CM10 motor LN2 test report

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Introduction

VSS32 Motor with elongated shaft

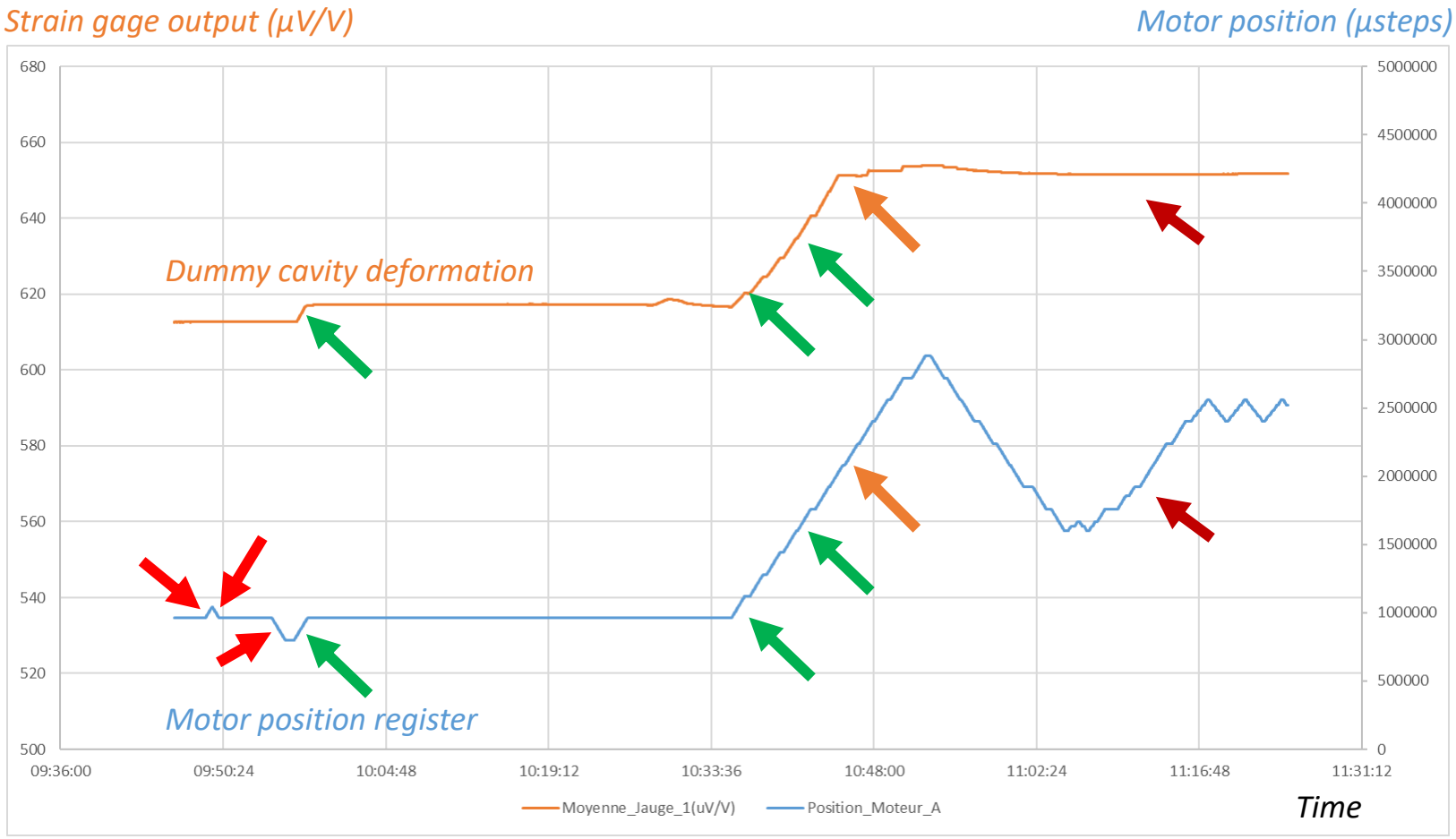
Configuration reminder :

