

Collimators stepping motors: Preliminary measurements

A. Masi

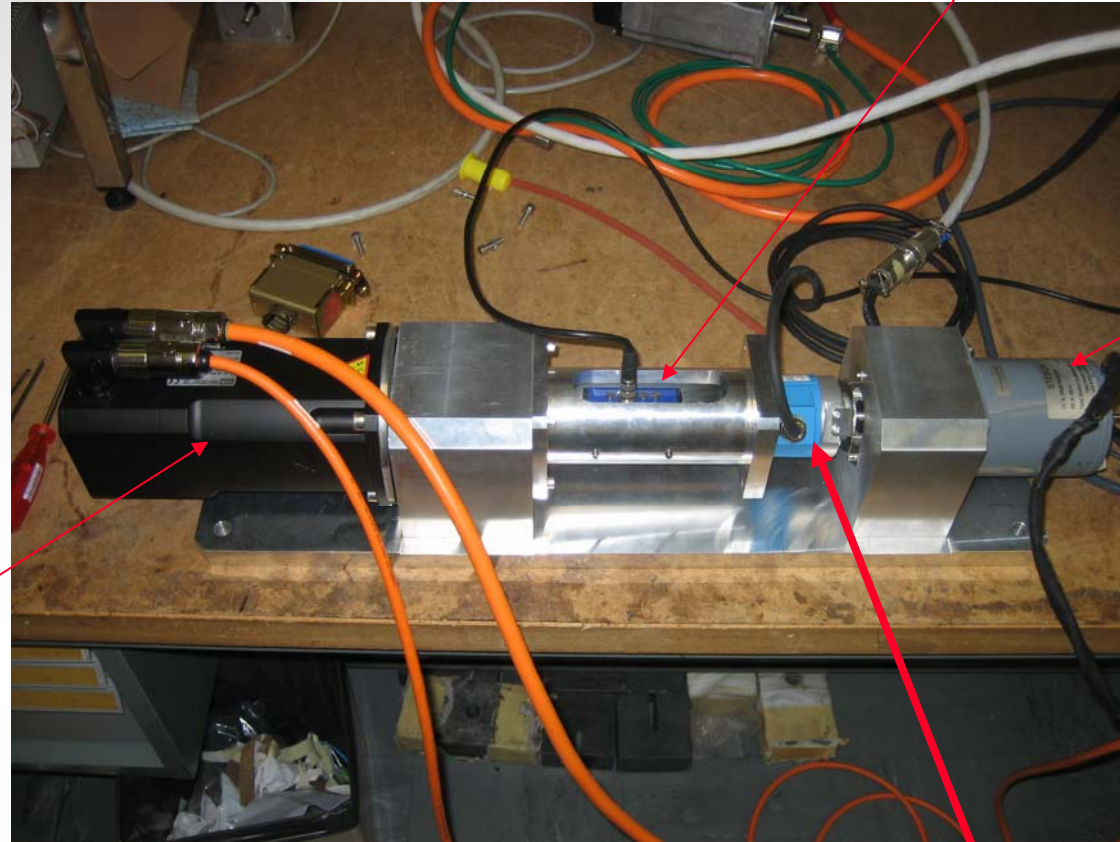
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Stepping motors test bench solution 2

Torquemeter

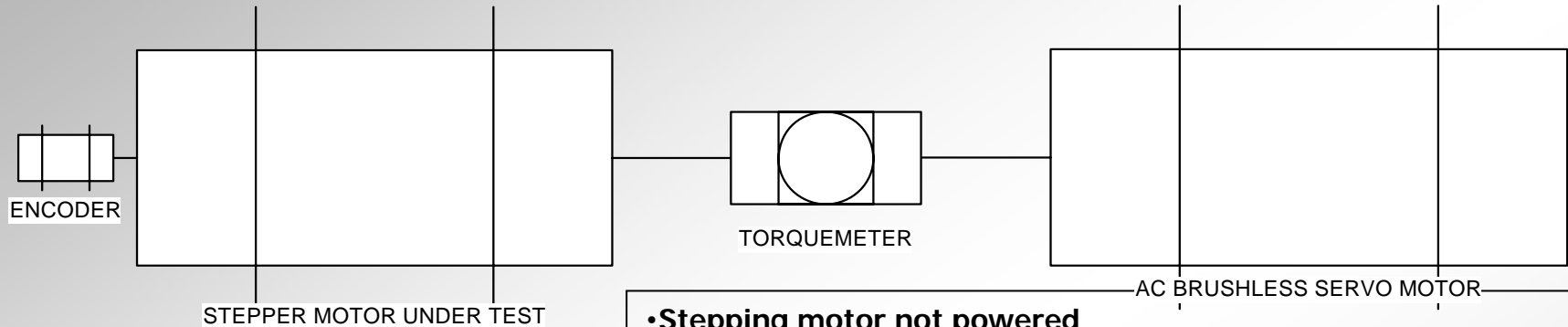
Stepping
Motor under
test



Motor AC
Brushless

Encoder

Parameters measured



Static Parameters



Detent torque:



- Stepping motor not powered
- Brushless AC motor turn at 0.1 rpm (works like motor)
- torquemeter output is acquired over 1 turn and synchronised with the encoder



Holding torque:



- MUT powered on
- Brushless AC motor turn at 1 rpm (works like motor). Its torque is changed till the stepping motor loses steps
- torquemeter output is acquired for 2 s and the detent torque corresponds to the last torque acquired before losing steps

Dynamic Parameters



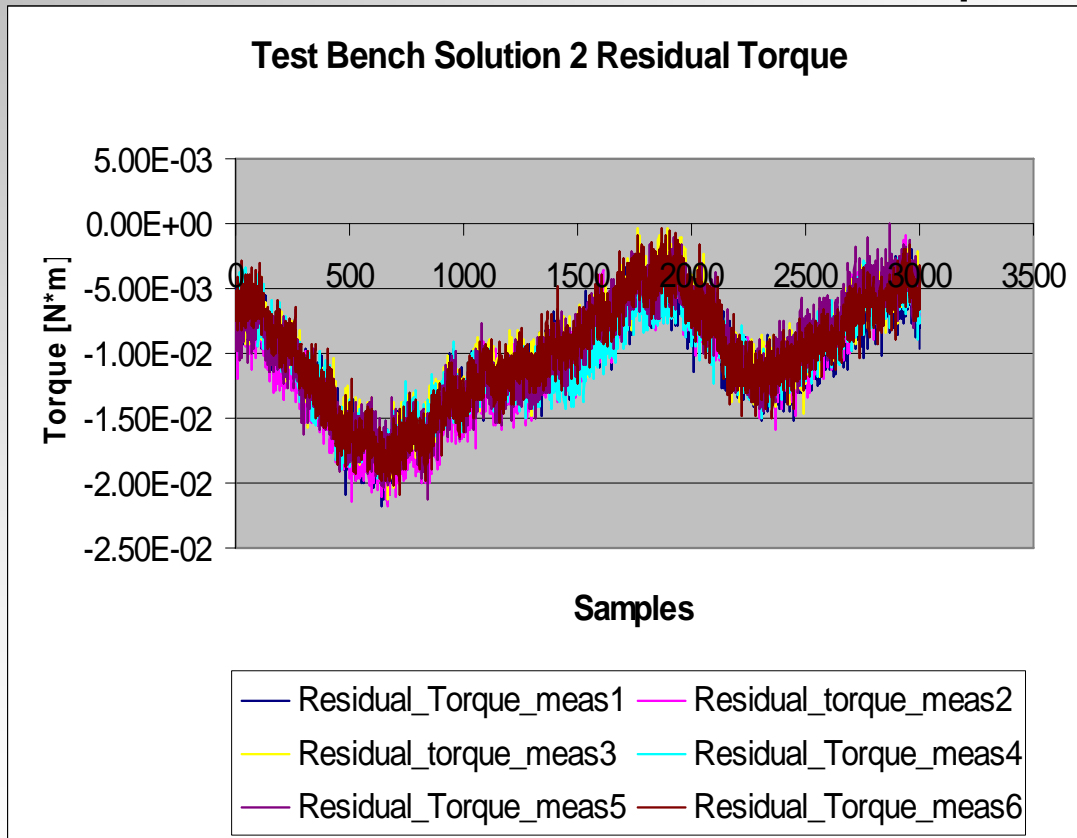
Pull-in/Pull-out torque:



- MUT powered on
- The brushless AC motor is controlled in torque (works like a brake)
- On the MUT a specific frequency (speed) is tested
- Pull-in: The Brushless torque is decreased until the MUT starts (checked with the encoder)
- Pull-out: the torque of the brushless is raised till the stepper loses steps

Test Bench Calibration

The residual torque over a complete turn has to be subtracted to the stepping motor detent torque measurement



Torquemeter Technical Characteristics:

- **Non linearity Error + Hysteresis:** <1%
- **Sensor Repeatability:** <0.1%

Improvements applied:

