

VISITOR RESEARCH REPORT

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Area of Research: Composite Structures and Materials

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The Shell Buckling Knockdown Factor (SBKF) project aims to redefine the design criteria originally developed during the 1940s – 1960s. Predicted buckling loads calculated from simplified analytical models were often much higher than observed experimental results. So called “knockdown factors” were introduced to try and bridge the lack of understanding between the analytical models and experiments and knockdown the predicted values closer to the experimental values. Such knockdown factors were also used as lowest-bound buckling design criteria for new thin-walled shell structures used prevalently in launch vehicles. At the time of the original models and experiments, the scientists and engineers were just starting to understand the importance of geometric imperfections, correct boundary conditions, load introduction effects, etc, and how they affect the buckling load on shell structures. The SBKF project is reinvestigating the buckling knockdown factors to match current manufacturing tolerances, testing techniques, and computational analyses to lead to lighter vehicle structures. An investigation into geometric imperfections and their affect on the buckling load for cylindrical shells is a component of Phase 2 in the SBKF project and is the area of study this summer.

Initial geometric imperfections under investigation enter under two categories: manufacturing variations, and dimples due to an applied lateral perturbation load. To complete the plans for the summer, a new lateral perturbation device and instrumentation plate must be designed and fabricated. Use of a laser scanning machine and new software package called Focus Inspection will be used to record and process data on geometric imperfections in the test articles. A MATLAB program will be used to produce point locations mapping to nominal test cylinder specifications, and geometric imperfection values at those points will be read by a STAGS finite element code to predict buckling loads. A test plan with instrumentation patterns, data acquisition requirements, and load sequences is to be developed from the results of the pre-test analysis. Experimental testing, data post-processing, and reporting the results will be the end of the project for the test samples provided.

A pneumatic actuator and mounting frame was designed and fabricated for use as the lateral perturbation device. One of the key drawbacks to the previous framework was the inconsistent methods of fastening the framework to create a stationary object during testing. It was observed that without added weight (i.e. sandbags over the feet), the frame could slide away from the test cylinder if the applied lateral load exceeded a certain amount. The new framework calls for two cantilevered beams that screw into a base plate sitting on the bottom loading platen. Figure 1 shows a perspective view of the base plate (red), mounting fixtures (blue), framework and support (black and yellow), and pneumatic cylinder (silver).

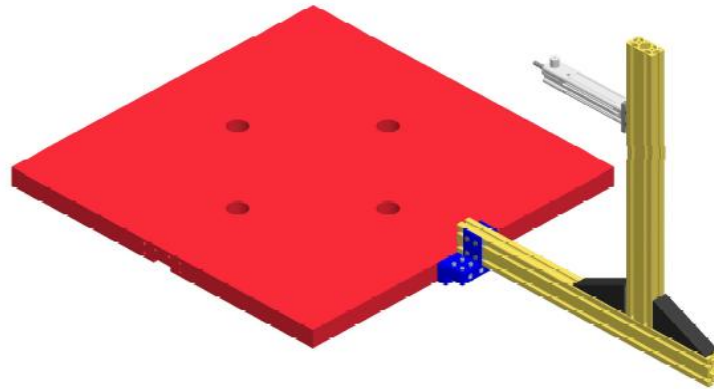


Figure 1: New base plate and mounting frame for the lateral perturbation device. Note that the base plate design has changed since the creation of this figure, but the concept is the same.

Item framework, Profile 8 80 X 40, makes up the two cantilevered beams to support the pneumatic cylinder. The vertical Item beam, holding the pneumatic cylinder, is able to slide along the length of the horizontal Item beam to leave the desired distance between the load application tip and the side of the test cylinder. Similarly, the pneumatic cylinder can slide along the vertical Item beam to apply a load along the bottom half of the test cylinders (which are 48 inches tall).

