DARPA DMACE Challenge Problem Statement

www.dmace.net

There are two problems to solve with two predictions to submit by 4:30 PM, December 6th. Both predictions are maximum compressive loads in newtons. The two problems are categorized by titanium spheres and polymer cubes. Although similar in principle, the two problems may require slightly different approaches.

Titanium Spheres

The machine used to digitally manufacture the titanium spheres (an Arcam A2) used an electron beam (e-beam) melting process and Ti6Al4V titanium alloy powder. During the build of the titanium spheres, two input parameters in the e-beam control were varied:

1) e-beam velocity (100, 200, and 300 mm/sec),
2) e-beam current (1.3, 1.7, and 2.1 mA).

The build direction is defined as the vertical axis at which the e-beam machine built the spheres. Furthermore, each sphere had two distinct geometric axes of symmetry, which were structurally different. The two axes of symmetry were recognizable on the sphere surface by a square grid of titanium mesh or a hexagonal grid of titanium mesh along the diameter of the sphere.

For the Challenge, the build direction was aligned through the sphere diameter along one set of the square grids. This particular set of square grids was referred to as 0° from build direction. Another set of square grids was located at 90° from the build direction. The hexagonal grids were located at 60° from the build direction. Each sphere was tested in compression to failure along one of these three axes -- 0°, 60°, and 90° to the build direction. During the compression tests, the maximum (or ultimate) compressive load was recorded. The average maximum load, standard deviation, and maximum load of repeated tests were summarized, along with individual and summary plots, in a single Excel data file. These files are available online at www.dmace.net for registered participants.

The first 9 Excel files of sphere data posted on the website were crushed at 0° from the build direction, consisting of a full factorial of the 3 beam velocities and 3 current settings with 9 repeats at each condition. This resulted in a total of 81 spheres. The second 9 Excel files of sphere data posted on the website consist of the same 9 combinations of e-beam velocities and current settings, however the spheres were tested at 90° from the build direction. Both the 0° and 90° scenarios are geometrically the same; however, the 90° scenario is perpendicular to the build direction. Additionally, a single set of 6 spheres at a single beam velocity and current were tested at 60° from the build direction.

In summary: 81 spheres were tested at 0° from the build direction, 81 spheres were tested at 90° from the build direction, and 6 spheres were tested at 60° from the build direction. This equals a total of 168 total spheres as a minimum, for which the data is available to participants for model development.

Each participant or team should use this sphere data to develop a model that will allow them to predict the maximum compressive load for various e-beam velocities, e-beam currents, and build directions.

A final set of spheres for the Challenge finale will be built at another beam velocity and current setting and tested at 60° from the build angle. This is the setting that the participants must predict based on the previous sphere data.

For the titanium spheres, build your models to predict ultimate compressive load based on the two complete factorial sets of data tested at 0° and 90° from the build angle, plus the one condition tested at 60° from the build angle. Then, make your prediction for the ultimate compressive load tested at 60° from the build angle with different beam velocity and current settings, which will be made known to all participants on December 3, 2010.

Polymer Cubes

The polymer cube problem is different from the titanium sphere problem in that initial tests were performed to establish basic material properties, and then subsequent tests evaluated structures made from the basic material.

The polymer material properties were suspected to be anisotropic and bi-modular, so the compression and tension tests were conducted in order to establish the basic material properties of the polymer (ABS-M30 production-grade thermoplastic) extruded by the 3-D printer (FORTUS 400mc). During the build of the compression and tension specimens, four processing variables were varied:

1) printer tip size (T12=0.178 mm and T16=0.254 mm),
2) machine raster angle (0° and 90°),
3) machine build angle (0° and 90°), and
4) bake time after fabrication (0 and 12 hours), referring to how long the sample remained in the printer-oven after fabrication.

Figure 1 below provides a visual reference for the raster and build angles.