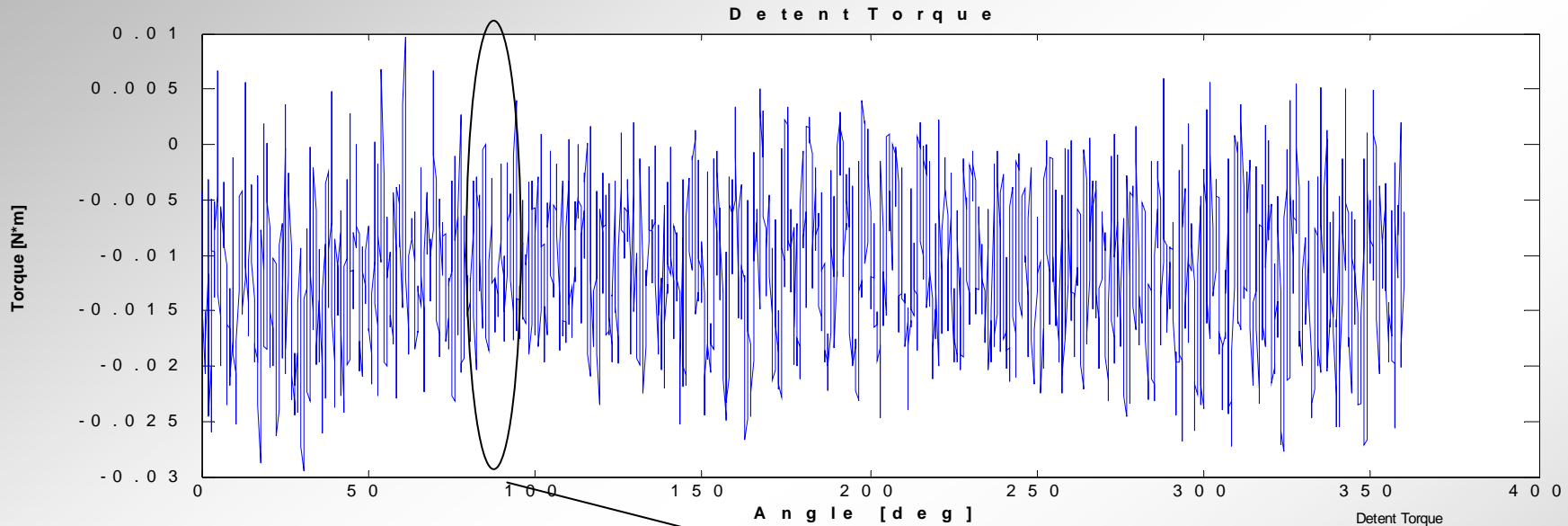
- Use of sensor calibration curve (10 points)
- 100 oversampling factor in the torque acquisition

Performances reached:

- **repeatability** : less than 1 mN*m
- **Sensitivity:** 5 mN*m
- **non-linearity** : In the range 0-200 mN*m the error is lowered to less than 0.1 %
- **Overall accuracy:** 5 mN*m on the detent torque

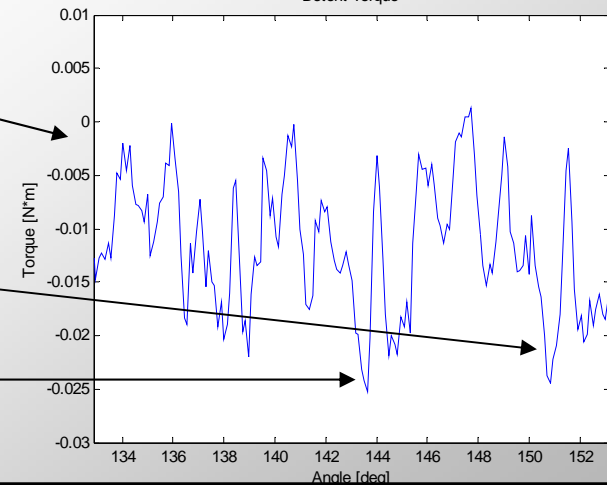
Detent Torque

Motor LEP 1 (S03362 - 1/19)



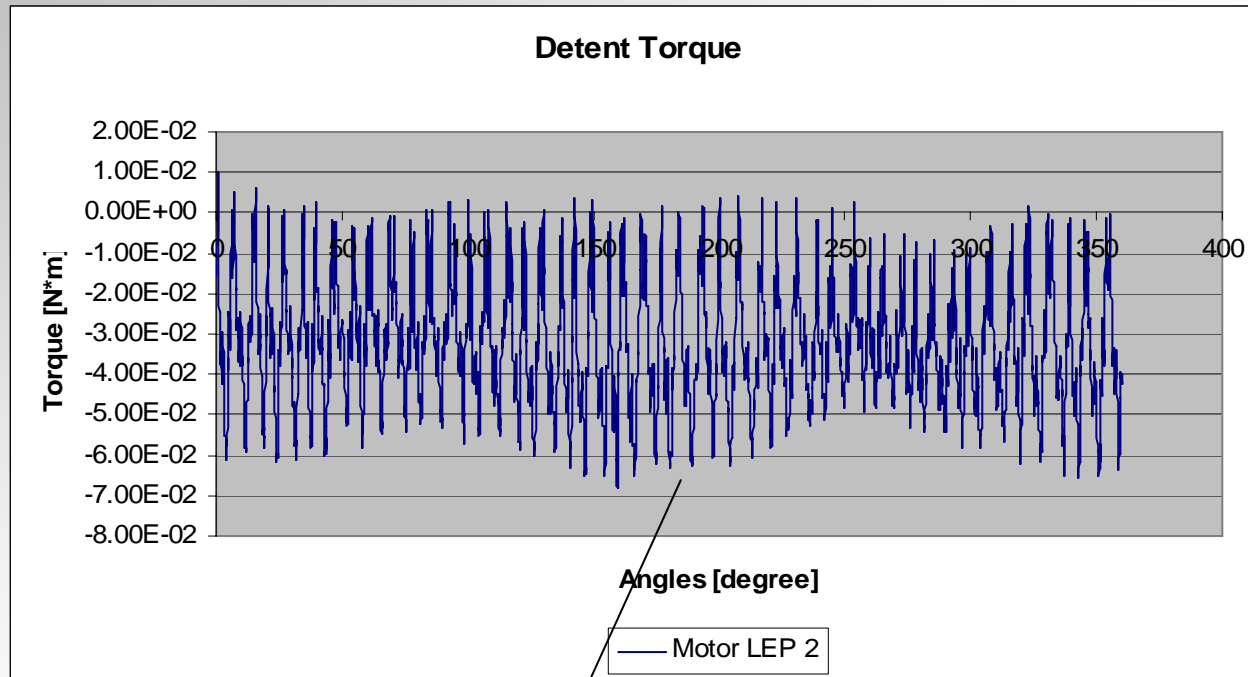
The max detent torque is 30
mN*m

Two consecutive magnetic poles
equispaced of 7.2 degree (the rotor
contains 50 magnetic poles)



Detent Torque

Motor LEP2 (D8L851-N1510 no ...-1/3)