- Production tuner with CM10 motor
  - Had firstly completely failed, only at low temperature, during the LHe qualification of cryomodule CM10 at Uppsala
  - Similar to CM3 test (replacement, and reparation of the motor)
  - Works always well at room temperature (but not tested at full torque)
  - Had previously failed twice in a row, even after rising the current from 0.6 to 1.0 A
  - Equipped with its copper collar
  - Equipped with elongated shaft
- Production tuner with prototype motor
  - Never failed in any configuration/project thus never extensively tested
  - Assembling variations already known : bearing adjustment, bearing coating

Goal: Observe any variation by adding elongated shaft that could confirm gearbox shaft misalignment theory proposed during previous meeting.

Day 1

1. Very first attempts failed
2. Then it started to move properly
3. And then quickly started to get stuck more and more
4. Finally stuck again



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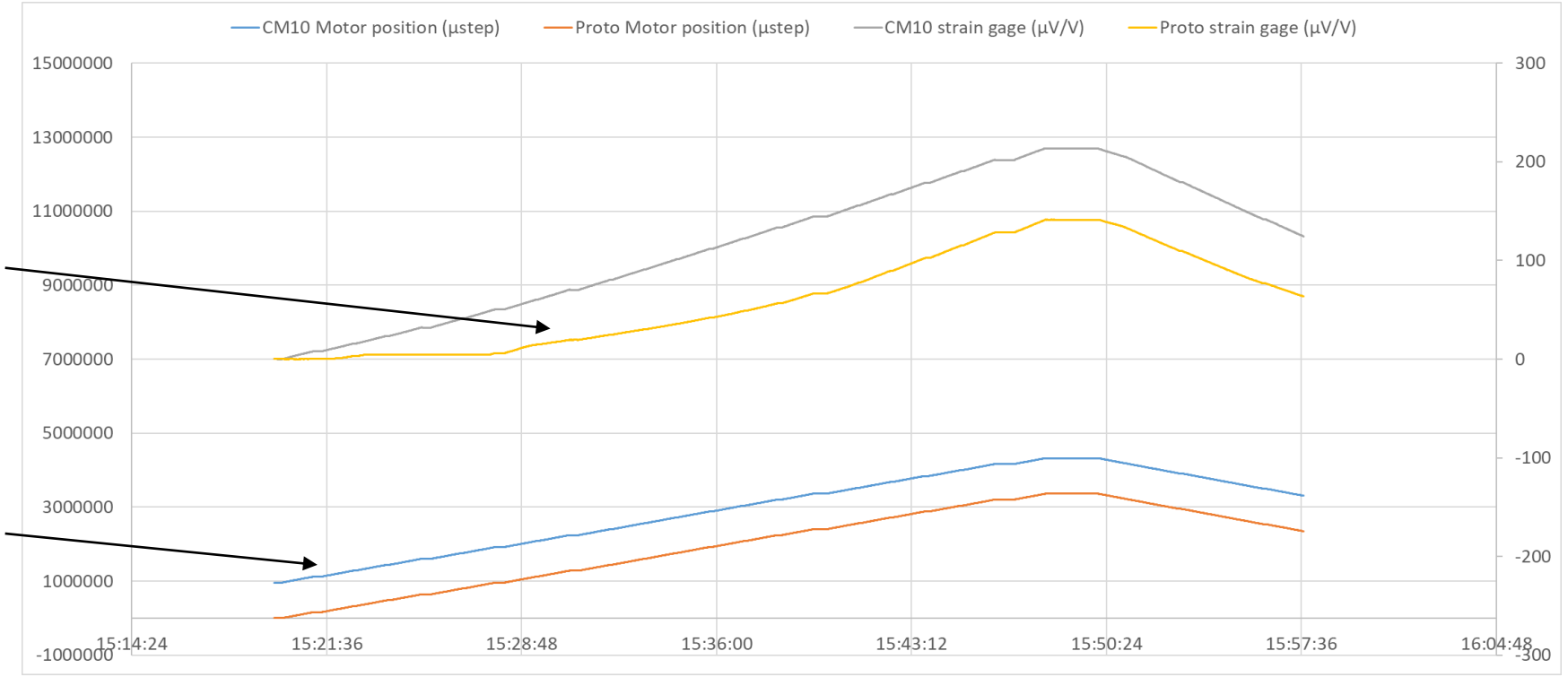
Non linearity issue due to proximity from home position. OK, not a concern. (proto motor only)

Offset due to wrong initialization, not a concern.

