DEVELOPMENT OF A MULTI-PRESS ASSEMBLY DEVICE FOR PLANAR DYNAMIC MATERIAL PROPERTY TARGETS

R.R. Paguio, W.D. Tatum, K. Tomlinson, G.E. Smith, M.P. Farrell, J.L. Taylor, R.R. Holt

General Atomics, P.O. Box 85608, San Diego, California 92186-5608

Contact: Reny Paguio, General Atomics (Phone: 505-845-7762; Fax: 505-844-0573)
Email: rrpagui@sandia.gov, paguior@fusion.gat.com

Pages
12 (excluding the cover page)

Tables

Figures

Work supported by the U.S. Department of Energy under Contract DE-NA0001808

Abstract

A class of dynamic material property (DMP) experiments on the Sandia National Laboratories (SNL) pulse power Z-Machine requires planar samples to be held in a panel assembly. A custom press device to fabricate the assemblies has the ability to assemble one sample, window, or stack at a time, resulting in a one week lead time for a typical three-pocket panel assembly. Fabrication of targets with more than three pockets can take longer. In late 2015, General Atomics (GA) conceptualized a new multi-press device to enable several samples, windows, or stacks to be assembled simultaneously, and a prototype was designed, procured, and outfitted in six months. Since June 2016, this multi-press design has successfully assembled 60 planar DMP targets. The development considerations for this new device and the resulting benefits for the fabrication of targets are discussed.

Keywords: Dynamic Material Property, DMP, DMP targets, multi-press, equation-of-state

I. Introduction

Staff in the Inertial Fusion Technology division at GA fabricates target components and assembles them into final targets for experiments on the SNL Z-Machine pulsed power facility. One class of target is the planar panel assembly for DMP experiments (referred to as planar DMP target).[1-3] The samples assembled into these planar DMP targets are used to evaluate and model materials behavior at very high pressures (millions of pounds per square inch). These planar DMP targets are composed of multiple pockets; each pocket contains a sample/material or a combination of samples/materials (sample stacks). Depending on the experimental goals, samples or stack utilize combinations that include metallic, plastic, foam, and aerogel materials. An illustration of a planar DMP target is shown in **Figure 1**. These planar DMP targets are

Work supported by the U.S. Department of Energy under Contract DE-NA0001808

fabricated using a single press assembly device (**Figure 2**), developed by R. Hickman et al, at SNL.[4] A primary concern regarding this single assembly press device is the time it takes to fabricate an entire planar DMP target.

This assembly press device allows an operator to only press one sample, window, or sample stack at a time. Each press operation takes 24 hours to complete to accommodate the required adhesive cure time. The single press cannot be placed into an oven due to the size of the device, its mobility, and the sensors and components on the device that would not survive in an oven to accelerate the cure of the adhesive. This results in the total lead time to complete a planar DMP target to be roughly one week for a typical three-pocket panel. Another constraint of this device is that it is too large to fit on the assembly station (having it on the assembly station would make it easier to assemble and position the samples into the panel pockets). The assembly station is camera-equipped for magnified viewing and precise positioning.

Due to the constraints of using the same adhesive, enabling parallel processing on the same panel was deemed the most straightforward approach to improve efficiency and decrease the lead time of the planar DMP target. GA began efforts to redesign the press device to enable several samples, windows, or sample stacks to be simultaneously pressed. This paper describes the development of the multi-press assembly device (design considerations) and the realized benefits for fabrication of planar DMP targets.

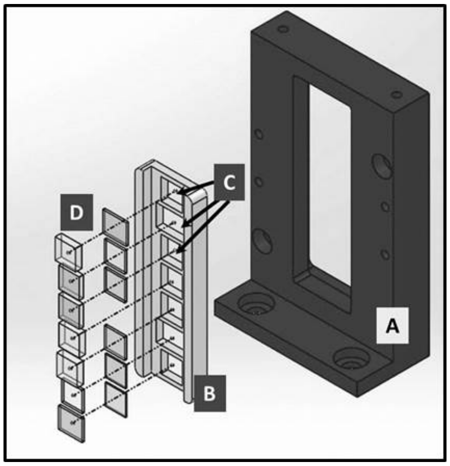

Figure 1: Illustration of an exploded view of a seven-pocket panel planar Dynamic Material Properties (DMP) target. The image shows the various parts components of the target such as the Panel Back (A), Target Panel (B), Panel Pockets (C), and the Various samples, samples stacks, and windows (D).

