Encoders

Optical linear encoders

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A B S T R A C T

The optical linear encoders are the preferred choice sensors for positioning machine tools' moveable parts. Machine tools' errors have been traditionally focused on the analysis and performance of the machine tool structure until recent works have treated the encoder itself as a source of error. Encoder error quantification has been done for several mounting conditions in static situations, but there is a lack of information regarding the performance of the encoder under dynamic solicitations. The aim of this work is to analyze the loss of accuracy of the sensor because of vibration for different mounting conditions. A finite element model of encoder has been developed and experimental results have been analyzed

1.Introduction

Optical encoders are the inevitable part of many of the major machine tools,meterology and electronic industrieslikerobotics,tracking systems,CNC.many other measurement applications and position tracking applications due to its higher efficiency ,low price,repeatability and precision etc.Basically an optical encoder converts the displacement,either rotary or linear, to the machine readable form by using an optical sensor which send the signals to the optical signal sensing system according to the movement of the scale having the grating for each unit of movement. The resolution of the system primarily depends on the number of gratings on the scale and it could be even in the range of nanometers.

Considering the mechanical construction ,There are two types of encoders, open-type and enclosed-type. Open type type encoders can measure up to 1 um and also capable of evaluate the multi DOF linear motion errors and are used in the applications where high accuracy is required. In this method the scale is mounted on the support of the application and on the scanning head . It works on non contact reflective scanning principle which is any physical contact with the application.

This case study focused mainly on the second type of encoders,The Enclosed type encoders,Which work on the the principle of Moire fringe scanning,which is measure only a omni directional or single axial linear displacement and are mainly used in the low accuracy applications (upto an tolerance of 10um per meter),where the encoder is controlled manually. These type of encoders have an aluminum protective case with prevents the scale from other external disturbances and noises like coolant splashing,chips etc. and due to this construction the errors in the accuracy could be affected by the friction and hysteresis effects.

2.Construction

Optical encoders are preferred because of its accuracy and resolution. Interferometric encoders are used in high precision applications such as calibration of machinery. Machines such as CNCs use encoders with reticles (diffraction gratings). A simple optical linear encoder consists of 3 principal parts: scale, signal source and sensing transducer.

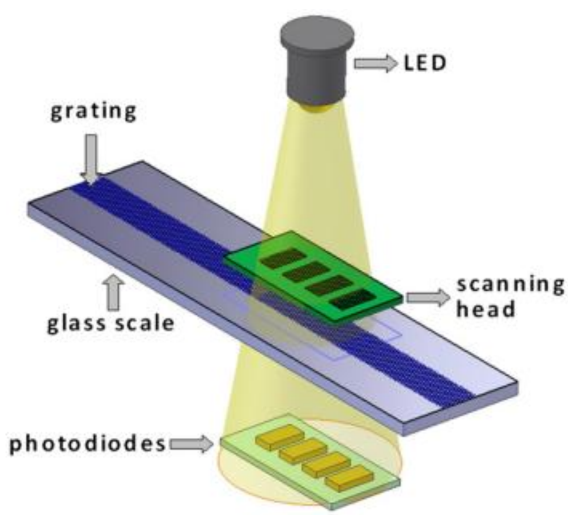

Figure 1:Basic Parts of an Optical Linear Encoder(OLE)

Signal Source: The signal source will be any light source like infrared/colored LEDs. The LED along with a lens will project parallel beam of light to the scale that have markings for position identification.

Scale: It is a linear scale with markings or gratings designed for intended accuracy and resolution. More the number of gratings, more the resolution. When the light pulse passes through the scale, it gets distorted depending on the markings.

Transducer/Photo sensor: The photodetector provides the sinusoidal wave outputs with respect to the scale position to the controller. In addition to these primary components, other parts like lenses, reticles, protective coverings etc. constitutes an encoder body.

Incremental encoders are used to obtain relative displacement between the scanning head and fixed scale while absolute encoders helps to determine the position of the scanning head with respect to an absolute position of the scale.