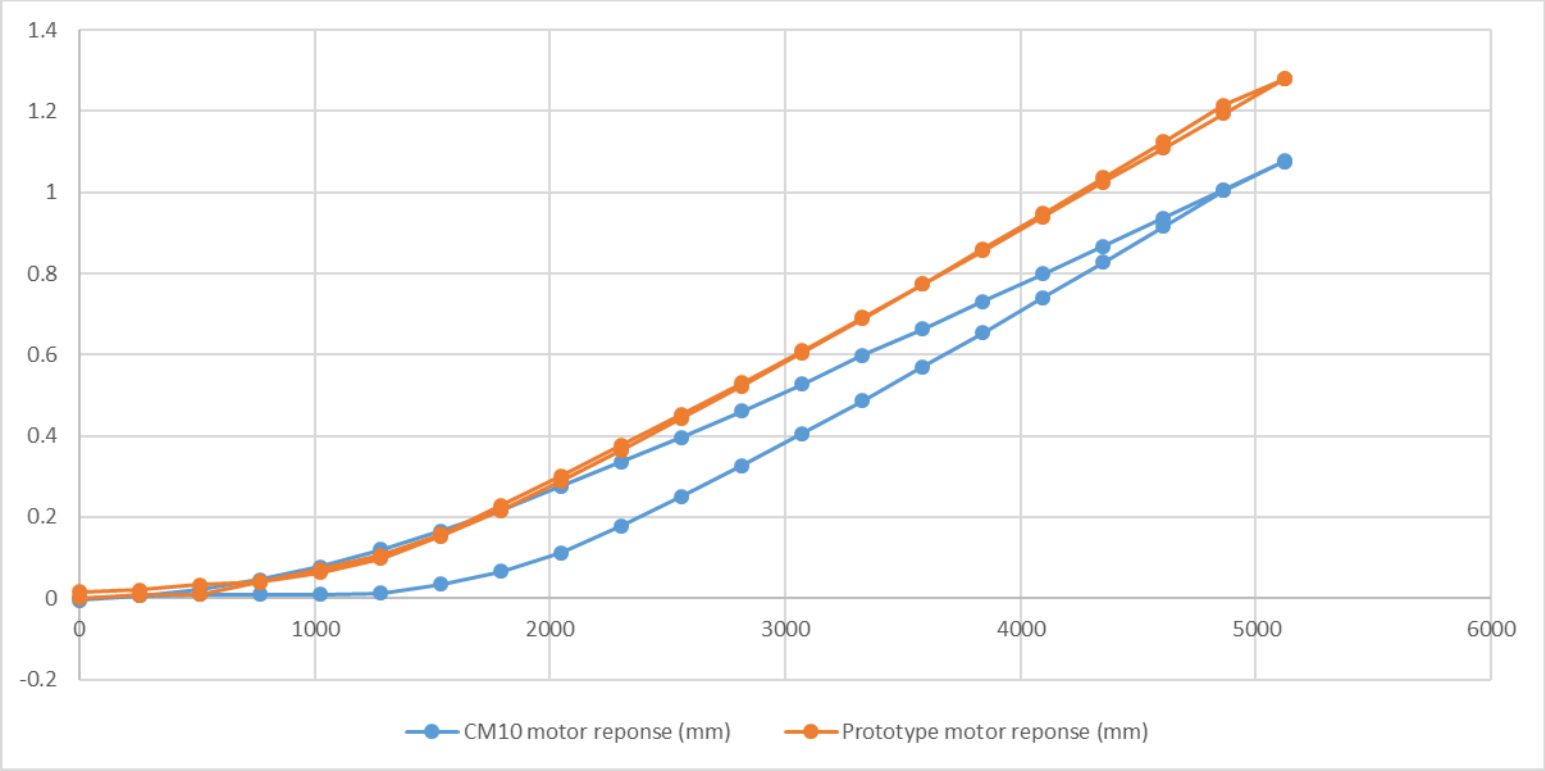


Day 2

- Large stroke testing (1.0 A), round trip

➔No issue

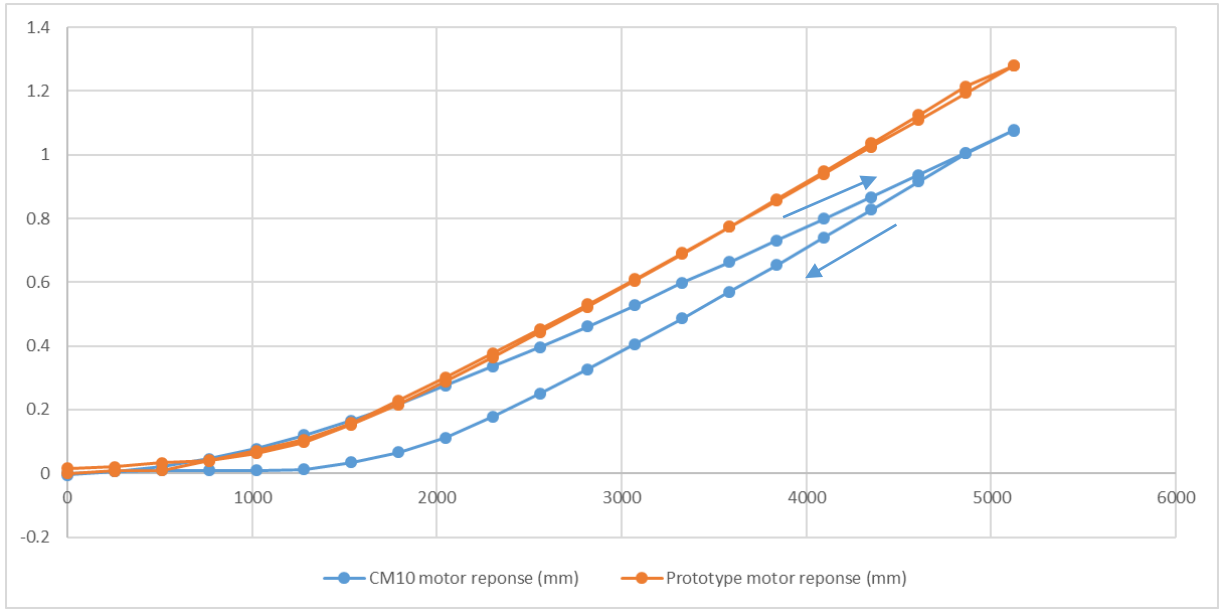
➔Hysteresis on CM10 motor tuner mostly imputed to mechanical slight issue, sometimes observed on some tuner testing. Not motor related.