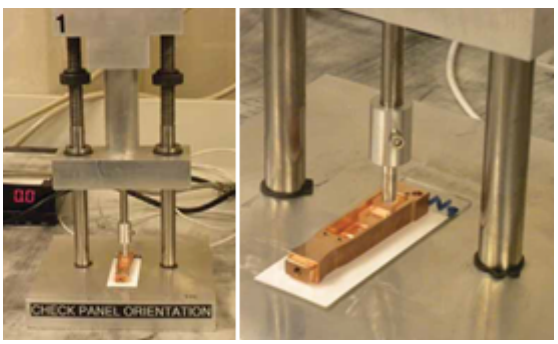

Figure 2: Image of the original single press assembly device used to fabricate planar DMP targets. This press allows the fabricator to press one sample, sample stack, or window at a time.

II. Multi-press assembly device design considerations

Some of the initial design constraints of the press were that it needed to fit under GA's current assembly station microscope. The multi-press is designed to fit on existing, camera-equipped assembly stations for magnified viewing and precise positioning of the stacks to avoid shifting. The multi-press is also designed to have a vacuum block that keeps the panel or base sample from moving during assembly and pressing. Since these dimensional constraints are smaller than the size of GA's existing ovens, the press can fit into GA's current ovens to speed up curing operations. The multi-press is designed to be mobile and easily removed from the assembly station and transported to an oven for accelerated curing.

Since these presses needed to go into an oven to speed up curing operations, the materials that are used for the press needed to be able to hold up to 70°C without off-gassing or significant coefficient of thermal expansion (CTE) effects. The materials that make up the multi-press are carbon fiber, aluminum, steel, and polycarbonate, which are not significantly affected by the 70°C temperature used for epoxy curing, thus enabling the entire press to go into the oven.

The press is required to accommodate planar DMP targets that can vary in size (50 mm length, 40 mm width, 14 mm height, or smaller) and the number of pockets (2-7) in the target. The clamps for pressing the samples need a clamp width that can accommodate or be less than minimum linear spacing of existing panel designs. Several clamp assemblies can be used on the press to press several sample stacks or to assemble several samples into several pockets in the target panel at the same time (hence the name, 'multi-press'). The current multi-press can accommodate a maximum of 10 clamps (referred to as a clamp assembly): this can accommodate more pockets than GA's largest existing target. The largest target the multi-press is designed to accommodate (110 mm length, 45 mm width, 80 mm height) is larger than GA's largest existing target, which shows that the multi-press can accommodate future planar DMP targets if the size of the target design is increased. Each clamp assembly can be independently adjusted to accommodate any stack height. Material type does not impact requirements for clamp adjustment.

The press was also required to easily apply 10 ±1 lb. of force to the sample (same as for the single press assembly device). The multi-press has a clam assembly that can apply a plunger load to the sample of 10 ±1 lb. (force range of 3-12 lbs.). The Calibration is independent of the stack height. The force is adjusted by changing springs and adjusting preload screw so there is no force feedback necessary to achieve ±1 lb. of the calibrated value. Plunger preload is adjusted to 9 lbs. by turning hollow lock set screw while measuring the preload force using a piezoelectric load cell. The plunger spring constant is 26.02 lbs./in., so a plunger displacement of .038" is required to achieve the desired force of 10 lbs. The lead of the vertical adjustment screw s .024", so each revolution of the screw, after the plunger begins to depress, adds 26.02 x .024 = .62 lbs. to the 9 lbs. preload, and ~1-1/2 revolutions is needed to achieve a force of 10 lbs. The stroke of the plunger is ~.174 in. from preload to coil bind, so the force at coil bind is ~13.5 lbs., and it takes about 7 revolutions of the screw to cause coil bind. The calibration is done on piezoelectric force transducer. Preload calibration is very stable due to design simplicity and generous tolerance of pressing force, so calibration is not part of the daily fabrication process. Calibration is checked/adjusted quarterly.

III. Multi-press assembly device design

The multi-press device design consists of five major components: a baseplate, a vacuum block, guiderails, clamp assemblies, and plunger swivel feet. An illustration showing the resulting multi-press design is shown in **Figure 3**. To accommodate the design constraints discussed above, the clamp assemblies, baseplate, and vacuum block were custom-designed and fabricated at local machine shops, and the guiderails were purchased from Thor Labs (RLA0600). The swivel feet were custom-manufactured by SNL using a Stratasys Fortus 400 3D printer.

The guide rails and vacuum block were mounted on top of the baseplate. Each clamp assembly can press one sample or pocket and apply a 10 lb. force to the sample via a spring-loaded plunger. The guiderails on either side of the work piece allow several clamp assemblies to be positioned for the pressing of samples in the desired pocket. Each spring-loaded plunger has a swiveling foot that distributes the load over the samples or sample stacks. Different styles of feet accommodate the sample dimensions, and they are additively manufactured (3D-printed) using carbon fiber, polyjet polymer, or polycarbonate. **Figure 4** illustrates the various feet, ranging from 2 – 14 mm in diameter.

