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Mechanical simulations of wire scanner components

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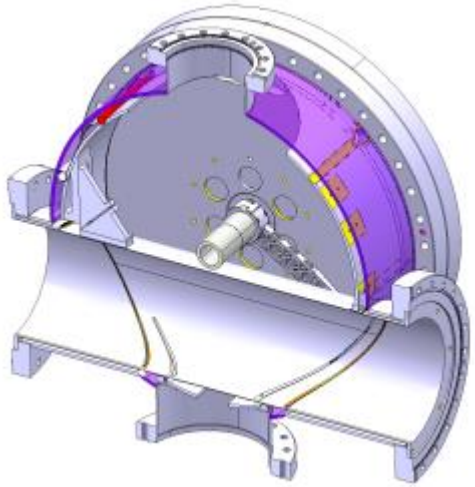
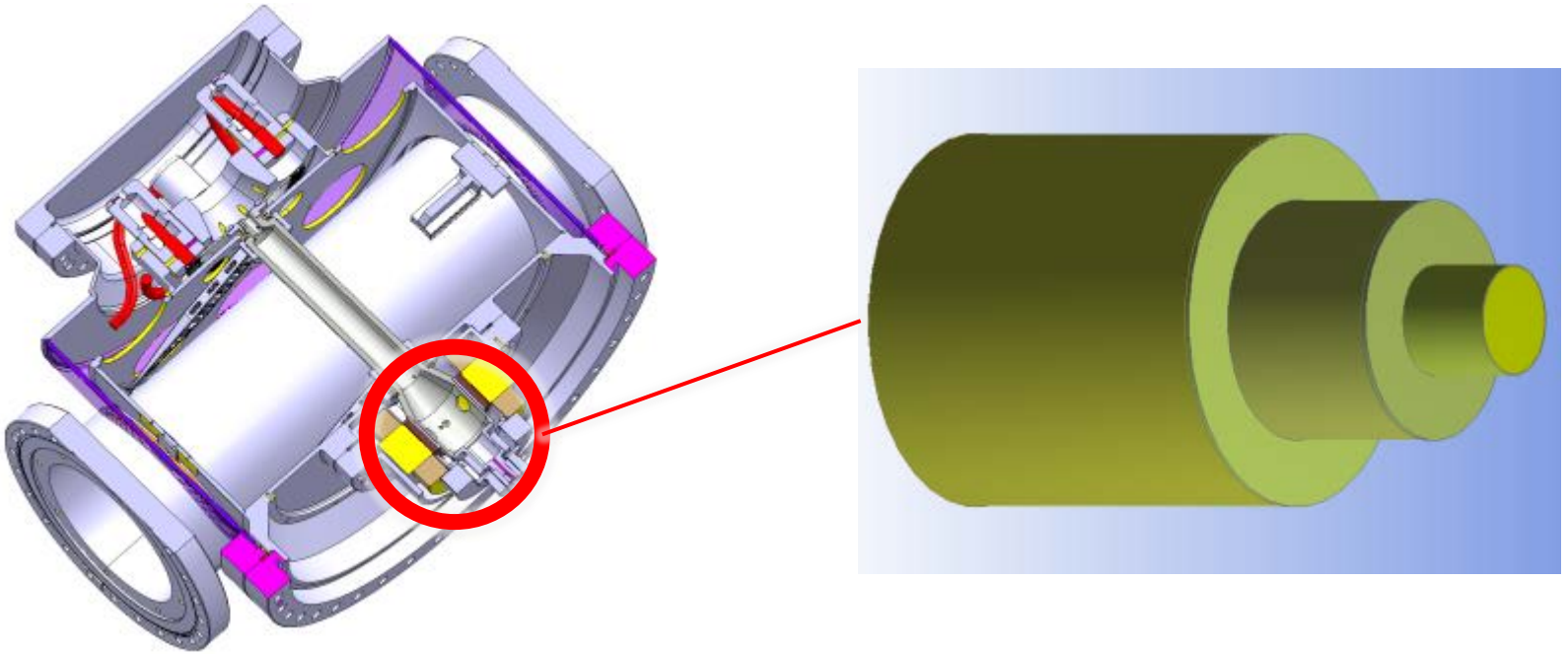
- Fork optimisation



