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PBX 9502 Stockpile-Returned Hemi Tension Directionality Study

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Introduction

This work is a continuation of work started in FY12 to evaluate whether the coring direction in PBX 9502 main charges affects the mechanical properties data. In FY13 we performed the compression and thermal expansion portions of the testing.[1] In FY14 we have performed the quasi-static tension and compressive creep parts of the study. This paper focuses on the tensile results while a companion paper details the compressive creep results.[2]

In an effort to obtain mechanical properties samples that would better characterize the density distribution within a main charge and, to a lesser extent, to more thoroughly describe the mechanical behavior of material that has been in the field for long period of time, the LLNL PBX 9502 Core Surveillance coring pattern had been changed between cycles 29 and 30. Where the orientation of the tensile and compression samples tested in surveillance prior to cycle 30 had been cored in the tangential direction, the new coring diagram has both the tension and compression samples being oriented in the hoop direction. Prior to this study, the authors were not aware of any work that systematically demonstrated the effect on tensile properties of samples cored in these distinct directions. The results from this study will inform us of if and how we should trend the data taken before and after the coring pattern change.

Experimental Details

A stockpile-returned main charge hemisphere of PBX 9502 was machined into tensile specimens. The specimens were cut out of the hemisphere in three orientations: hoop, tangential and radial. The hoop specimens were oriented parallel to the waist plane, stacked in two rows of four. The tangential parts were cored at an angle roughly tangent to the inner contour, in the direction between the waist and the pole. The radial parts were cut through the wall thickness. The parts were from the virgin lot of PBX 9502 HOL82L890018 that had been in the field for over 10 years.

Core Surveillance tensile test conditions for Insensitive High Explosive (IHE) systems were chosen for these tests: temperature = -20˚C and strain rate = 0.00000167/s. The sample geometry for the hoop and tangential samples were the same standard 3-in long dogbone specimens used for all IHE systems Core Surveillance tensile tests. The geometry for the radial specimens, due to spatial limitations, had to utilize a reduced-size contour tensile specimen geometry. Extensometers were used to measure the strain during testing. All of the tests were performed on our MTS servo-hydraulic system using strain rate control.

Samples from the three different orientations were tested sequentially. The samples were tested until failure and then the stress versus strain data was analyzed. The Peak Stress, the Strain-at-Peak Stress and the Initial Modulus were the three metrics used to compare the behavior of the samples cored from the different directions. In addition to comparing the samples cored from the same hemisphere but in different directions, we have also obtained Core Surveillance data from Pantex for the same lot of PBX 9502 material for comparison.[3] A summary table of the test metrics for the LLNL-tested tangential and hoop specimens as well as the Pantex-tested tangential specimens is shown in Appendix A.

Figure 1 shows the stress versus strain curves for the tension samples cored in the tangential direction. The tangential direction is the same direction as had been used historically for surveillance tests. If there are directional differences, this is the data that should compare best with data from Pantex.

The stress versus strain curves for this group overlaid one another quite well. The colored "X"s on the plot highlight the breakpoints for the respective test plotted in the same color. There was scatter in the actual breakpoint but the curves followed the same path. Sample #6 was an outlier in that it failed the earliest (at the lowest stress and the lowest strain), however the curve still matched the others tested from this group. During post-test inspection we noted that there was a small but noticeable inclusion on the fracture surface that was likely the cause of the early failure.

