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| TARGET FAT GALICIA |
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# Background

The target wheel and drive unit FAT took place week 7 2022 at Thune Eureka premises in Galicia Spain. This report contains analysis of some data acquired during the FAT tests.

## Equipment in scope

Each JJ X-RAY slit set consists of two motorized translation stages. Each translation stage can be

individually positioned in the vertical direction, Figure 1.

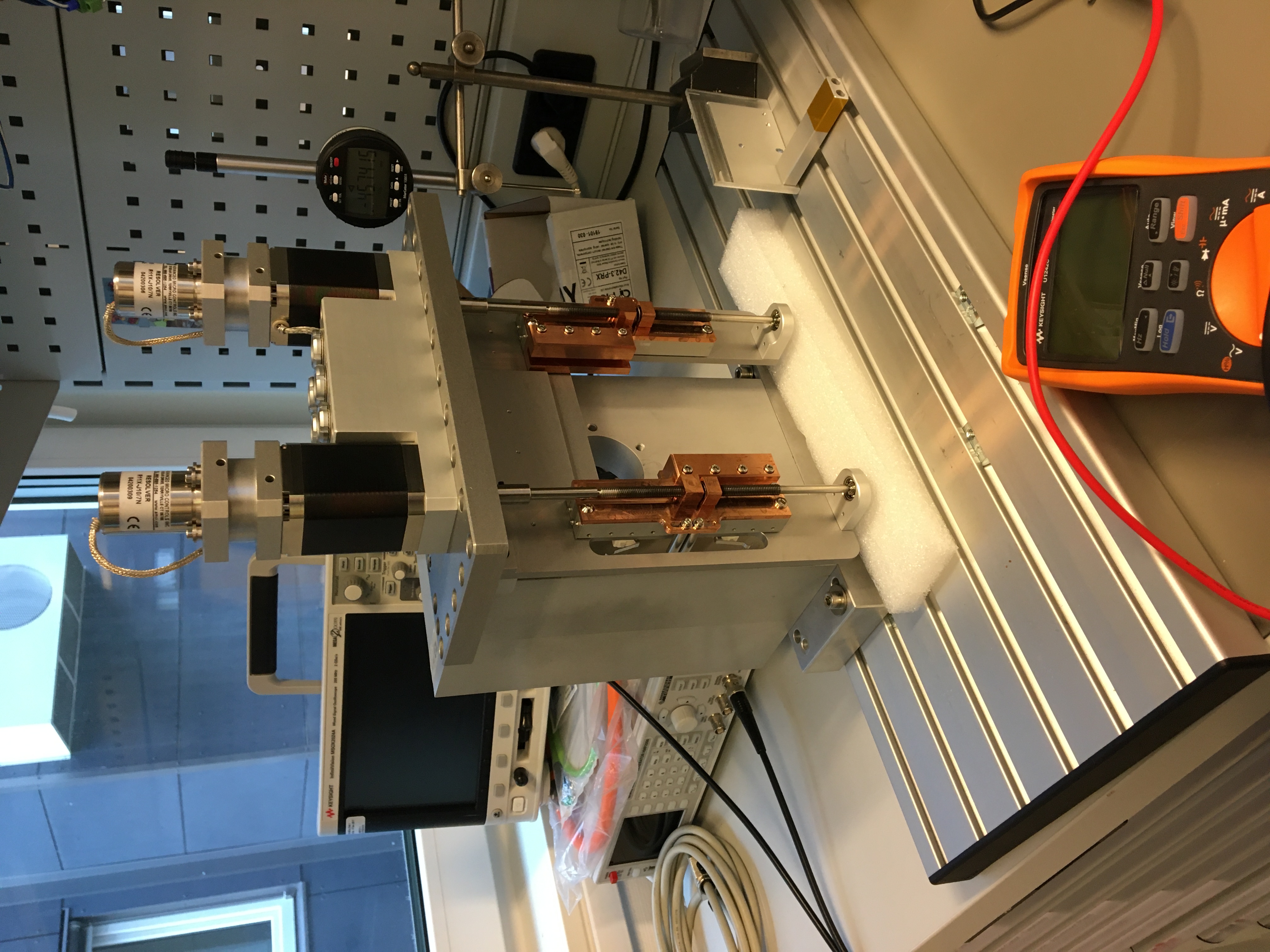


Figure 1: JJ X-RAY: Slit set

Each axis is equipped with the following components:

