Analysis of the Performance of Novel Truss Lattice Structures II

Background:
Lightweight structures are used in applications that require high fuel efficiency, blast resistance and heat dissipation. One type of lightweight structure is the sandwich panel construction, with attributes that have long been recognized. As compared to a single solid sheet of metal, an equal-weight panel with dense face sheets and a porous core (in Figure 1) will outperform the solid sheet in terms of bending stiffness (a critical parameter in designing advanced vehicles). The benchmark of lightweight structures has been the honeycomb core sandwiched between two solid panels (4). Although very efficient, the honeycomb core is costly to manufacture and is susceptible to durability problems - such as failure of the bond between the face sheet and the core.

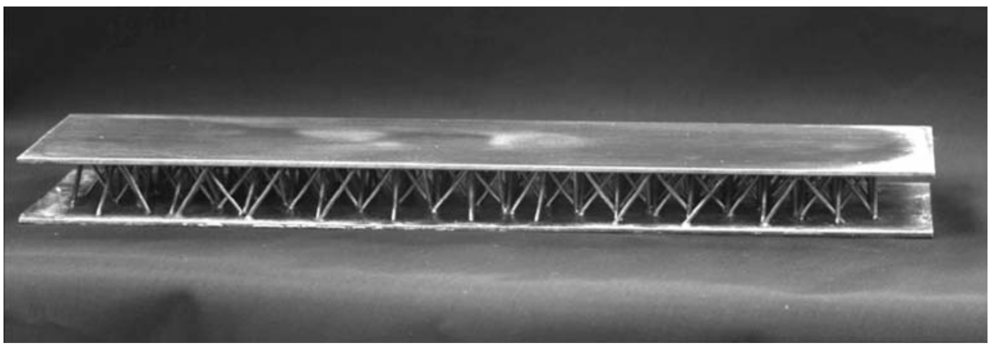

Figure 1. Example of a truss core sandwich panel fabricated by the pin and foam fabrication approach.

Recent research has led to a new class of sandwich structures with cores made of truss networks of small diameter. These cores can perform better in compression and shear at equivalent weight, if the core is designed properly. A key concept is to design the cores to respond to panel loading so that the individual core elements are loaded in compression or tension - not bending. These new structures have cores that are open (as opposed to closed, sealed cells in the honeycomb materials) that enable 'multifunctional' use of the lightweight structures. For example, in addition to supporting mechanical loads at minimum weight, the structures can act as efficient heat exchangers, using cooling air flowing through the core. This multi-functionality makes these materials quite promising for future use.

An alternative processing approach for truss core panels has been developed where a high temperature, ceramic insulation material (foam) is used to support the pins at a designed spacing and angle during brazing in a vacuum furnace. To date, research has been initiated to find the ideal geometric arrangement of pins in the foam (3). Some panels have been made with the pins in a pure pyramidal arrangement (1). Theoretical formulas have been put forth that compare the mechanical performance of alternative designs and arrangement of the pins in the structures (2). However, these designs have not yet been manufactured and tested. The research I am proposing will begin to do that.

Purpose:
Use of truss lattice structures in aircraft wings, ship hulls, and submarines is promising because they dramatically improve fuel efficiency over that of solid steel. The NAVY is particularly interested in this class of materials because of the need for more blast-resistant marine vehicles. All of these applications dictate that the most important consideration in the design of truss lattice structures is resistance to bending. In response to this, our research will examine advantages of leaving the ceramic foam in the panels after processing. The presence of this very lightweight material can provide a significant increase in the buckling stiffness of the core members, and may dramatically improve the mechanical properties with only a small weight penalty.

Objective:
The goal of this research is to continue current research efforts that were partially funded by UROP in Fall of 2003. This research will investigate strength of truss lattice structures with foam inside compared to those without foam and that the increased strength outweighs the disadvantage of added weight from the foam. We also want to continue to explore different geometric arrangements of the pins.

Approach:
The core and sandwich panels will be made of stainless steel. The core will be comprised of solid cylinders or hollow tubes, shown in Figure 2, where diameters, angles, and spacing are all variables for making the different panels that we will inspect and test. The octahedral unit cell will model the positioning of the pins in the core. In order to insert the stainless steel rods into the solid ceramic foam, we will drill holes into the foam to using a standard drill press with rotating head.

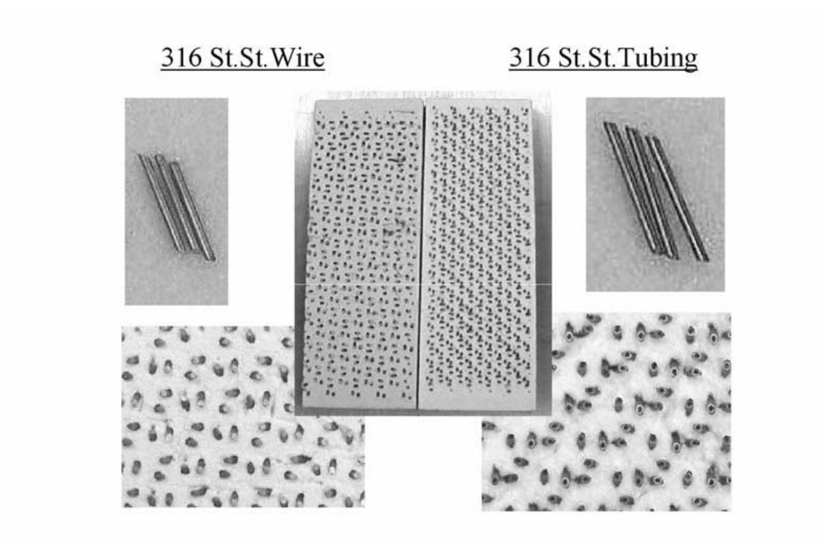

Figure 2. Core performs fabricated using solid pins and hollow tubes, illustrating the flexibility in manufacturing

