Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 201 (2017) 623–629

Procedia Engineering

www.elsevier.com/locate/procedia

3rd International Conference "Information Technology and Nanotechnology", ITNT-2017, 25-27 April 2017, Samara, Russia

Mathematical modeling of signal transfer process into optical system of a linear displacement encoder

M.V. Shishova[a]*, S.B. Odinokov[a], D.S. Lushnikov[a], A.Y. Zherdev[a], O.A. Gurylev[a]

[a] *Bauman Moscow State Technical University, 2nd Baumanskaya str. 5, Moscow, 105005, Russia*

Abstract

Linear displacement encoders are necessary in field of machine tools, metrology and electronic industry. Those devices provide nanometric resolution when constructed according to the interferometric scheme. Mathematical modeling of signal transfer process into its optical system to analyze an interference field is described. Signal intensity depending on a small displacement of moving grating phase shift correlations is considered. A sample model of the linear optical encoder is developed based on the optical scheme under research.

Peer-review under responsibility of the scientific committee of the 3rd International Conference "Information Technology and Nanotechnology".

Keywords: precision linear encoder; optical encoder; diffraction grating; interference field; phase shift

1. Introduction

Optical linear encoders are used in precision machine tools that require a nanometer resolution of displacement. Linear displacement encoders consists of two parts: a movable scale and a measurement head.

The shadow method or the interference method may be in the basis of an optical encoder. The shadow method [1] uses two gratings in a scale and a measurement head to create a Moiré pattern varying light intensity in some specific point depending on scale displacement. An optical sensor is placed in that point and scale displacement is calculated by optical signal processing. Recently, open type encoders operating on the interference method [2] can provide displacement measurements with nanometer resolution. That method uses two high-resolution diffraction

* Corresponding author. Tel.: +7-968-560-7696 .
E-mail address: maryshishova@hotmail.com

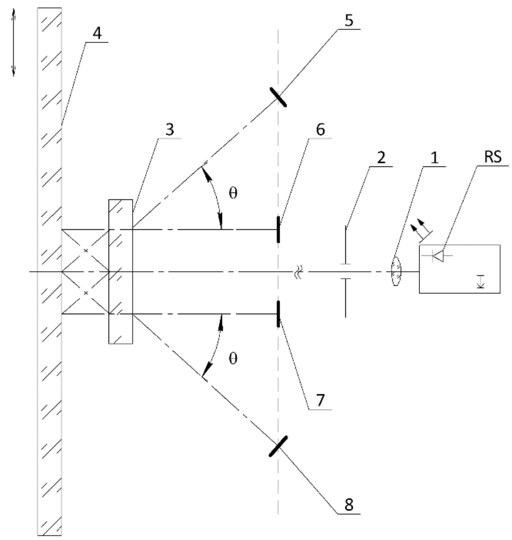
1877-7058
Peer-review under responsibility of the scientific committee of the 3rd International Conference "Information Technology and Nanotechnology".
10.1016/j.proeng.2017.09.676

gratings to create an optical signal by interference of light beams diffracted in different orders at these gratings. An interference strip of infinite width is forming on an optical sensor so the scale displacement can be calculated by the processing that optical signal. The measurement approach under study is based on a phase modulation information that signal consists.

These two gratings are phase ones and named as analyzing scale and coding scale. The coding scale as a reference scale that moves relative to a scanning measurement head that has the analyzing scale inside. The scales exactly have the greatest impact to the final resolution. Low periodic error is required for improved stability. The scales may be obtained by photolithographic, holographic, ruling imprint, electron beam lithographic and roller stamp methods. The photolithographic method [3] doesn't allow to obtain scales with period less than 10 μm and thus is suitable for shadow encoders only. The holographic method doesn't allow to obtain large format scales. The lithographic method requires the newest and expensive lithographs to avoid misphased technological frames in large grating structures. The roller imprint method [4] is relatively new one.

2. Optical scheme

Publications [5]–[9] present a variety of interference optical schemes for the linear encoder systems. Given modeling can also be implemented into angular encoding system with providing a nanometer resolution neither. Angular displacement encoders usually have a reference coding disk which is framed lithographic diffractive element [10]–[12]. The developed modeling considers the design with the analyzing scale operating as a beam-splitter, as shown in Fig. 1, and introduces the signal transfer processes there. The laser radiation (λ = 660 nm) is collimated with a lens (1) and then cuts by the aperture (2). Subsequently it is split into three beams with the analyzing scale (3) and transposed with the coding scale (4). The radiation redirects back to grating (3), and every beam splits again. That signal transfer process results in the interference signals in required directions of detectors (5)-(8).



RS — source of radiation; 1 — collimator; 2 — aperture; 3 — transparent phase diffraction grating (step *d*)
4 — reflective phase diffraction grating (step *d*); 5–8 — optical sensor; θ — diffraction angle (in «±1» orders)

Fig. 1. Optical scheme of linear displacement encoder.

The analyzing scale is a transparent phase grating with resolution of 1000 lines per mm. The coding scale is reflective phase grating with the same resolution. Its symmetrical shaped relief allows higher efficiencies in "+1" and "¬1" diffraction orders. That increases the contrast of the interference field to be received. A small displacement