OFF AXIS INCLINATION MEASUREMENT OF DRILLING SHAFTS

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ABSTRACT

The inclination of drilling shafts from vertical axis poses some problems to workers in the oil exploration fields. A simple device is developed and tested at KFUPM to give the exact angle of the shaft axis off the vertical. Further, the design is capable of determining the direction of the shaft in the horizontal plane. The device is based on a laser beam source placed at the center of a hemisphere with light sensors distributed over its inner surface. The laser beam is held fixed in space through frictionless hinge and a pendulum attachment. As the shaft inclines an angle θ off the vertical, the hemisphere, being attached to the shaft, will have its axis making the same angle with the vertical and the laser beam will fall on a prescribed sensor indicating both the vertical and the horizontal angles of inclinations. The device is reliable since it has no moving parts, robust and quite accurate. Some results of a crude prototype are presented.

Keywords: *Inclination sensors, Angle measurements, Drilling shaft inclination*

الملخص

إن ميل بريمة الحفر عن الإتجاه الرأسي عند حفر آبار البترول يمثل مشكلة للعاملين في هذا الحقل. تم في قسم الهندسة الكهربية بجامعة الملك فهد للبترول والمعادن بناء نموذج لجهاز يمكنه تحديد زاوية ميل البريمة بدرجة دقيقة. يعتمد الجهاز في عمله على بندول حر الحركة لتحديد الإتجاه الرأسي حيث يثبت عند مركز نصف كرة ويتصل به مصدر لشعاع ليزرذو إتجاه رأسي مطابق لإتجاه البندول. يغطى سطح نصف الكرة الداخلي بمصفوفة من الخلايا الكهروضوئية. عندما تميل بريمة الحفر يسقط شعاع الليزر على أحد هذه الخلايا فتتولد نبضة كهربية تشير إلى إحداثيات الخلية وبالتالي يتم تحديد زوايا الميل رأسيا وأفقيا .

1. INTRODUCTION

Oil is one of the most important substances in the world today. Its existence in commercial amounts made it the major source of safe and economical source of energy for most industrial and household applications. Oil exists underground at specific formations, which are well studied by geologists and scientists. The task of extracting oil from under the ground is extremely laborious, complicated and challenging. Extensive studies are done in all phases of the digging operations resulting in a massive literature in such field of knowledge. One important element in the drilling process is to continuously supervise and control the drilling shaft inclination off the vertical direction so that it follows a special track set by the well design. Generally, the drilling process in the ground continues properly until a critical point is reached. At this point the driller starts inclining from its vertical path. This results in a different drilling direction than intended and may lead to erroneous conclusions in addition to the waste of efforts and resources. It is the purpose of this paper to introduce a technique to measure this inclination as it occurs and display the results or use it to further control the driller direction. The device is simple to manufacture, durable and accurate. However, due to the drilling harsh environment and continuous severe vibration of the drilling shaft, anti vibration techniques as well as correction algorithm ought to be incorporated with the device for highly accurate results. In the followings, a brief description of the device is presented followed by the electric measuring circuit lay out and we conclude by some experimental results of a prototype device built at the electrical engineering department at King Fahd University of Petroleum and Minerals at Dhahran.

2. THE DEVICE

The device proposed is made of a hemispherical shell made of any appropriate material that can withstand the harsh conditions of well drilling. Over its inner surface a matrix of photocells forming one layer is installed covering most of the shell inner surface. A look up table is established between each photocell and it’s coordinates on the hemisphere surface. Next, a laser beam source is placed at the center of the hemisphere with its beam kept pointing always vertically through a pendulum assembly hinged at the center of the hemisphere. The device outline is shown in Fig.1. The device is fixed to the drilling shaft. Now, as the shaft inclines some angle θ off the vertical, the hemisphere axis will rotate in the vertical plane the same angle θ with respect to the fixed vertical direction of the pendulum. In this case the laser beam will fall on some prescribed photocell, which will emit an electrical signal through which the exact positioning of the shaft is determined.

2.1 Error correction

Since, while drilling, severe vibration takes place resulting in a highly fluctuating and inaccurate angle measurements, special arrangements must be implemented to guard against such unstable results. These may be divided into two parts; a proper anti vibration mechanical mounting system

Top

must be built to reduce the vibration effect by a considerable margin. Further, a dynamic equalizer using an appropriate error minimization technique must be utilized to bring the error down to a negligible value.

3. THE ELECTRIC CIRCUIT

The signal coming out of a photocell is very weak. Our first task is to amplify the signal to about 5 volts to be compatible with the TTL logic circuit to follow. The amplifier is followed by an encoder, which produces a specific code for each activated photocell. Finally, a 7-segments display is utilized to display the inclination angle θ. The angle ϕ in the horizontal plane may be similarly displayed. Details of the electric circuit is as follows:

3.1 Amplifier circuit

The set up is shown in Fig.2. The operational amplifier used is type LF-411 with the other circuit elements are as shown on the diagram. Two stages amplifiers were needed to achieve the required gain.

