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PROFILE ADJUSTMENT OF THE MIRROR SURFACE USING THE MAGNETIC FIELD

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Abstract

A novel monolithic bender was designed and fabricated for an active bendable polynomial grating to increase the resolution of the CEM design used in the Dragon type beamlines of the NSRRC. This bender provides an adjustable third-order polynomial surface profile and meets the specification for the range of adjustment of the grating. However, fabrication limits make perfectly flat surfaces difficult to obtain by polishing. A high-order term surface error cannot be ignored. It also makes the grating hard to rule precisely. In some applications, specified high-order terms beyond this bender adjustability are required. An additional mechanism that involves magnets to produce an adjustable magnetic field to fine-tune the mirror surface profile was designed, fabricated and tested. This study details the design and presents the test results.

1. Introduction

An earlier work demonstrated the excellent performance of a novel monolithic bender designed for an active polynomial grating to make a 3rd-order polynomial surface profile adjustment in NSRRC [1,2].
However, the fabrication limits sometimes make a perfectly flat surface difficult to obtain by polishing. A high-order term surface profile error of more than 3 is significant and dealing with it is time-consuming and expensive. Two prototypes were fabricated and tested during the development of this bender. After the surface was polished, one was good for testing but the other was not, because the 4th-order term surface profile error could not be eliminated. After adjusting with actuators, the RMS slope error of the proper one could be down to 2.5 μrad but the inadequate one only about 44 μrad as shown in Fig. 1. If the 4^{th} term was eliminated, the RMS slope error of the inadequate one could also be down to 2.5 μrad. Specified high order terms beyond the bender adjustability are required in some applications such as the K-B type mirror [3]. An additional mechanism or modification of the bender is desired to compensate for or provide high-order term profile adjustability.

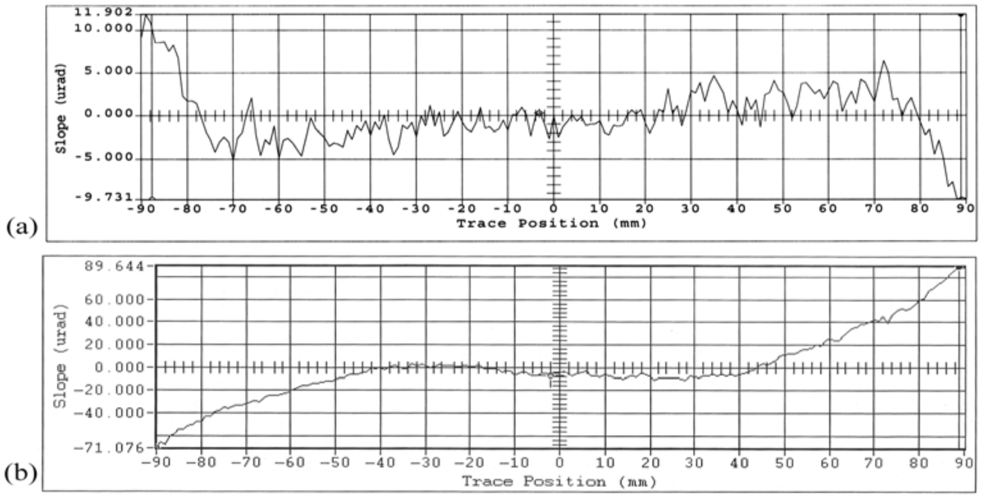

Figure 1. Slope error of the bender prototype measured by the LTP (Long Trace Profiler)
(a) The proper one (b) the inadequate one

As already known concerning the basic mechanics of materials, distributed loads on a prismatic beam will generate a deflection of 4th or even higher order. Consequently, if a normal distributed pressure is applied to the inadequate prototype, the 4th term can be eliminated and the desired surface profile obtained. This condition was enforced in a finite element method (ANSYS) simulation. With the measured profile model, given a normal distribution pressure of 5.7E-3 kgf/mm^2, a total force of 41kgf, the 4th order term of the prototype can be eliminated and a nearly flat surface is obtained as shown in Fig.2. The additional 41kgf force will be transfer to the load of actuators but still within the application rage of actuators.