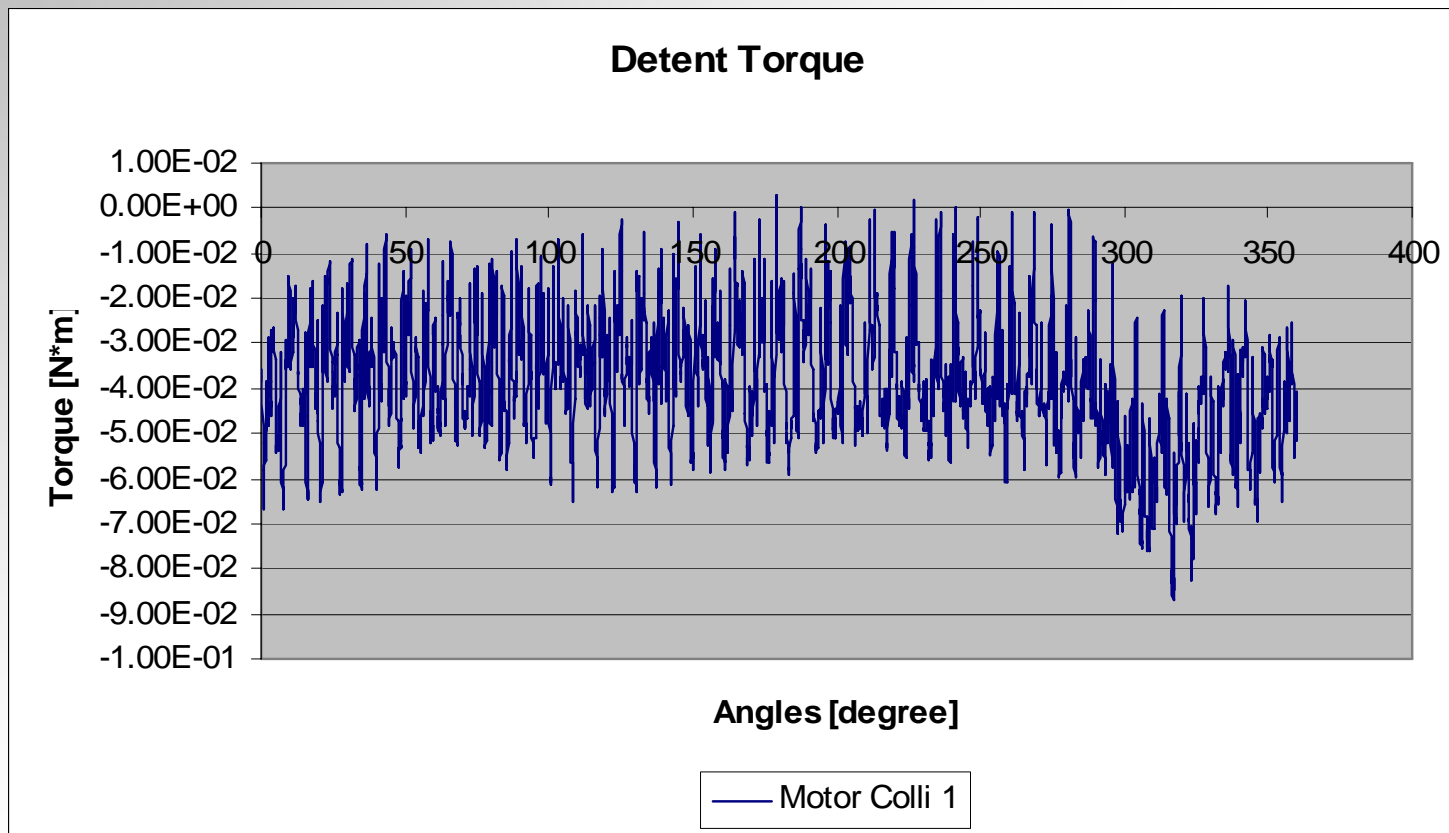


- Acquisition carried out over a complete revolution
- Test speed 0.1 rpm
- Sampling frequency torquemeter: 5 KS/s
- Acquisition decimation factor: 100

For this motor (more radioactive than the other one) the max detent torque is 60 mN*m

Detent Torque

Motor 1 Colli 3nd Proto (SD8L851-740-39N2166
10341-01/4)

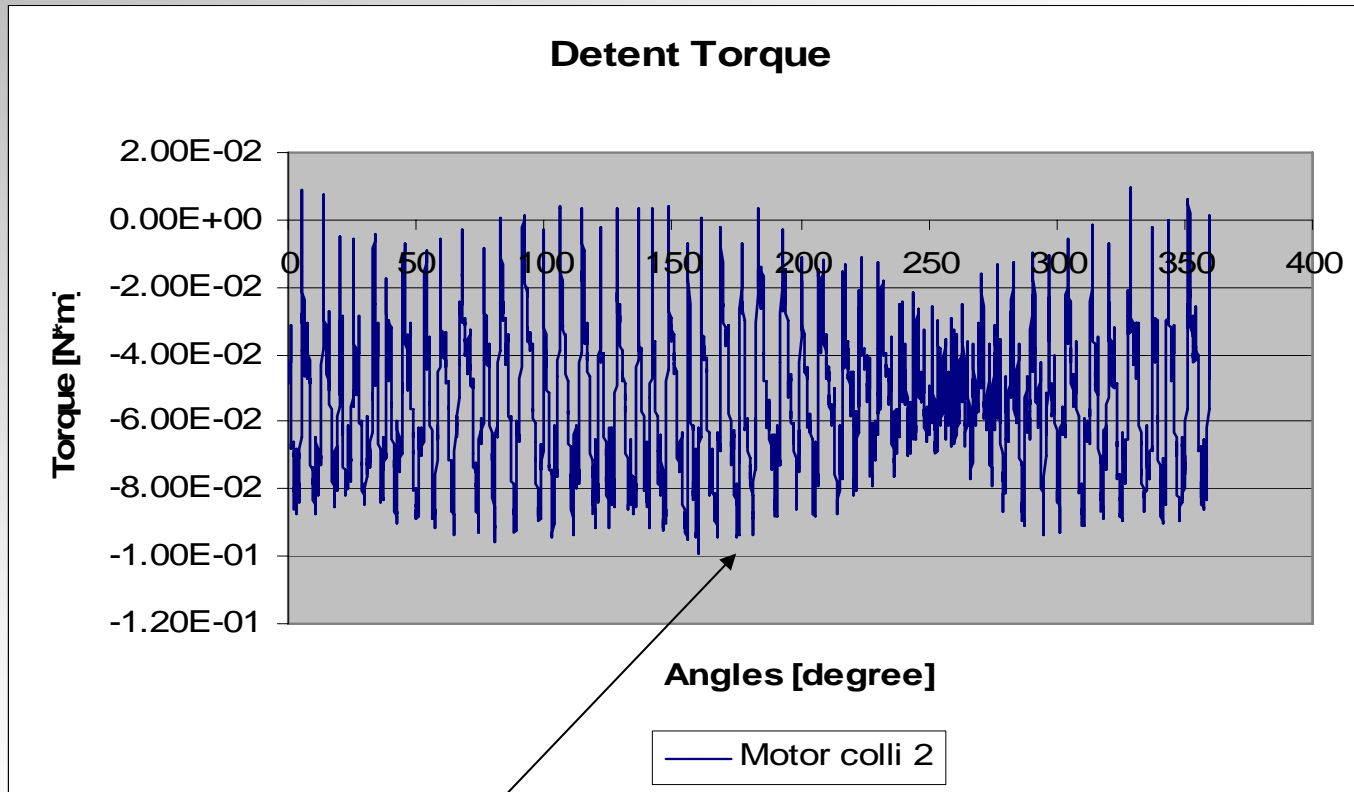


The detent torque is in agreement with the motor technical data (detent torque 80 mN*m)

Max Detent Torque=75 mN*m

Detent Torque

Motor 2 Colli 3rd Proto (SD8L852-740-39-N10287-01/2)

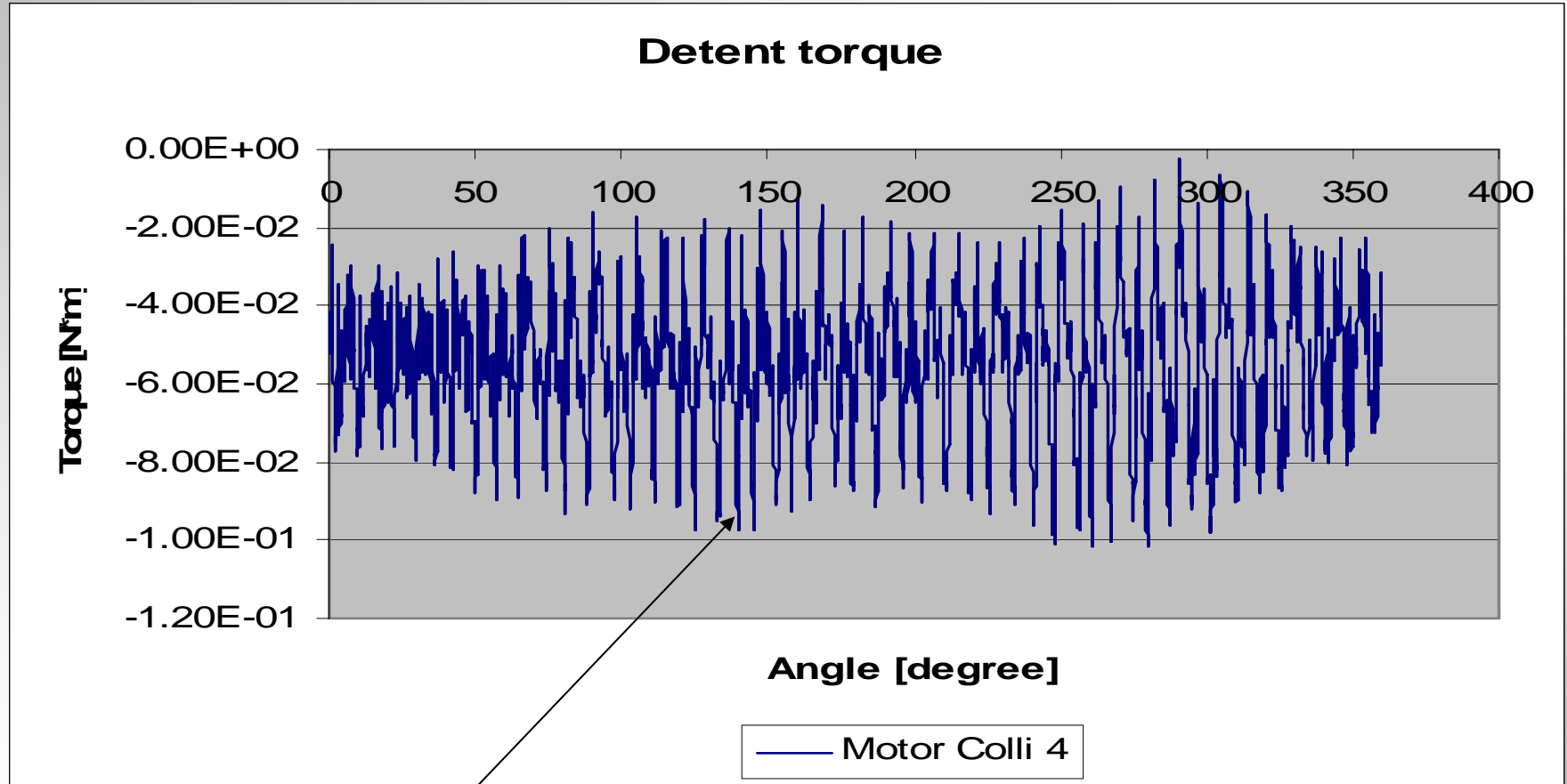


The detent torque is in agreement with the motor technical data (detent torque 80 mN*m)