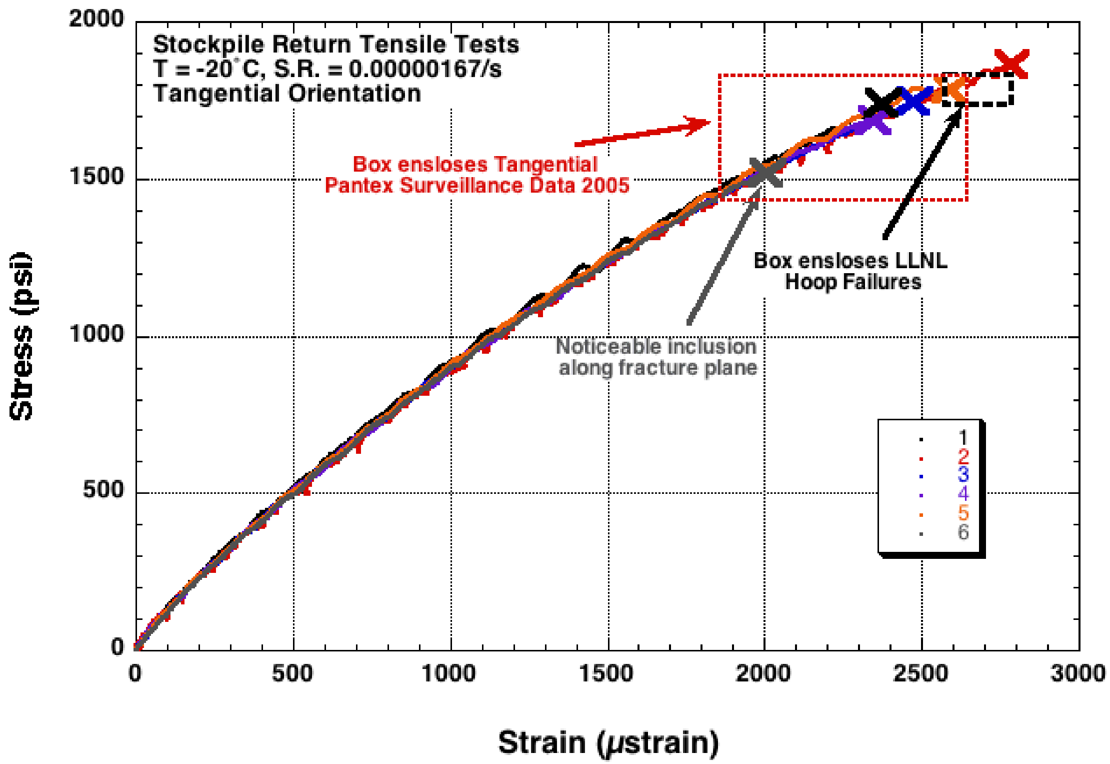

Figure 1. Stress versus strain data for the tangentially cored tensile specimens tested at T= -20˚C and a strain rate of 0.00000167/s. The dashed boxes show the hoop failure and the Pantex surveillance failure boxes. The samples fall mostly within the Pantex bounds.

The average Peak Stress for the samples machined in the tangential direction was 1725-psi with a standard deviation of 115-psi (6.6%). The average Strain-at-Peak Stress for the tangentially cored specimens was 2425-μstrain, with a standard deviation of 261-μstrain (10.8%). The average Initial Modulus (taken as the linear fit to the first 500-

μstrain data) was 998345-psi with a standard deviation of 16,740-psi (1.7%). Also shown in the figure are two boxes that summarize the boundary for the LLNL-tested hoop specimen behavior (shown in detail in Figure 2) and the behavior from Pantex surveillance data. The breakpoints for the LLNL tangential data are in line with the breakpoints from the surveillance data.

In comparison, out of 16 specimens tested at Pantex in 2005 (4 per hemi, from 4 hemis) the average Peak Stress for this lot of material was 1717-psi with a standard deviation 91-psi (5.3%). The average Strain-at-Peak Stress for the samples from Pantex was 2389-μstrain with a standard deviation of 200-μstrain (8.4%) and the Initial Modulus of 970216-psi, with a standard deviation of 26076-psi (2.7%).

Figure 2 plots the stress versus strain curves for the samples cored in the hoop direction. Once again, the curves overlay well, but this time the failure points bunch more closely together. The average Peak Stress for the hoop samples was 1780-psi with a standard deviation of 31-psi (1.7%). The average Strain-at-Peak Stress was 2643-μstrain with a standard deviation of 88-μstrain (3.3%) and the average Initial Modulus was 998039-psi with a standard deviation of 469-μstrain (0.05%). The hoop specimens showed similar results but with less spread in all three of the test metrics when compared to both the LLNL and Pantex samples cored in the tangential direction.