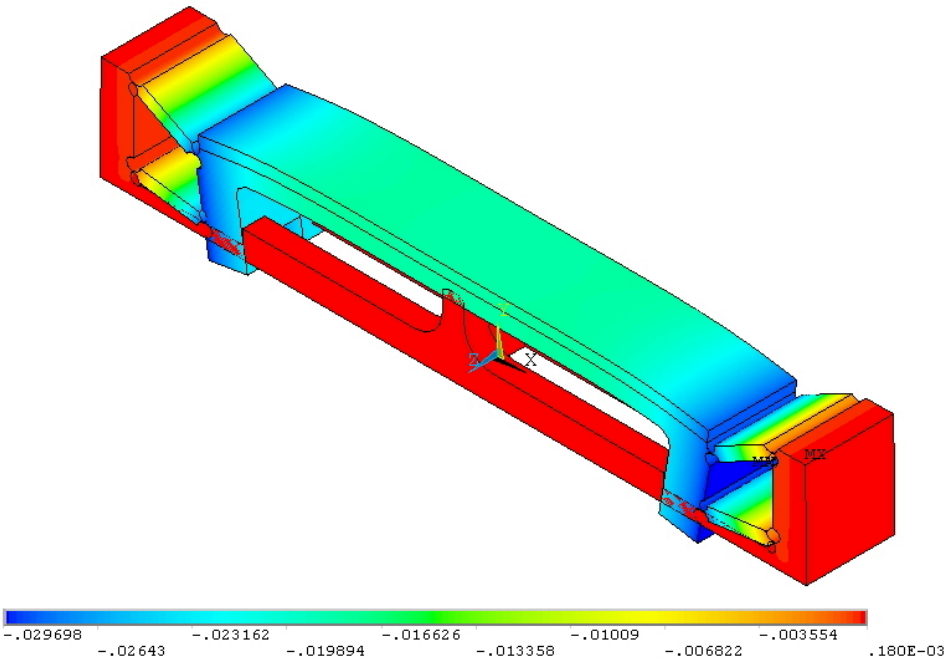

Figure 2. Simulated FEM model in which the measured surface profile of the bender is under a normally distributed pressure of 5.7E-3 kgf/mm^2

The installation situation and UHV environment are such that implementing a normally distributed load with only an additional mechanism is difficult. A magnetic field seems to be a good solution since it easily generates a normally distributed load through the action of a magnetic field with the bender plate. An additional mechanism combined with magnets to realize this idea was designed and tested. This study details the design and test results.

2. Mechanism Design

Figure 3 shows the ensemble mechanism designed using ten magnets to construct a sufficiently distributed magnetic force. The size of each magnet is 45mmx10mmx10mm. Both NdFeB and AlNiCo magnets are adopted for comparison. A copper housing plate is used to mount the magnets, because it is compact and easily assembled with the bender. Slots are cut into the housing plate, making it slender in the longitudinal direction, and facilitating the adjustment of the magnetic field by using the screw nuts in the assembly. Furthermore, the copper housing plate is also designed to be a cooling conductor by inserting a cooling medium, such as indium-gallium eutectic, between it and the bender (In this application, the copper plate has to be done electro-less nickel plating). Two bow-shaped side-connecting supports are screwed to the bender, and thus a high-order polynomial surface profile bender is realized.