3.Principle

Generally the working of a linear optical includes passing of a ray of light through gratings where the signals gets modulated due to the relative motion of the scales. These are converted to electric signals by photodetectors providing information about the position and displacement. The modulation of of light rays can be done using various methods like, Moiré effect, Lau effect, Generalized Grating imaging etc.

Incremental encoders consists of periodic diffraction gratings on the reticles of the scanning head as well as on the fixed scale. The relative motion of these two parts creates a periodic modulation of light. This is achieved by several reticles kept at an angular shift of 90 degrees. These reticles are associated with the scanning head. The modulated light is then converted to electrical signals by the photo detectors. Two sinusoidal signals A and B are obtained by this arrangement.

The displacement information is obtained by the formula

$$(N+Ø/2\pi)p$$

Where N is the number of whole displaced periods, p is the period of diffraction grating at the scale, and Ø the phase angle given by

$$Ø = \arctan\left(\frac{B}{A}\right)$$

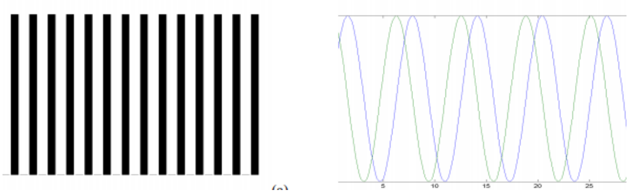

Figure 2: Signals produced by Incremental Gratings

Although, this technique does not provide information about the position of the scanning head with respect to the scale. For that an additional scale called the reference scale is introduced which produces a reference signal. The absolute position can be calculated by adding or subtracting the incremental values from the reference signals. This is achieved by providing randomly spaced slits. Arrays of photo diodes with the help of microcontrollers help converts the modulated light into interpolated data pertaining position of the head.

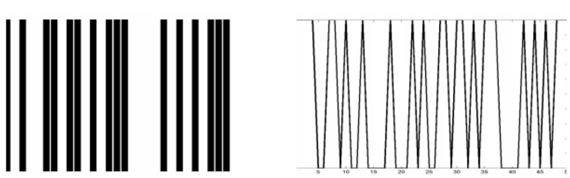

Figure 3: Signals produced by pseudorandom gratings

If the distance between photodetectors is d and width of the slits that forms the pseudorandom grating is p, the standard deviation of in the determination of the interpolated positions is

$$S = \frac{d}{\sqrt{N}}$$

Where N is the number of edges.

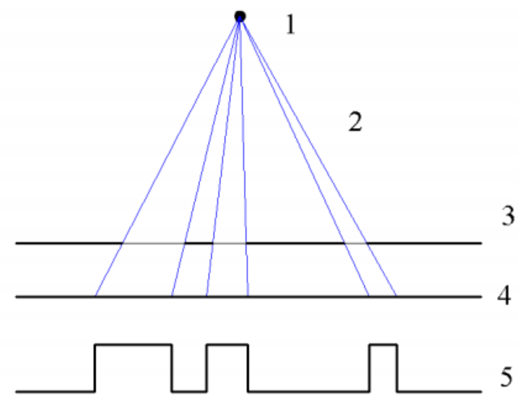

Figure 4: Absolute encoder: 1. light source 2. light beams 3. Plane of reading code 4. Photosensor arrays 5. Output signals

4. Working

As mentioned above a movable scanning unit consists of a light source, lens, graduated glass scanning reticule, and an array of photo cells. The transparent glass scale usually has opaque graduations and is attached to the host machine.

The light beam passes through the lens, the scanning reticules and falls on the array of photocells. As the scanning unit moves, the scale modulates the light beam so that the photocells generate sinusoidal signals. The reticules are so arranged that the signals produced are phase shifted sinusoidal outputs. The reference scale produces the reference signals which gives the position.

