Control Strategies for Nanometer Precision in Ultra Precision 3D Cordinate Meausuring Machines

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Abstract

This paper presents control strategies for the next generation of ultra precision 3D coordinate measuring machines realising a measurement uncertainty of 2nm. To achieve this high precision, a 6DOF positioning stage is applied with a total of 6 IFM beams. These signals are processed through an FPGA to obtain the position, inclusive of periodic non-linearity correction, for subsequent use by a feedback controller. By moving the stage under a fixed microscope or probe, a 2.414 pm resolution is achieved for the measurement of an object.

There are two requirements on the alignment of the object with respect to the stage:

R1. High reproducibility of the mounting of the object on the stage.

R2. Any movement during a measurement (up to 72 hours) should be avoided.

To achieve R1 a handler is used to accurately lower the object onto a kinematic mount on the stage, while the stage is activily controlled. An example of such a mount in given in Figure 1.

To achieve R2 the object should be placed without inducing stress between the contact points of the object and the stage. Any remaining stress could cause a sudden stress release which causes a nanometre jump of the object compared to the stage, see Figure 3 (top).

The handover process introduces forces in the XY plane of the stage (Figure 2). A conventional feedback controller for the stage will counteract this force, thereby introducing stress in the feet of the object, violating R2. Hence, to achieve both R1 and R2 a new control strategy is developed that both limits the forces of the stage during the placement of the object (R2) while guaranteeing the reproducibilty of the alignment of the object (R1). Implementation of the control strategy in this real time environment with FPGAs is described in this work. Results showing that nanometre level distruptions can be avoided with this new control strategy are presented, see Figure 3(b).

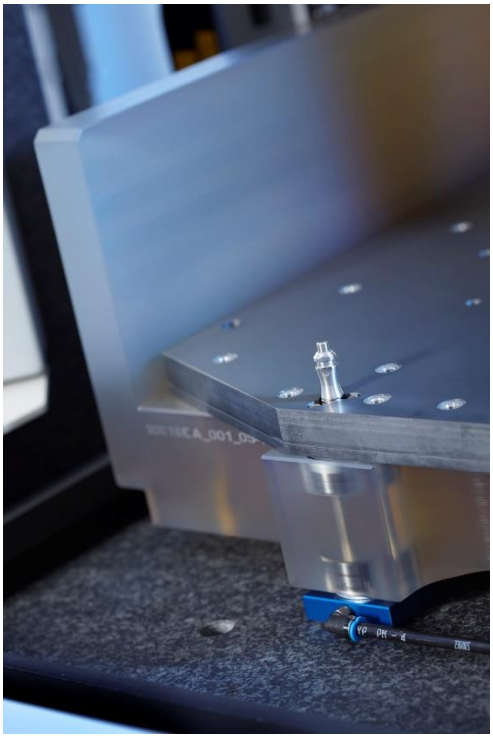

Figure 1: Example of product table with kinematic mount.

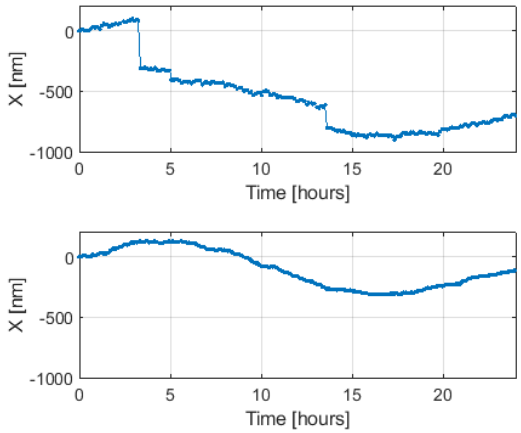

Figure 3: Measured X position of the object. Top: object loaded with stress introduced in the contact points, jumps are visible. Bottom: object loaded with control strategie that limits stress in the contact points, no jumps observed

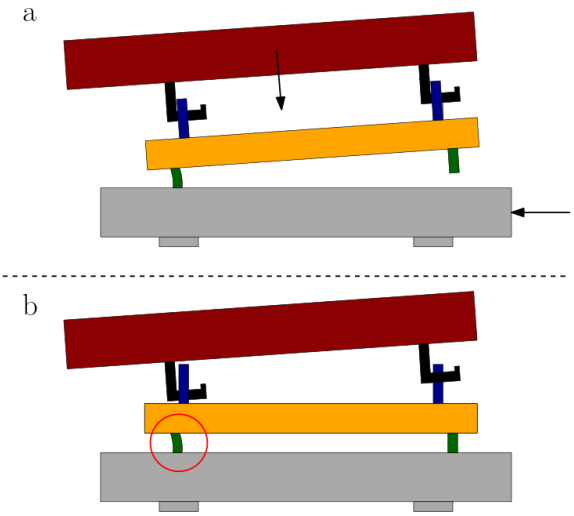

Figure 2: 2D representation of object placement. The handler in red; the object in yellow; the feet of the object in green; the stage in gray. a: first feet in contact; b: second feet in contact, stress induced in the contact point.