The detent torque is maximum under a magnetic pole: our motors have 50 poles on the rotor- Max value 90 mN*m

Detent Torque

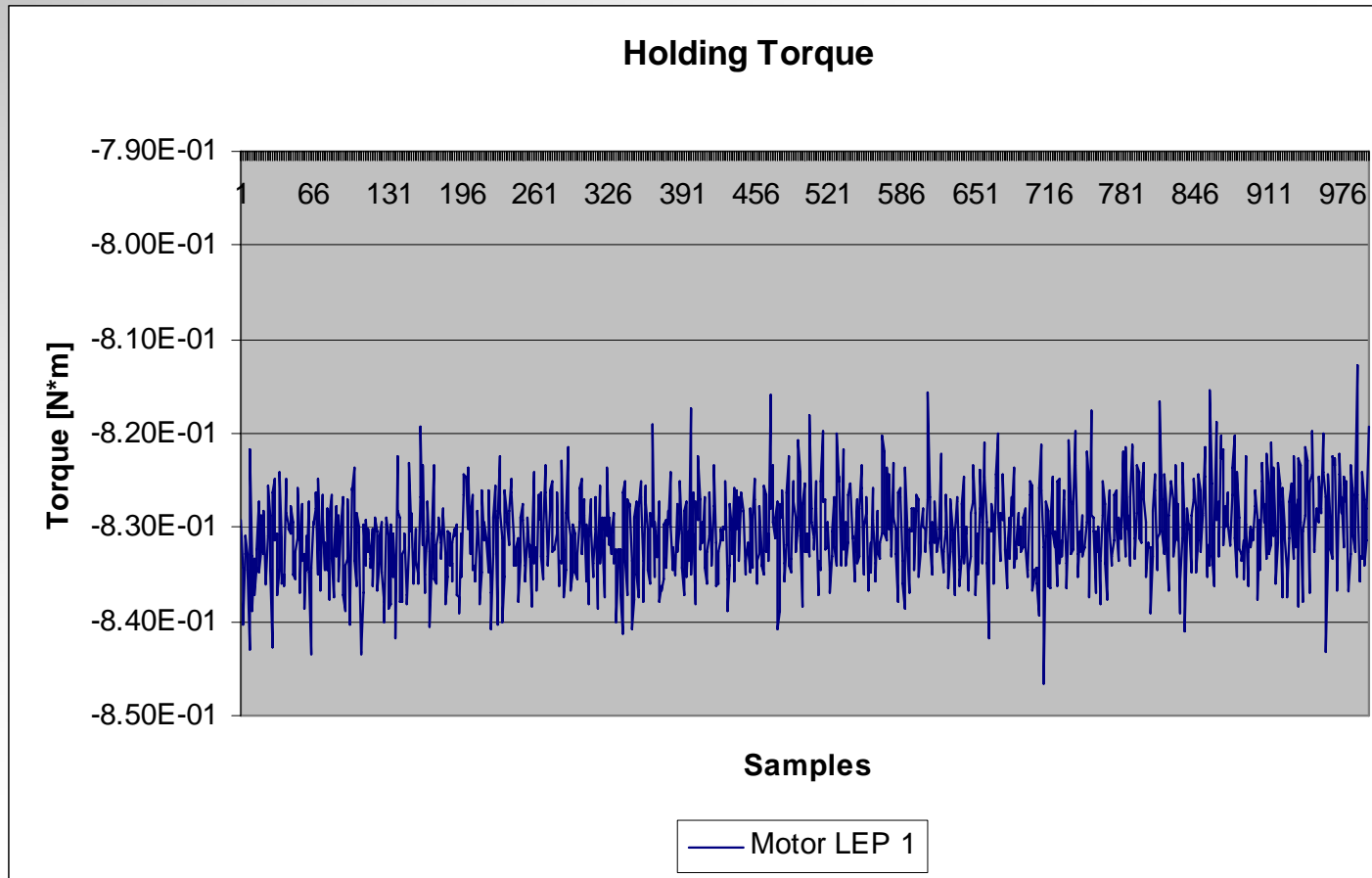
Motor 4 Colli 3rd Proto



The detent torque is maximum under a magnetic pole: our motors have 50 poles on the rotor- Max value 90 mN*m

Holding Torque (1 Phases on)

Motor LEP 1 (S03362 - 1/19)

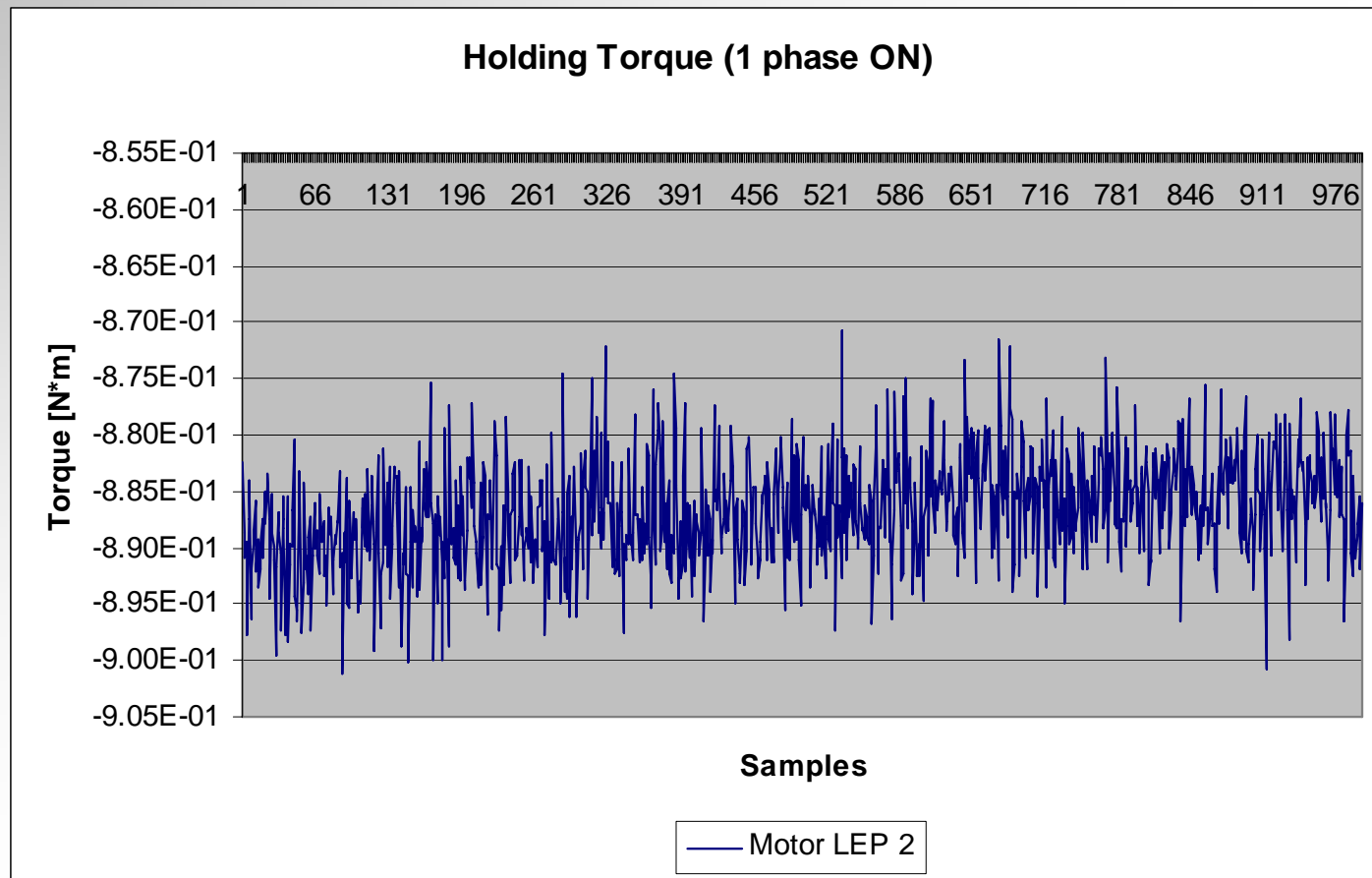


•Time span: 2 s

The Motor is powered at the same current value used for the test at TT40: 1.4 A (the motor nominal current is 1.2 A)

Holding Torque (1 Phase ON)

