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TEST BENCH FOR MOTOR AND MOTION CONTROLLER CHARACTERIZATION

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Abstract

To maximize beamtime usage motorization of beamline equipment is crucial. Choosing the correct motor is complex, since performance depends largely on the combination of motor and motion controller. This challenge, alongside renewing the twenty years old infrastructure at BESSY II, led to the demand for a motor test bench.

The test bench was designed to be modular, so it fits different motors, loads and sensors. It allows independent performance verification and enables us to find a fitting combination of motor and motion controller. The test bench is operated via EPICS and BlueSky, allowing us usage of Python for automated data acquisition and testing. An overview of the mechanical and electrical setup, as well as some data from different performance tests will be presented.

INTRODUCTION

BESSY II is nearly 25 years in service. Focusing on soft and tender x-ray radiation, over 2700 worldwide users per year conduct experiments on 48 beamlines [1]. Monochromators are needed to select the required photon energy from the spectrum. The monochromators depend on a precise positioning of their optical components. The positioning is usually done by stepper motors and controllers. Therefore, the combination of stepper motor and controller play a critical role in the success of an experiment. At BESSY II there is no uniform consensus about what stepper motor and controller combination should be used. Over the last 20 years many different philosophies and requirements led to a variety of different motion controllers and stepper motors in the experimental hall [2]. Various attributes of the controller and stepper motor combination add up to its performance for a dedicated task [3]. For example, the ability to perform µsteps precisely and reliably plays a key role in positioning. Whereas moving large inertias focuses on high torque.

Previously, finding a well-suited combination for a specific task depended on manufacture's data sheets and experiences. Because BESSY II was built in the early 90s, many of the motion controllers are out of service by their manufacturers today. Aside from that the information provided by them is usually not sufficient. The construction of a motor test bench allows a decision based on results of self-defined tests to find the right use for a combination.

IDEA

The test bench should help with characterization of the different motor-controller combinations used in the experimental hall at BESSY II. The idea was to build a test bench, which allows custom defined test sequences. The requirements of the test bench are:

- fit a variety of components,
- simple prototype,
- mobile,
- similar to the beamline environment.

The results of the tests performed on the test bench allow us to determine whether a combination of stepper motor and motion controller fits the requirements for a task.

IMPLEMENTATION

The test bench is divided into a mechanical setup (with experiment specific components mounted) and a control and data acquisition systems. Figure 1 displays the interconnections between the systems.

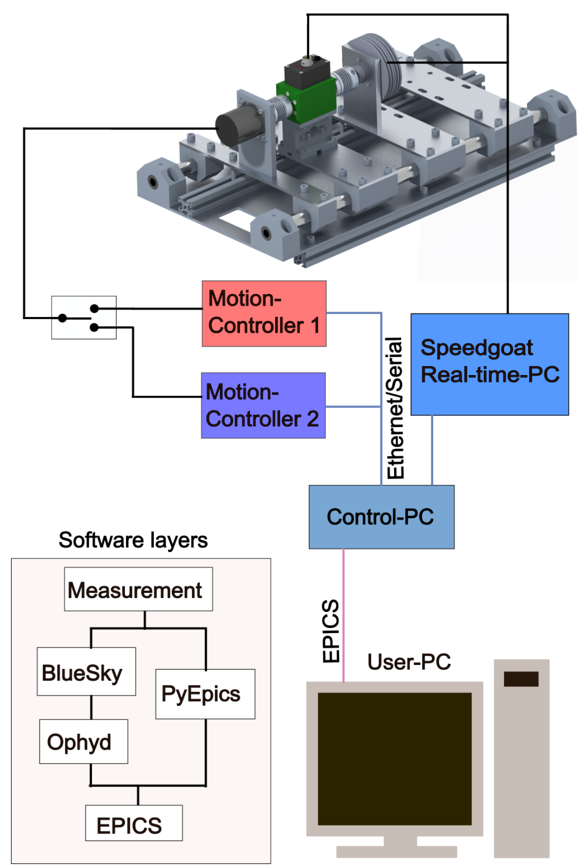

Figure 1: Schematic representation of the test bench.