* Stepper motor: AML-D42.3 (with new bearing type)[8]
* Resolver: AMCI R11X-J10/N [10]
* Limit switches: Saia-Burgess F4T7YC-GP-UL
* Stroke: Approx. 70mm
* Leadscrew (1mm pitch)

# Requirements

The following requirements have been set by the BIFROST team:

1. Stroke: 40mm
2. Accuracy: +-0.1mm
3. Repeatability: +-0.05mm
4. Resolution: 0.01mm minimum

# CONTROL SYSTEM

The SAT was performed with an EtherCAT [1] based control system, ecmc [2]. The configuration files, raw data and analysis results for the SAT have been added to a git repository [3].

All hardware needed for the tests have been integrated into the same system which then leads to that all sampled data have the same time base.

## Hardware

The following control hardware was used:

1. EL7037: Stepper motor drive [4]
2. EL1808: Digital input for switches [5]
3. EL2808: Digital output to feed switches [6]
4. El7201: Resolver interface [7]
5. ILD2300: Micro Epsilon laser triangulation sensor [8].

## EL7037 Stepper drive

The EL7037 stepper drive was configured in a similar way as was done in the JJ X-RAY FAT procedure, [9]:

1. Control mode: Open loop
2. Run current: 0.61A
3. Standby current: 0.087A
4. Micro stepping: 64fold (resolution 12800steps/rev for the 200m step motor)
5. Velocity: 0.75mm/s (slower than the 2.5mm/s what JJX-RAY used at FAT)

## EL7201 Resolver interface

The EL7201 resolver interface delivers a single turn resolution of 20bits (1048576 counts/rev).

## Feedback systems

Two different sensors are used as position feedback for the tests.

1. ILD2300 : Micro Epsilon Laser triangulation sensor [9].
2. Resolver : AMCI R11X-J10/N [10]

### Laser triangulation sensor Micro Epsilon ILD2300

The Micro Epsilon ILD2300 sensor was used as external measurement and verification system. The ILD2300 have the following specs:

1. Range: 50mm
2. Linearity: +-10 μm (protocol: Appendix A Micro Epsilon ILD2300 Calibration)
3. Resolution: 0.8 μm

This sensor can only cover parts of the approximate 70mm stroke.

### Resolver, AMCI R11X-J10/N

The AMCI resolver was delivered with the slits mounted on the second shaft of the motor. The AMCI R11X-J10/N resolver have the following specs:

1. Accuracy: 7 arcmin (0.12deg)
2. Input voltage: 7V
3. Input frequency: 5000Hz
4. Transformation ratio: 0.95+-5%

The accuracy of 7arcmin corresponds to a linear accuracy of 0.32μm.

# METHOD

## Rotation velocity stability

Velocity was measured by differentiating the position value of the rotational encoder. The velocity signal was then averaged over one sector, 10 degrees, in order to filter noise mainly derived from high sample rate of the encoder signal. The velocity stability then calculates as the maximum spread of the velocity signal over a time period.

## Rotation traction difference over revolution

Traction difference over the rotor revolution was measured by analysing the deceleration rate of the rotor with motor disabled (power less).

## Rotor displacement amplitude

The maximum rotor displacement was measured by 5 positional sensors:

* 3 eddy current sensors mounted in the horizontal x,y-plane in the pedestal, displaced 120 degrees.
* 1 eddy current sensor mounted in the z direction in the pedestal
* One optical triangulation sensor measuring the displacement of the circumference of the target wheel outer surface. The optical sensor was also used for calibration of the eddy current sensors by replacing and comparing it to the eddy current sensor positioned at 120 degrees.