Motor housing

Separates in-vacuum rotor from stator in atmospheric conditions

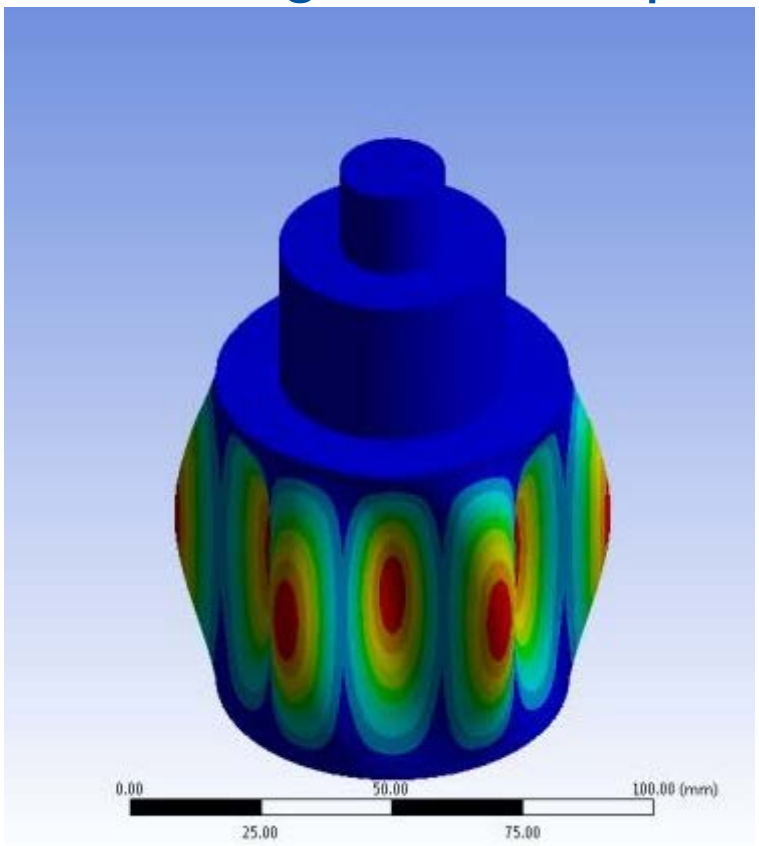


Motor housing - requirements

- Must be thin to fit in the motor's air gap (0.8 mm)
- Needs to be thick enough to ensure small deformation
- Must be structurally stable (i.e., not buckle)