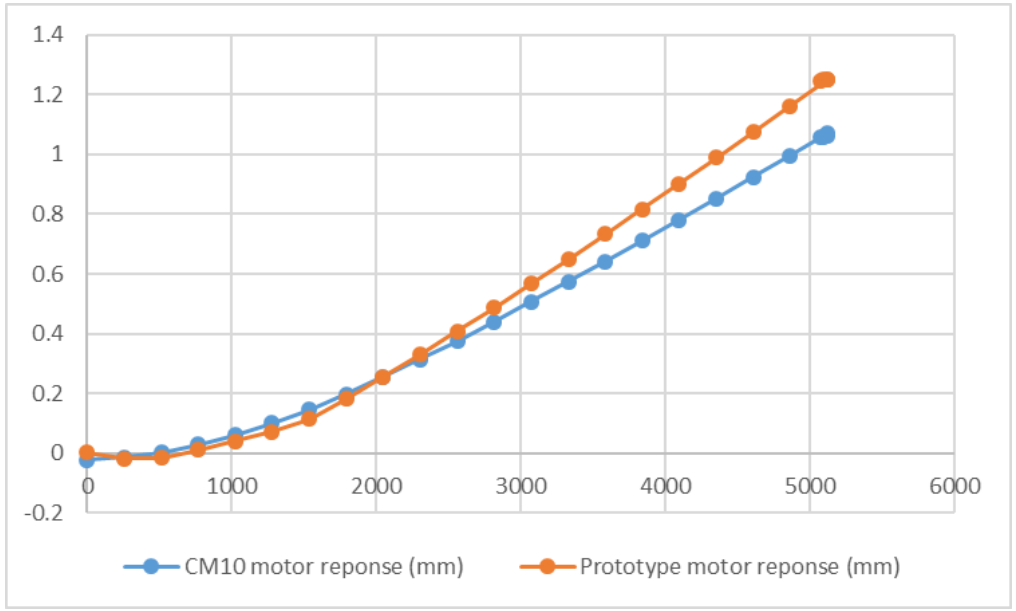
Day 3

- Single way to 5,120 rev (1.0 A)