Mechanical Setup

Figure 2 shows the mechanical setup in two views. Modularity is a key requirement for the mechanical setup of the

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test bench. It is reached by dividing the setup into movable mounts, a guiding system and a ground plate. The guiding system itself consists out of two shafts with linear bushings. Two bushings of same size are connected via plate. One of these plates is highlighted as Detail B in Fig. 2. It allows the possibility to screw components directly onto it, or fit a flange plate shown in Detail A. The guiding system is connected with the ground plate via shaft support blocks. In the current state each shaft holds four linear bushings. The sequence of their bushings and there number can be modified by detaching the shaft from the shaft support block.

The guiding system allows movements in one degree of freedom. This movement is used to install components of different sizes on the test bench. In the top-view of Fig. 2 Detail C points on holes in the plates of the guiding systems. These holes in the plates allow a component to be blocked in its linear movement. To do this, they are connected to the profile below with a screw. With this system the test bench is able to support a variety of test components.

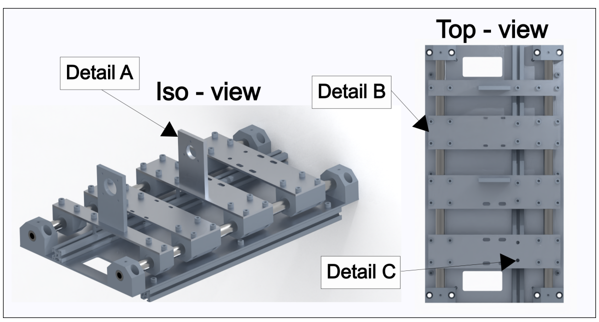

Figure 2: mechanical Setup of the test bench.

Due to the plate construction, the test bench can be easily extended, or parts can be newly manufactured with little effort. For example, to fit a more powerful brake as a load into the test bench, it is only required to create a new flange plate. In the top-view on the right-hand side of Fig. 2 holes to carry the test bench are visible. These can be used to carry the test bench. Figures 3 and 4 demonstrate two test setups that are currently used.

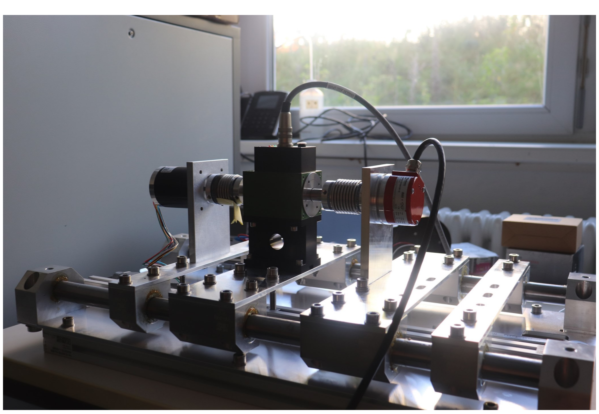

Figure 3: Setup for testing time resolved positioning.

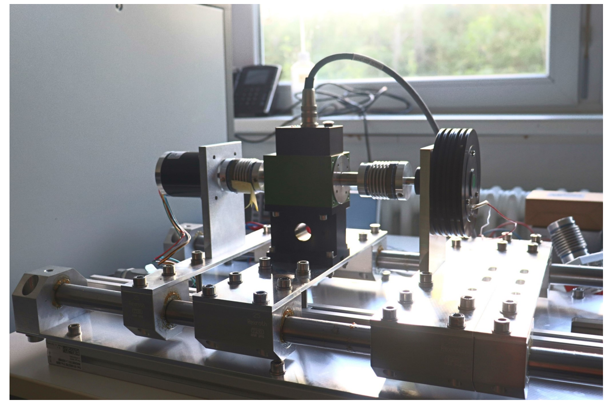

Figure 4: Setup for testing torque with different µstep-settings.

Controlling

The test bench was designed to create a similar environment to the experimental hall. Because of that, EPICS is the lowest level of the control system. Physical devices, like sensors, loads or motors are represented in EPICS by an IOC(Input/Output-controller) [4]. These IOCs enable an automated measurement process in the EPICS environment. There are two ways to control the tests and aquire data. Firstly, tests can be realized via scripts and functions in PyEPICS. The usage of Python makes it easy to program and therefore conduct unique tests. Another option is to use the embedded features of BlueSky. BlueSky offers a variety of pre-programmed plans for general tests.

