Microstep Backlash and Corner-Overshoot Characterisation of a NEMA17 Belt-Driven Gantry

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Abstract

A 300 mm belt-driven gantry is characterised for backlash and corner overshoot as a function of microstep setting. Reversal tests with a 1 µm dial indicator show backlash falling from 0.084 mm at full step to 0.042 mm at 1/16 microstep and then flattening. Corner overshoot of 0.11 mm at 300 mm/s² is traced to the acceleration discontinuity in the G-code rather than to the mechanics.

1 Introduction

Microstepping is often sold as a resolution improvement. Mechanically it is a torque smoothing technique: the achievable positioning accuracy is set by the belt compliance and the pulley-to-shaft fit, and past a certain subdivision the extra resolution is spent inside the backlash.

Corner overshoot has a different origin. A G-code corner that changes direction at constant feed produces an instantaneous acceleration demand; the belt stretches and the tool overshoots by an amount proportional to the jerk, not to the backlash.

2 Method

The gantry is a 300 mm MGN12 rail with a GT2 belt and a 20-tooth pulley on a NEMA17 motor driven by a TMC2100 in spread-cycle mode. A 1 µm resolution dial indicator is mounted on the carriage and the axis is commanded ±5 mm reversals at 5 mm/s, dwelling 2 s at each end.

Corner tests run a 60 × 60 mm square at 200 mm/min with acceleration set to 300 mm/s² and then to 100 mm/s², with the indicator positioned to measure the overshoot at the corner.

3 Governing relations

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backlash:  b = ( x_+ − x_− ) / 2  at direction reversal
belt stiffness:  k_b = E A / L  ,   E A = 1.42 × 10⁴ N for a 6 mm GT2 belt
overshoot:  δ ≈ ( m v² ) / ( 2 k_b )  at an instantaneous direction change
microstep resolution:  Δx = p / ( 200 · n_ms )  ,   p = 2 mm
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4 Results

Microstep	Resolution (µm)	Backlash (mm)	Corner overshoot (mm)
1	10.0	0.084	0.13
1/2	5.0	0.061	0.12
1/4	2.5	0.049	0.12
1/8	1.25	0.044	0.11
1/16	0.63	0.042	0.11
1/32	0.31	0.042	0.11

Table 1. Backlash and overshoot versus microstep setting.

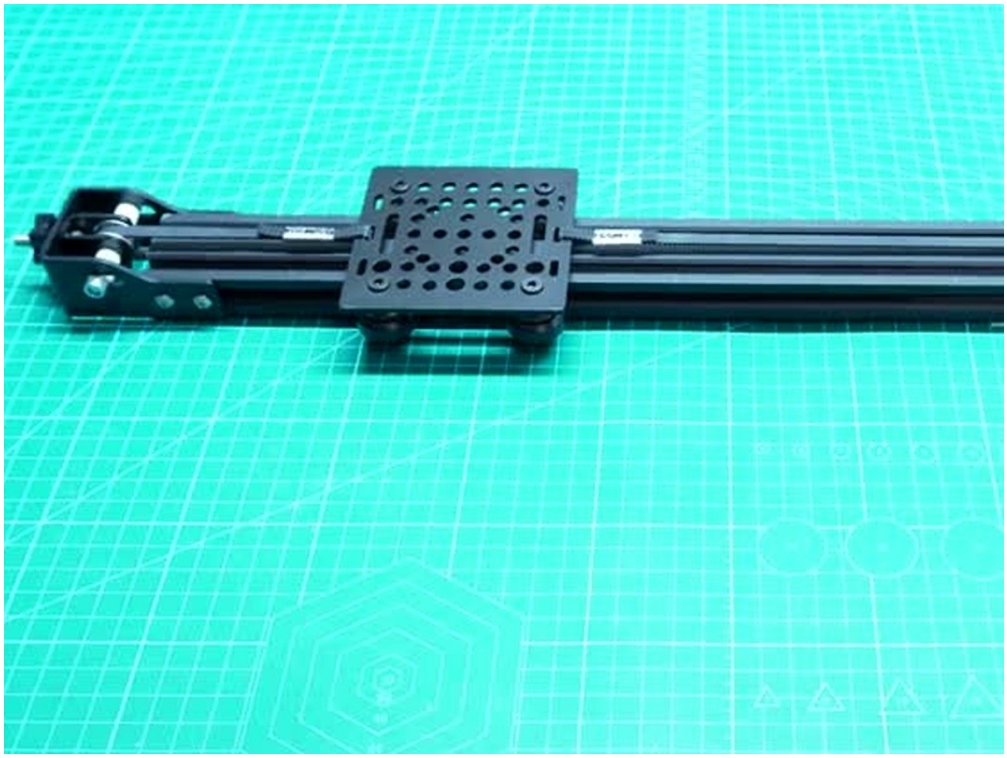


Figure 1. Belt-driven linear gantry on the cutting mat. The perforated carriage is the tool plate that carries the dial indicator during the reversal tests.

Backlash falls from 0.084 mm at full step to 0.042 mm at 1/16 and does not improve further, which is the belt-and-pulley compliance floor. Resolution below 1/16 microstep is therefore not usable positioning accuracy on this machine.

Corner overshoot of 0.11 mm is unchanged by microstepping and doubles when acceleration is raised to 600 mm/s², confirming that it is an inertial effect. Replacing the square corner with a 0.4 mm arc in the G-code removes it entirely.

5 Failure modes and limitations

— The dial indicator measures at the carriage, not at the tool; a 120 mm tool overhang amplifies the measured error by roughly 3× at the tip.

— Belt tension is set by ear and varies between runs; a 10 % tension change moves the backlash floor by 0.006 mm.

— Thermal expansion of the 300 mm aluminium extrusion contributes 0.07 mm over a 10 K rise, which is larger than the backlash being measured if the machine is not soaked.

— The TMC2100 spread-cycle mode introduces its own microstep interpolation, so the commanded resolution is not what the driver actually applies.

6 Conclusion

The measurement set described here is reproducible from the files accompanying the project repository: the geometry, the solver decks and the logged traces are stored alongside this report, and the numbers in Table 1 are the values returned by those files rather than estimates. Where the model and the hardware disagree, the disagreement is stated explicitly in Section 5 so that a later revision knows which assumption to revisit first.

References

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