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CHARACTERIZATION OF EMBEDDED SPHERES IN OPAQUE FOAMS

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This paper concerns the methods that were used to build an imbedded sphere in foam target for use on Omega to test theories of astrophysical jets. The core of the target is comprised of a titanium slab that is driven through a titanium washer into a low-density foam with an imbedded sphere. The critical dimension that needed to be known was the location of the center of the sphere with respect to the drive region. Initially, attempts were made to fabricate the sphere imbedded foam precisely, however the foam changed dimensionally during the drying phase of fabrication. The dimensional changes observed were often as large as the specified tolerances, so the foams required post fabrication characterization. Optical characterization of the foams weren't accurate enough and radiography was required for precision characterization. Once characterized, the sphere needed to be placed in the specified target geometry correct to an accuracy of ±25 µm. The radiography images were imported into a CAD program and these images were used to assemble the target precisely. The methods used provided a well-characterized target with a good build.

I. INTRODUCTION

Astrophysical jets have traditionally been observed and studied through telescopes.[1] Recently, these phenomena have been studied in computer simulations and scaled laser experiments.[2] Current experiments utilize different materials to mimic an astrophysical jet encountering a molecular cloud. Astrophysical jet HH 110 was studied through scaled laser experiments. Laser energy indirectly drove a 125-µm thick titanium slab through a titanium washer into a low-density (0.10 gm/cc) resorcinol formaldehyde foam. The slab became a jet and encountered a (1 gm/cc) CH sphere, offset 350 µm radially and 925 µm from the jet drive region. The diameter of the sphere was 1 mm and the titanium washer opening was 300 µm. The experimental set up was compared to the observed jet in Fig. 1.

In order to compare the simulation to the experiment, the placement of the sphere with respect to the jet was critical and the tolerance requested was ±50 µm. Precise placement of the sphere in the foam was difficult due to shrinking that occurs in the foam during the supercritical drying phase of foam casting. We overcame this by the precise characterization of the foam before assembly, then aligning the foam to place the sphere at the desired location. It was difficult to optically diagnose the sphere location, so the assembled targets were radiographed to ensure that the sphere center was correctly positioned with respect to the jet drive region. Three quarters of the targets were built with the sphere center offset 350 µm radially from the drive washer. One quarter of the targets were built symmetrically with the drive access and the sphere center aligned. The sphere center was always located at a height of 925 µm away from the drive washer. Targets were characterized with the use of two radiography systems, X-radia and a Manson source located at SNL. The fabrication of the foam, the characterization of the foam and the characterization of the assembled target are discussed.

II. FABRICATION OF SPHERE EMBEDDED FOAM

Fabrication of the sphere embedded foams was challenging. In past sphere imbedded foam experiments at Sandia national lab, spheres were suspended within foams without support.[3] At Sandia, the foam target is placed directly into the machine and is supported by integrated hardware. The design of the Omega jet experiments had no such support structure and required a support structure for the foam. The specifications for the cylindrical foam required it to be approximately 6 mm in length with an outer diameter of 4 mm. The center of the sphere was required to be located 350 µm (±50 µm) radially from the center and 925 µm (±50 µm) from the cylindrical end surface for 3/4 of the foams. The remaining 1/4 of the