➔No issue, good correlation with round trip of the day before



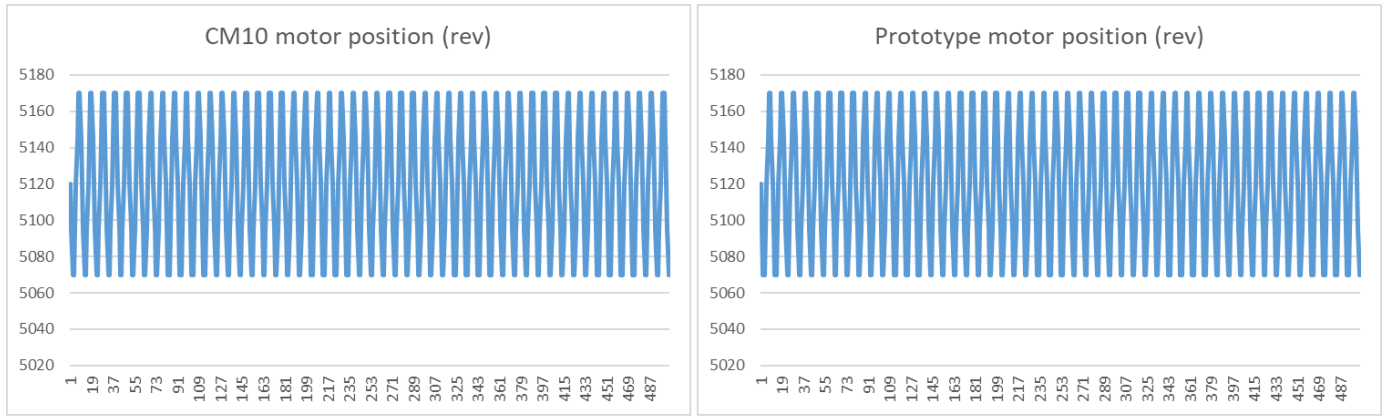
Day 2 round trip

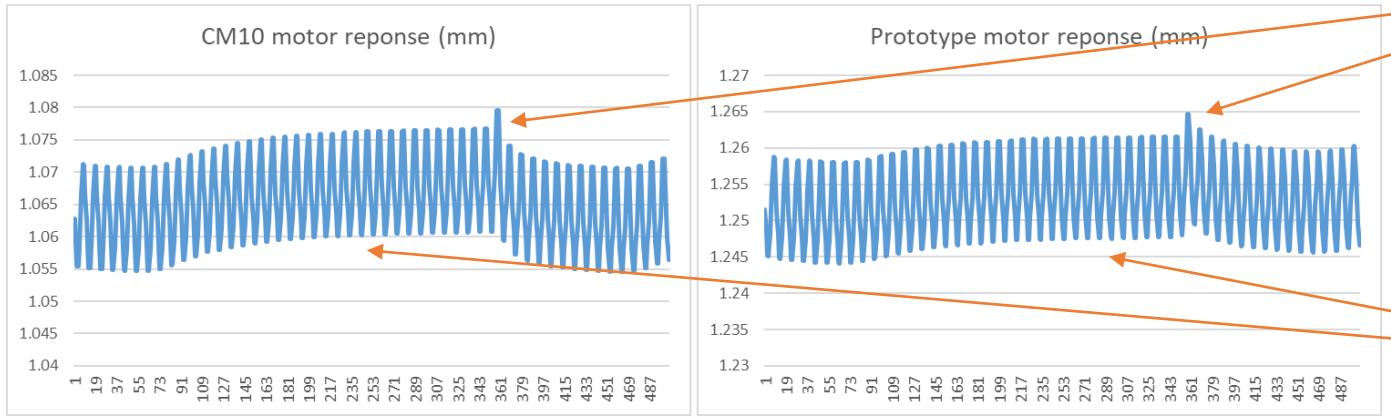


Day 3 single way

Day 3

- Evaluation of motor start current from 1.0 A down to 0.32 A ➔ **OK (!!)**
- Stress test 10,000 motor rev. (input of gearbox, not output), at <u>0.4 A</u> ➔ **OK (!!)**