### Rampup

#### X-Y

#### Z

#### Rotor circumference

### Steady state

### Rampup

X-Y

Z

Rotor circumference

### Rampdown

### Rampup

X-Y

Z

Rotor circumference



Figure 2: Test setup

All raw data and more detailed reports can be found in the following git repository:

<https://gitlab.esss.lu.se/mcag/instruments/bifrost/ecmc_bifrost_slits_sat/-/tree/master/tests_2>

## Analysis

# Analysis

## Torque variations during velocity ramp down

Encoder angular position data was sampled during ramp down with motor disabled meaning only the traction in the system, mostly in bearings, and inertia of the rotor will affect the deceleration ramp (no torque on motor). The zero value of the angular position is defined by a reference mark on the encoder ring and can therefore be used as an absolute angular reference of the wheel.

The lower graph in Figure 3 shows the angular position during ramp down from 23 to 0 rpm in unit degrees. Each red vertical line indicates one full revolution.

Velocity is calculated by differentiating the position value from the rotational encoder and (center graph). The total time to ramp down from 23rpm to 0 is approximately 94 seconds.

The average traction torque can be calculated by:

τ = Torque [Nm]

I = Inertia [kgm2] = 5260kgm2

α = angular acceleration [rad/s2], 23rpm to 0 rpm in 94s

The average traction torque can then be calculated to approx. 135Nm.

Unfortunately, the velocity values are too noisy to differentiate into acceleration. Instead the upper graph shows the velocity but without the pure linear deceleration component generated by the 135Nm traction. It can be concluded from the upper graph that the deceleration is not constant during the ramp down process and also varies cyclically within each revolution.

