A SIMPLE DIFFERENTIAL MICROMETER HEAD

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Received on December 27, 1973

ABSTRACT

The paper describes the design and fabrication of a differential micrometer head with an equivalent pitch of 35 microns capable of a resolution of about 0·1 micron. A teflon nut is used to reduce backlash. The performance of two models, one using teflon and the other using a brass nut, is compared.

1. INTRODUCTION

Most optical instruments require precise positioning of optical elements like mirrors, prisms, beam dividers, etc. The mechanical mounts used for the purpose should have the ability to control motions often as small as a fraction of a wavelength of light. Examples of such applications are to be found in optical and holographic interferometry. Highly stable mirror mounts, based on kinematic principles have been designed [1] for use in a He–Ne gas laser, using commercial micrometer heads, whose resolution is limited. The principle of a differential screw is quite well known and it has been applied for designing micrometer heads [2]. Strict design and fabrication involves precision ground screws and nuts. This paper describes a simple design, using teflon bushes to reduce backlash, that allows for fabrication in a small workshop of a modest laboratory, without even going in for precision ground screws.

2. CONSTRUCTION AND WORKING DETAILS

A schematic of the micrometer head is shown in Fig. 1. The micrometer spindle (2) has two threads cut upon it, one external thread with 40 threads per inch (tpi) and one internal thread of 0·6 mm pitch, both being right hand threads. The external thread of the spindle engages in the fixed nut in barrel (5). Another spindle (7) with external thread of 0·6 mm pitch engages in the internal thread of spindle (2). The spindle (7)