3.2 The encoder

The prototype assembly of photocells with which we have experimented is composed of an array of 6 elements. Each one of these elements when activated indicates an angle θ as shown in Table 1. An encoder is built with three outputs X,Y and Z representing a specific code for each activated photocell. The codes with their respective cells are shown in Table 1. The decoder design is sketched in Fig.3.

Table 1. Photocells locations and their respective encoding

Photocell	D0	D1	D2	D3	D4	D5
Inclination Angle θ	0^{o}	5^{o}	10^{o}	15^{o}	20^{o}	25^{o}
Decoder output XYZ	000	001	010	011	100	101

3.3 The latch

Since there is a physical gap between the positions of the photocells, a dark area exists where no information may be available. To overcome this problem, the preceding recorded position before the incidence of the laser beam on the dark area is preserved through the latch circuit shown in Fig.4. This is important in keeping track of the motion of the laser beam through the device and hence determining the shaft position with higher confidence. In fact the error due to the dark area may be made arbitrarily small through finer size of photocell matrices.

3.4 The 7-Segments display

Finally, two 7-segments display elements are incorporated into the system to display the results. The connection is as shown in Fig.5.

4. RESULTS

Experimental results are carried out on the prototype device. Some of the results of the angle θ are shown in Table 2. The margin of error is in the range of 2^{o} because of the crude design of the prototype. This, however, can be considerably reduced using fine photocells matrices. These are available commercially but were not available to the authors at the time of building the prototype.

Table 2. Experimental results.

Angle measured	0^{o}	5^{o}	10^{o}	15^{o}	20^{o}	25^{o}	30^{o}
Range of inclination	0^{o}-2^{o}	3^{o}-7^{o}	8^{o}-12^{o}	13-17^{o}	18-22^{o}	23-27^{o}	28-30^{o}

5. CONCLUSION

A robust device for measuring the oil well drilling shaft inclination is built and laboratory tested. Still, considerable improvements may be added to the design to enhance its accuracy, durability and stability under the harsh conditions of well drilling. This requires further work under true digging conditions which we hope to pursue on a later phase of the work.

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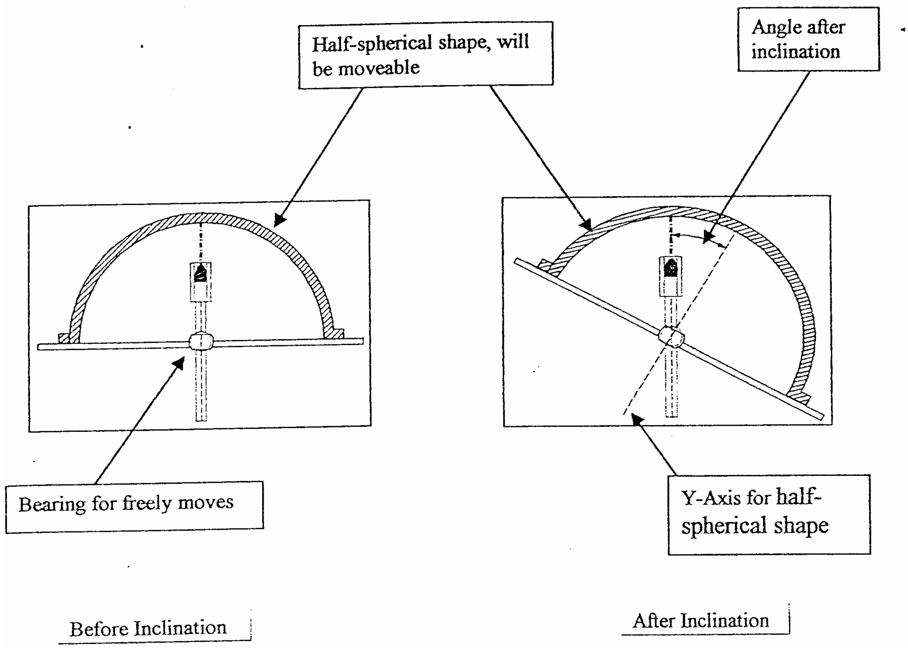