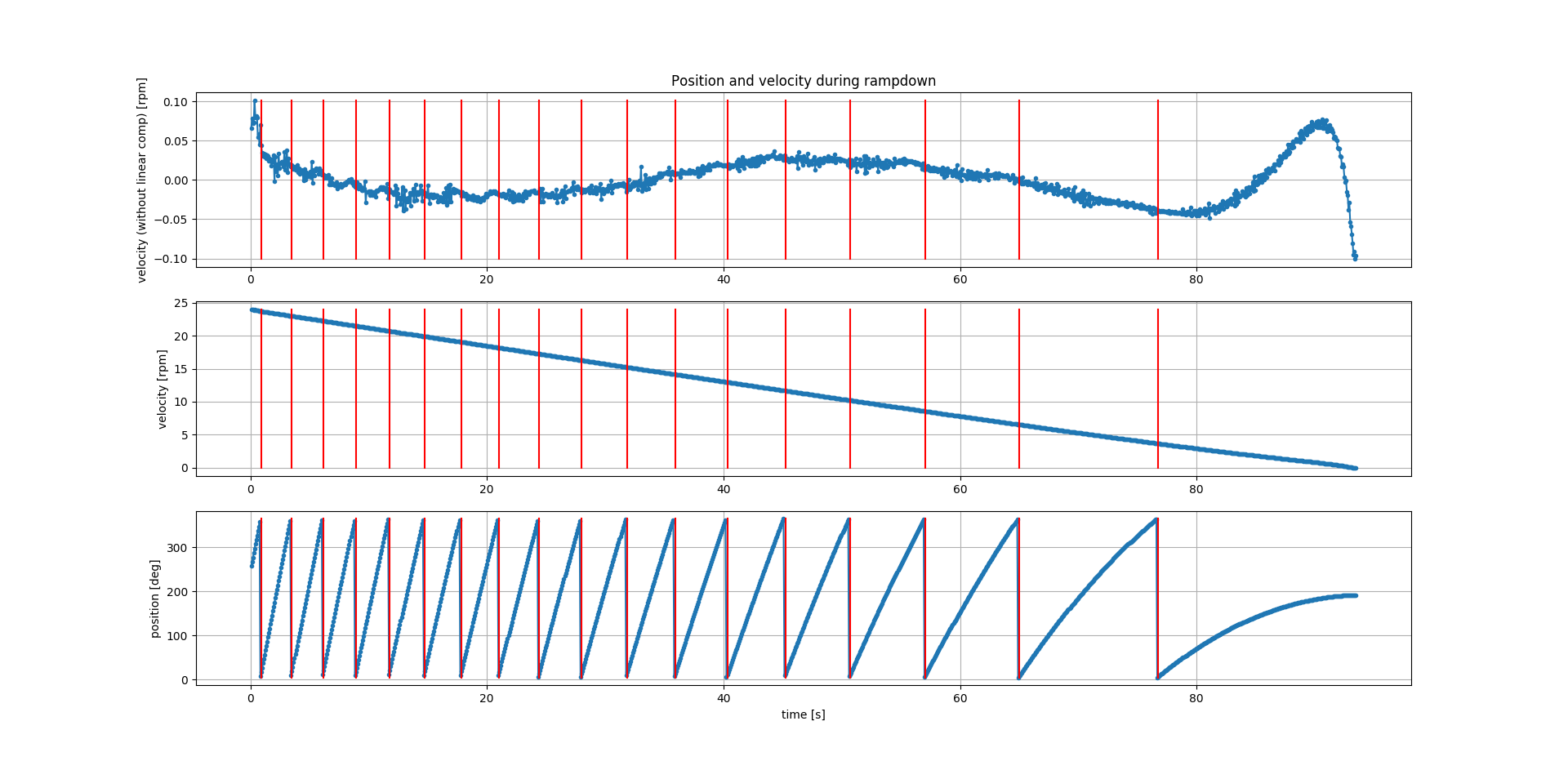


Figure 3: Ramp down from 23 rpm (lower = position, center=velocity, upper=velocity-minus linear component).



Figure 4: Velocity for each rev vs rotation angle and time (linear velocity component removed)

Detailed velocity changes for each revolution from the upper graph in Figure 3 is plotted in Figure 4, the upper graph shows velocity vs angular position and the lower graph shows velocity vs time. A polynomial fit for the dataset of each revolution is also plotted in the same color as the raw velocity data. All revolutions show a similar shape where in the first part of the revolution the deceleration is faster than in the second part of the revolution. This could be an indication that the traction torque is not same over the revolution. By analyzing the slope of polynomial fits it can be concluded that the torque difference within the revolution is in the order of +-10Nm in average for the analyzed revolutions.

PLOT TORQUE

In order to verify the results a second test with ramping down from 28rpm was executed.