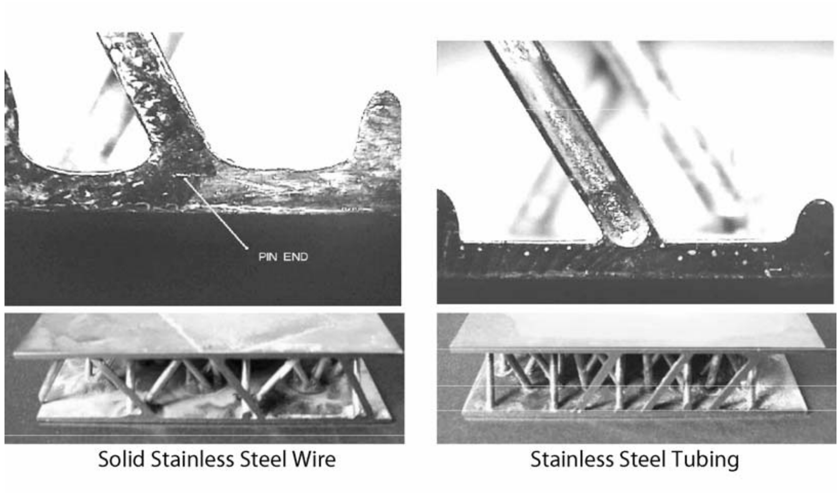

Figure 3. Cross sections through core element and the face sheet joints formed by transient liquid phased bonding, illustrating good metallurgical bonding and maintenance of hollow tube characteristics.

To attach the foam core and sandwich panels, a commercial transient liquid phase brazing material (appropriate for this stainless steel) will be applied at the nodes and the structure, which will be heated in a vacuum oven at 1100° C for one hour and cooled. The integrity of the brazing will be inspected with optical microscopy of metallurgical cross-sections taken through the pin/face sheet joints, as shown in Figure 3. Following inspection, three point bending tests will be preformed. Failure of the structure may occur when the brazed joints break, but the goal is to make the brazing strong enough so that the core element pins buckle first, as pictured in Figure 4.

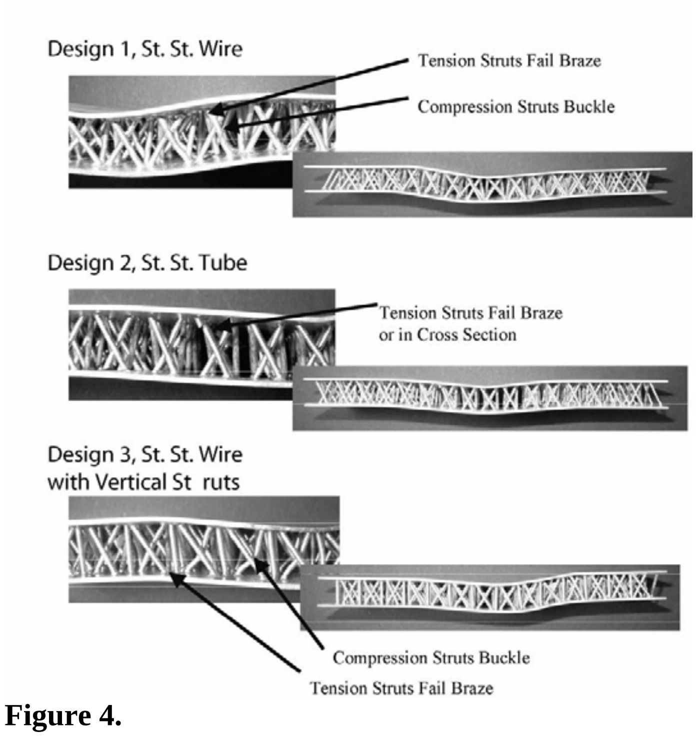

Figure 4.

Student's Specific Responsibility:
The student will be responsible for all manual labor (operation of cutting systems, oven, and loading tests) and most of the results analysis. The student will be involved in ordering materials and supplies. The student will write all findings with guidance from Professor Mumm. The student will also help submit findings to research journals for publication, including the *UCI Undergraduate Research Journal*. The student also aspires to present the research at the Winter Annual Meeting of the American Society of Mechanical Engineers in Anaheim.

References:

1 Bart-Smith, H., Hutchinson, J.W., Evans, A.G., "Measurement and Analysis of the Structural Performance of Cellular Metal Sandwich Construction," *International Journal of Mechanical Sciences* (2001), **43**:1945-1963.

2 Deshpande, V.S., Fleck, N.A., "Collapse of Truss Core Sandwich Beams in 3-Point Bending," *International Journal of Solids and Structures* (2001), **38**:6275-6305.

3 Deshpande, V.S., Fleck, N.A., Ashby, M.F., "Effective Properties of the Octet-Truss Lattice Material," *Journal of the Mechanics and Physics of Solids* (2001), **49**:1747-1769.

4 Evans, A.G., "Lightweight Materials and Structures," *MRS Bulletin* (2001), **10**:790-797.