Figure 1: Laser with half-spherical shape

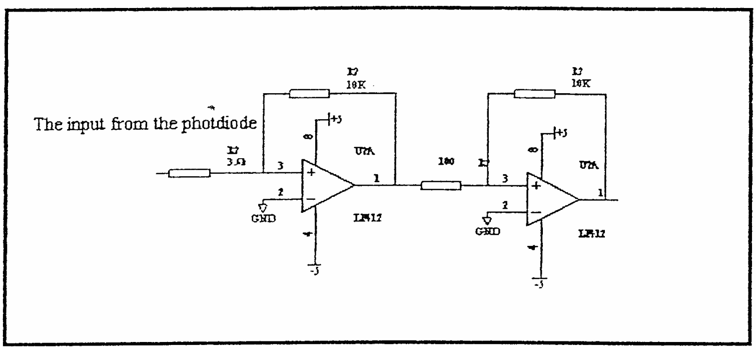

Figure 2 : Amplifier circuit

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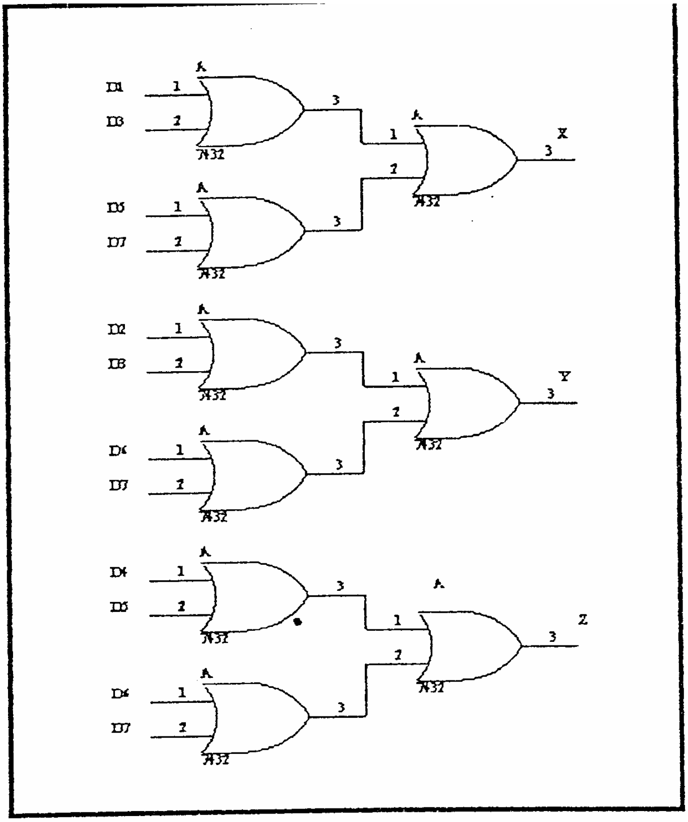

Figure 3 : Encoder Circuit

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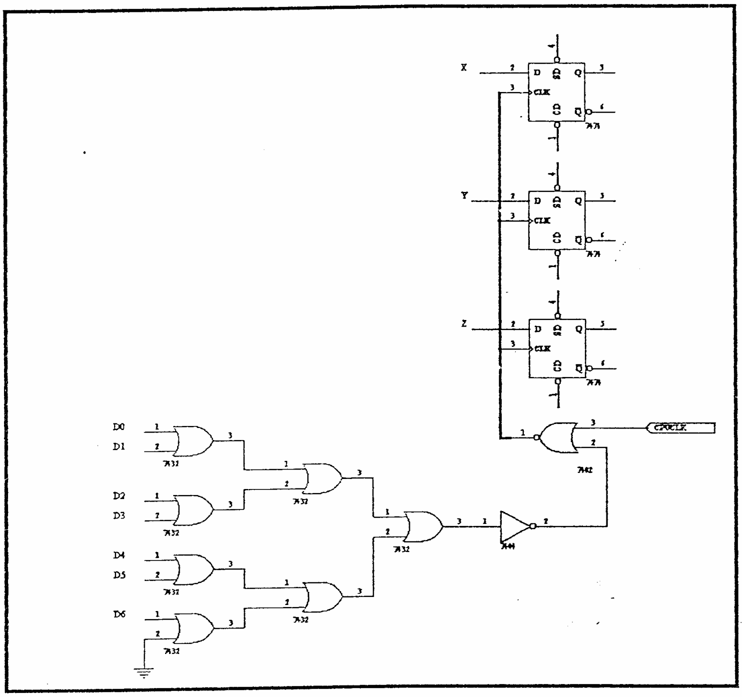

Figure 4 Clock and Latches Circuit

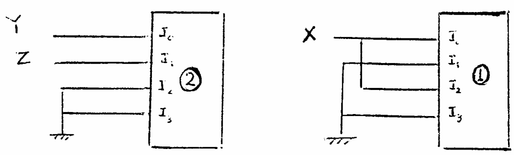

Figure 5 : Seven-Segment Display Circuit