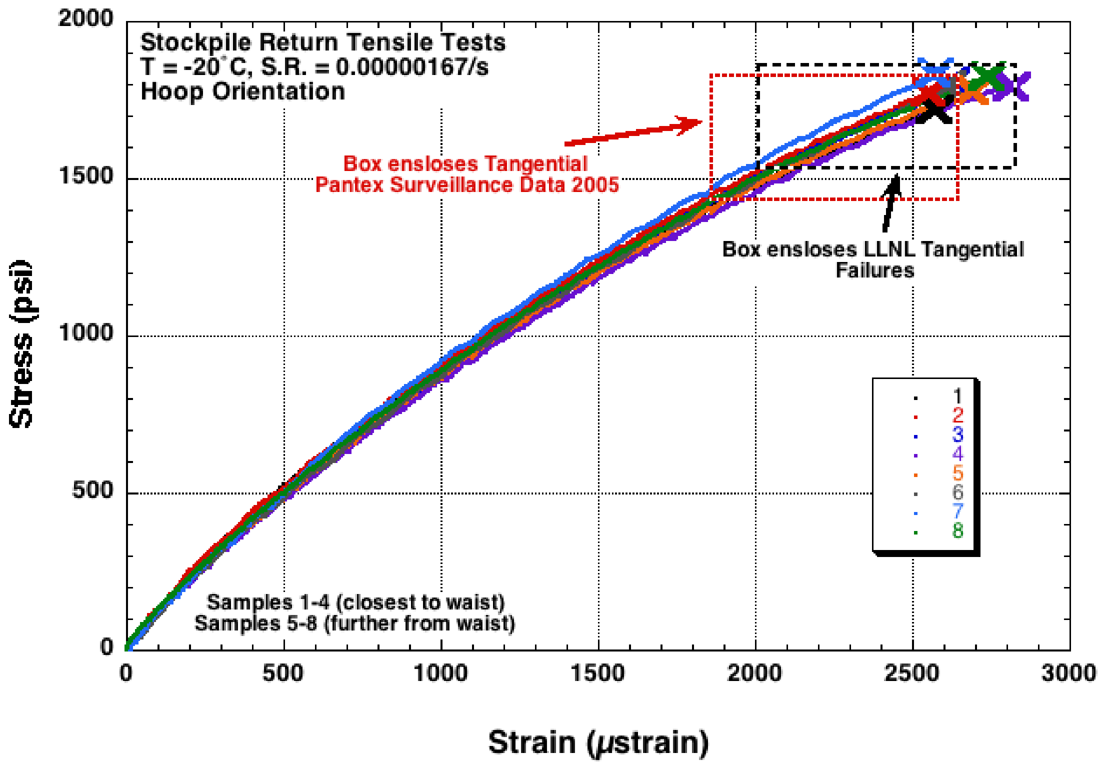

Figure 2. Stress versus strain data for the hoop cored tensile specimens tested at T= -20˚C and a strain rate of 0.00000167/s. The dashed boxes show the tangential failure for the LLNL-tested and the Pantex-tested specimens. The samples fall mostly within the previous boundaries.

The data for the radial specimens are omitted from this report because the glue joints used for the reduced-size tensile tests did not holdup under the temperature and strain rate conditions used in this test series. Originally, the effectiveness of the reduced-size contour tensile specimens was demonstrated across the temperature range of -20˚C up to 50˚C at a strain rate of 0.0001/s.[4] The reduced strain rate in this series proved to be a problem for the glue joints and the interface between the glue and the PBX 9502 specimen came loose far before the sample would have failed.

Conclusion

This study evaluated the effects of coring direction on PBX 9502 tensile surveillance tests. Samples cored in the hoop, tangential and radial directions were tested using the IHE Core Surveillance test conditions of T=-20˚C and a strain rate of 0.00000167/s. Data obtained in this study at LLNL were compared to Pantex surveillance data for the same lot of material tested back in 2005. The results showed that samples cored in the hoop direction (current surveillance coring pattern) compared well with samples cored in the tangential direction (former surveillance coring pattern) in tests run at both LLNL and Pantex on different stockpile-returned hemispheres of the same lot of PBX 9502 HOL82L890018. Peak Stress, Strain-at-Peak Stress and Initial Modulus values were evaluated and determined to be within a reasonable range to indicate that data taken before and after the coring pattern change are comparable.

Our technique for testing samples cored in the radial direction, the use of smaller samples with glued end caps, proved to not work at these temperature and strain rate conditions.

References

1. Gagliardi, F. J., Cunningham, B. J. and Pease, S. T., "Compression Directionality in PBX 9502 Stockpile-returned Hemisphere", ESC Annual Report (FY2013).
2. Gagliardi, F. J., Pease, S. T., and Cunningham, B. J., "PBX 9502 Stockpile-returned Hemi Compressive Creep Directionality Study", ESC Annual Report (FY2014).
3. PBX 9502 Core Surveillance data received from Pantex Mechanical Properties testing personnel.
4. Reduced Size Tensile – ESC FY12

Appendix A. PBX 9502 Tensile Directionality Summary Table

LLNL Tangential	Peak Stress (psi)	Strain-at-Peak Stress (µstrain)	Initial Modulus (psi)
1	1739	2390	1023500
2	1860	2787	980090
3	1743	2467	1004600
4	1699	2333	983440
5	1789	2570	1008500
6	1518	2003	989940
Avg	**1725**	**2425**	**998345**
Standard Dev.	**115**	**261**	**16740**

LLNL Hoop	Peak Stress (psi)	Strain-at-Peak Stress (µstrain)	Initial Modulus (psi)
1	1718	2590	998060
2	1773	2560	997120
3	1772	2600	998160
4	1791	2803	998390
5	1778	2698	998480
6	1775	2600	998280
7	1821	2568	997540
8	1813	2723	998280
Avg	**1780**	**2643**	**998039**
Standard Dev.	**31**	**88**	**469**

Pantex (Tang.) 2005	Peak Stress (psi)	Strain-at-Peak Stress (µstrain)	Initial Modulus (psi)
1	1823	2670	936360
2	1712	2360	999050
3	1648	2250	979370
4	1697	2390	999310
5	1773	2550	987870
6	1762	2670	908520
7	1711	2400	961140
8	1790	2620	940330
9	1431	1820	973650
10	1780	2430	960590
11	1797	2370	976950

12	1746	2370	1005400
13	1697	2340	989700
14	1736	2360	982670
15	1700	2310	968870
16	1661	2320	953680
Avg	**1717**	**2389**	**970216**
Standard Dev.	**91**	**200**	**26076**