Genetic Algorithm Optimization of Strain Gauge Load Cells

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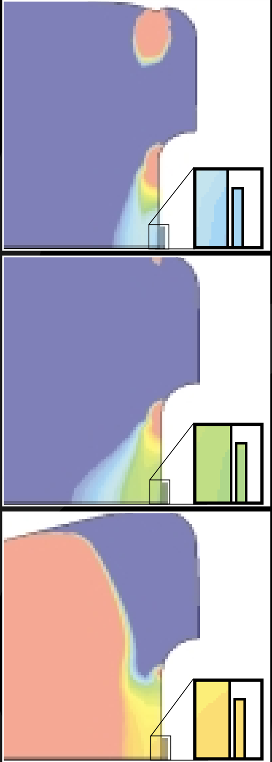
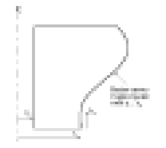
Most industrial measurements of force are made with strain gauge load cells. These utilise strain gauges, bonded to a steel or aluminium body (the elastic element), to give an electrical output proportional to the applied force. The output of load cells is found to be influenced by their end contact conditions, giving rise to so called end-effects. The standard method of evaluating this end-effect sensitivity, compares the strain gauge output when the same force is applied via plane, concave, and convex surfaces.



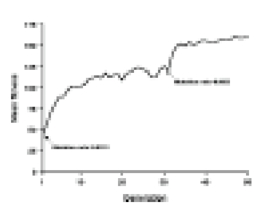
The influence of variation of the contact conditions on the strain gauge (shown enlarged) can be seen in the finite element calculations of strain in an upper radial cross section of a load cell of conventional shape.

Although the influence of end-effects can be predicted by finite element modelling, attempts to use finite element methods to design load cells of reduced end-effect sensitivity have been largely unsuccessful. This is a consequence of the discontinuous and rugged nature of the objective function. The ability to locate the optima of such functions is one of the advantages of genetic algorithm (GA) optimization. A genetic algorithm was therefore applied to the shape optimization of load cells.

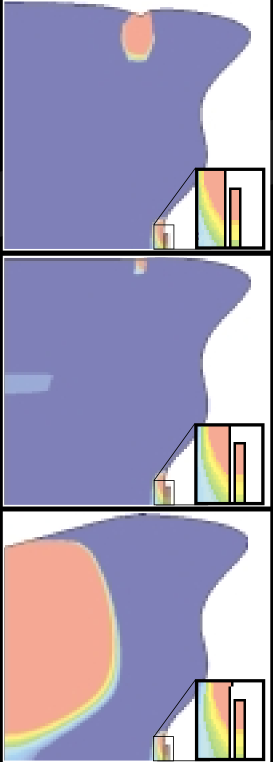
The algorithm worked upon generations of 100 strings, each string encoding the load cell geometry using the parameters illustrated below.



Mating pairs were selected according to fitness, calculated from finite element evaluations of end-effect sensitivity. Members of the new generation were created by partially matched crossover and random mutation of the parent strings.



The mean fitness of the members of each generation for a typical optimization is shown above.



The figures show the strain distributions in a 3 MN (~300 tonne force) genetic algorithm optimized load cell.

Although the strain patterns in the bulk of the load cell still show large variations, it is apparent that the strain in the strain gauge is much less sensitive to the changes in end loading conditions than the conventional design. The prototype of the GA optimized load cell is shown below. Tests on the prototype confirmed the finite element prediction that the GA optimized design would have one tenth of the end-effect sensitivity of a conventional design.

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