Motor housing - model

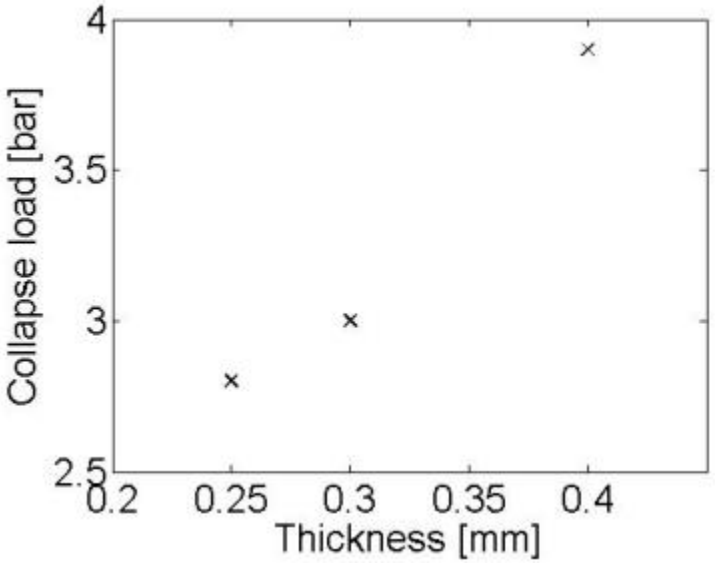
Buckling mode shape



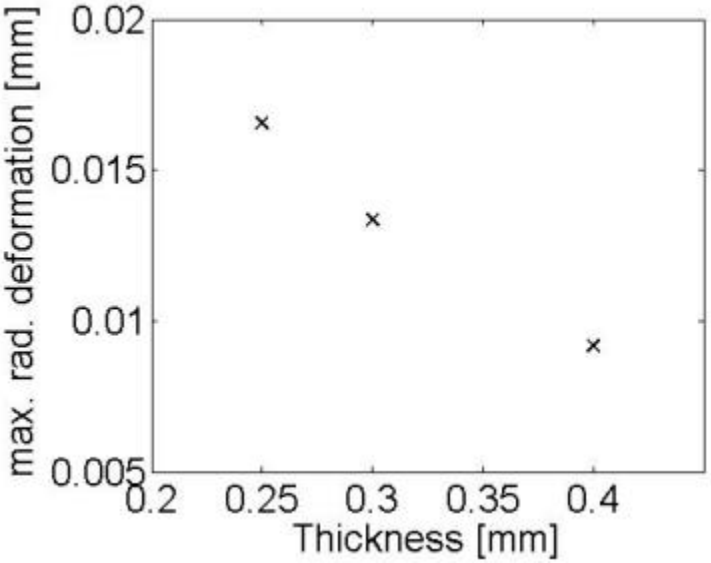
- Mode shape is used to introduce geometric imperfections in the model
- External pressure is successively increased until the structure becomes unstable

