5.8 TASK 8
Cylindrical Composite Spring Analysis Code
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Task 8 Technical Requirements

Thin-wall cylindrical springs fabricated of carbon/epoxy offer numerous advantages over similar metallic cylindrical springs, including improved stiffness and strength, lower weight, and lower manufacturing cost, and better long-term environmental resistance. The primary objective of this research effort is to develop a computer analysis program for designing and analyzing thin-wall cylindrical springs composed of carbon/epoxy, where the user will need to define the geometry (diameter, length, thickness) parameter ranges as well as material properties, loads, and attachment points. It is envisioned that springs will be fabricated by filament winding, where grooves (or slots) will be machined in to the spring walls to accurately control the stiffness. This task will include the development of the analysis program (either finite element or Ritz based) along with a material coupon testing program to provide the needed material property data for the code.

During the past year, a number of tasks were accomplished including;
(1) Selection of the range of geometric, material, fabrication, slot definition, and load parameters that need to be addressed by the analysis program,
(2) Development of a flow chart that identifies how all of the different codes would interact (data transfer) as well as identifying the different required theories that are needed for each code to analyze the broad range of variables,
(3) Development of a raw material database composed of nine different fiber types (boron, e-glass, s-glass, Kevlar, and four different types of graphite) and ten different resin types (polyester, vinyl ester, two polyimides and six different epoxies) that serve as the baseline materials throughout the studies, where this database can be expanded based upon LANLs needs,
(4) Programming of the micro-mechanics material modules that takes the user-defined fiber-type, resin-type, fiber volume fraction, and filament wind angle specifications and then calculates the laminate stiffness and strength properties,
(5) Calculation of cylindrical shell failure loads based upon laminate failure strength as well as wall-buckling considerations. This module was limited to shells without machined slots.

During the next year, the following seven tasks are proposed which will complete the project and the resulting code will be supplied to LANL. These topics include:
(1) <u>Extend current analysis code</u> to include cylinder wall slot definitions based upon arcuate beam approach as well as an improved model based upon large deflections and shear deformation (nonlinear spring behavior). Nonlinear finite element analysis of slotted cylindrical shells will be performed to provide needed data for analysis code.
(2) <u>Determine analysis sensitivities</u> (change in output parameter with design variables) and investigate the use of an optimizer program to automatically design springs based

upon a minimum number of design parameters. Potential output parameters include spring stiffness, displacement, maximum load, or minimum weight. All linear sensitivities are calculated in closed form, while nonlinear sensitivities are calculated numerically. This effort will require interaction with LANL personnel.

(3) Fabricate a range of filament wound composite springs and experimentally test to provide data for code evaluation. A minimum of three design variables will be investigated where a minimum of three variations of each variable will be fabricated for code verification. This represents a minimum of seven different filament wound tubes that can be cut and slotted to make springs. Currently the variables under consideration include: shell diameter, wall thickness, and wind angle. Different springs will be fabricated from the seven different tubes by varying the length and slot definition.

(4) A better micro-mechanics material model will be proposed and incorporated if it is found from experimental correlation studies that it is needed.

(5) A final report will be generated that covers the program flow chart, the analysis procedures, the input and output definitions, sample analyses, and the results of the correlation studies.

Task 8 Deliverables

	Task 8 - Deliverables	Due Date (days after contract award)
8.1	Current Analysis Code Refinements. Report progress in 2nd quarter report.	180
8.2	Determine analysis sensitivities and design optimization code option and report progress in 3rd quarter report.	240
8.3	Fabricate and test a wide range of filament wound composite springs for code validation and report progress in quarterly report.	300
8.4	Develop and incorporate a better material model; report in discussions and final report.	360
8.5	Provide a final report that covers analysis method, correlation results and a brief program user's manual	360