Software Fine Tunes a Nitinol Stent

An optimization program finds geometry that reduces strain in a crimped stent.

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The stent function is simple: Prop open clogged or collapsing arteries to keep blood flowing. Designing one, however, is an entirely different proposition. Their diameters range from about 5 to 10 mm and lengths from 20 to 40 mm. Stainless-steel stents are expanded by balloons, but the favorite material, shape-memory nitinol, expands with body heat.

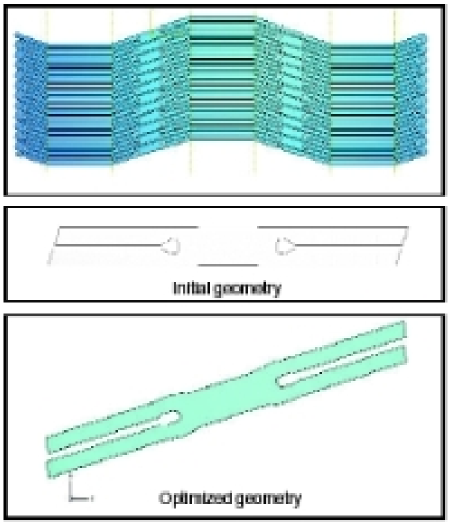
The process of expanding and crimping nitinol stents is a problem because doing so sometimes generates strain beyond an allowable limit. The initial laser-cut pattern influences the strain, but time consuming computer simulations limit the conventional exploration of different geometries. One stent manufacturer wondered if a shape optimizer could find geometry that would lower the strain.

Optimization software called Heeds (Hierarchical evolutionary engineering design system), was tapped for the task.

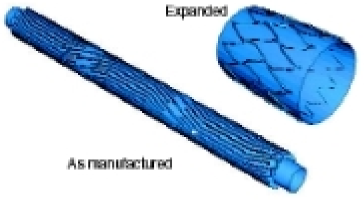
The design goal is to find an initial laser-cut shape that minimizes principal strains created when the finished stent is crimped to a smaller diameter on a catheter.

How to make a stent

In a nutshell, stents are laser cut from small diameter tubes so that when expanded they look like wire-link fences. The mesh or links allow crimping the stent so it can be expanded later in an artery. Annealing the expanded stent gives the nitinol a shape to "remember." Then it's crimped onto a catheter at low temperature.



The model represents a flattened stent. The dotted line surrounds a submodel. The drawing shows some stent geometry before applying the shape optimizer. Blue geometry shows modified details generated by Heeds. Stent engineers say the maximum principal strains in the new design were reduced by 60%.



Stents are laser cut from small-diameter tubing, expanded, and then crimped to a catheter for

During design, engineers apply nonlinear finite-element analysis to a full stent model. Analysis includes simulating expanding and crimping the stent. But this takes about four days to run on a Pentium-based computer. One result is the maximum principal strain after crimping. Simulations with the initial design showed maximum strains in excess of magnitudes mandated by safety considerations.

A full optimization sequence requires reanalyzing the stent for many different shapes. To get around long run times, engineers let the optimization software work on submodels, smaller portions of the full model. These run in a matter of hours to minutes. A few complete geometry runs are still needed to validate the coupling between full model and submodel. Validation shows that submodels accurately describe how the full model will behave.

Optimization steps

The design team generated a parametric model of the stent to explore shape variations during optimization runs. The parametric model is needed so the team could assign variable names to geometric features, such as lengths and radii. This model is remeshed for every shape change. The team assigned a range of allowable variation in Heeds to the geometry. The team also set limits on stresses and displacements. This was enough for the software to control geometry and ultimately identify a design that best satisfied the performance criteria - a reduction of the maximum principal strain by 60%. The project met the goal.

insertion.

A setup screen from Heeds shows how users would set the maximum and minimums for variables.