Motor housing - results

Buckling load



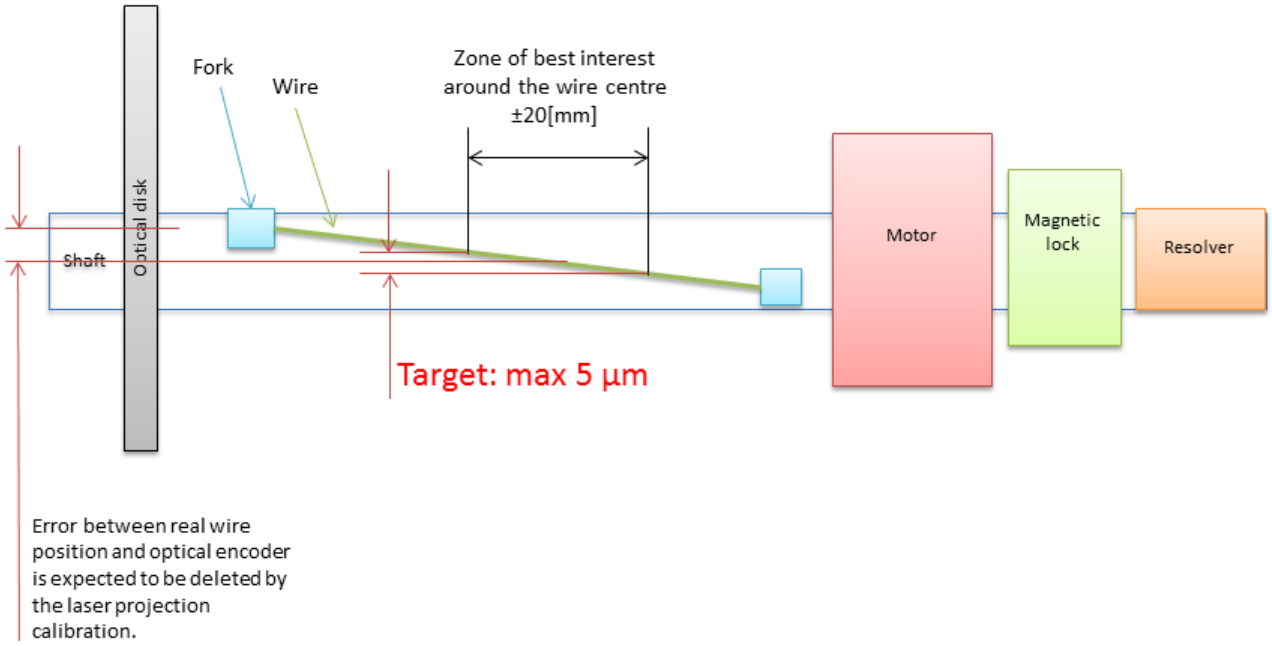
Radial deformation under 1 bar load



0.3 mm wall thickness is needed

Shaft - requirements

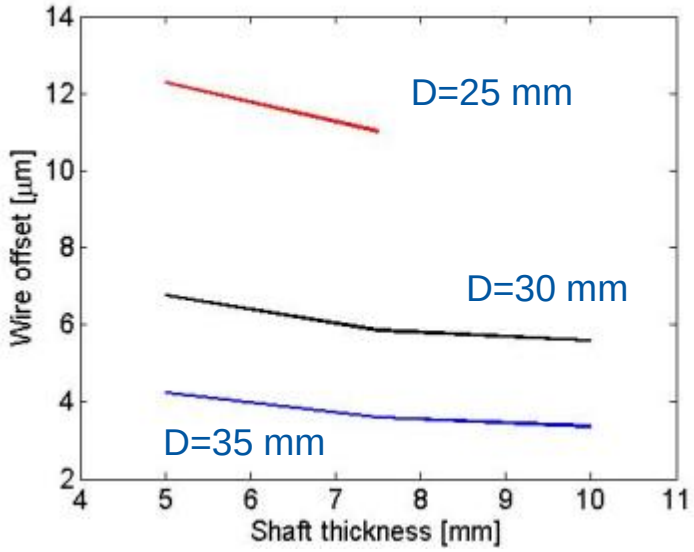
- Needs to be dimensioned with two objectives:
  - Minimise torsional deformation
  - Minimise inertial load