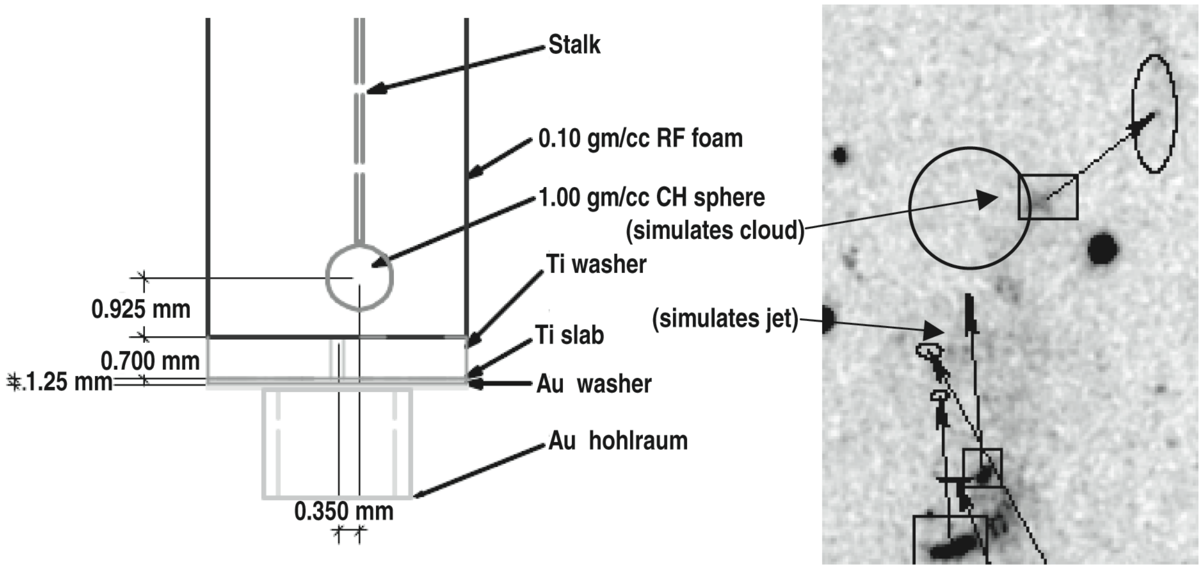

Figure 1. (left) The experimental set up is designed to mimic astrophysical jet HH 110 (right) — the arrows on the HH 110 jet image indicate the direction and magnitude of the observed jet. The deflection is seen in the right quarter of the HH 110 image.

foam components displaced the sphere 925 µm (±50 µm) along the radial axis from the end surface. To accomplish this, a pre-casting assembly was made. The pre-casting assembly was comprised of a machined end cap with a hole drilled into it to support a 100 µm stalk. The cap also had a notch cut out which served as a fiducial during assembly and radiography. After insertion, the 100 µm stalk was then trimmed to the correct length (±10 µm of the desired length) and the CH sphere was glued in place. A glass sleeve was then placed around the assembly, meeting an edge of the end cap. The glass sleeve was the mold to set the o.d. of the foam.

To synthesize the foam, a 1:2 mole ratio of resorcinol and formaldehyde was mixed in an aqueous solution.[4] The reactants were then stirred and placed in vacuum for about 20–25 minutes and pumped down to –7.62E2 Torr to remove any residual air. The gel solution was then poured into the glass sleeves, which were sealed off and placed in a curing oven where the resorcinol formaldehyde (RF) solution remained over a period of two days. The wet foam was then released from the glass sleeve and remained attached to the end caps. The released wet foam had a reddish brown color and maintained the shape of a smooth cylinder with a flat end and sharp edges. No cracks or bubbles were observed within the internal structure of the semi transparent foam. The water was removed from the foams through many isopropyl alcohol (IPA) exchanges. The IPA was then removed with repeated carbon dioxide (CO_2) exchanges. The foam was then supercritically dried by taking the CO_2 to above its critical pressure and temperature. The system was then vented while being held above critical temperature. In this phase of fabrication the foam changed dimensionally in that the foam shrank along the radial axis, and bowed at the end near the sphere location. The changes were as large as the specified tolerances. These changes necessitated post fabrication measurements of each target.

Figure 2 illustrates the foam casting process.

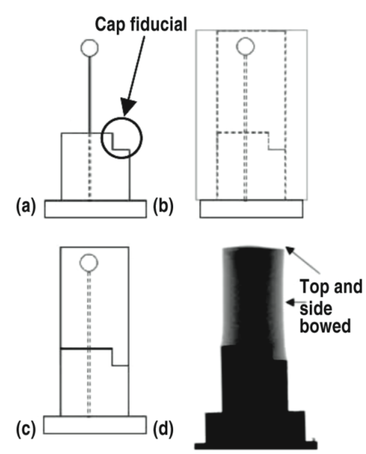

Figure 2. (a) The support stalk and sphere are mounted into the cap, (b) the foam is cast into the glass sleeve placed around cap base, (c) the wet foam is released and the specifications are maintained, (d) the foam changes dimensionally during the drying phase (the fiducial is observed in these images).

III. THE FINAL DIMENSIONS OF THE FOAM WERE CHARACTERIZED

Backlighting the foams enabled us to see the sphere, but the sphere center was difficult to diagnose. Optically the sphere location could be characterized to ±40 μm, but the center of the sphere needed to be characterized to ±25 μm. Radiography was required for more precise characterization.

Two radiography systems were used to quantify the sphere location before and after fabrication. Initially, the X-radia machine at General Atomics in San Diego was used. The X-radia MicroXCT is a commercial radiography system.[5] The images from this system were generated with a 25 keV x-ray source over a 30 s period. The energies of the X-radia were high and the density of the foam was low, so the images produced had a low contrast. These images were useful in initial screening to ensure foam integrity, however the edges of the foam were very light and similar to the background shade, which made the edges somewhat difficult to define. Further characterization was needed to better define sphere location.