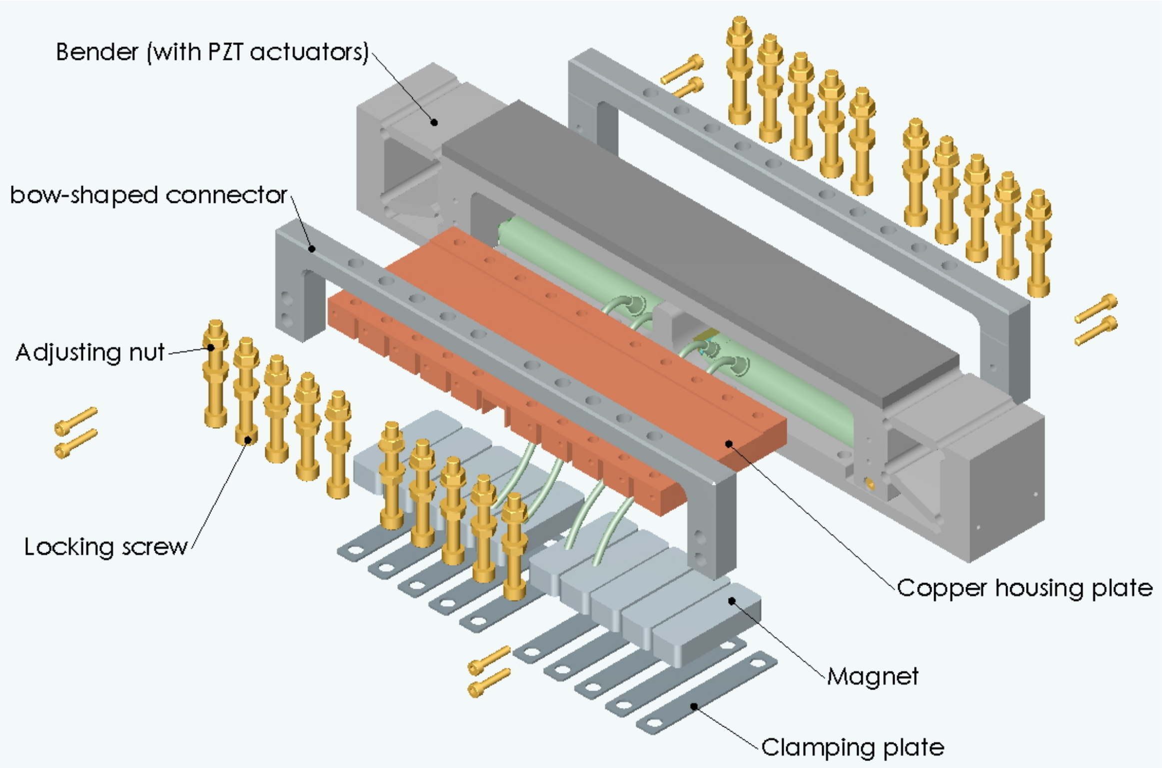

Figure 3. Explosive assemblage drawing of magnetic mechanism

3. Test Results

Figure 4 presents the testing assemblage. The total magnetic force was initially measured. When the magnets are assembled in the direction of the field, a total attractive contact force of only 20kgf is acquired. When they are assembled in the opposite field direction, as shown in Fig. 5, a total attractive contact force of 70kgf is reached, regardless of whether the magnets are NdFeB or AlNiCo.