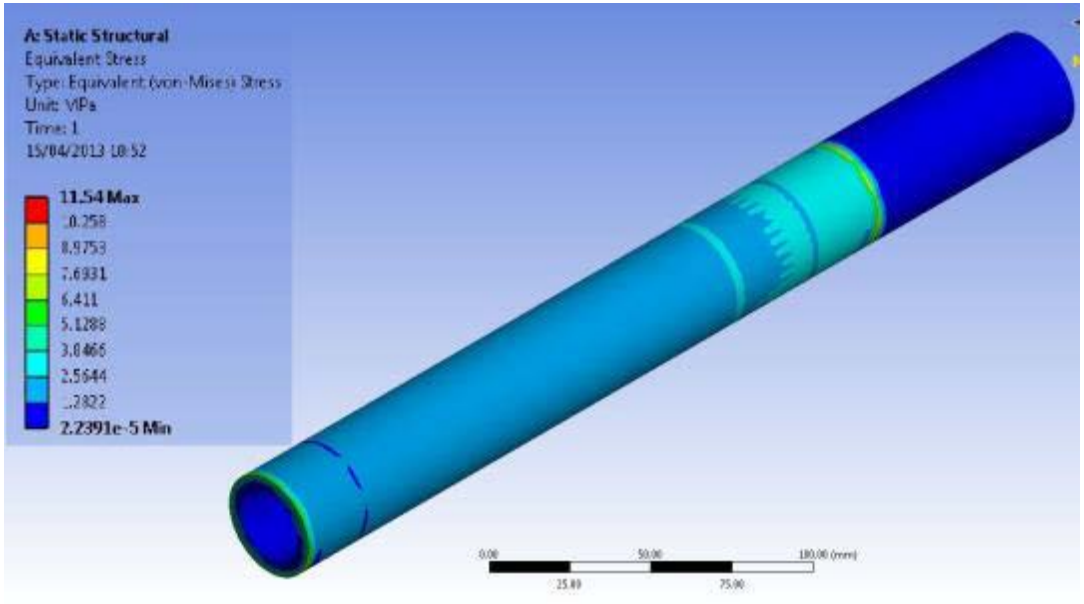
Shaft - results

Load: Angular acceleration of 6700 rad/s^2

Shaft twist for different dimensions



Shaft stress



Use 35 mm shaft with 5 mm wall thickness

Forks - requirements

- High stiffness to minimise deformation
- Low inertia to minimise shaft twist and bending, and to minimise the load on the motor

Forks - approach

- Topology optimisation
  - Find the optimal mass distribution
- Shape optimisation
  - Find an optimal shape contour
- Combine the optimal topology and optimal shape into a design
- 3D-printing gives design freedom

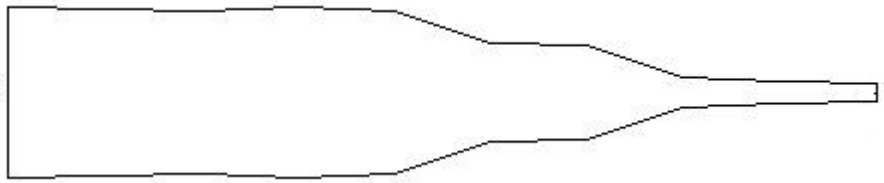
Forks - results

Optimised topology (2D)