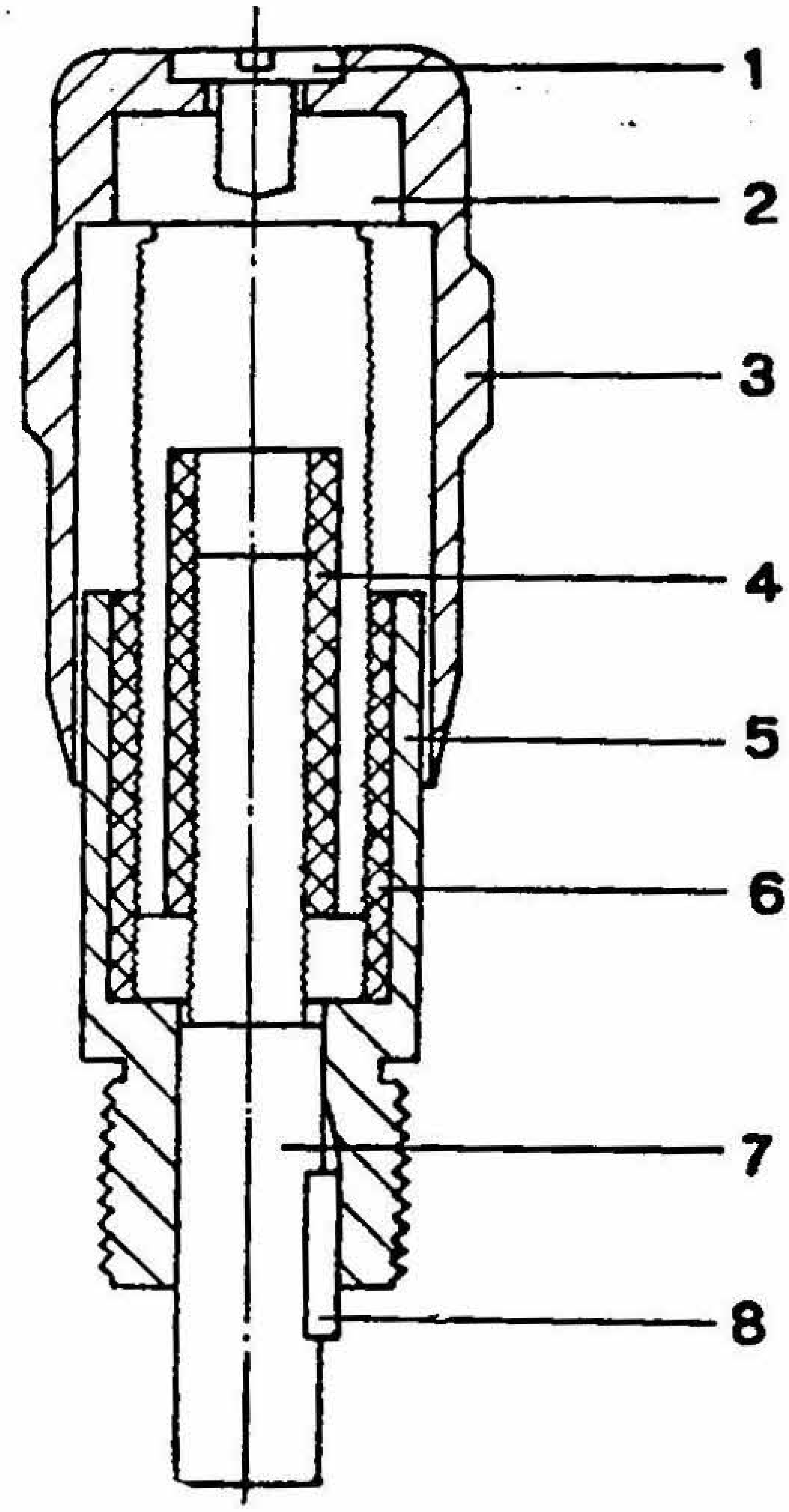

FIG. 1. Section view of the differential micrometer head.

is free to move in the barrel (5), but is prevented from rotation by a key (8). The spindle (2) is fixed to a thimble (3) by a screw (1). One differential micrometer head was made with teflon inserts for the nuts (4) and (6) and another one with brass inserts. One revolution of the thimble (3) results in a nett movement of the difference in pitch of the two screws. This is the basic principle of the differential screw.

Converting into proper units the difference in pitch amounts to 0·035 mm or 35 microns. This can be defined as the equivalent pitch. It amounts to having a screw of 726 tpi. The smaller the difference in pitch between the external and internal thread on the spindle (2), the smaller will be the equivalent pitch and hence finer the motion.

Normally most centre lathes which can cut both metric and inch threads, have standard thread-cutting gears resulting in increments of about 2 tpi in the case of inch threads and 0·05 mm in the case of metric threads. To obtain as small a difference in pitch as possible the external thread was cut in inch system and the internal thread in metric. By this odd choice one can arrive at even smaller differences in pitches than chosen here by using the thread-cutting charts provided with the lathes.

If the thimble is divided into 100 divisions each say 1 mm apart on its periphery, each division represents

$$0{\cdot}035/100 = 0{\cdot}00035 \text{ mm}.$$

The magnification is of the order of $1/0{\cdot}00035 = 2857$

as compared with about 60 for a commercial micrometer having a 40 tpi screw with an half-inch thimble. The resolution which is defined [1] as the movement observed for one degree of rotation of the screw is $0{\cdot}035/360 = 0{\cdot}1$ micron. One inch of movement of the spindle (2) results in about only 2 mm advance for the spindle. Hence the total range is limited.

3. Performance Results

The micrometer heads were checked on the Carl Zeiss Universal Metroscope Figure 2 shows the travel of the spindle for a number of turns of the thimble, for both the micrometer with brass insert and teflon insert. In Fig. 2 *a*, it can be seen that backlash is distributed unevenly about the median line amounting to as much as 6 microns for 12 turns of the thimble. In the case *b* of Fig. 2 the error rarely exceeds 2 microns for successive turns using teflon inserts. For the same pitches chosen, *b* shows a lower gradient indicating that the teflon nuts shrink on to the screw reducing the equivalent pitch.

If this is used in a kinematic mirror mount with a lever arm of 75 mm the tilt that can be obtained per turn of the thimble would be $0{\cdot}035/75 = 0{\cdot}0046$ radians = 26 arc seconds. If the thimble is divided into 100 divisions the tilt of the mirror per division will be 0·26 arc seconds. Often it would be possible to achieve a resolution of 0·01 arc second for the mount by choosing the equivalent pitch of less than 5 microns for the micrometer head. It is to be pointed out that a differential micrometer head cannot be used for absolute measurements without proper calibration. However, the micrometer can be used where fine motions are required as in linear translation stages and tilting mirror mounts.