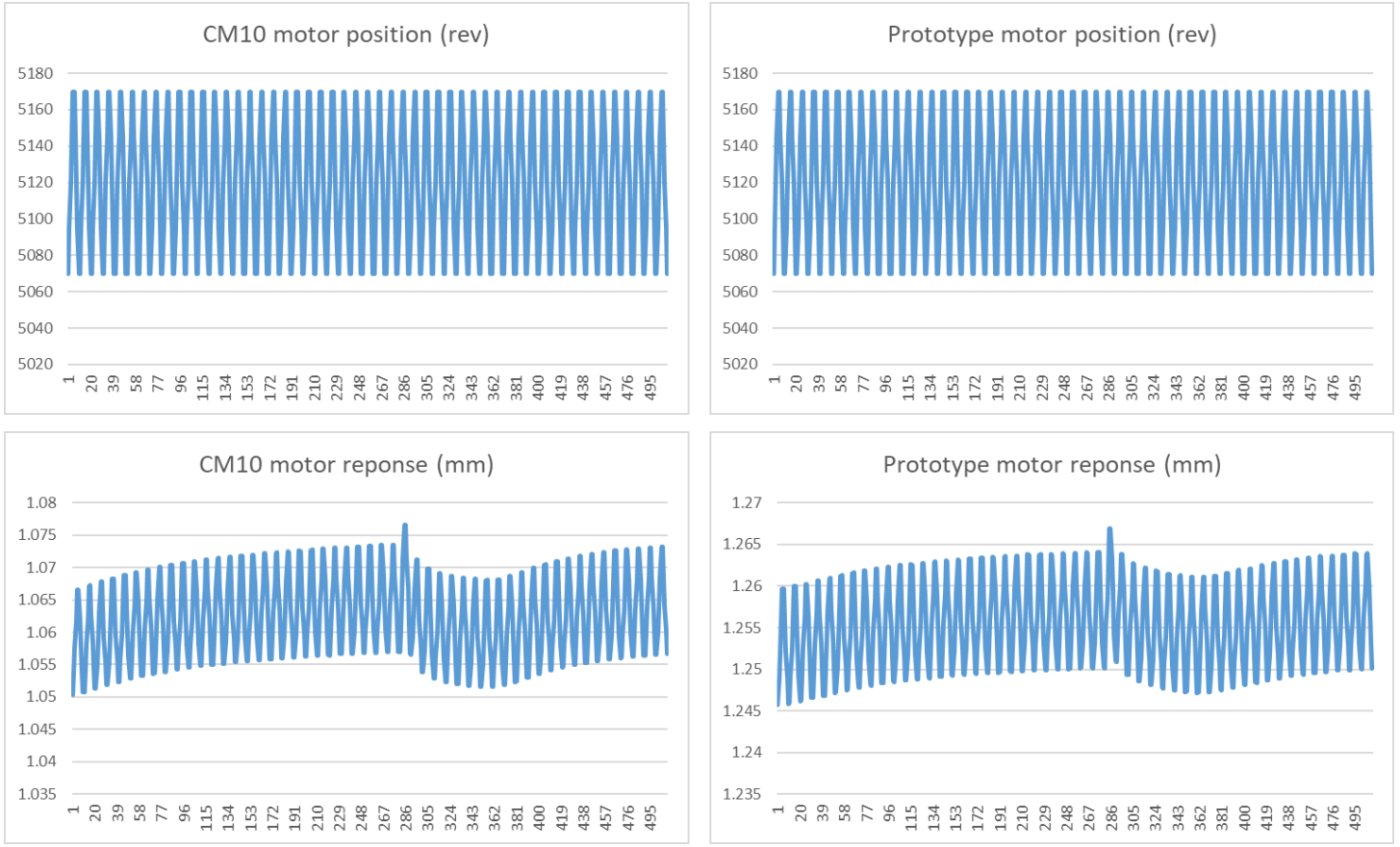


Y axis : Strain gage output of dummy cavity

Thermal instabilities due to LN2 refilling

Day 4

- Again, stress test 10,000 motor rev. (input of gearbox, not output), at <u>0.4 A</u> ➔ **OK**