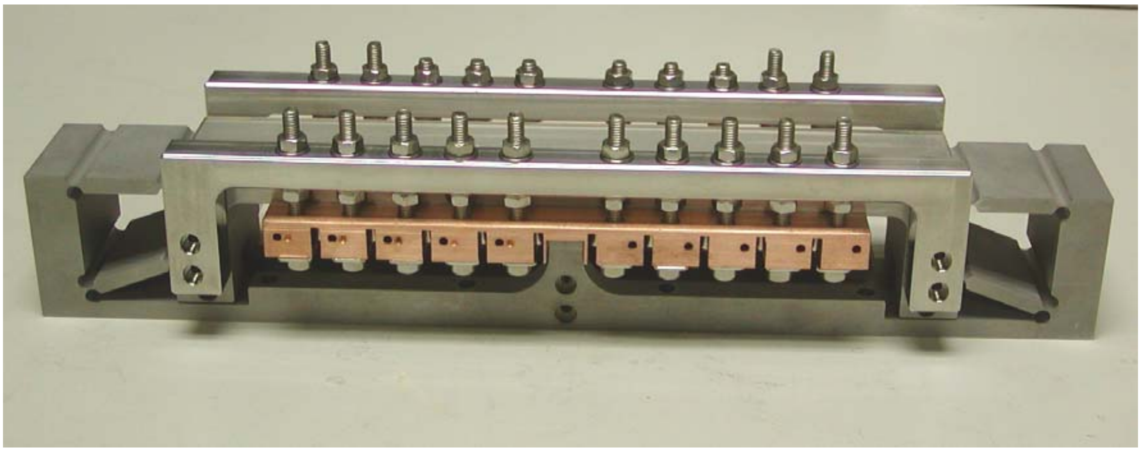

Figure 4. Testing assemblage

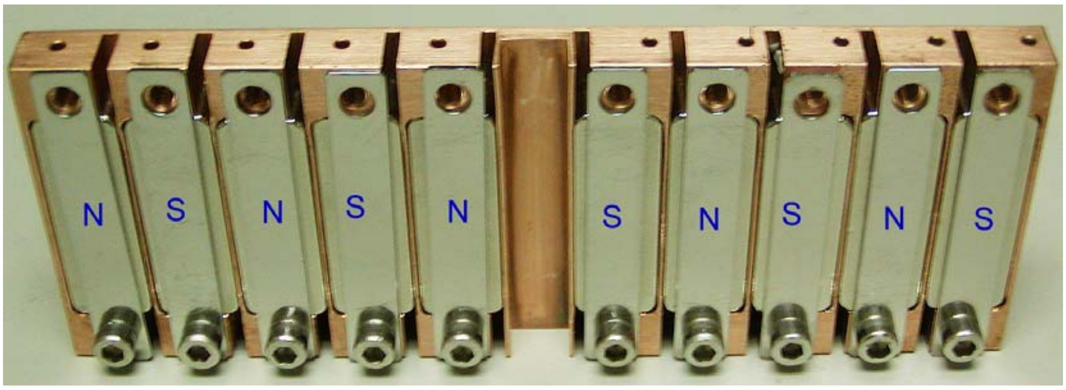

Figure 5. Assembling sequence of magnets

The assembling nuts are adjusted to control the gap between the copper plate and the bender, and thus change the magnetic field strength. After testing, the magnitude of 4^{th} order term can be adjusted by ±2.5E-10 in this testing assemblage (unit: mm). This range is sufficient to compensate the profile error of the bender prototype, of which the 4^{th} order term profile error was calculated to be 9E-11. Adjusting carefully, the slope error of the prototype bender can be reduced to 3.8μrad as shown in Fig. 6. Moreover, an adjustment of the 5^{th} order term by ±1.3E-12 can be reached by adjusting the assembling nuts and this range is limited by the adjusting space between the bender and the housing plate. Nevertheless, These ranges cannot be reached simultaneously, since the magnitude of each order will be changed when the nuts are adjusted.

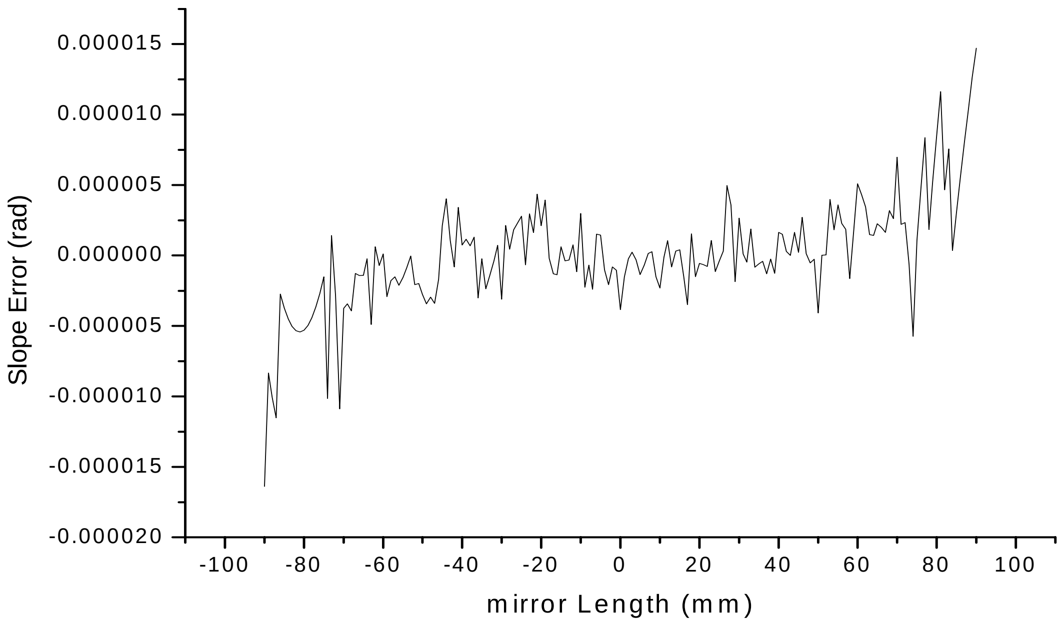

Figure 6. Measured slope error of the prototype bender with the compensation of the magnetic force

The terms of order above five can still be finely adjusted but limited by the tenderness of the housing plate and their range is hard to determine because all high order terms are changed when the nuts are adjusted. Meanwhile, the poor roughness of the prototype (10nm RMS) also influences the measuring accuracy of the high-order terms above 5. However, profile error compensation up to 5^{th} order should reduce the error drastically and a good mirror surface could be obtained as in our case.

4. Conclusion

An additional magnetic mechanism was designed to compensate for the high-order terms (of order greater than 3) of the surface profile of a previously designed monolithic bender. The copper housing plate was also designed as a cooling conductor, by the use of a liquid metal medium to cool the bender. The prototype test results reveal the effectiveness of this design. A mirror surface profile error compensation or modification up to 5^{th} polynomial order is possible by using this mechanism.

The adjusting range of this design is limited by the original bender design. A modification to the bender design will be made in the future manufacturing to increase the range. Furthermore, since this design includes 20 adjustable nut pairs, the nuts should be carefully and patiently adjusted to obtain a satisfied mirror surface. Meanwhile, the adjustment should be as symmetric as possible to prevent lateral distortion of the bender. An efficient adjusting algorithm or modification still demands further study.

In the cooling conductor application, the gap between the copper plate and bender should be as small as possible, thus limiting the adjustability of this design and requiring that the magnetic field be carefully calculated case by case in order to compensate for the profile error.

5. Reference

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