Motor LEP2 D8L851-N1510 no ...-1/3

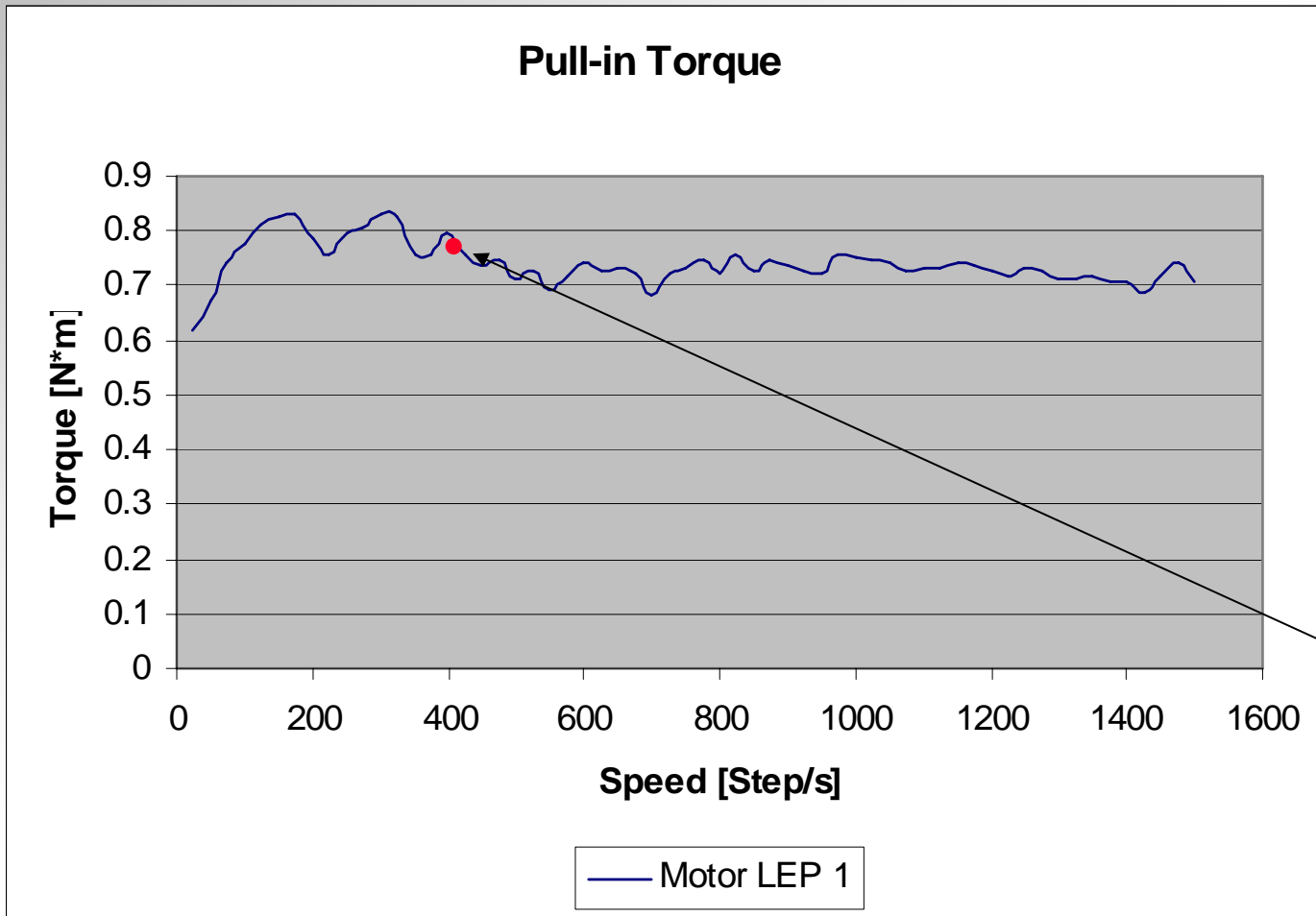


•Time span: 2 s

The Motor is powered at the same current value used for the test at TT40: 1.4 A (the motor nominal current is 1.2 A)

Pull-in

Motor LEP 1 (S03362 - 1/19)

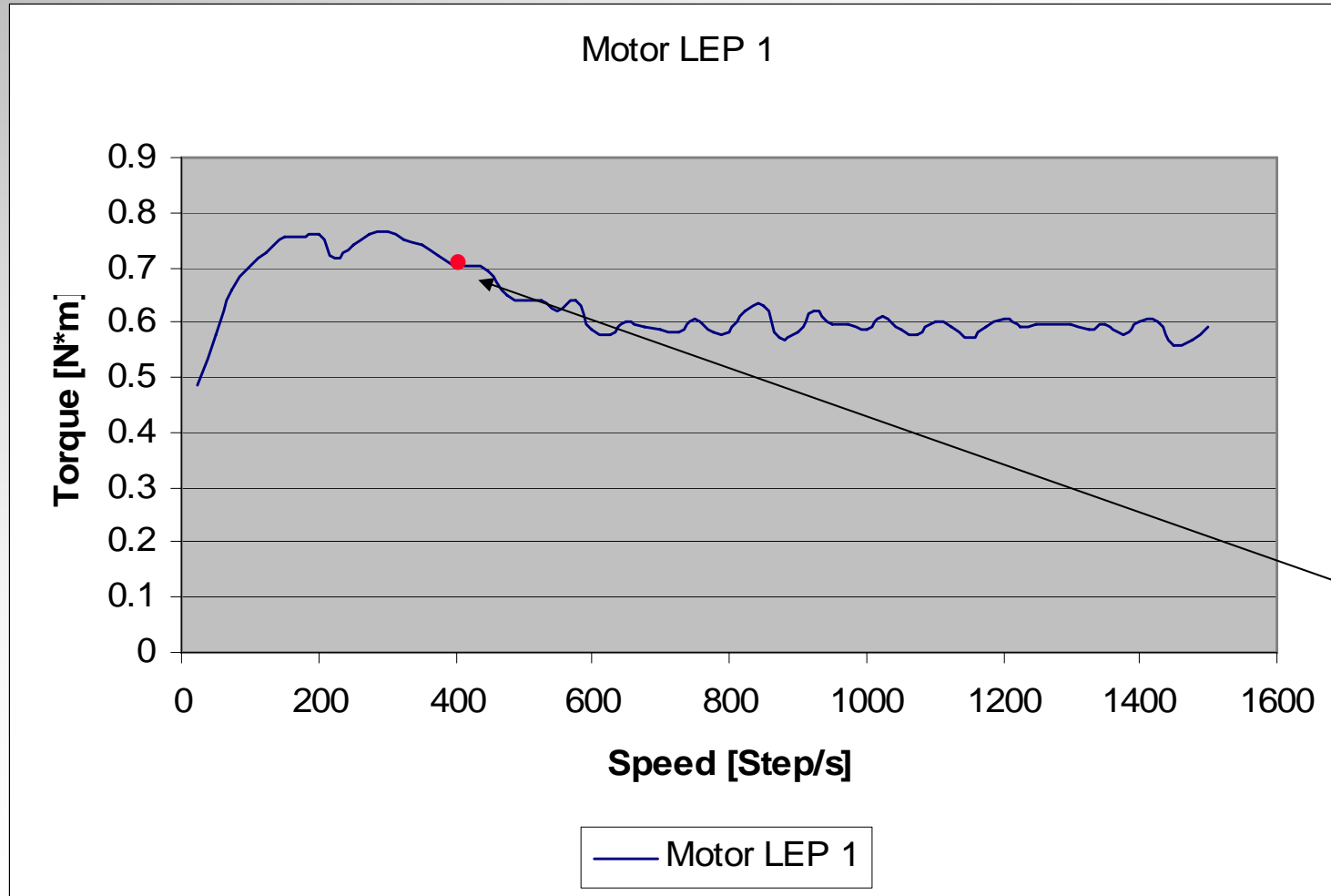


The Motor is powered at the same current value used for the test at TT40: 1.4 A (the motor nominal current is 1.2 A)

At the collimator nominal speed (400 step/s) the dynamic torque is less than 0.8 N*m