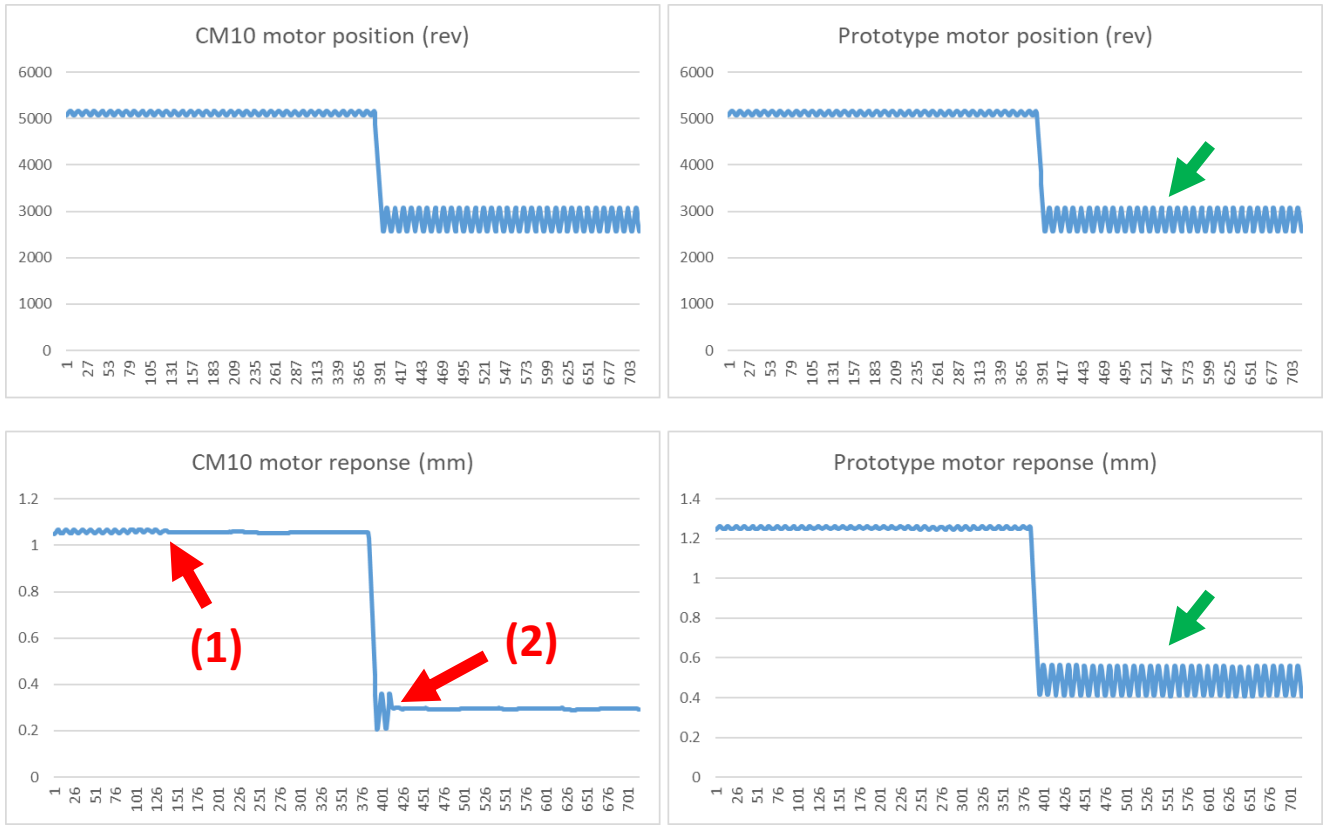


Y axis : Strain gage output of dummy cavity

Day 5

- Again, stress test 10,000 motor rev. (input of gearbox, not output), at 0.4 A ➔ **NOK (1)**
- Put tuner at 2,560 rev (1.0 A) ➔ **OK**
- Evaluation of motor start current from 1.0 A down to 0.32 A ➔ **OK (!!)**
- Again, stress test 10,000 motor rev. (input of gearbox, not output), at 0.4 A ➔ **NOK (2)**

Carefull, Y scale is larger than previous slides



Also, prototype motor is full OK

Overview

- Day 1 – Monday
  - Stuck at the very beginning, then work for a while until lost of steps
  - Loss of steps, more and more at half-nominal current (0.6 A)
  - Motor works if the current is pushed to 1.0 A (driver limit)
- Day 2 – Tuesday
  - Large tuner stroke measurement at 1.0 A (0 → 5,120 rev) ➔ **Passed** (max stroke : 5,888 rev)
- Day 3 – Wednesday
  - Put tuner at 5,120 rev position using 1.0 A ➔ **Passed**
  - Start current motor measurement : **0.32 A**
  - Stress test at 0.4 A : 10,000 rev around the max position ➔ **Passed**
- Day 4 – Thursday
  - Stress test again ➔ **Passed**
- Day 5 – Friday
  - Stress test again ➔ **Failed**
  - Recovery by pushing the current again to 1.0 A ➔ **Ok**
  - Moving to lower position (2,560 rev) at 1.0 A ➔ **Ok**
  - Start current motor measurement : **0.32 A**
  - Stress test again at 0.4 A ➔ **Failed after few successful cycles**
- Day 6 – Monday
  - Quick trials, motor seems ok to work only if current is pushed (0.8 A / 1.0 A tested)

Conclusions

- Elongated shaft seems to have improved the motor behavior (previous attempts of current rising always failed at LT)