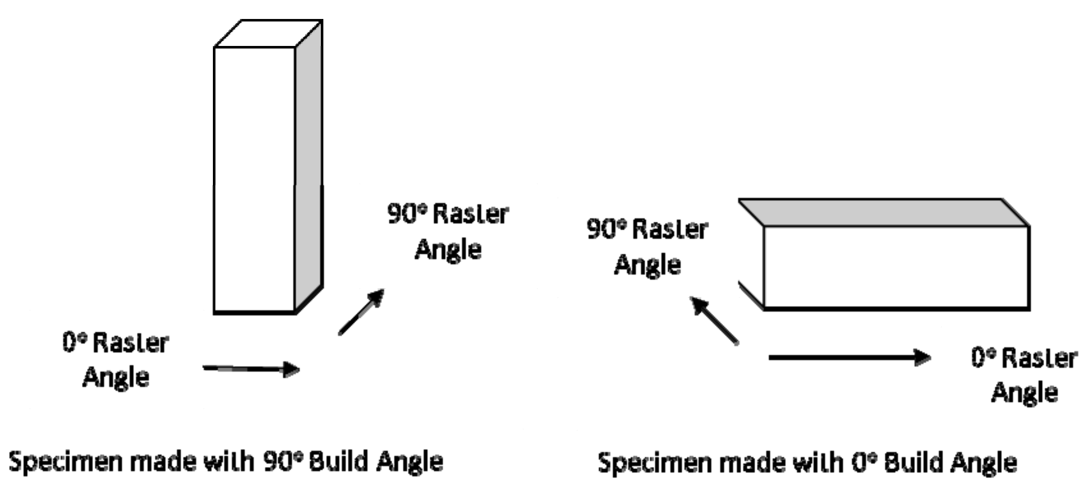

Figure 1. Depiction of build angles and raster angles

The second series of tests were cubes of various geometries to introduce Challenge participants to basic structural properties and to test their models. Figure 2 depicts representative cube geometries.

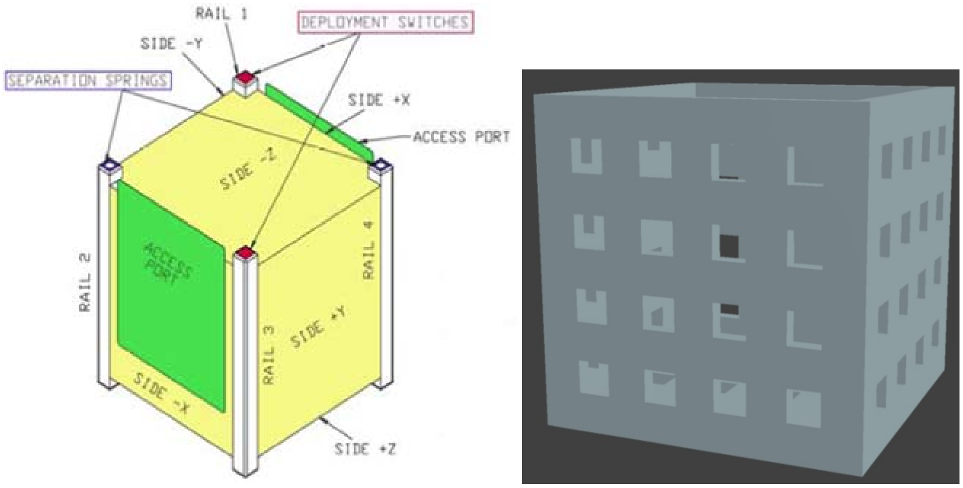

Figure 2. Depiction of cubes of various geometries

These cubes were then tested in compression to failure, and the maximum (or ultimate) compressive loads were recorded and posted online. Based on both the material property tests and the cube tests, participants should build a model that can predict the ultimate compressive load of a cube design given the geometry of the cube. Similar to the spheres, the final cube geometry will be available to all participants on December 3, 2010.

<u>Putting it all together</u>

For the DMACE Challenge, participants must submit predictions for the maximum compressive load in newtons for both the final titanium sphere configuration and the final cube configuration. Predictions and model descriptions must be submitted by 1630 EST, December 6, 2010. A winner will be determined by DARPA, and the winning team or individual will receive the $50,000 Challenge prize.