Mechatronics 21 (2011) 92–99

Contents lists available at ScienceDirect

Mechatronics

journal homepage: www.elsevier.com/locate/mechatronics

Giant magnetostrictive clamping mechanism for heavy-load and precise positioning linear inchworm motors

Bintang Yang [a,*], Guang Meng [a], Zhi-Qiang Feng [b], Dehua Yang [c]

[a] State Key Laboratory of Mechanical System and Vibration, Shanghai Jiao Tong University, Shanghai, China
[b] Laboratoire de Mécanique et d'Énergétique d'Évry, Université d'Évry-Val d'Essonne, Évry, France
[c] Institute of Astronomical Optics and Technology, Chinese Academy of Science, Nanjing, China

ARTICLE INFO

Article history:
Received 17 November 2009
Accepted 27 August 2010
Available online 25 September 2010

Keywords:
Giant magnetostrictive material
Blocked-force
Inchworm clamping principle
Precision linear motor

ABSTRACT

This paper focuses on the development of a novel clamping principle and the mechanism that may be used to realize a linear motor capable of performing not only large thrust but also secure movement with high blocked clamping force. To verify this principle, a clamping prototype (size: $\phi 32 \times 130$ mm) is constructed and tested. It generates a clamping force of 1050 N with an initial experimental set-up, and, a clamping force up to 1525 N with a modified set-up employing a hydro-press bench clamp. The theoretical and numerical analyses are carried out and suggest that the mechanism may generate a clamping force up to 2148 N with an adequate rigid guide-way.

1. Introduction

Using smart-material actuators rather than linear motors has been the focus of many works, such as the work in precise positioning over micron-level span, in active vibration control, etc. Delivering and accumulating the high precision deformation of solid-state smart-materials is a critical research task to challenge the usual belief that the deformation of smart-materials is too small to adapt in long stroke driving applications. The feasibility of applying inchworm moving principle to build a linear motor by step accumulation has attracted those who aim to change the small span driving actuator into a precise long distance driving motor. Different prototypes of linear motors have been developed in the last decade, mainly based on the integration of smart-materials and inchworm driving principles such as the piezoelectric driving [1,2], the giant magnetostrictive driving [3,4] and piezo-magnetostrictive hybrid driving [5,6]. Although researchers have recognized the importance of the clamping mechanism in inchworm motors, they have emphasized more on its linear driving part and on the solution to the inherent problems such as hysteresis [7] and Joule heat [8]. In fact, we believe that without an adequate clamping mechanism, it is difficult to achieve a high precision smart-material inchworm motor even the above-mentioned problems could be well solved. For instance, in the previous work [9], due to the fact that the eletromagnetic clamping mechanism brings about sway and tilt at doing clamping actions, the small inchworm motor can hardly perform the nominal nanometric step traveling even its linear driving part is able to render nanometers elongation. So the clamping mechanism can affect the motor both on the positioning precision and on the thrust capacity. The giant magnetostrictive material is largely used in developing inchworm motors because it possesses interesting properties of high compression strength, high output force and giant magnetostriction. In addition, it has the potential to generate high blocked clamping force in static case. However, it is difficult to fulfill blocked-forcing in movement regime. In this work, we propose a novel blocked-force clamping principle and the corresponding mechanism using the giant magnetostrictive material TeDyFe. An experimental set-up and a numerical model are developed to validate the proposed principle.

2. Magnetostrictive clamping mechanism of linear inchworm motor

A typical structure of a linear inchworm motor can be illustrated as an H-shape structure, as shown in Fig. 1. The motor is most necessarily constructed by Parts A and C (the clamping mechanism), Part B (the driving mechanism) and Part D (the guide-way). The motor can move when Parts A–C are excited in sequence and alternately to do the action of clamping-on/off by A and C against D, and stretching-on/off by B (see [9] for more details). The parts A and C are placed into the guide-way D to generate a deformation in the vertical direction, while the driving part B is configured to produce an elongation in the horizontal direction.

* Corresponding author. Tel.: +86 21 34206332x836.
E-mail address: btyang@sjtu.edu.cn (B. Yang).

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doi:10.1016/j.mechatronics.2010.08.011