- Still, this system is not sufficient to fully recover the motor presumably damaged since cryomodule qualification
- Performances have been temporarily restored even at very low current (0.32 A around max position)

Next steps :

- Test without copper collar to identify any performance variation (W.49)
- Stress test with fresh motors w/ and w/o elongated shaft (W.50/51)

Further more :

- Test of old CM3 failed motor (which was repaired by Phytron early this year)
- Test of 2nd batch motor (2019 procurement vs 2017, clearly not the same play on output shaft)
- Internal inspection, coating wear evaluation, dimensional measurement around front bearings)

Full explanation tentative of the root cause (to be consolidated) :

Motor issue observed on LHe cryomodules qualification (at least CM10 and CM3, after having solved the driver current issue) might be explained by the addition of 2 causes :

1. **Misalignment of shaft : Allows high contact mechanical stress of internal pinions of planetary gearbox due to mechanical interference of the teeth.**
2. **Weak pinions coating : ADLC (amorphous carbon) appears to have a limited lifetime in vacuum, which can be strongly reduced depending of mechanical contact pressure. This also seems antagonist with MoS2 / Ws2 coating where friction rate (and then wear rate) drops when high contact pressure are applied**

Both causes participated to quick degradation of the coating while maintaining a steel on steel high pressure contact leading to galling issue (friction coefficient super high). At room temperature (but possibly especially at 1 bar), the steel on steel interface is less an issue.