The advantages of a pneumatic cylinder are the ease of setup, operation, and continuous movement. Pressurized air pushes against the piston of the pneumatic cylinder, causing the rod to extend on the work stroke and retract on the return stroke. Control valves and rod-clamping devices may be added to fulfill the design requirements of having direct, adjustable control over the force applied to the test cylinder and having a clamp fix the dimple depth during loading. Figure 3 shows a schematic for the setup of the pneumatic system.

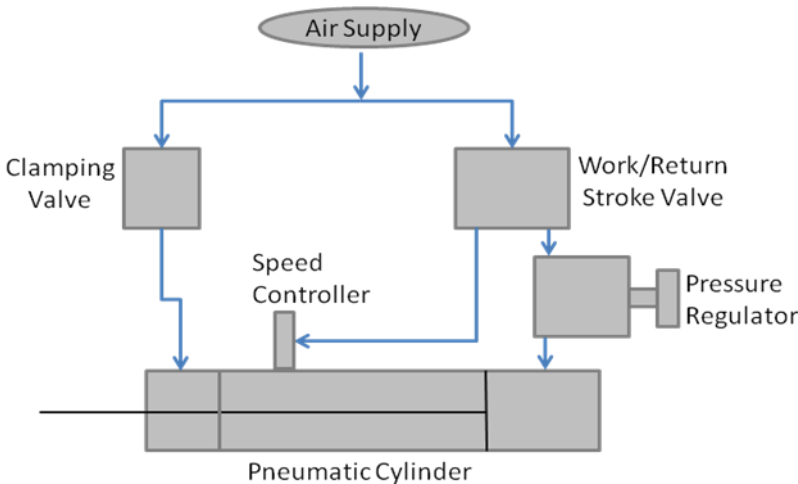


Figure 3: Schematic (left) of pneumatic system showing all key components except the load cell at the end of the pneumatic rod. Not to scale. Photograph (right) of the layout and connections of the constructed pneumatic system after verification of basic performance.

Jordan Handler, another intern working with Mark Hilburger on Phase 2 of the SBKF project, performed most of the geometric imperfection measurements and data processing for the MATLAB programs he created. I focused on learning STAGS and creating a model capable of capturing all important properties for an eigenvalue analysis and nonlinear analysis. Within that part of the project, the main highlights of the STAGS computational analysis include an end-shortening displacement of 0.054 inches from a simple linear analysis, a critical buckling load of approximately 42,000 pounds from an eigenvalue analysis and mesh convergence study, and a bending boundary layer length of approximately three inches under a 4000 pound load used to balance the loading platens before testing. Table 1 provides the attenuation distances along the axial direction for 20%, 10%, and 1% of the maximum amplitude compared to the mid-length displacement. Other intermediate loading factors were used in between the last two, but did not contribute significant change.

Load Factor, PA	% Attenuation & Bending Boundary Layer Length (in)			
	Applied Load (lbs)	20%	10%	1%
0.100000	4000.00	2.45486	2.60376	4.11406
0.200000	8000.00	2.40168	2.50804	4.08216
0.274941	10,997.64	2.30158	3.29353	4.90645
0.387245	15,489.80	2.77751	3.30627	4.89254
0.611380	24,455.20	4.13089	5.40253	9.35652
0.976906	39,076.24	4.19050	5.52174	11.9793

Table 1: Attenuation lengths for the bending boundary layer.

Due to a broken load cell in the 600 kip testing platform, the cylinders were not able to be tested as originally planned for this summer. Depending on availability with other projects, the testing window is tentatively moved to anytime between October and December. Future work with the pneumatic cylinder will consist of calibrating the load cell and linear variable differential transformer closer to the test date. Future computational calculations with STAGS may include an eigenvalue analysis with a lateral perturbation load to determine the change in the buckling load, a nonlinear analysis with the perturbation load to determine the effect on the bending boundary layer, and a dynamic/transient analysis with and without a perturbation load to determine post-buckling modes.

There are no pending publications or scheduled seminars to present this work. A key factor in creating publishable work is the ability to test the cylinders to gather data and validate the computational methods used to predict the test behavior, but without a testing platform we are not able to gather such data yet.