TEST RESULTS AND DISCUSSION

The test bench allows a variety of test setups. In this section some results from different characerization tests is presented. In the tests a ZSS 57 stepper motor from Phytron was controlled by a "PhyMotion-I1AM01" and a "Copley-StepNet2" [5, 6].

Attributes from the ZSS 57: [7]

- 2-phase hybrid stepper motor,
- 200-step (step angle 1.8°),
- Holding-torque 700 mN m.

Testing Microstep Accuracy

Performing microsteps with repeatable accuracy is an essential feature in positioning. Depending on the technology used to regulate the current in the motor coils by the motion controller, a motor can behave very differently. Therefore, measuring open loop time-resolved positioning of one motor with different motion controllers connected can show the controllers´s traits. In the test, a motor moves from 0° to 180°, alternating with two controllers. Both runs are performed with 20 microsteps per step. Increment of motion:

$$\frac{1.8\ ^\circ}{20 \text{ microsteps}} = \frac{0.09\ ^\circ}{\text{microstep}} \tag{1}$$

The motor was supplied with 1500 mA run current and 1000 mA stop current. Figure 5 and 6 display the results of

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the test.

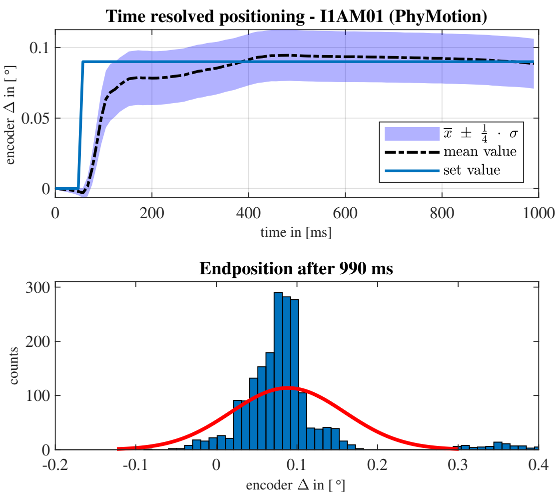

Figure 5: Statistical analysis of the microstep accuracy - I1AM01.

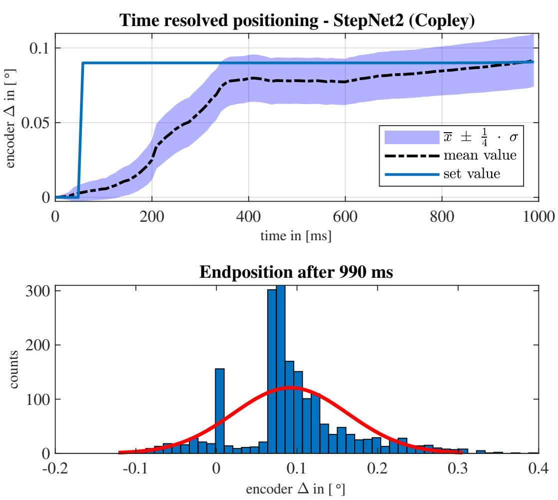

Figure 6: Statistical analysis of the microstep accuracy - StepNet2.

Furthermore the Encoder-Δ for every individual microstep is displayed in the plot in Fig. 7.

Figures 5, 6 and 7 reveal a different motor behavior. The first difference is the speed of the positioning. In Fig. 5 the I1AM01-controller reaches the set-Value much faster than the StepNet2-controller. The second difference is shown in the histograms in the second line in Fig. 5 and 6. The controllers show differences is the range of deviations. For Example, there a many high deflections from the intended value of 0.09 ° with the I1AM01-controller. This impression is confirmed by Fig. 7. The I1AM01 has a periodical error on every eleventh, twelfth and thirteenth step, where it travels up to 4 times the called value. This experiment provides insight into the open loop running behavior of combination of motor and motion controller.

