay, LOW);        //turn off relay initial state
        digitalWrite (RightRelay, LOW);       // turn off relay initial state

 //call updateEncoder () when any high/low changed seen
 //on interrupt 0 (pin 2), or interrupt 1 (pin 3)

        attachInterrupt (0, updateEncoder1, CHANGE);
        attachInterrupt (1, updateEncoder1, CHANGE);
        attachInterrupt (0, updateEncoder2, CHANGE);
        attachInterrupt (1, updateEncoder2, CHANGE);
 }
Void loop ()
 {
       if (RotaryEncoderValue >= 0)
              {
                          if(LinearEncoderValue>= RotaryEncoderValue)
                                 {
                                        digitalWrite (LeftRelay, LOW);
                                        break();
                                 }
```

```
                        if(LinearEncoderValue> RotaryEncoderValue)
                                {
                                        digitalWrite (LeftRelay, HIGH);
                                        break();
                                }

                }

        if (RotaryEncoderValue <= 0)
                {
                        digitalWrite(RightRelay, HIGH);
                                if(LinearEncoderValue<= RotaryEncoderValue)
                                {
                                        digitalWrite (RightRelay, LOW);
                                        break();
                                }
                                if(LinearEncoderValue< RotaryEncoderValue)
                                {
                                        digitalWrite (RightRelay, HIGH);
                                        break();
                                }
                }

        Serial.println (RotaryEncoderValue);
        Serial.println (LinaerEncoderValue);
        delay (1000); //just here to slow down the output, and show it will work even during a delay
}
Void updateEncoder1 ()
{
        int MSB1 = digitalRead (encoderPin1);           //MSB = most significant bit
        int LSB1 = digitalRead (encoderPin2);           //LSB = least significant bit
        int encoded1 = (MSB1 << 1) |LSB1;               //converting the 2 pin value to single number

        int sum1 = (lastEncoded1 << 2) | encoded1;  //adding it to the previous encoded value
                if (sum1 == 0b1101 || sum1 == 0b0100 || sum1 == 0b0010 || sum1 == 0b1011)
                        {
                                RotaryEncoderValue ++;
                        }
                if (sum1 == 0b1110 || sum1 == 0b0111 || sum1 == 0b0001 || sum1 == 0b1000)
                        {
                                RotaryEncoderValue --;
                        }
                                lastEncoded1 = encoded1; //store this value for next time
}
Void updateEncoder2 ()
{
        int MSB2 = digitalRead (encoderPin3);           //MSB = most significant bit
        int LSB2 = digitalRead (encoderPin4);           //LSB = least significant bit
        int encoded2 = (MSB2 << 1) |LSB2;               //converting the 2 pin value to single number

        int sum2 = (lastEncoded2 << 2) | encoded2;  //adding it to the previous encoded value
                if (sum2 == 0b1101 || sum2 == 0b0100 || sum2 == 0b0010 || sum2 == 0b1011)
                        {
                                LinearEncoderValue ++;
                        }
                if (sum == 0b1110 || sum == 0b0111 || sum == 0b0001 || sum == 0b1000)
                        {
                                LinearEncoderValue --;
                        }
                                lastEncoded2 = encoded2; //store this value for next time
}
-------------------------------------------------------------Code End-------------------------------------------------------------------
```

VII. DISCUSSION:

1. With this the long shaft of the steering wheel is eliminated. Due to the encoder fixed near to the steering wheel.
2. There is precise control available due the high resolution of the encoder.
3. More the resolution more the accuracy of the steering mechanism.
4. Weight of the system is reduced.
5. Cost of manufacturing and assembly is increased due to electronic component.
6. Autonomous driving system is possible due to introduction of the encoder.

REFERENCES

[1] "Steering system of vehicle", Mitsuya Serizawa, Makoto Sato, Yoshimitu Akuta, Patent Number US 5097917, March 24, 1992

[2] "Steering angle detecting apparatus for motor vehicles based on the phase difference between a steering angle detection signal and steering angle estimated signal", Hiroyuki Hirano, Yoshihiko Tsuzuki, Satoshi Haseda, Akira Fukushima, Hideo Inoue, Osamu Takeda, Patent Number US 5343393, Augut 30, 1994.

[3] "Method for determining steering position of automotive steering mechanism", Dinu Petre Madau, Behrouz Ashrafi, Patent Number US 5787375, July 28, 1998.