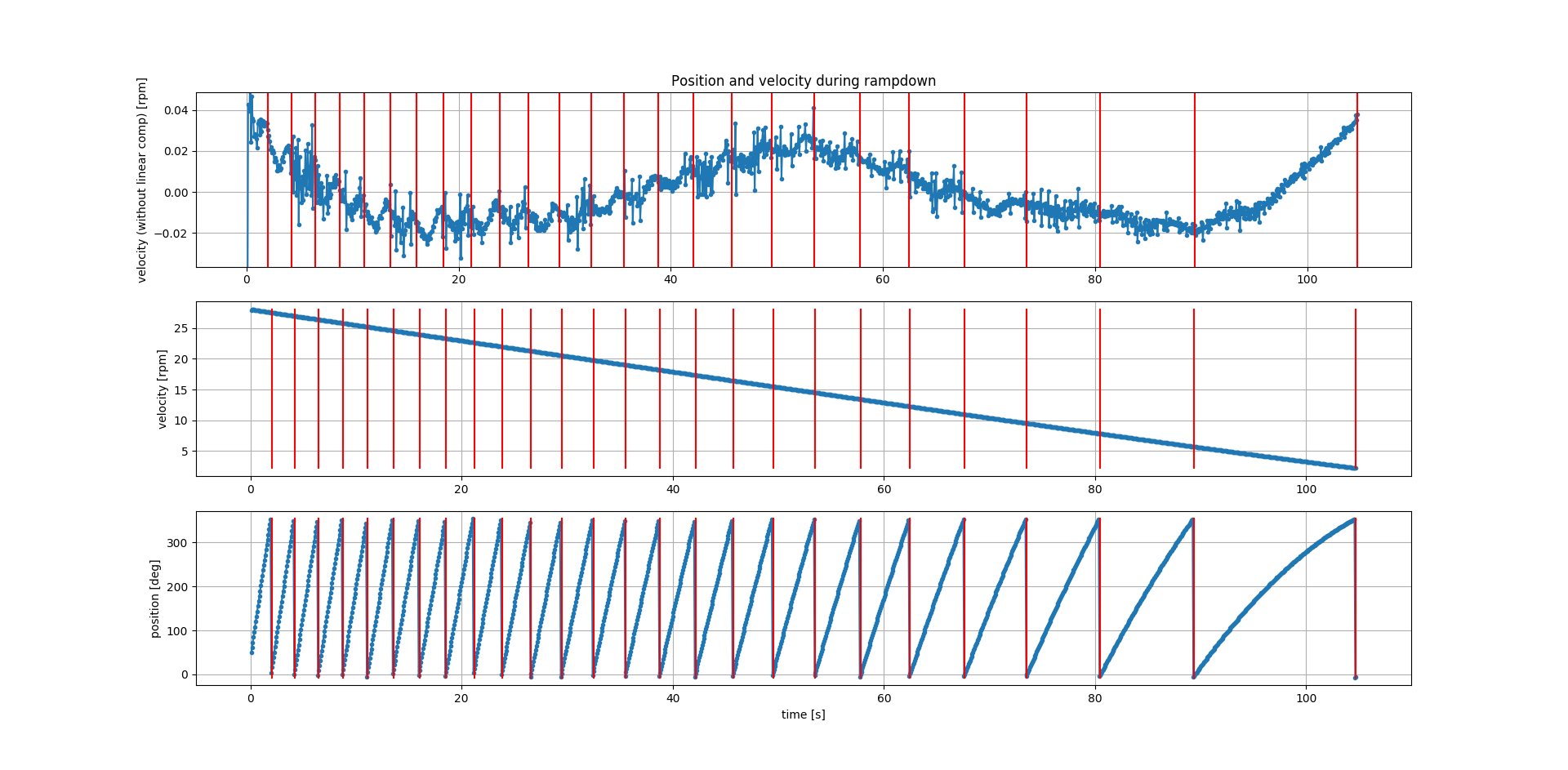


Figure 5: Ramp down from 28 rpm (lower = position, center=velocity, upper=velocity-minus linear component).

