Differentiating Guidance from Support Functions in Ultra Precision Mechanism Design

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A principal recurring limitation on the positioning precision of a mechanism is friction between sliding or rolling interfaces which both support and guide the motion (ie plain or rolling element bearing surfaces). In many (if not most) instruments and machine tools, its seems to be taken as a design premise that gravitational mass forces on a moving carriage or member shall be supported by static guide-ways.

This putative necessity that support forces should equate to guidance forces is questioned. If such a design constraint is removed, it is shown that, with support forces treated differentially from guidance forces, levels of the latter employed at guide-way interfaces may be considerably lower by design. Examples are given from a range of applications where support force offset techniques have been employed to achieve major reductions in coulomb (interface) friction. These include counterbalance mechanisms, elastic elements, auxiliary 'slave' carriages and drives and partial support using hydrodynamic films, hydrostatic flotation and aeroelastic elements. Examples of each will be given and salient features reviewed. An example will be analysed showing five orders of magnitude difference between the friction associated with the drive force and that required for guidance. In such a regime, reductions in levels of guideway-friction of two orders of magnitude are then quite modest objectives which may be readily achieved.

It is suggested that, using the highlighted 'guidance/support divorce' approach, radical improvement in the design performance of mechanisms and machines is possible for particular applications including wafer-steppers and scanning probe instruments.

For such design improvements in precision positioning systems, it is seen that it is productive to adopt a vicarious approach to a wide range of applications in areas which might not seem to relate to requirements. It is suggested that 'applications-based' categorisation of techniques might constrain such an approach and that perhaps a more lateral approach is needed using a wider intellectual 'trawl'.

If given the opportunity for an oral presentation, questions will be posed as to how these underlying techniques may be more readily accessed by the precision engineering community. In particular, how does one 'teach' graduate students to seek such radical techniques from both within and outside their apparent 'field' of research?