Pull-out

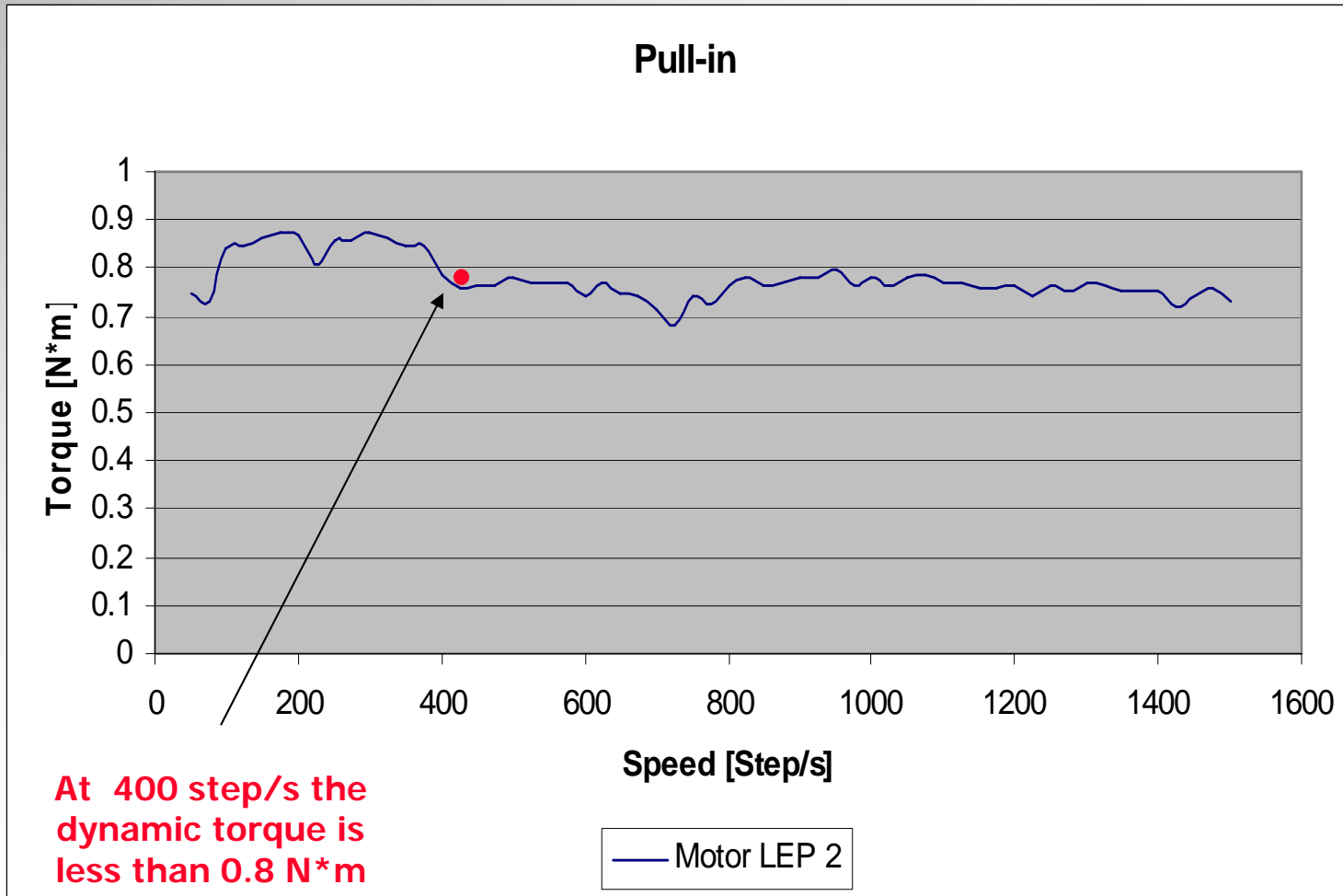
Motor LEP 2 (S03362 - 1/19)