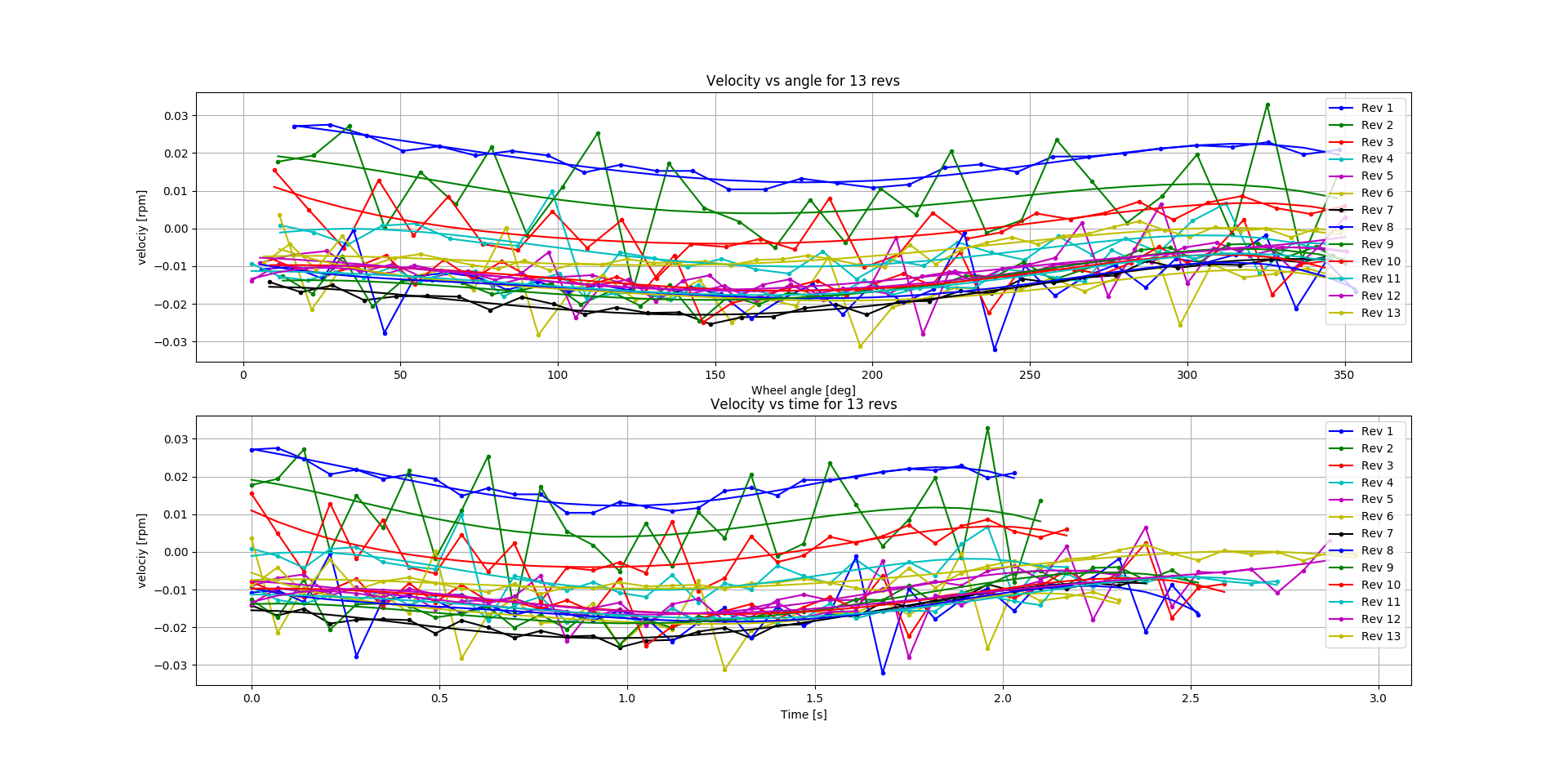


Figure 6: Velocity for each rev vs rotation angle and time (linear velocity component removed)

# Results

## 11359 Axis 1

Table 5: Results 11359, axis 1

# CONCLUSIONS

The results of this second SAT presented in chapter 5 can be summarized as follows:

* Accuracy and repeatability:
  + All axes fulfill the requirements with good margin.
* Switches:
  + The switches identified with bent actuation brackets had been fixed/replaced.
  + 11358, axis 1 was found to have worse performance of the low limit switch compared to what was found during the first SAT test.
* Noise:
  + Mechanical grinding noise was still observed from most of the axes. However, the situation has improved a lot since the first SAT.
  + Two of the axes was almost silent.
* 11360 slit set:
  + Electrical connection was fixed and could now be tested for the first time.
  + axis 1: Mechanical grinding noise, the worst numbers of accuracy and performance of all the axes but still within spec.
  + axis2: No mechanical noise and well within spec for accuracy and repeatability.

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# Appendix A Micro Epsilon ILD2300 Calibration REPORT

