VISITOR RESEARCH REPORT

Visitor Name: **Mr. Jordan Handler**

Area of Research: **Composite Structures and Materials**

Period of Visit: **June 6, 2011 – August 12, 2011**

Goal

The primary goal of summer research, conducted at the NASA Langley Research Center, is to become familiar with the process of research from design and fabrication all the way to test plan development and testing. The secondary goal is to implement the next phase of lateral perturbation buckling tests. This next phase includes using current technology to determine how geometric imperfections, represented by a lateral perturbation, affect the buckling behavior of cylindrical shells.

Strategy

The strategy for implementing the next phase of buckling tests is to begin with design and fabrication of a lateral perturbation device. The device should be able to connect to the loading mechanism for extra rigidity. Next, the cylinders need to be scanned to determine geometric imperfections. These imperfections will be placed in finite element software to determine analytical lower bound buckling loads of the cylinders. The analysis will include a linear bifurcation and non-linear evaluation. After this, a test plan will be developed. It will include the necessary instrumentation and data acquisition requirements. Finally, strain gages will be installed on the test articles and testing will be conducted.

Accomplishments

To accomplish the goals of the summer, multiple steps had to be taken. To start, a lateral perturbation system and fixture had to be designed. Last year's perturbator consisted of a pulley system with too long of a reaction time. We chose to use a pneumatic cylinder to place a lateral perturbation on the cylinder because of its shorter reaction time and more precise control. Once set up, the pneumatic cylinder will be easier to use as well.

A fixture to connect the cylinder to the loading mechanism was first designed, where an 'L' shape bracket will be attached to a base plate on the testing mechanism. This is to ensure a constant force when we're working with high loads. A computer model of the frame is shown in Figure 1. The Item framework is shown in yellow, the base plate is in red, and connections between the base plate and framework are shown in blue. These connections in blue were designed to withstand the loads of the cylinder and were sent out to NASA Marshall to be fabricated.

The pneumatic cylinder also had to be designed to work with different regulators and switches. We chose to use a double acting cylinder, which contains air pressure on each side of the cylinder to ensure that the cylinder doesn't move in either direction too fast. A 1-way control valve is attached to the front end of the cylinder where it controls the air speed out of the cylinder. When closed, the piston in the cylinder cannot protract. Similarly, a hand lever and precision regulator were connected to the rear of the cylinder where we can accurately tune the amount of pressure that pushes on the piston. The lever allows us to turn the pressure off completely for the cylinder to retract. A small load cell will additionally be placed at the end of the piston to obtain lateral force data during experimentation.

After designing the perturbation system, we scanned the test articles with a coordinate measurement machine (CMM). These scans are used to project the exact geometric imperfections of the cylinders. Due to the large size of the cylinders, multiple scans had to be taken. We first created an algorithm for the scanner by strategically placing it in different positions and angles; the algorithm was used for subsequent scans. Once the scans were completed, they were aligned with Focus Inspection software. As this was the first time a specimen of such a large size was scanned, there was some trial and error when placing the scans together. Different approaches included aligning the scans with a best fit cylinder, using small spheres glued onto the cylinder to align the scans, and deleting overlapping data. We have since aligned the cylinders well, but have found some areas where deviations from a perfect cylinder seem too high. More work will have to be done with the scans, but all past work and procedures were documented.