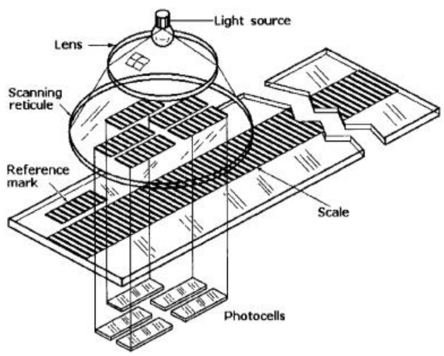

Figure 5: Working of an OLE

The space between the scanning reticule and the fixed scale must be narrow and constant to eliminate diffraction. The entire scanning unit is mounted on a carriage which moves on ball bearings along the glass scale. This unit is connected to the host machine by a coupling. External circuits interpolates the sinusoidal signals from the encoder head to subdivide the line spacing on the on the scale such that it can measure minute motion increments.

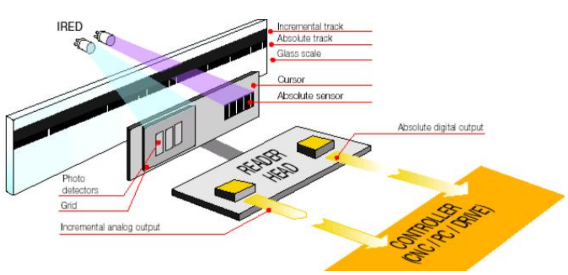

Figure 6:Scheme of the optical encoder with other numeric control with other numeric control

The device thus has two tracks, one intended for incremental signals and other for absolute signals. The incremental measuring mostly uses Moiré effect while absolute measuring is based on reference signals as mentioned earlier. Linear encoders can make direct measurements that overcome the inaccuracies in mechanical stages due to backlash, hysteresis, and leadscrew error. But the performance depends on the condition of metallic chips, grit oil and other contaminants.

4. Applications

Optical encoders are used in a wide range of applications that require monitoring or control, or both, of mechanical systems. There are two main areas of application for linear encoders:

Measurement

1)A coordinate measuring machine (CMM):

It is a device that measures the geometry of physical objects by sensing discrete points on the surface of the object with a probe. Various types of probes are used in CMMs, the most common being mechanical and laser sensors, though optical and white light sensor do exist. Depending on the machine, the probe position may be manually controlled by an operator or it may be computer controlled. CMMs typically specify a probe's position in terms of its displacement from a reference position in a three-dimensional Cartesian coordinate system (i.e., with XYZ axes). In addition to moving the probe along the X, Y, and Z axes

2)A digital readout (DRO):

It is a numeric display, usually with an integrated keyboard and some means of numeric representation. Its integral computer reads signals generated by linear encoders or (less frequently) rotary encoders installed to track machine axes, using these measures to keep track of and display to a machine operator the workpiece position (e.g., milling machines), or tool position (lathes, grinders, etc) in space.

DRO providing a three-axis display with pitch calculator, diameter/radius conversion, absolute incremental toggle, and inch metric toggle

Motion systems

1) *CNC machines*

In CNC machines,to provide positional feedback while in use, to make sure the machine tool is operating with appropriate speed and accuracy for the job.

An encoder is an electromechanical position feedback device that converts movement data into electrical signals. This digital feedback is used by a machine controller to determine position, speed or direction so it can issue commands to perform a specific function.

2)Optical Feedback Linear Actuator

To locate the exact positioning of the actuators, the Optical Feedback series is what required. This powerful, reliable actuator comes with a built-in optical sensor that provides feedback when you need it. The Optical Feedback has no built-in controller, but does provide single-phase pulses as a feedback signal that can be input to an external controller such as an Arduino.

5. Conclusion

The optical linear encoders are the preferred choice sensors for positioning machine tools' moveable parts. Machine tools' errors have been traditionally focused on the analysis and performance of the machine tool structure until recent works have treated the encoder itself as a source of error. Encoder error quantification has been done for several mounting conditions in static situations, but there is a lack of information regarding the performance of the encoder under dynamic solicitations. The aim of this work is to analyze the loss of accuracy of the sensor because of vibration for different mounting conditions. A finite element model of encoder has been developed and experimental results have been analyzed.