Pull-out torque
at 400 step/s
around 0.7 N*m

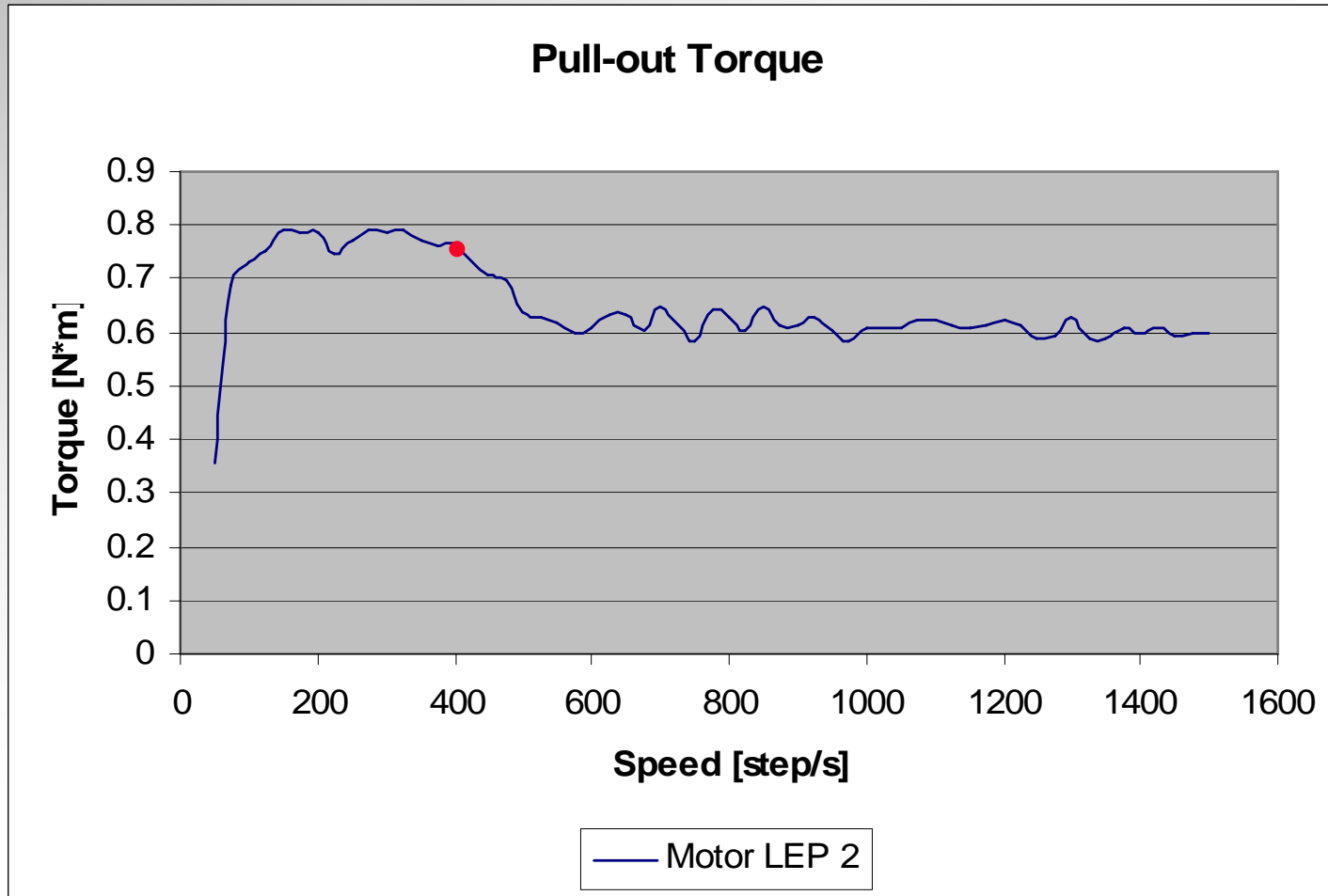
Pull-in

Motor LEP2 D8L851-N1510 no ...-1/3



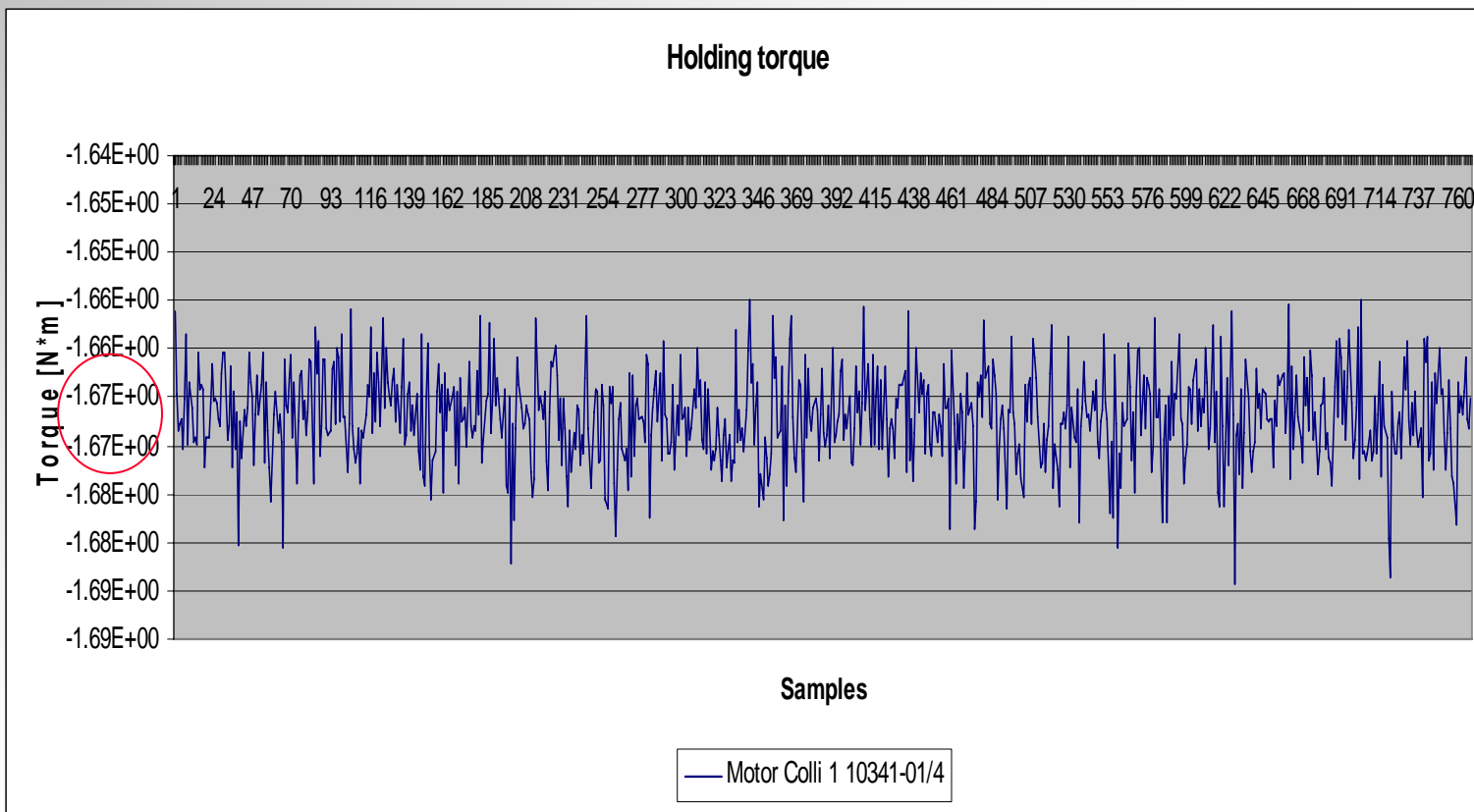
Pull-out

Motor LEP2 D8L851-N1510 no ...-1/3



Holding Torque 1 Phase ON

Motor 1 Colli 3nd Proto (SD8L851-740-39N2166
10341-01/4)



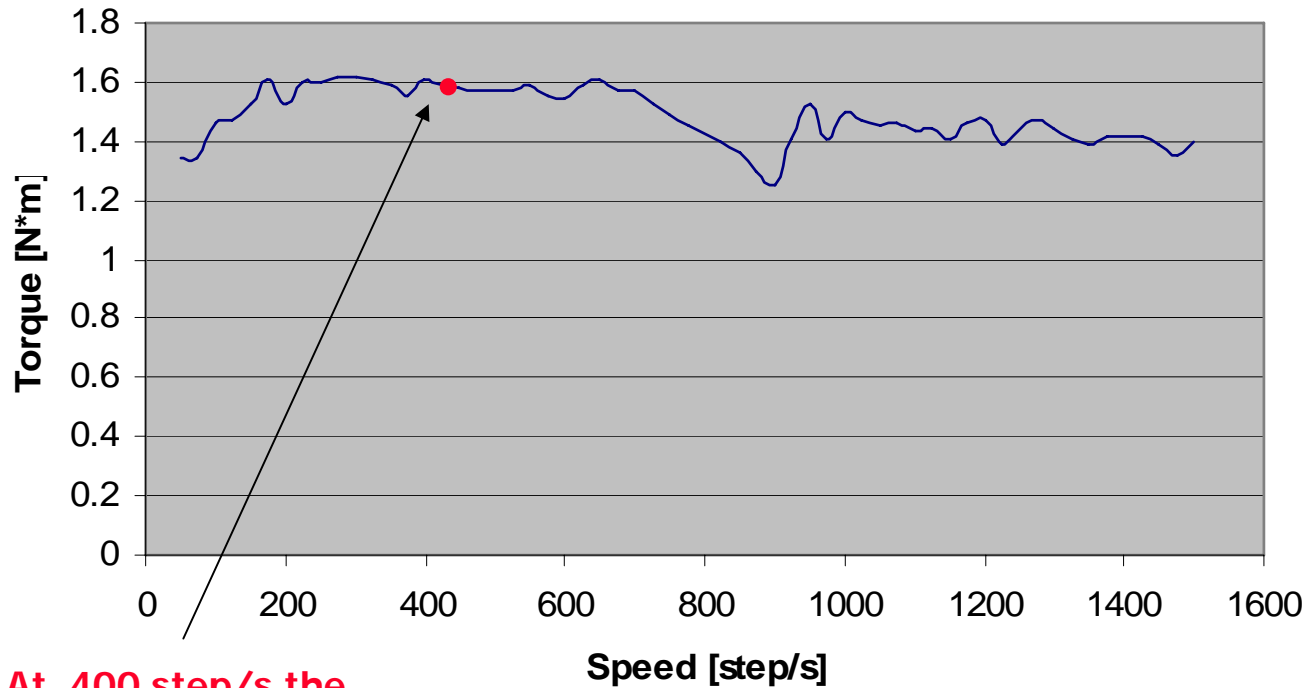
- Acquisition time: 2 s
- Sampling frequency torquemeter: 5 KS/s
- Acquisition decimation factor: 1

Motor phases
current: 2 A

Pull-in

**Motor 1 Colli 3rd Proto (SD8L851-740-39N2166
10341-01/4)**

Pulli-in



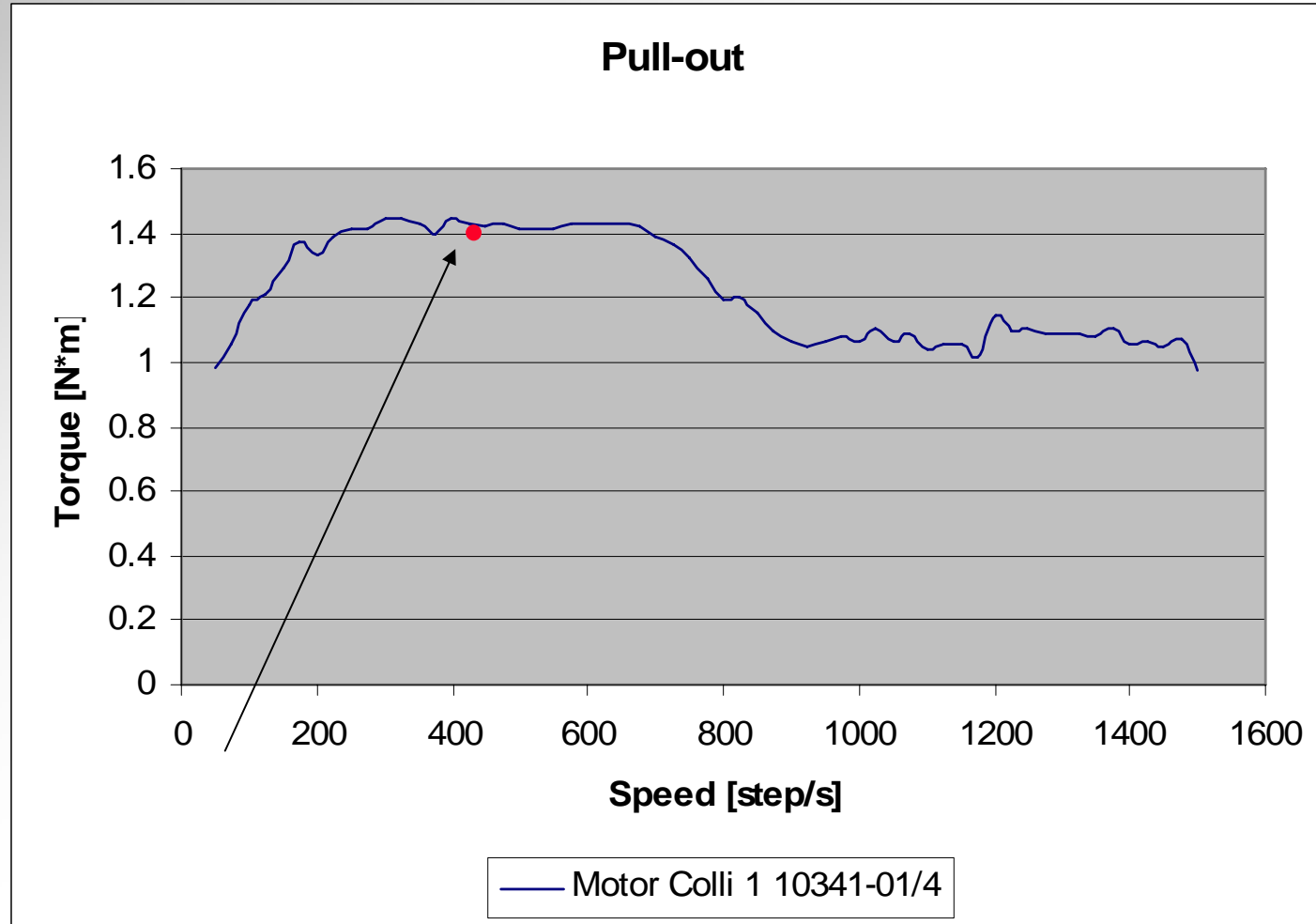
**At 400 step/s the
dynamic torque is
1.6 N*m**

