Optimisation of a thick-film 10...400 N force sensor

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Thick-film piezoresistive force & pressure sensors

- Ruggedness, good stability and reliability
- Low cost, repeatable industrial fabrication process
- Cantilever force sensors good for low forces only
- Complex machined load cells expensive
- Up to now, no « simple » sensor for high forces

“MilliNewton” cantilever-type force sensor for 0.2...2 N range.
Range is limited in practice by the cantilever and by the solder or glue joint to the sensor base.

Steel + thick-film high range force sensor for total knee arthroplasty - ligament balancing

New “CentoNewton” ca. 100 N force sensor

- Sensor based on the **ring-on-ring** bending test
- Higher achievable forces than cantilever or 4-point bending
- Sensing & electronics integrated on a **single substrate**
- Dielectric “loading rings” screen printed onto the substrate
- 2 piezoresistors in the centre (under ceramic disc)

Mechanical model & dimensioning

Force F [N]	10	20	40	100	200	400
Substrate thickness h [mm]	0.25	0.30	0.50	0.80	1.00	1.50
Nominal stress σ [MPa]	80	111	80	78	100	89
Nominal response r [mV/V]	1.9	2.7	1.9	1.9	2.4	2.1

Improvements in sensor design

- Silicone adhesive on loading rings : lateral compliance to ideally eliminate friction
- Sensor substrate permanently bonded on base to eliminate reproducibility errors
- Also tested with steel ball ring to validate friction hypothesis

The different tested boundary conditions for the outer ring

Initial results

Friction at loading points is a source of **hysteresis & non-reproducibility**, up to > 5% full scale !

Response of some sensors, with one sample (red) exhibiting considerable hysteresis

Hysteresis of a series of nominally identical sensors

Results of improved sensors

Effect of modifying two sensors (A, initial condition) with steel ball ring (B) or with added silicone glue (C) on the hysteresis behaviour (several cycles).

- Friction largely eliminated by using a laterally compliant outer ring contact
- Both methods (steel balls & silicone) successful

Conclusions

- Simple, compact, sturdy **low-cost force sensor** for ca. 10...400 N range
- Basic design : **hysteresis** from **friction at loading rings** and **reproducibility error** from variable positioning on base
- **Silicone adhesive bonding to base plate** : simple method for improving both **reproducibility** and **hysteresis** characteristics