Volume fraction 0.4

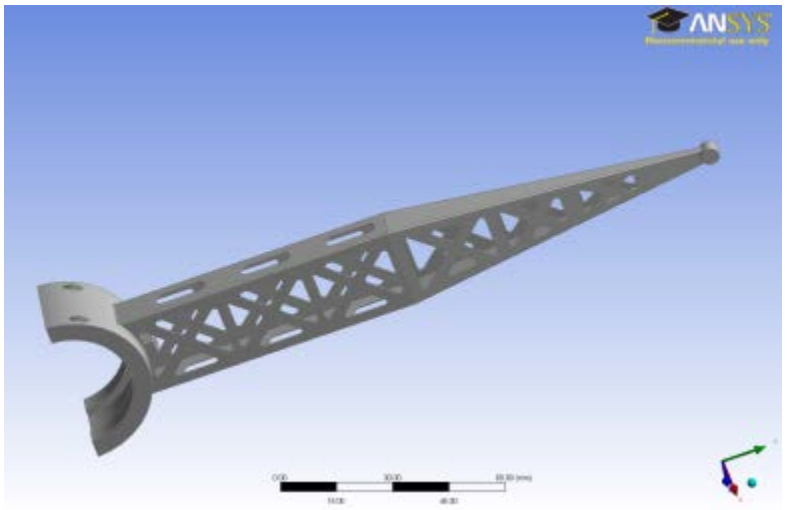
Volume fraction 0.3

Optimised shape



Forks - design

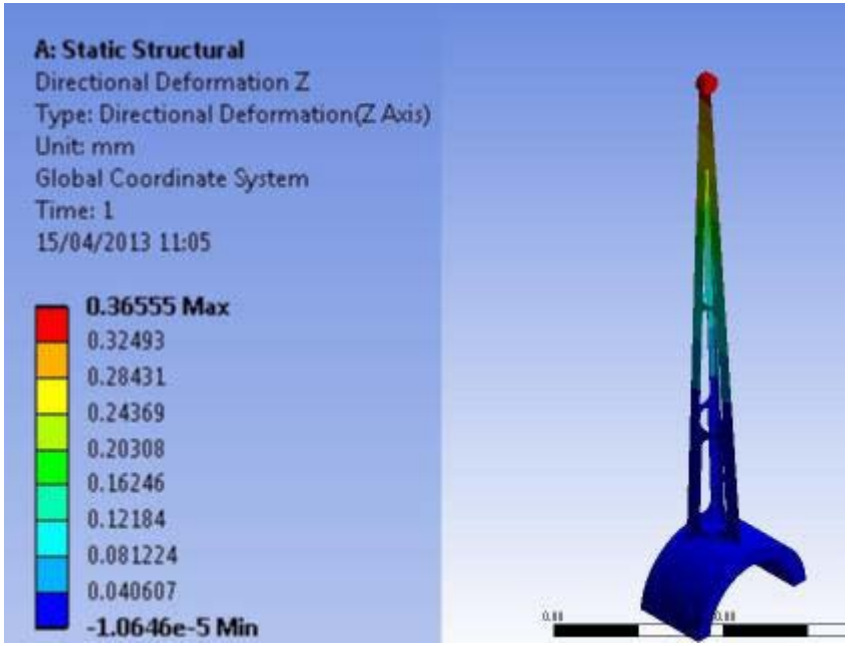
Combined design

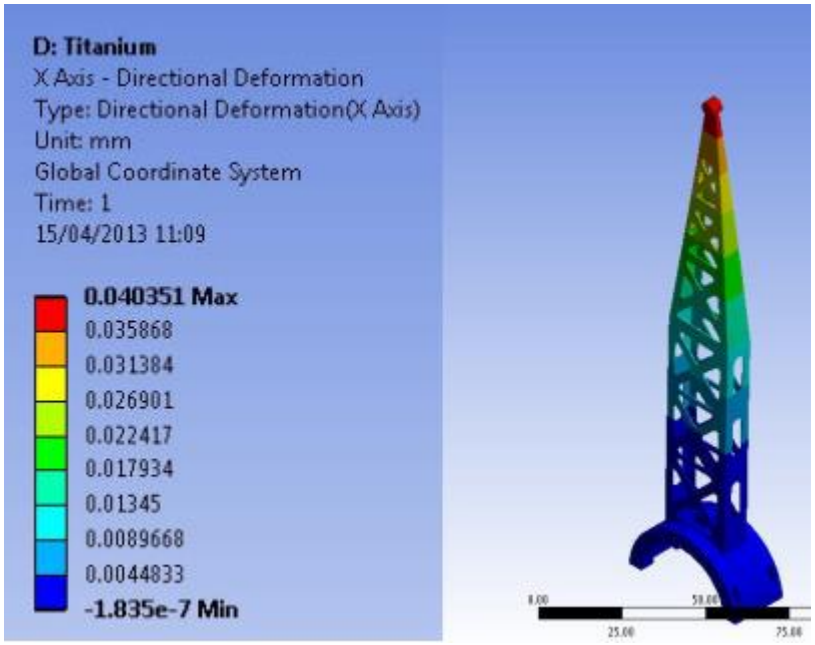


- Truss structure suggested by topology optimisation
- Titanium has good stiffness to density ratio
- Titanium is cheaper than stainless steel for 3D-printing