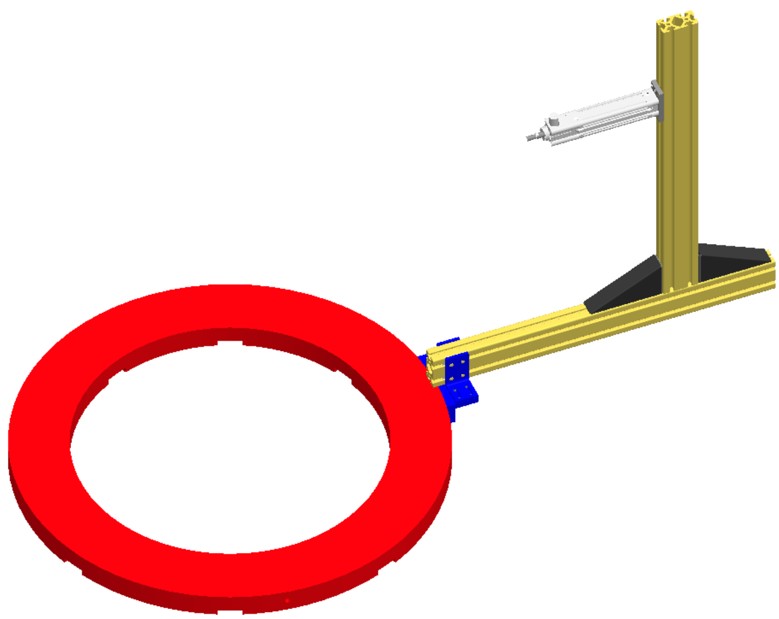

Figure 1: Test setup with framework connected to base plate

When scanned data is properly aligned and fit to a perfect cylinder, deviations can be extracted from Focus Inspection for use with finite element programming. To obtain these deviations, a Matlab program was written that output a series of points along a perfect cylinder that correspond to the point system used by STAGS, a finite element program used at NASA and other institutions. The Matlab program outputs points for a cylinder composed of multiple shells around its circumference. It has the same numbering scheme as STAGS, where numbering for each shell begins at node 1 and works along each row before increasing in height. Inputs for the program include arc angle, radius, the number of rows, and the number of columns for each shell. Figure 2 below shows a plot of coordinates for a cylinder with a seam. There are more data points in the seam to pick up extra detail.

In addition to a cylinder, Matlab programs were written to output coordinates for other geometries such as a fluted core panel and a stiffened panel. These points can be used with future tests to obtain deviations for use with STAGS. There has already been some analysis with STAGS with regard to both linear bifurcation and non-linear analyses. At this point, we have not imported cylindrical deviation data into the program.

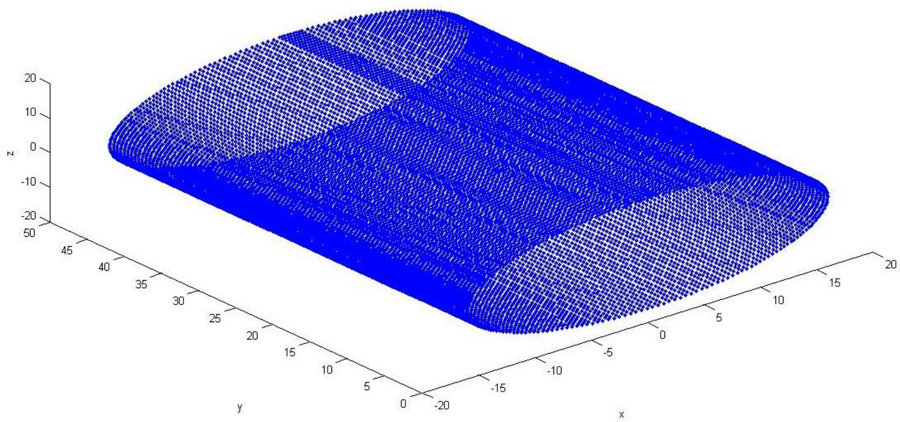

Figure 2: Coordinate points corresponding to a perfect circle with a seam

Future Work

While we have performed a global comparison between scanned data and a perfect cylinder, scans still need to be aligned in differing sequences to determine which procedures yield the lowest error. Furthermore, scans for each new barrel should be aligned according to newly recommended procedures. Coordinates output from Matlab will need to be compared to data within Focus Inspection software. The resulting deviations should be incorporated into STAGS to obtain theoretical buckling loads of the cylinders. An additional program needs to be implemented into STAGS that fits a curve to the imperfection data and interpolates imperfections where holes in the mesh occur.

Strain gages will still need to be applied to each cylinder, on both the exterior and interior. While interior strain gauging has already begun, exterior gauging may be held off until it's certain that there needs to be no re-scanning of each cylinder (due to current alignment issues). Furthermore, a test plan needs to be created that incorporates instrumentation and data acquisition requirements. A video image correlation system should be set up to determine strains and stresses within the specimen. At this point, the load cell on the 600kip loading frame is faulty. Until the load cell is fixed, testing will be postponed. Testing is expected to take place between October and December of 2011.

Pending Publication

There are no pending publications at this time. After testing, results may be incorporated in a number of papers.

Seminar Presented

No seminar was presented because testing has been held off until the load cell of the 600kip loading machine is fixed.