To provide good contrast imaging of the targets, an x-ray system having a vacuum sample chamber and a Manson source at Sandia National Lab was used. The Manson source can be described as an electron impact source, in which energy heats up a filament to create electrons that are accelerated down a voltage gradient, then impact a Molybdenum anode and generate x-rays.[6] The x-rays then travel through a filter comprised of 7.62 μm of polyimide, which was coated with 2000 Å of aluminum on both sides, producing 5 keV broadband energies. The images were acquired by exposing the foams for a 5 min period. This method provided good contrast in imaging the targets. The three features needed for sphere location quantification (the sphere, the cap fiducial and the foam edge) were then easily viewed. The fiducial in the cap was aligned edge on in the radiography system and the first 5-min exposure was taken. Following, the target was rotated three times and 5-min exposures were taken at 45°, 90˚ and 135˚. Two of the orthogonal views allow for sphere quantification measurements to approximately ±26 μm. Figure 3 illustrates the different images acquired by the two systems.

IV. RADIOGRAPHY USED FOR ASSEMBLY

To quantify the needed parameters for assembly, the radiographic images were then imported into a CAD software package to model the individual foams. Once the foams were modeled, they were exported to an overlay that was displayed on the assembly station viewing system. The targets were then built to specification by aligning the component with the CAD image on the screen. The final target was then radiographed once more and the sphere location was quantified to ±26 μm with respect to the jet drive region. Figure 4 illustrates how the target was assembled to ensure that the sphere center was assembled precisely with respect to the jet drive region.

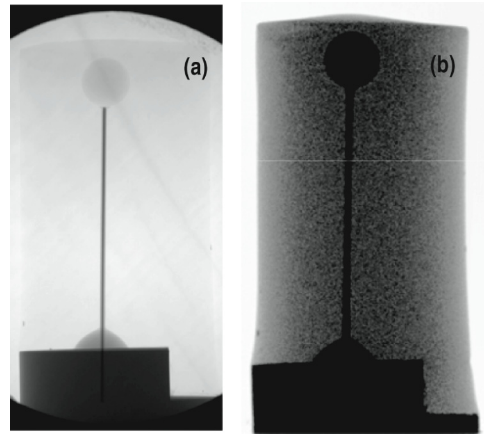

Figure 3. (a) X-radia image and (b) SNL Manson source image.

V. CONCLUSIONS

Quantification of the sphere location with respect to the jet drive source was needed to provide feedback for computer simulations.[2] The radiography were required to completely characterize the foam components, one for the foam integrity the other for sphere location. The X-radia machine at General Atomics allowed for the foam/sphere integrity assessment. The sphere location, with respect to the jet drive source, was quantified by using the Manson source at Sandia National Lab. Precision target assembly was achieved using radiography and CAD overlays. The targets for this series were fabricated to tolerance ≈75% of the time with the remainder being off ≤25 μm beyond tolerance. In the future we would like to pursue completing this characterization with high-resolution x-ray imaging (similar to X-radia) at lower energies.

ACKNOWLEDGMENTS

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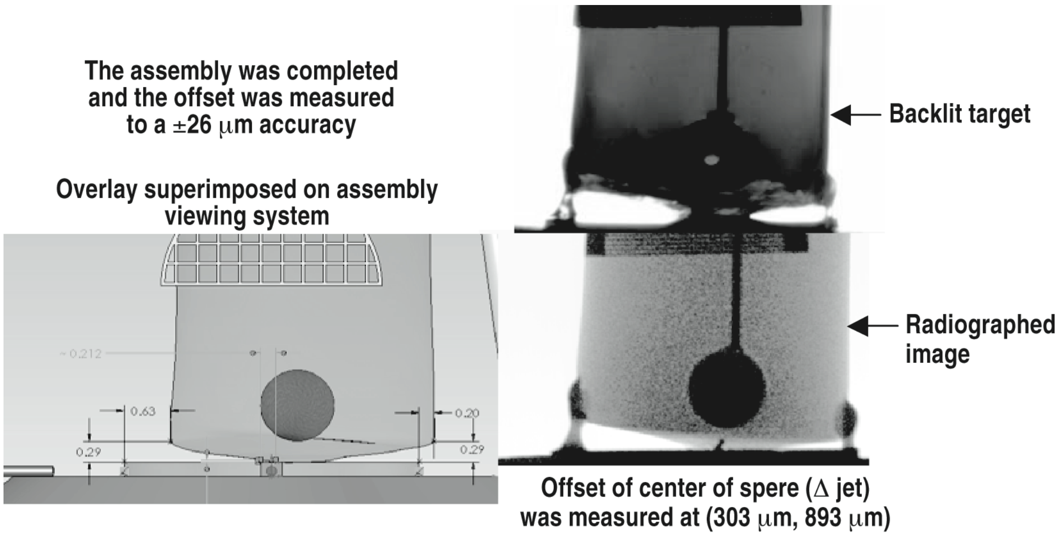

Figure 4. Jet source and sphere center were simultaneously positioned and measured using CAD overlay acquired from radiography images.

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