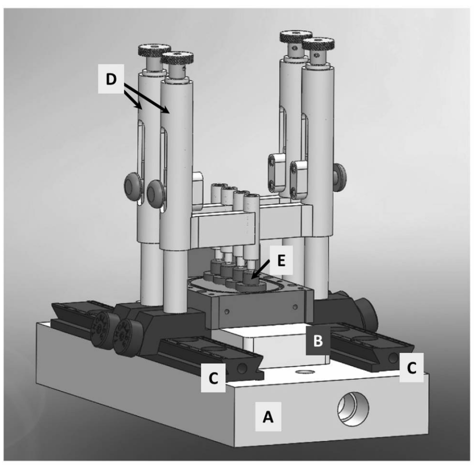

Figure 3: Illustration of the multi-press assembly device. Baseplate (A), Vacuum Block (B), Guiderails (C), Clamp Assemblies (D), and plunger swivel feet (E).

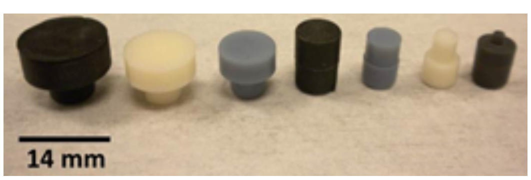

Figure 4: Picture of the various sizes of 3D-printed feet that range from 2 –14 mm in diameter. These swiveling feet are mounted to clamp assembly, which distributes the load over the samples or sample stacks.

IV. Experimental

The planar DMP targets were assembled using the multi-press assembly device using a custom assembly station, which allows magnified viewing and precise positioning of the stacks to avoid shifting of the samples in the panel pockets. The custom assembly station consists of a visual measurement microscope (Nikon MM-60), top and side cameras (Nikon ES-2MV), and a Dyno light camera (for a third view used at various positions). Leica Micromanipulators emplaced on the assembly station allow the components to be positioned and assembled at the required location. The assembly station is on an air table to minimize vibration during target assembly. A picture of the multi-press on the custom assembly station being used to assemble a planar DMP target is shown in **Figure 5**.

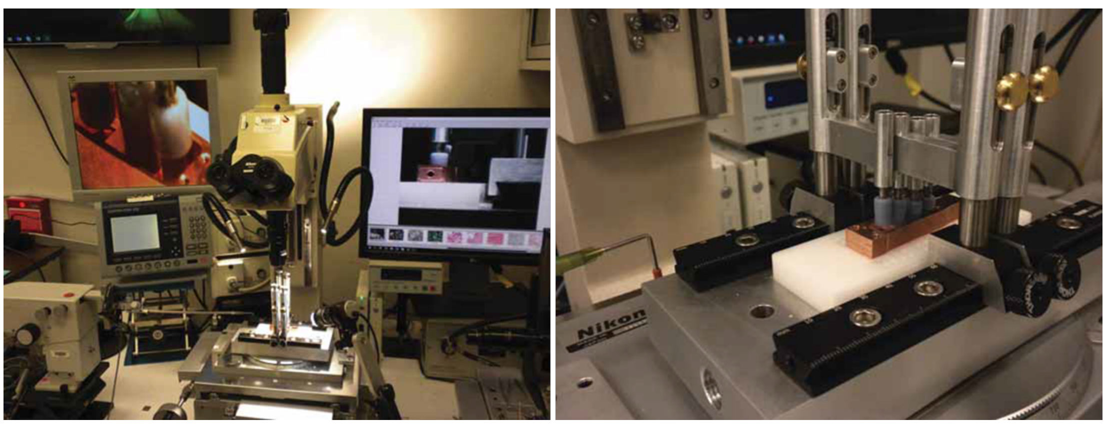

Figure 5: Image of a planar DMP target being assembled using the multi-press. The press is being used on the custom assembly station which allows the use of cameras for magnified viewing and precise positioning of the stacks to avoid shifting (L). An enlarged image of a planar DMP target being assembled using the multi-press (R).

To assemble the samples and sample stacks into the panel pockets, two types of epoxies were used: Angstrombond (AB 9110 LV) and EPO-TEK 301. Once the samples were positioned and glued into the pockets, the multi-press was placed into a 70^{o}C lab oven (VWR International) for approximately 1 hour to cure the epoxy. The sample location was characterized on the assembly station using a measuring microscope. As necessary, additional dimensional analysis such as thickness and planarity were conducted using a Nikon Nexiv 3020 microscope. Thickness measurements were also made using a Heidenhain (SG 60M) thickness/length gauge. Out-of-flat samples can affect glue bond thickness or flight distance, depending upon the target design, so PI's check pre-assembly flatness measurements of the samples or sample stacks prior to the panel target assembly.