Fork deformation

Load: Angular acceleration of 6700 rad/s^2



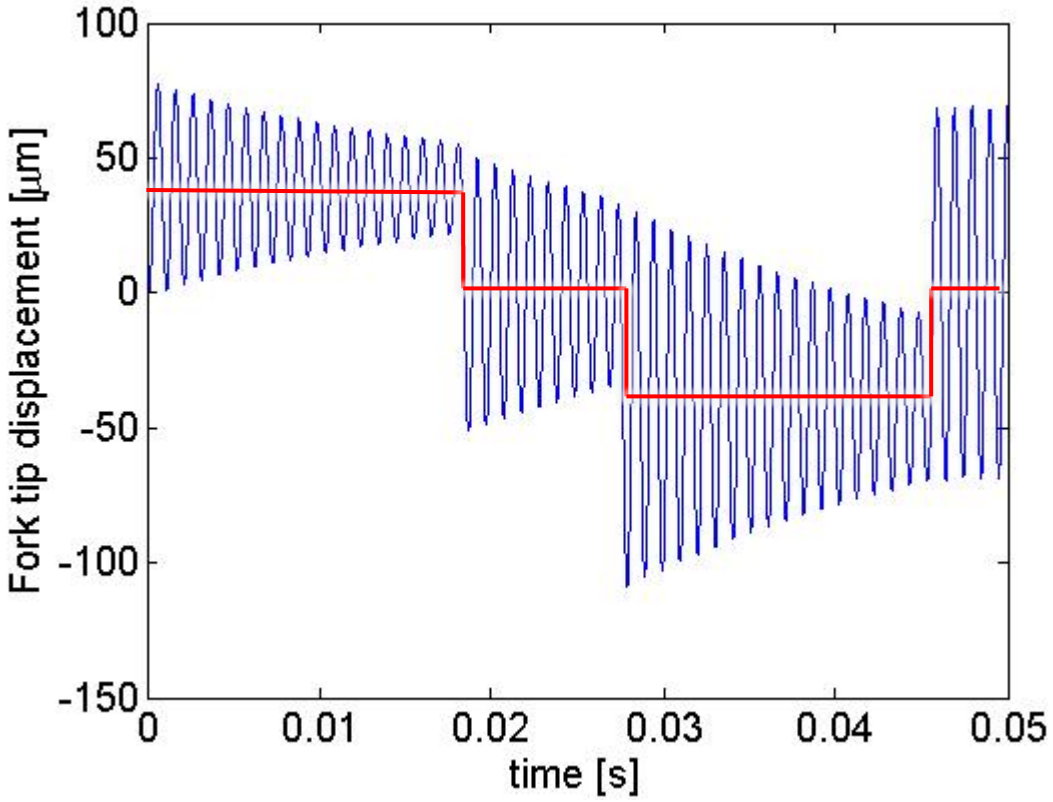


Original design (Titanium) **Optimised design (Titanium)**

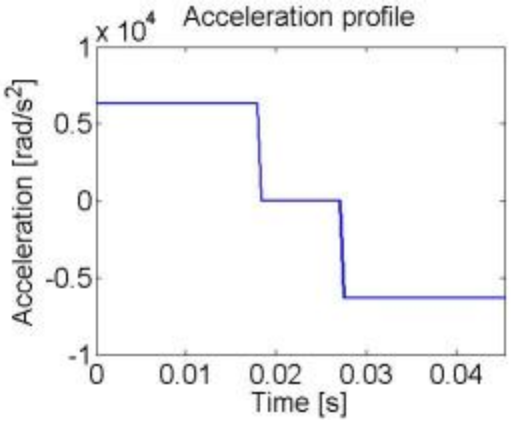
9 times smaller tip deflection after applying optimisation methods

Fork vibrations

ANSYS simulation results



- Mean deflection follows acceleration profile
- Amplitude increased for every change in acceleration
- Further studies needed to evaluate the behaviour for different acceleration profiles



Inertia values

Mass moments of inertia (J) and required torque (T) for an acceleration (6700 rad/s^2) corresponding to a wire scanning speed of 20 m/s

(max. torque of motor: 18 Nm at 4300 rpm)

Component	J (kgm^2)	T (Nm)
Bearing 1	1.96E-05	0.132
Bearing 2	2.45E-06	0.016
Disc	1.45E-04	0.975
Disc holder	2.01E-05	0.135
2 Forks	1.51E-04	1.475
Resolver	4.00E-06	0.027
Magnetic lock	6.61E-05	0.445
Rotor	3.40E-04	2.287
Shaft	2.91E-04	1.960
Total	**1.04E-03**	**7.453**

Shaft, rotor and forks make up most of the inertial load

Conclusions

- Motor housing of 0.3 mm thickness is needed
- Shaft dimensions: 35 mm outer diameter with 5 mm wall thickness
- Roughly 9 times smaller max. deformation of optimised fork design compared to original design
- Available torque of the motor is 2.4 times the required torque