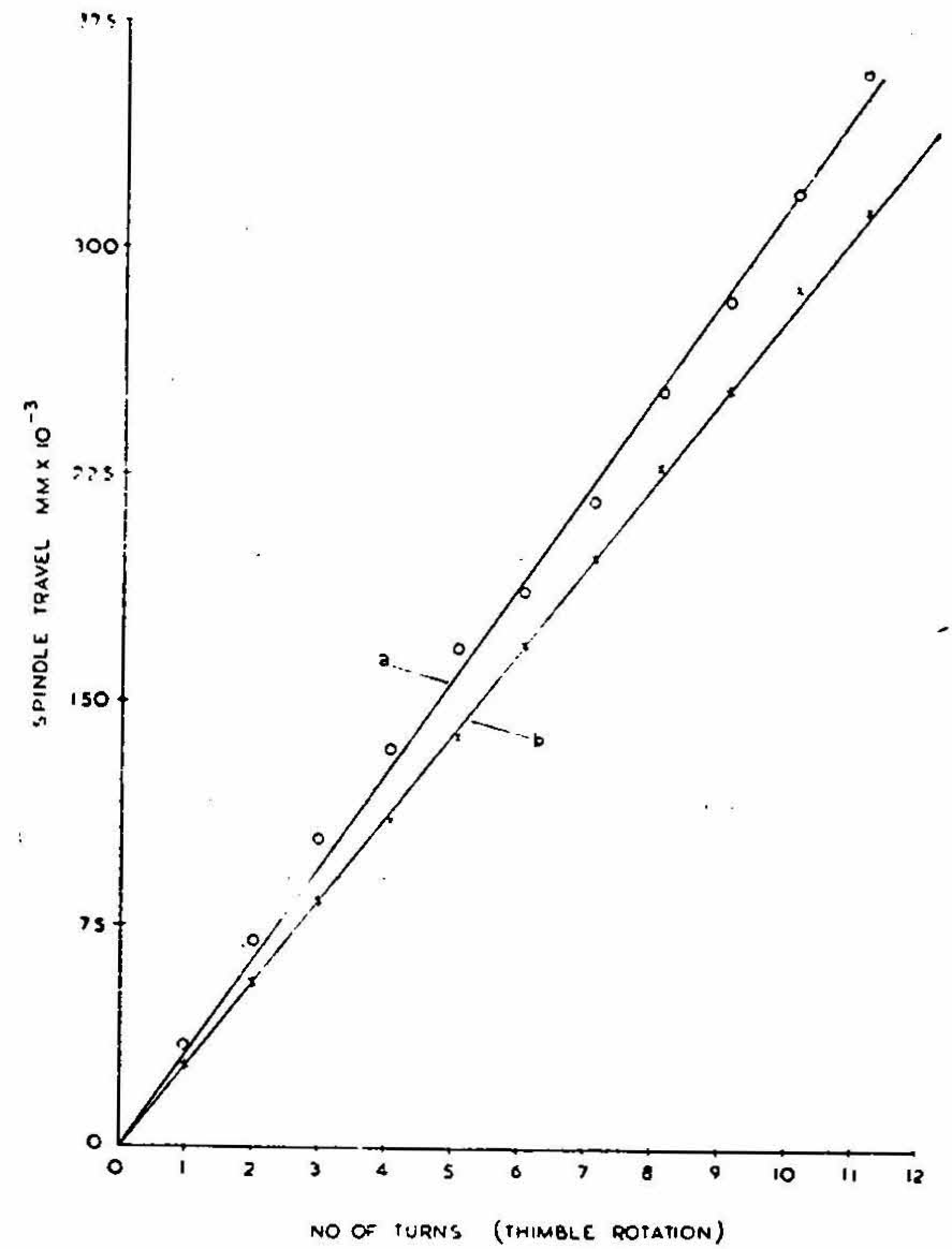

FIG. 2. Spindle travel against number of turns of thimble. (*a*) nuts made of brass, (*b*) nuts made of teflon.

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