— Motor Colli 1 10341-01/4

**Motor phases
current: 2 A**

Pull-out

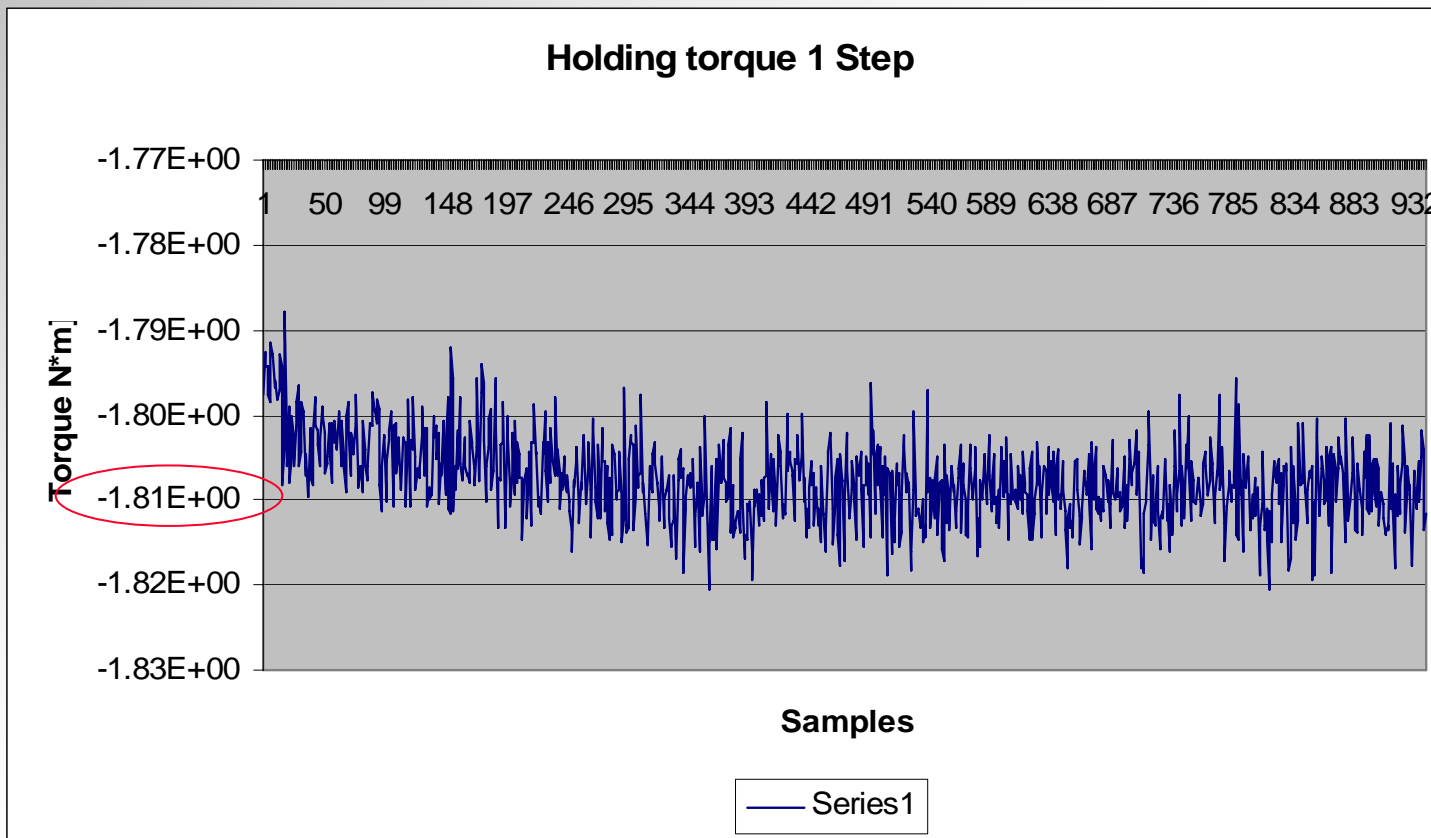
Motor 1 Colli 3rd Proto (SD8L851-740-39N2166
10341-01/4)



Motor phases
current: 2 A

Holding Torque (1 Phase ON)

Motor 2 Colli 3nd Proto (SD8L852-740-39-N10287-01/2)

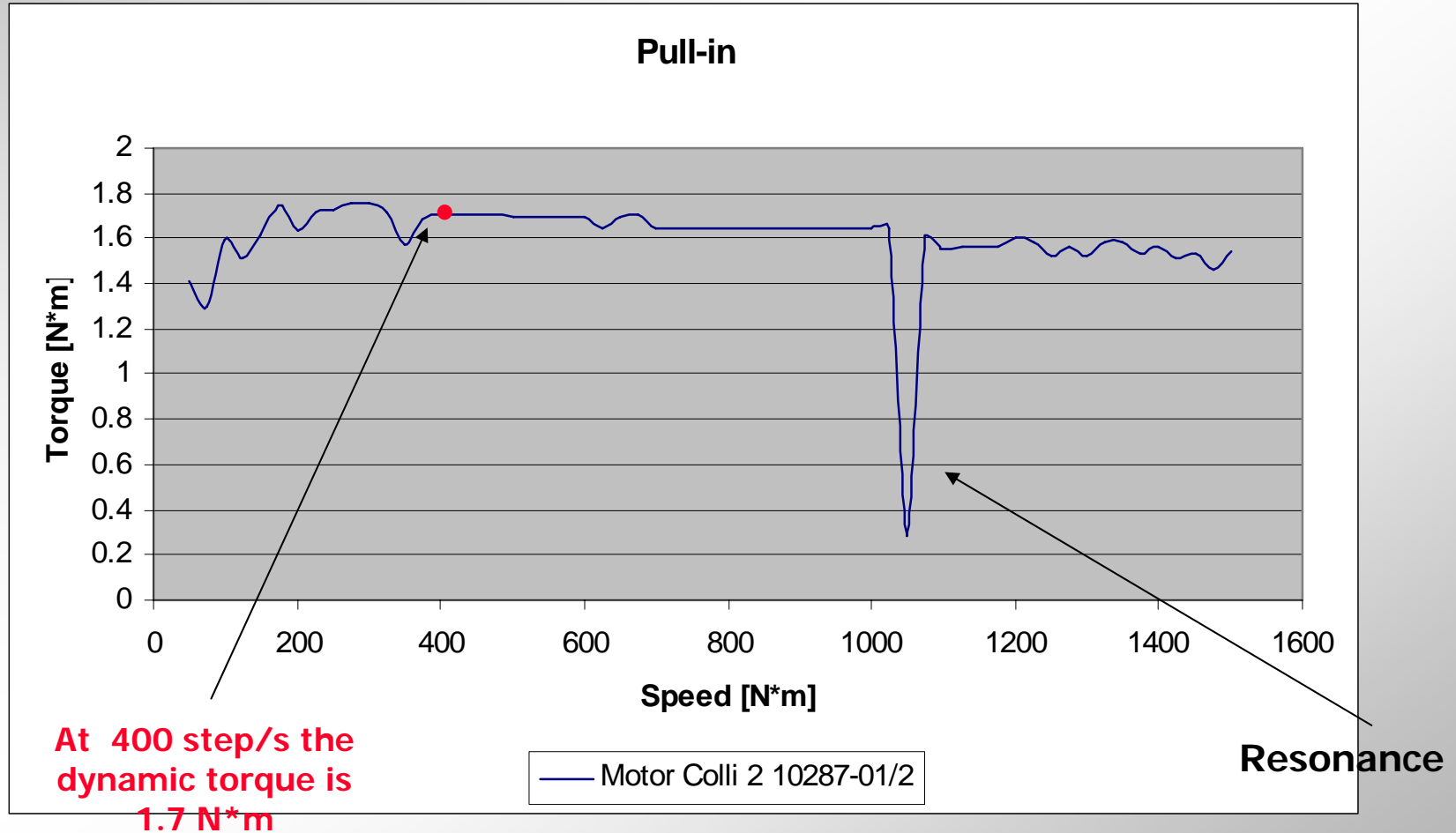


- Acquisition time: 2 s
- Sampling frequency torquemeter: 5 KS/s
- Acquisition decimation factor: 1

Motor phases
current: 2 A

Pull-in

Motor 2 Colli 3rd Proto (SD8L852-740-39-N10287-01/2)



Pull-out

Motor 2 Colli 3rd Proto (SD8L852-740-39-N10287-01/2)



Conclusions

- ◆ The test bench solution 2 is now full operational and successfully working
- ◆ For accurate detent torque measurements an automatic calibration has been implemented in order to compensate the residual test bench torque
- ◆ The two old LEP motors used to move the upper jaw of the third collimator prototype as well as the Torque of new Stebon motors was measured. Even if the motors satisfy the detent torque spec. differences between motors of the same type up to 20-30 mN*m were measured
- ◆ At 400 Step/s the old LEP motors supplied in the same conditions of the TT40 tests have showed a dynamic torque less than 0.8 N*m

Conclusions

- ◆ A huge difference has been found between rated Torque and measured Torque. After discussions with several producers, this does not seem unusual.

Motor	Rated Torque	Measured torque
LEP collimators	1.5 Nm	0.7÷0.8 Nm
LHC prototype	3.5 Nm	~1.6 Nm

Acknowledgements

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