The planar DMP targets assembled using the multi-press assembly device were compared to targets fabricated using the single press assembly device. Targets compared in this study had three-, four-, five-, six-, and seven-panel pockets. The time to fabricate the targets was documented (in days) to show which process was more efficient. For the planar DMP targets fabricated using the single press assembly device, data on targets fabricated in 2015-2016 (same operator) were used. The resulting data is provided in **Table 1**.

Table 1: Fabrication Days to Assemble Planar Dynamic Material Property Targets by Press Type

Pockets per Target	Single press device (days)	Multi-press device (days)
3	5	1-2
4	6	1-2
5	6-7	3
6	8	3-4
7	10	4

V. Results and Discussion

Numerous types of planar DMP targets were fabricated using the multi-press assembly device and compared with planar DMP targets fabricated using the single press assembly device both for assembly quality and time to execute a full planar DMP target. Time study results are presented in **Table 1**. Depending on the number of pockets in a panel, the multi-press device offers a 2-6 times improvement in assembly time. Two factors that substantially contribute to this improvement are: 1) simultaneous pressing of several samples, and 2) the device's compact size fits into available ovens and enabled faster curing times (1 hour at 70^{o}C vs. 24 hours at room temperature). The single press assembly device could not be placed into the available ovens. **Figure 6** depicts several planar DMP targets fabricated using the multi-press assembly device.

The quality of planar DMP targets fabricated using the multi-press assembly device was similar to that of the single press assembly device. The targets met the specifications. The sample position within the panels was found to be similar. Target operator feedback indicated that it was easier to position the samples in the panel pockets using the multi-press because it could be positioned on a custom assembly station with three cameras that allowed for magnified viewing of the sample and pockets and precise positioning. The glue gaps made with these two assembly devices were also similar and (both <1 μm). The glue bond thickness is determined by subtracting individual material thicknesses from the bonded stack thickness and are normally on the order of 1 micron thick. We have measurement system which uses dual, confocal, white light displacement sensors to measure thickness to within +/- 0.44 micron expanded uncertainty, but even this is not sufficiently accurate to reliably measure glue bonds in many cases because they are typically so thin.

The development and testing of the multi-press assembly device took roughly six months, and was implemented for all planar DMP targets beginning in June 2016.

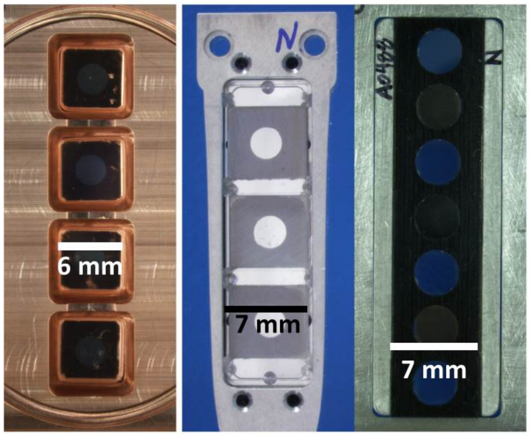

Figure 6: Pictures of a variety of planar DMP targets fabricated using the multi-press assembly device. Four-, three- and seven-pocket planar panel planar DMP target).

VI. Conclusion

A new multi-press assembly device designed and manufactured by GA's onsite target fabrication team at SNL improved fabrication efficiency for planar DMP targets on an order of magnitude of 2-6 times as compared to the single press assembly device. This improvement has also increased flexibility for SNL's DMP program.

Since the multi-press has been implemented it has been used to fabricate 60 planar DMP target assemblies, with 100% specification adherence and acceptance. GA's engineering and technical expertise with assembling this class of target and general tooling knowledge and design allowed an improved device that has substantially reduced the lead time to fabricate multi-sample planar DMP targets.

VII. Acknowledgements

Work support by U.S. Department of Energy under Contract No. DE-NA0001808.

VIII. References

1. Jean-Paul Davis et al., "Analysis of shockless dynamic compression data on solids to multi-megabar pressures: Application to tantalum," Journal of Applied Physics 116, 204903 (2014).
2. Seth Root et al., "Shock Response & Phase Transitions of MgO at Planetary Impact Conditions," Physics Review Letters, 115, 198501 (2015).
3. C. Seagle et al, "Mechanical response of lithium fluoride under off-principal dynamic shock-ramp loading," Journal of Applied Physics 120, 165902 (2016).
4. Randy Hickman, Personal Communication, 2016.

Work supported by the U.S. Department of Energy under Contract DE-NA0001808