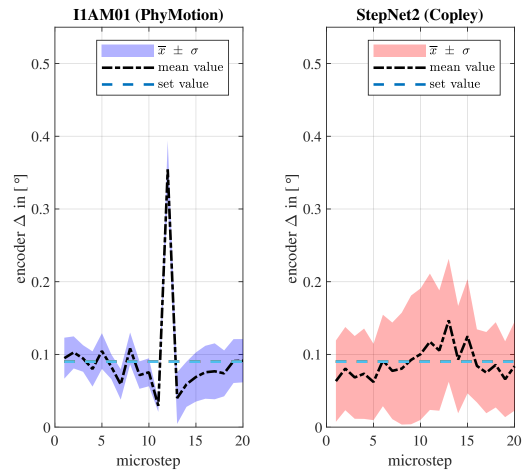

Figure 7: Individual microsteps in a movement of 180 °.

Testing Maximum Torque with Different Controllers

Manufactures often provide only one motor curve for their motors. This curve strongly depends on the used motion controller as well as the electrical power provided by the controller. With the test bench it is possible to measure the motor curve with different motion controllers and different currents applied.

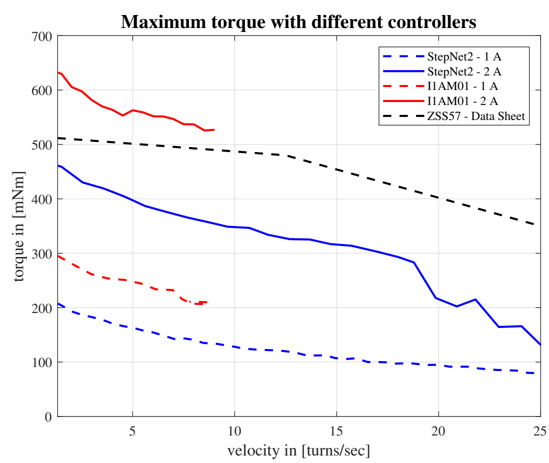

Figure 8: Torque vs. velocity with different motion controllers.

The plots in Fig. 8 reveal a distinctive motor curve with another motion controller connected. There is a large difference between the Copley and PhyMotion-Controller in maximum torque and maximum velocity with identical currents applied. The PhyMotion is not capable of reaching over 10 turn/s without overheating, whereas the Copley-Controllers enables the motor to reach a velocity of 25 turn/s. This example demonstrates how the test bench helps finding the right use cases for the different combination of motion controllers and motors. With the large velocity advantage, a gearbox could realize high torque applications with

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the Copley-controller. The PhyMotion, on the other hand, achieves higher torques for lower speeds.

Testing Maximum Torque with Different Microstep Settings

Depending on the motion controller an increase in position accuracy via higher microstep setting can come with side effects, such as decrease of maximum velocity or torque. Testing and quantifying the impact of a change in microstepping on other parameters is important for the motion controller's classification. Figure 9 presents the maximum torque for different microstep settings.

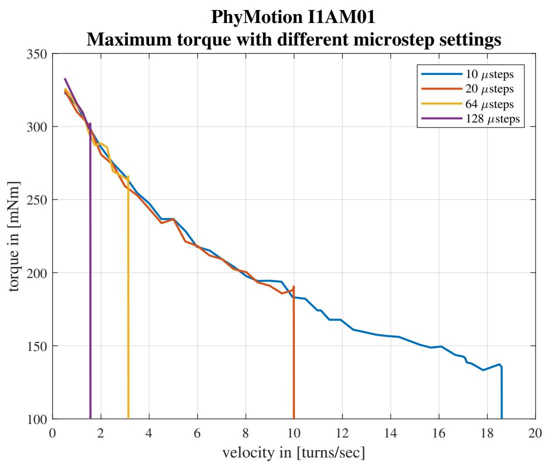

Figure 9: Torque vs. velocity with different µstep-settings - I1AM01.

The test was conducted with 1000 mA run current. While the plot vary in their maximal velocity the PhyMotion is capable of performing 128 µstep/step with the maximum torque from Fig. 8.

CONCLUSION

The test bench presents the first prototype for testing stepper motors and motion controllers at BESSY II. By running a variety of tests, it is already possible to measure and characterize different motor-controller combinations. This characterization enables us to select motor-controller combinations best suited for their needs. In addition to that no beamtime is used for these tests.

The project is still in development. It is planned to build more test benches. This increases the number of experiments and creates the opportunity for new tests. The following list contains some examples of tests planned in the future:

- start-up behaviour with different inertias,
- positioning accuracy with different inertias,
- synchronous driving of two or more motors.

ACKNOWLEDGEMENTS

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